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BRIEF REPORT

Clinical High Risk for Psychosis Syndrome Is Associated With Reduced Neural Responding to Unpleasant Images

K. Juston Osborne[1], Wendy Zhang[2, 3], Tina Gupta[1], Jaclyn Farrens[2], McKena Geiger[2], Brian Kraus[1], Chloe Krugel[1], Robin Nusslock[1], Emily S. Kappenman[2, 3], and Vijay A. Mittal[1, 4, 5, 6]

[1] Department of Psychology, Northwestern University
[2] Department of Psychology, San Diego State University
[3] Department of Psychology, SDSU/Department of Psychiatry, UC San Diego Joint Doctoral Program in Clinical Psychology
[4] Department of Psychology, Institute for Policy Research, Northwestern University
[5] Department of Psychiatry, Institute for Policy Research, Northwestern University
[6] Department of Medical Social Sciences, Institute for Innovations in Developmental Sciences (DevSci), Northwestern University

Deficits in emotion processing are core features of psychotic disorders. Electrophysiology research in schizophrenia suggests deficits in sustained engagement with emotional content (indexed by the late positive potential [LPP]) may contribute to emotion processing impairments. Despite similar behavioral emotion processing dysfunction in those at clinical high risk (CHR) for psychosis, limited research has examined neural mechanisms of impaired emotion processing in the high-risk period, where research can inform risk models. To examine mechanisms of emotion processing deficits in those at CHR for psychosis, the present study used a passive viewing task to elicit the LPP in response to emotionally engaging and neutral stimuli in 28 CHR and 32 control participants (60% female). Relative to controls, CHR participants showed reduced LPP amplitude when viewing unpleasant images ($d = 0.75$, $p = .005$) but similar LPP amplitude in response to both neutral ($d = 0.35$, $p = .19$) and pleasant images ($d = 0.31$, $p = .24$). This pattern suggests that individuals at CHR for psychosis exhibit a deficit in sustained engagement with unpleasant stimuli. Clinical and trait questionnaires were administered to examine potential exploratory explanations for group differences in LPP amplitude. Consistent with evidence suggesting LPP amplitude reflects engagement of approach/avoidance motivational systems, greater LPP amplitude was associated with greater trait-level behavioral avoidance in control participants ($r = .42$, $p = .032$) but not CHR participants ($r = -.21$, $p = .40$). Together, the present research is consistent with LPP studies in psychosis and implicates reduced sustained engagement with emotional content in the high-risk period.

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Correspondence concerning this article should be addressed to K. Juston Osborne, Department of Psychology, Northwestern University, 2029 Sheridan Road, Evanston, IL 60208, United States. Email: juston.osborne@u.northwestern.edu

General Scientific Summary

Deficits in emotion processing are prevalent in individuals at risk for developing psychosis. This study supports the notion that for individuals at risk for psychosis, impairments in orienting and sustaining engagement with emotional content may underlie emotion processing deficits and be due to abnormalities in approach–avoidance motivational systems. Together, these findings suggest that deficits in orienting and sustaining engagement to emotional content may be present before illness onset and reflect a core feature of the illness.

Keywords: clinical high risk, psychosis, event-related potential, emotion, late positive potential

Supplemental materials: https://doi.org/10.1037/abn0000862.supp

Impaired emotion processing is a core feature of psychosis, including altered emotional experience (Barch, 2005; Docherty et al., 2014; Lee et al., 2021; Strauss & Gold, 2012; Trémeau et al., 2009), reduced emotional expression (Marder & Galderisi, 2017; Zou et al., 2018), and impaired emotion perception and regulation (Irani et al., 2012; Ludwig et al., 2019; Painter et al., 2019). Given strong behavioral evidence for impaired emotion processing in psychosis, much work has focused on elucidating the underlying pathophysiology of emotion processing difficulties in schizophrenia. Clinical neuroscience research utilizing the event-related potential (ERP) technique has shown that patients with schizophrenia exhibit a specific abnormality in maintaining engagement with emotionally engaging stimuli (Andersen et al., 2016; Horan et al., 2010). Recently, evidence for deficits in emotion processing has also been observed in individuals at clinical high risk (CHR) for psychosis (Gupta et al., 2019; Haining et al., 2020; Vines et al., 2022). However, these studies have largely focused on behavioral measures, and it is unclear whether similar neural mechanisms underlie emotion processing deficits in the high-risk period as those observed in schizophrenia. Given that behavioral emotion processing deficits are sensitive to illness severity and progression in the CHR period (Bjornestad et al., 2022; Chen et al., 2016), examining the potential neural mechanisms contributing to emotion processing deficits in individuals at CHR for psychosis stands to inform the field's understanding of the pathophysiology and risk for psychotic disorders. Thus, the present study used the ERP technique to investigate deficits in sustained engagement with emotional content as a potential neural mechanism that may contribute to emotion processing impairment in individuals at CHR for psychosis.

Emotion Processing Impairment in Psychosis

Behavioral evidence for impaired emotion processing in patients with psychosis is complex. Specifically, although there is strong evidence of blunted facial expressivity in schizophrenia (Kring & Caponigro, 2010; Kring & Elis, 2013), findings from studies of emotional experience are more mixed. For example, though findings are not always consistent, laboratory studies suggest that patients with schizophrenia self-report comparable, and sometimes even greater, frequency and intensity of in-the-moment positive emotional experiences than those without psychosis (Cohen & Minor, 2010; Kring & Moran, 2008). In terms of negative emotions, patients with psychosis tend to rate positive and neutral stimuli presented in laboratory paradigms as more negative (Cohen & Minor, 2010; Docherty et al., 2014; Ursu et al., 2011), which in turn has been associated with illness duration and functional outcomes (Trémeau et al., 2009). Patients with psychosis also experience deficits in the ability to change their emotional experience or expression (i.e., emotion regulation; Ludwig et al., 2019). Given the complexity of emotion processing findings in psychosis, it is important to characterize the temporal course of emotion processing to help clarify distinct emotion-related impairments in psychosis (Kring & Caponigro, 2010; Kring & Elis, 2013).

