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Intact Differentiation of Responses to Socially-Relevant Emotional Stimuli Across Psychotic Disorders: An Event-Related Potential (ERP) Study

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Abstract

Event-related potential (ERP) studies of motivated attention in schizophrenia typically show intact sensitivity to affective vs. non-affective images depicting diverse types of content. However, it is not known whether this ERP pattern: 1) extends to images that solely depict social content, (2) applies across a broad sample with diverse psychotic disorders, and (3) relates to self-reported trait social anhedonia. We examined late positive potential (LPP) amplitudes to images involving people that were normatively pleasant (affiliative), unpleasant (threatening), or neutral in 97 stable outpatients with various psychotic disorders and 38 healthy controls. Both groups showed enhanced LPP to pleasant and unpleasant vs. neutral images to a similar degree, despite lower overall LPP in patients. Within the patients, there were no significant LPP differences among subgroups (schizophrenia vs. other psychotic disorders; affective vs. non-affective psychosis) for the valence effect (pleasant/unpleasant vs. neutral). Higher social anhedonia showed a small, significant relation to lower LPP to pleasant images across all groups. These findings suggest intact motivated attention to social images extends across psychotic disorder subgroups. Dimensional transdiagnostic analyses revealed a modest association between self-reported trait social anhedonia and an LPP index of neural sensitivity to pleasant affiliative images.

Keywords

schizophrenia; psychotic disorders; emotion; event-related brain potentials (ERPs); late positive potential (LPP); social stimuli

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1. Introduction

Prominent emotional deficits, such as social anhedonia, have long been considered cardinal features of schizophrenia and are quite pervasive, contributing to functional disability and reduced quality of life (Horan et al., 2005; Strauss and Cohen, 2018). In this context, a striking finding from studies using affective science methods is that "in-the-moment" subjective reports of emotion in response to evocative laboratory stimuli appears to remain largely intact in schizophrenia (for reviews, see Cohen and Minor, 2010; Kring and Moran, 2008; Llerena et al., 2012). Evidence of intact bottom-up emotional responses is also reflected in the late positive potential (LPP), which is an event-related brain potential (ERP) thought to reflect a neural index of motivated attention (Hajcak, Macnamara, Foti, Ferri, & Keil, 2013; Weinberg & Hajcak, 2010a, 2011). The LPP is a centroparietal positivity that begins approximately 400 ms after the onset of an emotionally salient image that, in healthy individuals, is augmented when viewing unpleasant and pleasant images as compared to neutral images (Foti and Hajcak, 2008; Hajcak and Olvet, 2008). Schizophrenia patients have shown the typical pattern of elevated LPP to standardized emotional vs. non-emotional images in several studies (Horan et al., 2012; Horan et al., 2010; Okruszek et al., 2016; Strauss et al., 2015; Sullivan and Strauss, 2017), and these findings are consistent with broad meta-analytic work on P3/LPP in schizophrenia or schizoaffective disorder (Castro et al., 2019). While existing ERP studies point toward intact bottom-up neural responses to emotional stimuli in schizophrenia, the current study sought to extend this line of investigation by addressing three open questions.

First, almost all LPP studies have used IAPS images that include diverse content, but it is unclear whether impairment is detectable for only certain types of stimuli, such as socially-relevant stimuli. As noted above, social anhedonia has long been regarded as a core feature of schizophrenia (Horan et al., 2006; Meehl, 2001; Strauss & Cohen, 2018) that may serve to diminish the motivational salience or reward value of pleasant social stimuli (Lee et al., 2019). Further, schizophrenia is characterized by wide ranging social cognitive impairments, including disturbances in social perception (Green et al., 2019), which may contribute to reduced attention (i.e., diminished LPP) for social stimuli depicting pleasant or unpleasant content (e.g., affiliative or threatening images). We sought to explore this possibility in a large sample of patients with schizophrenia and other psychotic disorders by examining LPP responses during a passive viewing task, during which participants viewed only socially-relevant images involving people.

Second, schizophrenia represents only one segment of the psychosis spectrum (Guloksuz and Van Os, 2018; Linscott et al., 2010), and little is known about motivated attention to emotional stimuli in other psychotic disorders. Two studies point to possible deficits in LPP emotional responding in other psychotic disorders, including studies of bipolar disorder (Trotti et al., 2020) and youth at high risk for psychosis (Strauss et al., 2018). However, two larger studies reported normal LPP response patterns across patient subgroups including schizophrenia spectrum disorders (schizophrenia, schizoaffective disorder) and affective psychoses (bipolar disorder, major depressive disorder; Culbreth et al., 2018; Trotti et al., 2021).