The Late Positive Potential (LPP) in Psychosis

ERP emotion research in schizophrenia has largely focused on the LPP (see Castro et al., 2019), a sustained positive deflection of the ERP waveform that is elicited in tasks that require participants to view emotionally engaging stimuli (e.g., aversive or appetitive images; Hajcak & Foti, 2020; Lang et al., 1997). The LPP is most prominent over centroparietal electrode sites and typically begins approximately 300 ms after stimulus onset and can be sustained from several hundred milliseconds to much longer time periods depending on task specifics (Hajcak et al., 2012). Consistent with evidence suggesting the LPP reflects sustained processing of emotion-related content, research has demonstrated that the LPP waveform is more pronounced when viewing emotionally valenced stimuli (e.g., pleasant and unpleasant images) compared to neutral stimuli (Hajcak et al., 2012). Emotionally engaging stimuli are thought to evoke an increased LPP by activating approach and avoidance motivational systems (Bradley, 2009; Hajcak & Foti, 2020).

Previous studies have provided mixed evidence for how the LPP is altered in patients with psychosis versus healthy controls (HCs). For example, some studies have observed group differences in LPP amplitude in response to pleasant and unpleasant stimuli between patients with schizophrenia and HCs (Andersen et al., 2016; Horan et al., 2010), as well as an absence of the expected LPP effect (i.e., increased LPP to emotional compared with neutral stimuli) in patients with psychosis. However, other studies have not observed any differences in LPP amplitude between those with and without psychosis (Horan et al., 2012; Wichniak et al., 2016). A recent meta-analysis has helped clarify these findings (Castro et al., 2019). Specifically, meta-analytic evidence suggests that individuals with schizophrenia exhibit smaller LPP amplitude relative to controls when viewing unpleasant stimuli, whereas LPP amplitude does not significantly differ between groups for pleasant and neutral stimuli. However, the meta-analytic effect size for the nonsignificant reduction in LPP amplitude in response to pleasant stimuli in patients with psychosis is considered small by convention

($g = -0.27$), and it may be there is a true effect for reduced engagement in response to pleasant stimuli in psychosis that most studies are not well powered to observe. Thus, there appear to be deficits in the sustained processing of unpleasant stimuli in psychosis, and potentially to a lesser extent for pleasant stimuli, which may reflect a deficit in underlying motivational systems that naturally direct and sustain attention to threatening and/or appetitive environmental cues. Indeed, abnormal LPP amplitude in response to reward outcome processing (e.g., wins vs. losses) has been observed in patients with schizophrenia (Abram et al., 2020). Notably, the neural regions involved in purportedly generating the LPP (e.g., amygdala, prefrontal cortex, insula; Hajcak & Foti, 2020; Liu et al., 2012; Sabatinelli et al., 2007, 2013) overlap heavily with neural regions that are consistently found to exhibit reduced activity in patients with psychosis using similar paradigms (Anticevic et al., 2012; Taylor et al., 2012). These neuroimaging findings provide converging evidence for an association between reduced engagement with emotional stimuli and the pathophysiology of emotion processing abnormalities in psychosis.

Emotion Processing Impairments in CHR

Together, LPP findings in schizophrenia suggest that reduced engagement with emotional stimuli may contribute to emotion processing deficits in psychosis. However, it is difficult to differentiate if these deficits are related to the etiology and pathophysiology of psychosis, or are the result of illness-related confounds such as medication use and illness duration (Kring & Caponigro, 2010). Individuals at CHR for psychosis have not yet developed formal psychosis, but are considered at heightened risk of developing a psychotic disorder in a short window of time (Kempton et al., 2015). Thus, this group is ideal to investigate the etiology and pathophysiology of the disorder in the absence of illness-related confounds. Similar to patients with psychosis, behavioral evidence from CHR research indicates that the high-risk period is also characterized by altered emotional processing (van der Steen et al., 2017; Yee et al., 2019), reduced emotion expression (Gupta et al., 2019, 2020), and deficits in emotion regulation (Lincoln et al., 2018; Vines et al., 2022). Moreover, these emotion processing deficits have important implications for functioning (Cowan et al., 2020; Damme et al., 2022; Foussias et al., 2014) and have been associated with symptom severity and conversion (Corcoran et al., 2015; Gupta et al., 2021; Piskulic et al., 2012), indicating emotional functioning impairment may be closely tied to the pathophysiology of psychosis.