Third, self-reported social anhedonia may be dimensionally related to LPP responses to socially-relevant images across psychotic disorder subgroups (Barkus and Badcock, 2019; Husain and Roiser, 2018; Strauss and Cohen, 2017). A dimensional focus is consistent with NIMH's Research Domain Criteria (RDoC) initiative that emphasizes relationships between core neural systems and clinical syndromes that cut across traditional diagnostic categories (Kozak and Cuthbert, 2016). In a healthy sample high in social anhedonia, LPP amplitudes were small relative to comparison group low in social anhedonia (Martin et al., 2020). We sought to determine whether neurophysiological responses (i.e., LPP) to socially-relevant images and self-report trait social anhedonia are related in a similar fashion across psychotic disorders and a healthy control group.

In summary, we examined ERPs to socially-relevant images in a broad sample with diverse psychotic disorders. We predicted that participants with psychosis would show intact bottom-up emotional responding, as indexed by LPP, based on a large body of work showing a typical valence-related LPP response in patients with schizophrenia (e.g., Horan et al., 2012; Sullivan and Strauss, 2017). We also predicted that statistically significant group differences would not be observed across psychotic disorders, which is consistent with recent large studies (Culbreth et al., 2018; Trotti et al., 2021). Lastly, we examined the relationship between LPP responses to socially-relevant images and self-reported trait social anhedonia across groups. This analysis will help determine whether studies that rely on the examination of traditional diagnostic categories might be missing a key individual-differences relationship between social anhedonia and LPP amplitude that is revealed when using a transdiagnostic approach. We predicted that higher social anhedonia would relate to lower LPP amplitude for affiliative images, and that this relationship would be similar across groups.

2. Methods

2.1 Participants

Initial study enrollment included 100 patients with psychosis and 41 healthy comparison participants that were recruited as part of a study sponsored by the National Institute of Mental Health ("Social Affiliation in Psychosis: Mechanisms and Vulnerability Factors", MH107422, PI: William Horan). We used a broad recruitment strategy to enroll patients with any history of clinically significant primary psychotic symptoms (i.e., psychotic symptoms not secondary to illicit substance use or medical illness). Patients between 18 – 65 years old were recruited from the VA Greater Los Angeles Healthcare System (VAGLAHS), the University of California, Los Angeles (UCLA), and outpatient clinics, outpatient board and care facilities in the greater Los Angeles area, and postings on websites. Psychiatric diagnoses were assessed using the Structured Clinical Interview for DSM-IV Axis I Disorders – Patient Edition (SCID-I/P; First et al., 1996) by interviewers trained according to established procedures (Ventura, Liberman, Green, Shaner, & Mintz, 1998). The patient group comprised participants who met criteria for schizophrenia (n = 44), bipolar I disorder with psychotic features (n = 21), an unspecified psychotic disorder (n = 17), schizoaffective disorder (n = 8), major depressive disorder with psychotic features (n = 3), delusional disorder (n = 2), schizophreniform disorder (n = 1), and a brief psychotic

disorder (n = 1). All patients were clinically stable as indicated by no hospitalizations within three months, and no medication changes within four weeks, prior to study participation.

Healthy comparison subjects ages 18–65 were recruited through advertisements posted on websites. Selection criteria for healthy controls included: no psychiatric history involving schizophrenia spectrum disorder (including avoidant, paranoid, schizotypal, schizoid, or borderline personality disorders), or other psychotic or mood Axis I disorder according to the SCID-I and SCID-II (First et al., 1996); no family history of a psychotic or bipolar disorder among first-degree relatives based on participant report. Additional exclusion criteria for all participants included: substance dependence in the last six months or abuse in the last month; a current mood episode, an identifiable neurological disorder, loss of consciousness for more than one hour, and limited fluency in English.

Clinical symptoms were assessed for all participants using the Brief Psychiatric Rating Scale (BPRS; Ventura et al., 1993), and social anhedonia was assessed using a brief 24-item version (SAS-Brief; Reise et al., 2011) of the Social Anhedonia Scale (SAS; Eckblad et al., 1982). The research was approved by the Institutional Review Board at the VAGLAHS, and all participants provided written informed consent.

2.2 Experimental Task

Participants viewed 86 images[1] from the International Affective Picture System (IAPS; Lang et al., 1999) that included at least one person prominently shown in the scene. In total, there were 26 unpleasant images, 30 neutral images, and 30 pleasant images presented in each of two blocks (180 total trials). The duration for each exposure was 1,500 ms, separated by an intertrial interval of 1,000, or 1,500 ms (pseudo-randomly and evenly distributed within each block). Participants were instructed to maintain fixation on the monitor throughout the duration of the procedure and to avoid unnecessary movements.

Following completion of the passive viewing task, participants provided valence and arousal ratings using the Self-Assessment Manikin (SAM; Bradley and Lang, 1994) on a nine-point scale. For valence, images were rated from one indicating the most unpleasant to nine indicating the most pleasant, and for arousal from one indicating not at all arousing to nine indicating the most arousing. All IAPS images were shown in pseudo-random order until participant response via space bar (i.e., duration of images was self-paced) after which participants rated the image for valence then arousal using the numbers on a keyboard.

[1]Unpleasant: 2120, 2130, 2683, 2691, 2694, 3550, 6211, 6213, 6243, 6314, 6561, 6562, 6571, 6825, 6830, 6832, 6834, 6836, 9230, 9254, 9402, 9419, 9423, 9425, 9426, 9427; Neutral: 2002, 2026, 2038, 2102, 2190, 2200, 2211, 2214, 2220, 2308, 2309, 2385, 2393, 2396, 2397, 2411, 2484, 2487, 2493, 2495, 2512, 2570, 2595, 2749, 2840, 2890, 7497, 7640, 9070; Pleasant: 2045, 2058, 2071, 2075, 2150, 2155, 2158, 2160, 2208, 2209, 2216, 2303, 2345, 2347, 4597, 4599, 4601, 4603, 4610, 4612, 4623, 4626, 4628, 4640, 4641, 4645, 4689, 8380, 8496. Four unpleasant images were unintentionally included that did not prominently show people. These images were 2682, 6200, 6210, and 6410. These images were excluded from behavioral or EEG analyses. Additionally, images were not balanced across conditions with respect to the number of persons shown in each image. Images were also not balanced with respect to low-level visual features (e.g., luminance, complexity, or saturation). However, LPP condition-related effects appear robust against differences in low-level visual features (e.g., De Cesarei & Codispoti, 2011; Miskovic et al., 2015).

2.3 Electrophysiological Data Recording and Reduction

Continuous EEG was recorded using an ActiveTwo BioSemi amplifier (BioSemi, Amsterdam, Netherlands). EEG signals were pre-amplified at the electrode with a gain of one and were digitized at a sampling rate of 1,024 Hz with a 24-bit analog-to-digital converter (least significant bit: 31.25 nV). EEG was filtered online using a low-pass, fifth-order sinc filter with a half-power cut-off of 204.8 Hz. EEG was recorded from 64 active scalp electrodes placed based on the 10/20 system using a custom cap (Cortech Solutions, Wilmington, North Carolina, USA). Two additional scalp electrodes were placed on the left and right mastoids. Electrooculogram was recorded from four additional sensors placed above and below the left eye and near the outer canthi. Electrodes were referenced online to a common mode sense electrode that formed a monopolar channel and were algebraically rereferenced to averaged mastoids offline.

Data were subsequently filtered offline using ERPLab v6.1.4 (Lopez-Calderon and Luck, 2014). EEG data were digitally filtered using a sixth-order IIR Butterworth filter with half-amplitude cutoffs at .05 and 20 Hz. Stimulus-locked epochs were extracted for each image presentation and spanned from 200 ms prior to image onset to 1,000 ms following stimulus onset. Eye blinks and horizontal and vertical saccadic eye movement were then removed using independent components analysis (ICA)[2] implement in the ERP PCA Toolkit (Dien, 2010).

Following artifact correction, channels with more than a 100 μV step within 100 ms intervals, a voltage difference of 300 μV through the duration of the epoch, or an absolute correlation with the nearest six neighboring channels that fell below .4 were marked as bad for the epoch. Channels that were marked as bad for more than 20% of epochs were considered globally bad. Bad channels were interpolated using spherical splines (Perrin et al., 1989), but if more than 10% of channels were marked bad for an epoch, the entire epoch was rejected. The period from 200 ms to 0 ms prior to image onset was used for baseline adjustment.

Individual-subject ERPs were then analyzed, and EEG sites for analysis were chosen based on visual inspection and prior work (see Strauss et al., 2015). All ERPs were scored using a mean amplitude approach, which mitigates the impact of background noise on ERP measurements (Clayson et al., 2013; Luck, 2014). LPP amplitudes were extracted as the average activity from 400 to 1,000 ms across five centro-parietal sites (Pz, CPz, CP1, CP2, Cz). Early posterior negativity (EPN) amplitudes[3] were extracted as the average activity from 125 to 175 ms across five cento-occipital sites (POz, O1, Oz, O2, Iz).

2.3.1 ERP Score Internal Consistency.—

The internal consistency of scores was assessed to ensure that ERP scores met appropriate standards (Clayson, 2020; Clayson et

[2]For the ICA procedure, epoched EEG data from all channels were processed through a binary version of EEGLab's *runica* function called binica (Delorme and Makeig, 2004). Any ICA components that correlated at .9 or above with the scalp topography of a blink template and at .8 or above with the scalp topography of vertical and horizontal saccade templates were removed from the data. The templates that were used for artifact correction include those that were automatically generated by the ERP PCA Toolkit and those that were created by the present authors from the dataset.