The LPP in CHR

Research on the underlying electrophysiology correlates of impaired emotion processing in those at CHR for psychosis has been limited. Strauss et al. (2018) showed that individuals at CHR for psychosis did not exhibit the expected increase in LPP amplitude for either pleasant or unpleasant stimuli compared to neutral stimuli, suggesting that engagement with emotionally engaging content may be impaired during the CHR period. However, the paradigm utilized in their study only displayed stimuli for a brief duration (i.e., 500 ms), making it unclear how sustained engagement with emotional stimuli over time might be impacted in CHR. This is because the LPP is typically sustained for the entire time a stimulus is presented (Hajcak & Olvet, 2008), versus other ERPs that have a more transient duration (Hajcak & Foti, 2020). Evidence from studies rapidly presenting arousing images suggests that the early portion of the LPP reflects a relatively automatic orienting response to the emotional context of the stimuli (Flaisch et al., 2008; Schupp et al., 2004), while later portions reflect a sustained engagement with emotional content (Hajcak & Foti, 2020). Thus, research utilizing longer stimulus presentation periods is required to disentangle these processes in the high-risk period.

The Present Study

In the present study, we used the ERP technique (i.e., the LPP) to investigate sustained engagement with emotional content in individuals at CHR for psychosis. We used a passive viewing paradigm in which each image was presented for 2.5 s. This length of presentation allows for the assessment of both the early automatic orienting to emotionally salient aspects of the stimuli as well as later sustained engagement with the emotional content of the images. If LPP amplitude is reduced in those at CHR for psychosis, this would suggest deficits in the ability to orient and sustain engagement with emotional stimuli in the psychosis-risk period. We had two competing hypotheses: First, consistent with meta-analytic evidence from studies in patients with schizophrenia (Castro et al., 2019), we predicted that CHR participants would exhibit reduced LPP amplitude for unpleasant stimuli (but not pleasant or neutral stimuli) compared to HCs, implicating a specific deficit in orienting and/or sustaining engagement with aversive emotional information. Alternatively, consistent with the one previous study conducted in individuals at CHR for psychosis (Strauss et al., 2018), we predicted that CHR participants may not show the expected modulation of LPP amplitude by stimulus valence (i.e., no increased amplitude for pleasant/unpleasant images relative to neutral). In exploratory analyses, we examined associations between LPP amplitude, positive and negative symptoms, and social and role functioning within the CHR group. Finally, we examined several potential exploratory explanations for groups differences in LPP amplitude, including anxiety and depression symptoms (Addington et al., 2017), presence of a mood or anxiety disorders diagnosis (Burkhouse et al., 2017; Klawohn et al., 2021), habitual emotion regulation strategies (Lincoln et al., 2018; Osborne et al., 2017), and trait-level tendencies for motivational approach and avoidance (Bartolomeo et al., 2019).

Method and Materials

Participants

Data for the present study were collected from 34 HC participants and 29 individuals at CHR for psychosis at the Adolescent Development and Preventive Treatment (ADAPT) program at Northwestern University (see Table 1 in the online supplemental materials for demographics/clinical/questionnaire descriptive statistics). A subset of the CHR participants had 12-month clinical follow-up assessments and was used in a longitudinal examination of the association between LPP measures and symptoms and functioning (see below for *N*s). Consistent with lab protocol, we excluded one CHR participant with greater than 50% of trials rejected for electroencephalogram (EEG) artifacts. In addition, two HC participants were unable to remain awake and attentive during

the task and were excluded from analyses. Thus, the final analytic included 32 HC and 28 CHR participants ($N = 60$; 15–30 years old, $M_{age} = 20.92$, $SD_{age} = 2.76$, 60% female). Longitudinal analyses were conducted on a subset of 21 CHR participants with 12-month follow-up symptom assessment data, and for 20 CHR participants with 12-month follow-up functioning assessment data. See the online supplemental materials for additional inclusion/exclusion criteria and details on clinical and functioning assessments used for diagnoses and quantification.

Stimuli and Task

The LPP was elicited with a passive viewing task, in which a series of neutral, pleasant, and unpleasant images selected from the International Affective Picture System were presented (IAPS; Lang et al., 2008). Sixty pictures were selected from the IAPS image set: 20 neutral, 20 pleasant, and 20 unpleasant (see the online supplemental materials for stimuli details and arousal/valence ratings). On each trial, an image was displayed for 2,500 ms, followed by an interstimulus interval of 1,750–2,250 ms (see Figure 1). The experiment was split into two blocks, with each image appearing once in a randomized order within each block. This resulted in 120 trials total, with 40 trials in each condition (neutral, pleasant, and unpleasant). Participants were instructed to view each image as it was displayed and that no responses were required.

Self-Report Questionnaires

Depression and Anxiety Severity Scales

Because there is evidence that emotion processing deficits in those at CHR for psychosis may be influenced by comorbid depression and anxiety (Addington et al., 2017, 2021; McAusland et al., 2017), we examined potential associations between LPP amplitude and depression and anxiety symptoms using the Beck Depression Inventory-II (BDI; Beck et al., 1996) and Beck Anxiety Inventory (BAI; Beck et al., 1988), respectively. BDI scores were available for 32 HC and 27 CHR participants. BAI scores were available for 28 HC and 26 CHR participants. See the online supplemental materials for additional details on the scales.

Emotion Regulation Scale

Given evidence for emotion regulation deficits across the schizophrenia spectrum (Vines et al., 2022) and associations between habitual emotion regulation strategies and LPP amplitude (Harrison & Chassy, 2019), we examined potential associations between LPP amplitude and habitual emotional regulation strategies using the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). ERQ scores were available for 25 HC and 19 CHR participants. See the online supplemental materials for additional scale details.