[3]EPN analyses are presented in the supplementary material. EPN was not sensitive to condition effects in either group and was not significantly related to social anhedonia or psychiatric symptoms.

al., 2021b; Clayson and Miller, 2017b). The number of trials needed to achieve a reliability threshold of .70 was calculated. Generalizability theory was used to calculate dependability (ϕ), which is a measure of internal consistency analogous to coefficient alpha from classical test theory (see Baldwin et al., 2015; Brennan, 2001; Clayson et al., 2021a; Shavelson and Webb, 1991). ERP score reliability was separately examined for each stimulus type and group using the ERP Reliability Analysis Toolbox v 0.5.0 (Carbine et al., 2021; Clayson et al., 2021c; Clayson and Miller, 2017a). Data from three patients and three controls were excluded for having an insufficient number of trials to obtain adequate internal consistency. The overall internal consistency of ERP scores after excluding the six participants was reasonably high (patients: .81 < ϕs < .86; controls: .74 < ϕs < .88).

2.4 Data Analysis

Participant ratings of arousal and valence and LPP amplitudes were examined using a 2-Group (patients, controls) x 3-Condition (unpleasant, neutral, pleasant) repeated measures analyses of variance (ANOVAs). For all ANOVAS, *partial-eta*^{2} (η_p^2) was reported as a measurement of effect size, and a Huynh-Feldt epsilon adjustment was applied to correct for possible violations of sphericity for factors with more than two levels. Significant effects were followed up with contrasts of estimated marginal means. Two subgroup analyses examined possible LPP differences between psychotic disorder groups. The first analysis compared patients with schizophrenia versus other psychotic disorders, and the second compared patients with non-affective psychosis versus affective psychosis.

Regression analyses were then conducted to predict LPP amplitude from self-reported trait social anhedonia (SAS-Brief), group (controls vs. patients), and their interaction. Regression analyses were also performed to examine relationships between LPP amplitude and psychiatric symptoms. LPP amplitude was predicted from BPRS symptoms, group, and their interaction, using separate models for positive symptoms and negative symptoms.

3. Results

3.1 Sample Characteristics

The groups did not differ in age or race/ethnicity, but patients had a higher proportion of male participants than controls (see Table 1 for summary information and statistical analyses). Patients also had lower levels of education than controls as expected but did not differ in parental education. With regard to clinical symptoms, patients had higher BPRS-rated positive and negative symptoms, and endorsed higher social anhedonia, than controls.

3.2 Arousal and Valence Ratings

Participant arousal and valence ratings for the IAPS images presented are summarized in Table 2 and Figure 1.

3.2.1 Arousal Ratings.—A Group x Condition ANOVA yielded a main effect of condition, $F(2, 266) = 42.53$, $p < .01$, $\eta_p^2 = .24$, and a nonsignificant main effect of group, $F(1, 133) = 0.57$, $p = .45$, $\eta_p^2 = .004$. In addition, there was a significant Group x

Condition interaction, $F(2, 266) = 4.20$, $p = .02$, $\eta_p^2 = .03$. Regarding within-group effects, both groups separately rated unpleasant and pleasant images as more arousing than neutral images (unpleasant/pleasant > neutral, $|ts| > 2.1$, $ps < .001$). Patients with psychosis also rated pleasant images as more arousing than unpleasant images, $t(266) = 4.17$, $p < .001$, whereas controls rated pleasant and unpleasant images as similarly arousing, $t(266) = -.37$, $p = .71$. Regarding between-group effects, patients showed a smaller difference between unpleasant and neutral images and a larger difference between unpleasant and pleasant images than healthy controls did (patients: unpleasant minus neutral < controls: unpleasant minus neutral, patients: unpleasant minus pleasant > controls: unpleasant minus pleasant, $|ts| > 2.4$, $ps < .02$). Group differences were not observed for the differences between pleasant and neutral images, $t(266) = 0.04$, $p = .97$.

3.2.2 Valence Ratings.—

The Group x Condition ANOVA yielded a main effect of condition, $F(2, 266) = 522.02$, $p < .001$, $\eta_p^2 = .80$. Valence ratings were in the expected order (pleasant > neural > unpleasant), and the differences between each valence category were significant ($|ts| > 13.4$, $ps < .001$). The main effect of group and the Group x Condition interaction were not significant ($Fs < 0.3$, $ps > .11$).

3.3 Late Positive Potential

Grand average waveforms and voltage maps are shown in Figure 2, and LPP amplitudes are summarized in Table 2 and Figure 1. A Group x Condition ANOVA on LPP amplitudes[4] yielded main effects of group and condition, $F(1, 133) = 8.02$, $p < .01$, $\eta_p^2 = .06$; $F(2, 266) = 17.31$, $p < .001$, $\eta_p^2 = .12$, respectively. For the group effect, overall LPP was smaller in patients than in controls. For the condition effect, LPP amplitude was largest following pleasant images and decreased in the order of unpleasant and then neutral images (pleasant > unpleasant > neutral), and the difference between LPP amplitude to each valence type was significant ($|ts| > 2.5$, $ps < .02$). The Group x Condition interaction was not significant, $F(2, 266) = 0.83$, $p = .44$, $\eta_p^2 = .01$.

3.3.1 Subgroup Analyses.—

Patients with schizophrenia ($n = 44$) were compared to patients with other psychotic disorders ($n = 53$), which included bipolar I disorder, unspecific psychotic disorder, major depressive disorder with psychotic features, delusional disorder, schizophreniform disorder, and brief psychotic disorder (see Supplementary Table 1 for demographic information). A 2-Patient Group x 3-Condition ANOVA yielded a main effect of condition with a pattern consistent to the previous analysis, $F(2, 190) = 20.95$, $p < .001$, $\eta_p^2 = .18$. However, the main effect of patient group and interaction effect were not significant, $F(1, 95) = 0.90$, $p = .34$, $\eta_p^2 = .01$; $F(2, 190) = 0.31$, $p = .73$, $\eta_p^2 = .003$, respectively.

The non-affective psychosis group ($n = 65$) included patients with schizophrenia, an unspecified psychotic disorder, delusional disorder, schizophreniform disorder, and a

[4]The age range of the sample was wide, but groups were similar in age. An exploratory analysis was conducted that included age as a covariate in the ANOVA on LPP amplitudes. The main effects of group and condition remained significant ($ps < .01$), and the age covariate was not significant ($p = .93$). Therefore, the age range of the samples did not systematically bias the LPP results.

brief psychotic disorder, and the affective psychosis group[5] (n = 24) included patients with bipolar I disorder and major depressive disorder (see Supplementary Table 2 for demographic information). The ANOVA yielded a main effect of condition with a pattern consistent to the previous analysis, $F(2, 174) = 14.57$, $p < .001$, $\eta_p^2 = .14$. However, the main effect of patient group and interaction effect were not significant, $F(1, 87) = 0.18$, $p = .67$, $\eta_p^2 = .002$; $F(2, 174) = 0.40$, $p = .67$, $\eta_p^2 = .005$, respectively.

3.4 LPP Relationships with Social Anhedonia and Symptoms

Regression analyses predicted LPP amplitude[6] to each condition from SAS-Brief total scores, group (controls, patients), and their interaction (see Table 3). Higher SAS-Brief total scores were related to smaller LPP to pleasant images, β = −.21, p = .03 (see Figure 3). None of the remaining predictors from any of the models using the full sample were significant (|βs| < .16, ps > .29). Separate regression analyses were performed on the various subgroups and similarly yielded significant relationships between higher SAS-Brief total scores and smaller LPP to pleasant images (βs < −.24, ps < .03) and nonsignificant main effects of group and Group x SAS-Brief interactions (|βs| < .22, ps > .28).

Regarding BPRS-rated negative and positive symptoms, none of the predictors (symptom rating, group [controls, patients], and their interaction) were significant for any of the LPP task conditions (|βs| < .59, ps > .28; see Table 4). Regression analyses performed on the various subgroups similarly yielded nonsignificant group differences (|βs| < .47, ps > .11).

4. Discussion

Patients with a variety of psychotic disorders showed enhanced LPP to affiliative/threatening vs. neutral social images to a similar degree as healthy controls, despite lower overall LPP in patients. Further, no statistically significant LPP differences were seen among psychotic disorder subgroups, which is consistent with prior studies comparing non-affective and affective psychosis subgroups on paradigms using diverse image content (Culbreth et al., 2018; Trotti et al., 2021). Thus, intact motivated attention appears to extend beyond schizophrenia to other schizophrenia spectrum and affective psychotic disorders, even when using exclusively social images.

The patients' intact differentiation of LPP responses to emotional pictures were mostly consistent with the self-report data. Patients and controls reported similar valence ratings across pleasant, neutral, and unpleasant social images, which converges with many prior studies using diverse IAPS image content (Cohen and Minor, 2010). Regarding arousal ratings, however, the groups did differ. Although both groups reported higher arousal for emotional than neutral stimuli, controls reported similar arousal for pleasant and unpleasant stimuli whereas patients reported higher arousal ratings for pleasant than unpleasant stimuli.

[5]It is unclear whether schizoaffective disorder belongs to the affective psychosis group or the non-affective psychosis group. Therefore, patients with schizoaffective disorder were not included in the analysis. The inclusion of schizoaffective disorder in either group did not change the results. The main effect of group and interaction effect remained nonsignificant in both instances (ps > .36).

[6]Alternative regression analyses were conducted that predicted SAS Total scores from LPP amplitudes to each condition, group, and their interaction. Although all the overall models were significant (ps < .03), only LPP amplitude to pleasant images significantly predicted SAS total scores (β = −.20, p = .03). Therefore, group differences in SAS Total scores do not likely account for the relationship between LPP amplitude and SAS Total scores.

This atypical finding for patients stands in contrast to many laboratory-based studies finding normal arousal effects for images with mixed non-social and social stimuli (Llerena et al., 2012). Further, in studies that directly compared social vs. non-social stimuli within the same paradigm, patients have also shown normal arousal effects for socially-relevant images (Okruszek et al., 2016; Peterman et al., 2015). The current paradigm is somewhat unique in presenting exclusively social stimuli in the absence of any other type of IAPS image content, which may have influenced how patients experienced the pleasant affiliative images.