Trait Avoidance and Approach Scales

Given evidence for impairments in trait-level motivation in psychosis (Reddy et al., 2014; Scholten et al., 2006) and evidence suggesting the LPP reflects sustained attention to the motivational significance of emotionally evocative stimuli (Hajcak & Foti, 2020), we examined potential associations between trait-level motivational systems and LPP amplitude using the behavioral avoidance (inhibition) system (BIS) and behavioral approach system (BAS) scales (Carver & White, 1994). In addition, we examined associations with both the full BIS scale (BIS-full) and with the reverse-scored items removed (BIS-true keyed) because it has been demonstrated that the two reverse-scored items on the BIS often load poorly on the BIS factor and are associated with method effects (Campbell-Sills et al., 2004; Maack & Ebesutani, 2018; Weydmann et al., 2020). BIS/BAS scores were available for 26 HC and 19 CHR participants. See the online supplemental materials for additional scale details.

EEG Recording and Measurement

The EEG was recorded from 58 passive Ag/AgCl electrodes mounted in an elastic cap positioned according to the international 10–20 system. A subset of these electrodes was selected for further processing (see online supplemental materials). Data were amplified using a Neuroscan Synamps RT amplifier with 24-bit resolution at DC with a 100 Hz antialiasing filter digitized at 500 Hz. All impedances were kept below 5 kΩ. See online supplemental materials for additional recording details.

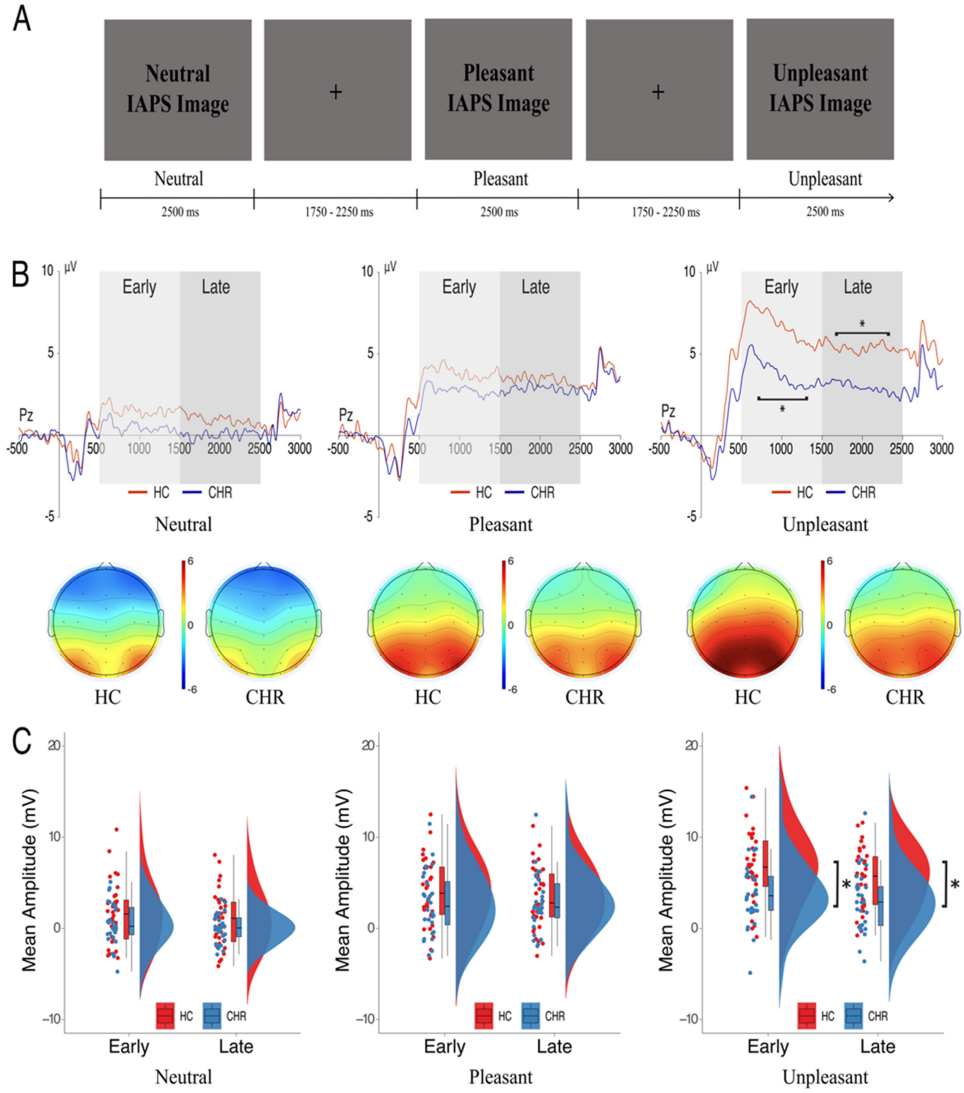
Continuous EEG data were segmented between −500 and 3,000 ms relative to stimulus onset and baseline corrected using the −500 to 0 ms prestimulus interval (see online supplemental materials for EEG processing and artifact rejection details). The average percent of data segments rejected was 12.66% for HCs and 14.70% for CHR participants. The average number of trials included in group average waveforms across picture condition were as follows: neutral (HC: $M = 34.66$, $SD = 4.09$; CHR: $M = 34.11$, $SD = 5.20$), pleasant (HC: $M = 34.25$, $SD = 5.19$; CHR: $M = 34.68$, $SD = 4.30$), and unpleasant (HC: $M = 35.09$, $SD = 4.61$; CHR: $M = 34.54$, $SD = 4.44$). There were no group differences in average number of trials included in average waveforms ($ps > .64$). Following prior work (Hajcak et al., 2009), mean LPP amplitude was quantified in both an early (500 and 1,500 ms) and late (1,500 and 2,500 ms) measurement window. The measurement site for the LPP was selected a priori and was quantified at the posterior-midline site Pz where the LPP is typically maximal (Dunning & Hajcak, 2009; Kappenman et al., 2015).

Statistical Analysis Approach

Independent *t* tests and chi-square tests were employed to examine group differences in demographic variables. A series of 2 (Group: CHR vs. HC) × 3 (Condition: Neutral vs. Pleasant vs. Unpleasant) repeated measures analyses of variance (ANOVAs) were used to examine group effects, condition effects, and interactions predicting LPP measures. Pearson correlations were used to examine associations of LPP amplitude measures with baseline symptoms and functioning within the CHR group. We did not examine associations with symptoms or functioning within the HC group due to an expected restriction of range. Partial correlations were used to examine associations between LPP amplitude measures and symptoms and functioning at 12-month follow-up, partialling out baseline values of the corresponding outcome variable. Point-biserial correlations were used to examine associations between the presence of a mood or anxiety disorder diagnosis and LPP amplitude within the CHR group. We were not able to examine associations for other disorder domains due to low frequency of these diagnoses in the current sample (see Table 1 in the online supplemental materials for details).

Figure 1

Example Trials of the Passive Viewing Task (A), Grand Average LPP Waveforms and Topographical Maps (B), and Raincloud Plots for Group Distributions (C)



Note. (Row A) Example trials of the passive viewing task. Actual IAPS images used in the task are not displayed in the trial examples in order to maintain novelty and efficacy of the stimulus set. All images within blocks were displayed in randomized order (not depicted). (Row B) ERP waveforms reflect grand average LPP waveforms at Pz. Shading reflects measurement window. Asterisk "*" defines the presence of significant between-group difference. Topographical maps reflect mean amplitude collapsed across the early and late measurement windows. (Row C) Figures depict raincloud plots that provide a visualization of the raw data, box plots, and distribution of the mean amplitude for early and late LPP waveforms across conditions by group. Asterisk "*" defines the presence of significant between-group difference. IAPS = International Affective Picture System; HC = healthy control; CHR = clinical high risk for psychosis; LPP = late positive potential. ERP = event-related potential. See the online article for the color version of this figure.

A series of multiple regressions were used to examine associations between self-report scales (e.g., the BIS) and LPP amplitude measures (e.g., unpleasant condition amplitude), as well as group differences in those associations. In each model, the self-report scale, group (CHR vs. HC), and their interaction were included as predictors of LPP amplitude. When a statistically significant interaction was observed, Pearson correlations were used to test associations between the self-report scale and LPP amplitude separately within CHR participants and within HC participants. For these analyses, we also calculated difference scores for the LPP (e.g., unpleasant–neutral and pleasant–neutral) using the residuals of a linear regression model (Meyer et al., 2017). However, as there are a number of methodological issues involved in the use of difference scores in individual differences research (Draheim et al., 2019; Meyer et al., 2017), these analyses are reported in the online supplemental materials.

Two-tailed tests with an alpha level of .05 were used for all statistical tests, and a Greenhouse–Geisser epsilon correction for nonsphericity was used to adjust relevant probability values.

Transparency and Openness

The target sample size for EEG data collection was based on power analyses conducted for a larger project. The task used in the present study was administered to all study participants for that larger project, except when time ran out within the testing session. In addition, we aimed for a minimum of 30 participants per group. We fell slightly short of this target for the CHR group and slightly exceeded this target for the HC group. We report all data exclusions and manipulations. Additional measures were collected but are beyond the scope of the present research. We did not include public data sharing in the initial consent process. Given this, combined with the sensitive nature of the sample and research question, we have not made data publicly available. Data were analyzed using IBM SPSS (Version 28) and R (Version 4.0.3; R Core Team, 2020). This study's design and its analysis were not preregistered.

Results

There were no significant group differences in age, sex, education, or parent education (a proxy for socioeconomic status; see Table 1 in the online supplemental materials for statistics). The ERP waveforms for group comparisons across conditions are presented in Figure 1. The LPP mean amplitude measures are summarized in Table 2 in the online supplemental materials and depicted in Figure 1.

Early LPP (500–1,500 ms)

Pleasant and unpleasant pictures elicited greater early LPP amplitude than neutral pictures, resulting in a main effect of condition, $F(2, 116) = 74.62$, $p < .001$, $\eta_p^2 = 0.56$. The main effect of group was also significant, such that the CHR group exhibited reduced LPP amplitude across conditions compared to the HC group, $F(1, 58) = 4.21$, $p = .045$, $\eta_p^2 = 0.07$. These main effects were qualified by a statistically significant Group × Condition interaction, $F(2,116) = 4.54$, $p = .02$, $\eta_p^2 = 0.07$. Follow-up pairwise comparisons showed the LPP amplitude elicited by unpleasant pictures was significantly smaller in the CHR group compared to HCs, $t(58) = 2.90$, $p = .005$, $d = 0.75$, 95% CI [0.22, 1.27]. By contrast, the LPP amplitude did not differ statistically between groups for neutral pictures, $t(58) = 1.33$, $p = .19$, $d = 0.35$, 95% CI [−0.17, 0.85], or pleasant pictures, $t(58) = 1.18$, $p = .24$, $d = 0.31$, [−0.21, 0.81].