This study also explored whether individual differences in trait social anhedonia relate to LPP responses across diagnostic boundaries. Higher social anhedonia was significantly associated will LPP responses to affiliative images in the combined full participant sample. This relationship was not moderated by group status, with comparable associations present across patients and controls. Furthermore, this relationship held across psychotic disorder subgroups. Other research indicates that social anhedonia shows a domain-specific relationship with social stimuli over non-social stimuli in healthy participants (Chevallier et al., 2016; Xie et al., 2014) and those with depression (Ait Oumeziane et al., 2019), and a study of healthy participants similarly showed a small LPP to pleasant stimuli in a psychometrically defined social anhedonia group (Martin et al., 2020). The present research extends these findings by showing that social anhedonia relates to reduced attention to affiliative social stimuli in a transdiagnostic fashion. While these findings are broadly consistent with the RDoC framework, the magnitude of the association between self-report and ERP measures was small ($\beta = -.21$), which could be due to other LPP component processes including novelty detection and emotion regulation (Hajcak and Foti, 2020).

The study had some limitations. First, patients with were, on average, in their late forties and many years past the onset of psychosis; it is unclear whether the present findings would generalize to individuals in the early course of the illness. Second, patients were clinically stable and it is uncertain whether the results would differ during more symptomatic mood or psychotic episodes. Third, patients were receiving various antipsychotic and other psychotropic medications at clinically determined dosages, and their impact on LPP amplitude is unknown. In fact, some research indicates a beneficial impact of antipsychotics on emotional processing (Juckel et al., 2006; Schlagenhauf et al., 2007). Fourth, the present study focused on the early time course of LPP due to the focus on bottom-up processing of emotion, but abnormalities could be present during later stages of LPP or during paradigms that encourage the use of emotion regulation strategies (e.g., Bartolomeo et al., 2020; Strauss et al., 2013).

Despite these limitations, the current findings bolster the case that intact motivated attention, even for exclusively social images, is present in schizophrenia and extends to other psychotic disorders. Intact early “in-the-moment” physiological and experiential responses to emotional stimuli reflect an area of relatively preserved function, which contrasts markedly with the social isolation and community disengagement so commonly seen across psychotic disorders (Green et al., 2018; Green et al., 2020). Further work is needed to understand how these apparently normal initial responses unravel and fail to translate into social engagement and adaptive goal-directed behaviors (Pillny et al., 2020; Weittenhiller et al., 2021).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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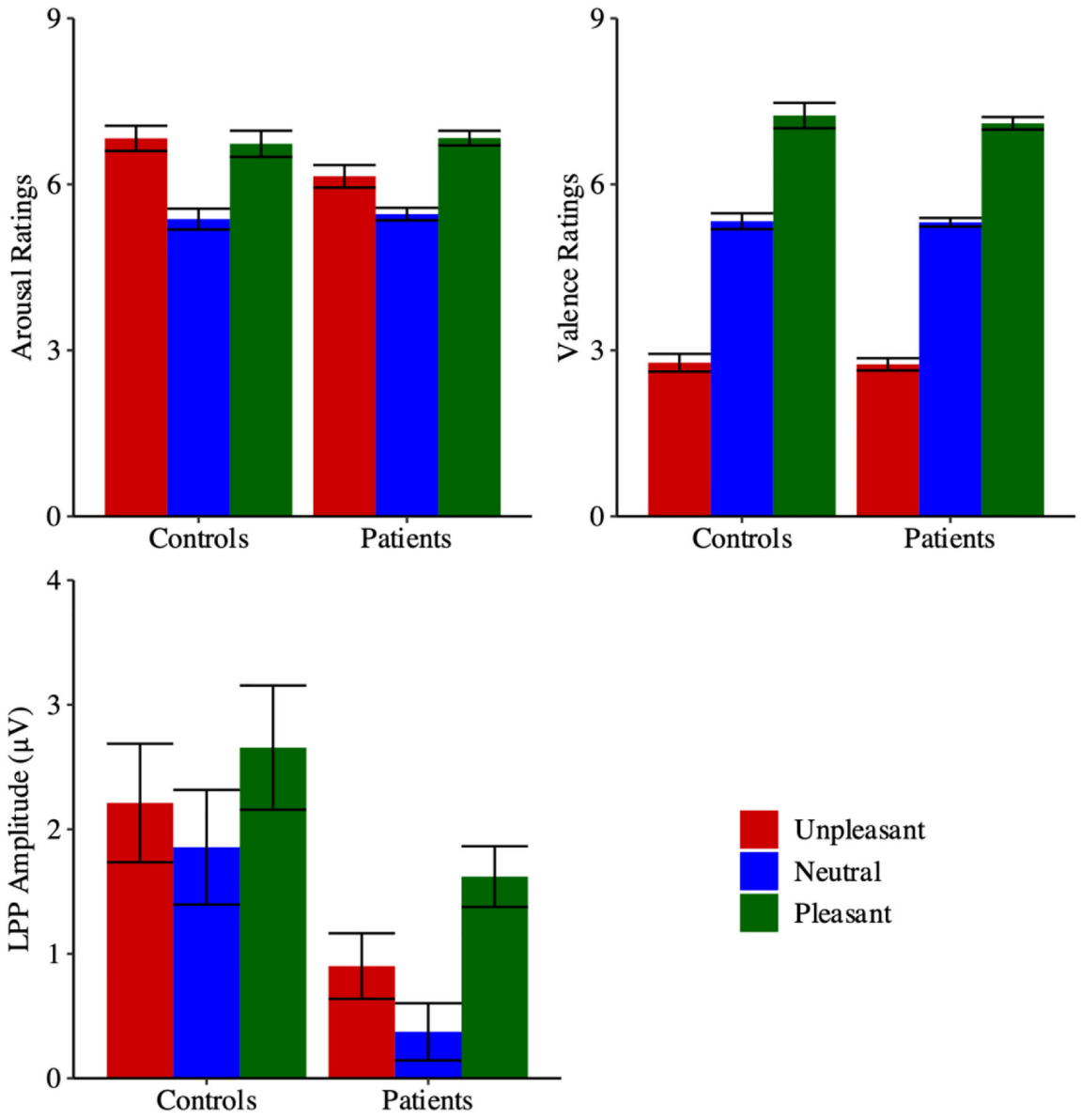