Notably, both groups exhibited enhanced engagement with pleasant compared to neutral stimuli, CHR: $t(27) = 5.34$, $p < .001$, $d = 1.01$, 95% CI [0.55, 1.50]; HC: $t(31) = 6.10$, $p < .001$, $d = 1.08$, [0.64, 1.51], and unpleasant compared to neutral stimuli, CHR: $t(27) = 6.05$, $p < .001$, $d = 1.14$, [0.67, 1.62]; HC: $t(31) = 8.40$, $p < .001$, $d = 1.48$, [0.97, 1.98].

Late LPP (1,500–2,500 ms)

Results in the late LPP measurement window were similar to those observed in the early time window. Specifically, pleasant and unpleasant pictures elicited greater late LPP amplitude than neutral pictures across participants, resulting in a main effect of condition, $F(2, 116) = 59.28$, $p < .001$, $\eta_p^2 = 0.51$. The main effect of group was marginally significant, such that CHR group exhibited marginally reduced LPP amplitude across conditions compared to the HC group, $F(1, 58) = 3.57$, $p = .06$, $\eta_p^2 = 0.06$. Notably, the Group × Condition interaction observed in the early window persisted into the late window, $F(2, 116) = 4.20$, $p = .02$, $\eta_p^2 = 0.07$. Follow-up pairwise comparisons revealed that the LPP elicited by unpleasant pictures showed a significantly smaller amplitude in the CHR participants compared with HCs, $t(58) = 2.80$, $p = .01$, $d = 0.72$, 95% CI [0.20, 1.25]. By contrast, the difference in LPP amplitude did not differ statistically between groups for either neutral pictures, $t(58) = 1.43$, $p = .16$, $d = 0.37$, 95% CI [−0.14, 0.88], or pleasant pictures, $t(58) = 0.65$, $p = .52$, $d = 0.17$, [−0.34, 0.68].

Similar to the early LPP, both groups exhibited enhanced engagement with pleasant and unpleasant stimuli compared to neutral stimuli, CHR pleasant vs. neutral: $t(27) = 5.66$, $p < .001$, $d = 1.07$, 95% CI [0.60, 1.53]; HC pleasant vs. neutral: $t(31) = 5.61$, $p < .001$, $d = 0.99$, [0.56, 1.41]; CHR unpleasant vs. neutral: $t(27) = 5.54$, $p < .001$, $d = 1.07$, [0.58, 1.50]; HC unpleasant vs. neutral: $t(31) = 8.12$, $p < .001$, $d = 1.44$, [0.93, 1.93].

Associations of LPP Amplitude With Symptoms, Functioning, and Self-Report Scales

The full results from exploratory analyses are provided in the online supplemental materials. Notably, analyses between self-report scales and LPP amplitude difference scores were consistent with those observed using the raw waveform amplitudes (see the online supplemental materials for details).

Symptoms and Functioning

There was no evidence for significant associations between LPP amplitude and either baseline or follow-up symptoms and functioning within the CHR group (see the online supplemental materials for statistics).

Mood and Anxiety Disorders Diagnosis

There were no statistically significant associations between the presence of either a mood or anxiety disorder diagnosis and LPP amplitude in the CHR group (see the online supplemental materials for statistics).

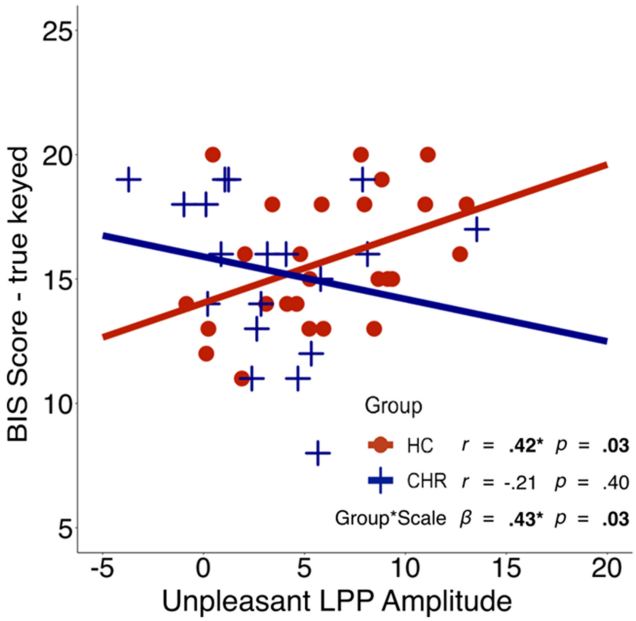
Self-Report Scales

There were no statistically significant Group × Scale interactions for depression, anxiety, habitual emotion regulation, or BAS scales predicting LPP amplitude (see the online supplemental materials for full results). There was a significant interaction between group and the BIS-true keyed score predicting LPP amplitude in response to unpleasant images ($\beta = 0.43$, $t = 2.23$, $p = .032$). Follow-up correlation analyses revealed there was a significant association between greater LPP amplitude in response to unpleasant images and greater BIS-true keyed scores in the HC group ($r = .42$, $p = .032$) but not in the CHR group ($r = -.21$, $p = .40$; see Figure 2).

To determine whether the observed relationship between BIS-true keyed scores and LPP amplitude within the HCs was specific to the LPP response to unpleasant images, we conducted follow-up analyses examining condition × BIS-true keyed interactions predicting LPP amplitude within the HC group. Results from these analyses

Figure 2

Scatter Plot Displaying Associations Between Unpleasant LPP Amplitude and BIS Scores-True Keyed Across Groups



Note. HC = healthy control; CHR = clinical high risk for psychosis; LPP = late positive potential; BIS = behavioral avoidance (inhibition) system. See the online article for the color version of this figure.

showed that while the association between BIS-true keyed scores and LPP amplitude within the unpleasant condition was significantly different from the association between BIS-true keyed scores and LPP amplitude within the neutral condition, $t(48) = 2.13$, $p = .038$, the association between BIS-true keyed scores and LPP amplitude within the unpleasant condition was not significantly different from the association between BIS-true keyed scores and LPP amplitude within the pleasant condition, $t(48) = 1.52$, $p = .135$.