Figure 1.

Bar plots for arousal ratings, valence ratings, and late positive potential (LPP) amplitudes are separately shown for healthy controls and patients. The error bars represent the standard error of the mean.

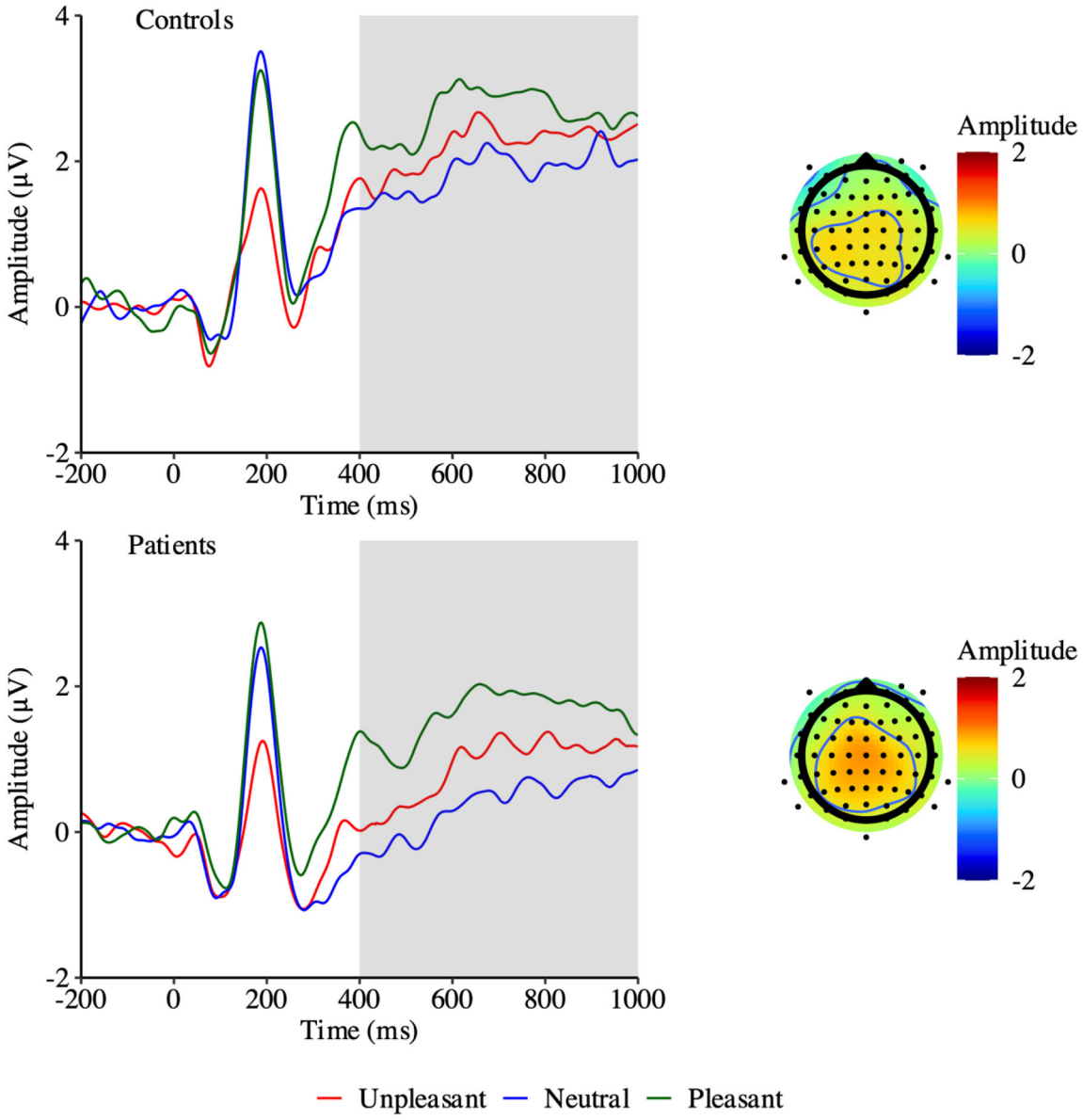

Figure 2.