Discussion

The current study sought to determine if individuals at CHR for psychosis exhibited deficits in sustained engagement with emotional stimuli. Consistent with previous research in schizophrenia (Castro et al., 2019), individuals at CHR for psychosis exhibited smaller LPP amplitude when viewing unpleasant images compared to HC participants, indicating a deficit in sustained attention to unpleasant emotional stimuli. This pattern was consistent for the early and late LPP measurement windows, suggesting that both orienting and sustained engagement processes may be affected in the high-risk period. Furthermore, although there appears to be a deficit in sustaining engagement with unpleasant stimuli in CHR, those at CHR for psychosis still exhibited preferential processing of unpleasant and pleasant stimuli compared to neutral stimuli (i.e., the typical LPP effect). Taken together, these results provide the first electrophysiology evidence that deficits in orienting and sustained engagement with emotional content in those at CHR for psychosis parallel those observed in patients with schizophrenia and underscores the importance for examining potential neural mechanisms of emotion processing in psychosis risk.

The present finding of reduced LPP amplitude in response to unpleasant stimuli in those at CHR for psychosis is consistent with recent meta-analytic findings in schizophrenia populations (Castro et al., 2019), and suggests that reduced LPP amplitude in response to unpleasant stimuli is present in both the psychosis-risk period and after illness onset. Given deficits were present for both orienting and sustained engagement, it is possible that both processes are attenuated in those at CHR for psychosis. However, it is also possible that impairment in early orienting to unpleasant stimuli exerts a cascading effect that results in reduced sustained engagement as a byproduct of low initial orienting and attention. This notion is consistent with evidence for deficits in orienting and attention in both highrisk and schizophrenia samples (De Herdt et al., 2013; Kalkstein et al., 2010; Osborne et al., 2020), as well as evidence demonstrating relationships between abnormalities in emotion–attention interactions when viewing unpleasant stimuli and deficits in emotion processing in emotion regulation LPP studies in psychosis (Bartolomeo et al., 2020; Strauss et al., 2015).

Interestingly, Castro et al. (2019) suggested that reduced sustained engagement (i.e., smaller LPP amplitude) when viewing unpleasant images in those with psychosis may be because unpleasant stimuli seem less significant when baseline negative affect is already so high. Another possible explanation for these results is based on theories and evidence indicating that the LPP reflects the neural activation of approach–avoidance motivational systems (Bradley, 2009; Hajcak & Foti, 2020; Lang et al., 1997). For example, the present study found that greater LPP amplitude was associated with trait-level behavioral avoidance in HC participants. The effect was statistically significant in the unpleasant stimuli condition, but the strength of the association did not significantly differ between the unpleasant and pleasant stimuli conditions. Thus, within HCs, trait-level behavioral avoidance may be implicated in processing of negative stimuli or of emotional stimuli more generally. This is consistent with evidence implicating the behavioral inhibition system in processing emotional stimuli in HCs (Balconi et al., 2012; Klackl et al., 2018).

Notably, the behavioral inhibition system is thought to increase attentional allocation to aversive environmental cues in order to activate defensive and withdrawal behaviors (Maack & Ebesutani, 2018). Interestingly, the association between LPP amplitude and BIS scores significantly differed between HC and CHR participants. The association was statistically significant and positive in HCs, but statistically nonsignificant and negative in the CHR group. This may suggest that the behavioral inhibition system does not orient and sustain engagement with aversive stimuli the same way in individuals at CHR for psychosis as in HCs. This interpretation is consistent with evidence for trait-level motivational deficits in both schizophrenia (Reddy et al., 2014; Scholten et al., 2006) and CHR samples (Schlosser et al., 2014). Further, it is also possible that altered BIS functioning may contribute to reduced sustained attention in psychosis and ultimately contribute to increased negative affect. For example, the activation of the behavioral inhibition system should result in subsequent attentional allocation to relevant environmental cues that further motivate an individual to avoid potential negative consequences. Thus, disruptions within this system in those at CHR may result in reduced attentional allocation and motivation to avoid potential negative consequences that result in more trait negative affect.

In contrast to findings for unpleasant stimuli, significant group differences in LPP amplitude were not observed for pleasant and

neutral stimuli in the present study. Although it is tempting to interpret the null and conclude from this pattern of findings that there is a specific deficit in sustained engagement with negative relative to pleasant and neutral emotional content in psychosis-risk, there are several important factors to consider which may temper this conclusion. For example, although nonsignificant, the effect sizes for the pleasant (*d*s of 0.17 and 0.31) and neutral (*d*s of 0.35 and 0.37) group differences are considered small effects by conventional standards. Further, because LPP amplitude tends to be smaller overall in response to pleasant and neutral stimuli, lower signal-to-noise ratios in these conditions may require more power (e.g., larger sample size, more trials across conditions) to observe significant group differences. Indeed, meta-analytic results show a small but nonsignificant reduction in LPP amplitude for pleasant stimuli in psychosis and may suggest similar power issues in other psychosis studies (Castro et al., 2019). Thus, it may be that orienting and sustained engagement to pleasant or neutral stimuli are also affected across the schizophrenia spectrum, but potentially to a lesser extent than sustained engagement with negative stimuli.

Interestingly, less impairment in orienting and sustaining engagement with pleasant stimuli relative to unpleasant stimuli across the schizophrenia spectrum may be of potential use in understanding the "emotion paradox" in psychosis (Strauss & Gold, 2012). The emotion paradox reflects findings that patients with psychosis report similar positive emotions as controls in laboratory-based paradigms but report less trait positive affect in daily life. Consistent with findings from the present study and meta-analytic evidence in psychosis (Castro et al., 2019), small reductions in orienting and sustained engagement with pleasant stimuli may not be sufficient to substantially influence experiences of positive emotion in laboratory-based paradigms. However, deficits in later emotion processes may still result in less positive affect in daily life. Indeed, recent research has shown that patients with psychosis exhibit deficits in sustained elaborative processing of positive stimuli (Martin et al., 2019; Siegle et al., 2010), which may lead to reduced trait positive affect (Martin et al., 2019). Further, Strauss et al. (2017) have shown that stimulus intensity is an important consideration for understanding responses to positive stimuli in schizophrenia patients. Together, there are several important future directions for further elucidating emotion processing deficits in the high-risk period.

Apart from the aforementioned group by BIS scale interaction findings, no other associations were observed between LPP amplitude and self-report measures or with symptoms or functioning in the current study. One possibility is that the current study was underpowered to detect small associations and future research in large cohort studies may reveal other potential individual difference and clinical explanations for reductions in LPP amplitude in the high-risk period. Indeed, one area of future research may examine associations between LPP amplitude and individual areas of positive and negative symptoms such as grandiosity or amotivation which may be more closely tied to approach–avoidance motivational systems.

Further, the presence of a mood or anxiety disorder diagnosis was also not significantly associated with LPP amplitude in the current study. This is in contrast to Strauss et al.'s (2018) finding that the presence of a mood disorder diagnosis accounted for a small amount of variance (i.e., 13%) in LPP amplitude in their CHR group. However, it remains important to consider the possibility that comorbid diagnoses or symptoms in the CHR group unrelated to the pathophysiology of psychosis may have contributed to the present findings. The CHR syndrome is often comorbid with a wide range of psychiatric conditions (e.g., anxiety and depressive disorders), and it is often difficult to disentangle potential contributions of the various clinical conditions to observed effects. This is an important limitation of the CHR approach, as well as the majority of studies in psychiatric disorders. For example, comorbid psychopathology is not often accounted for in schizophrenia LPP research and there is mixed evidence for the effects of mood disorders on LPP modulation (see Castro et al., 2019; Nikolin et al., 2022; Whalen et al., 2020). Further, anxiety disorders are most often associated with an increase in LPP amplitude to unpleasant stimuli (see MacNamara & Proudfit, 2014; MacNamara et al., 2016), which would be expected to mask potential reductions across schizophrenia spectrum disorders. Together, future well-powered research in heterogeneous samples is needed to directly investigate the relative contributions of comorbid psychopathologies to LPP modulation and its associations with symptoms, diagnosis, and functioning across the schizophrenia spectrum, which will aid in informing pathophysiological models of psychosis.

The pathophysiological implications for the current findings may be best understood through an examination of the neural regions involved in purportedly generating the LPP (e.g., amygdala, prefrontal cortex; Hajcak & Foti, 2020; Liu et al., 2012; Sabatinelli et al., 2007, 2013). Consistent with an approach–avoidance motivational framework, the regions involved in generating the LPP are also thought to be key regions involved in processing the significance of environmental stimuli that motivate and prepare relevant responses (Cunningham & Brosch, 2012). Notably, these same regions are also implicated in increased risk for developing psychosis (Allen et al., 2012; Guimond et al., 2022), and have also been demonstrated to exhibit underrecruitment during emotion processing in both the high-risk period (Gee et al., 2012) and in patients with psychosis (Anticevic, Repovs, & Barch, 2012; Modinos et al., 2015). Thus, the current findings are consistent with the notion that deficits within prefrontal and amygdala network connectivity that process the significance of environmental stimuli may contribute to deficits in orienting and sustained engagement during emotion processing across the schizophrenia spectrum. Taken together, these findings suggest that models seeking to identify and predict outcomes for individuals with high risk for psychosis syndromes may benefit from incorporating measures of emotion processing in risk models. Indeed, at the present time, emotion processing dysfunction is not represented in prominent risk calculators for this population (Cannon et al., 2016; Zhang et al., 2019).

The following limitations of the present research should be considered. First, the use of a passive viewing task did not allow us to compare and contrast potential differences between electrophysiology measures and self-report ratings of emotion stimuli and/or emotion experience. Second, due to the small sample size and large number of comparisons, no associations revealed in the exploratory analyses would have survived correction for multiple comparisons. As such, exploratory analyses of individual differences across the self-report measures may have led to Type-1 errors, and the small sample size may have also contributed to Type-2 errors. The goal of these exploratory analyses was to provide useful clues for future investigations, but the results of those exploratory analyses should not be considered confirmatory without external replication. Third, no CHR participants converted to formal psychosis over the 12-month follow-up period (de Pablo et al., 2021), precluding the examination of potential

associations between deficits in attentional allocation to emotionally evocative stimuli and conversion. Given evidence for associations between emotion processing impairments and increased risk for conversion, future work will be important to determine if deficits in sustained attention to emotional stimuli are also predictors of illness onset.

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