Grand average waveforms for the late positive potential (LPP) separately shown for each stimulus type and group. Waveforms show activity over centro-parietal sites (Pz, CPz, CP1, CP2, Cz). Voltage maps show the weighted difference of activity between unpleasant and pleasant images against activity from neutral images from 400 to 1,000 ms, which corresponds to the temporal window from which LPP amplitudes were extracted (the gray background of the waveforms).

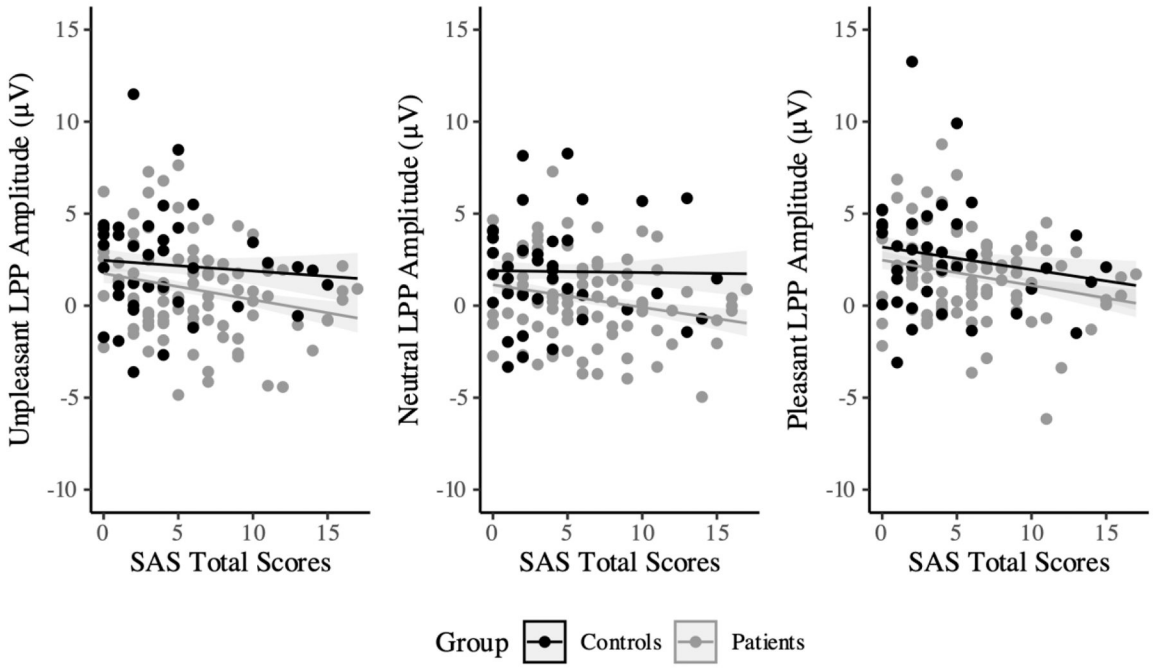

Figure 3.

Scatterplots showing the relationship between Social Anhedonia Scale – Brief (SAS) total scores and late positive potential (LPP) amplitude. Trend lines are shown separately for each group (controls vs. patients) based on the estimated marginal means from the regression models.

Table 1

Summary of Demographic Information and Clinical Symptoms

Characteristic	Controls		Patients			
	***n* = 38**		***n* = 97**			
	n		***n***			
Female/Male	11/27		28/69		$X^2 < 0.01$, $p > .99$	
Race					$X^2 = 6.10$, $p = .19$	
African American	8		39			
Asian	5		6			
Caucasian	22		42			
Hawaiian/Pacific Islander	1		2			
More than one race	2		8			
Ethnicity					$X^2 = 0.03$, $p = .87$	
Hispanic/Latino	4		13			
Not Hispanic/Latino	34		84			
	Mean	**SD**	**Mean**	**SD**	**t**	**p**
Age (yrs)	48.2	9.3	48.0	12.2	0.10	.92
Education (yrs.)	15.2	1.8	13.6	2.0	4.46	<.01
Parental Education (yrs.)[1]	14.8	2.7	14.2	3.6	1.06	.29
SAS-Brief Total Scores	4.3	4.3	6.2	4.2	−2.32	.02
Symptoms						
BPRS: Negative	1.2	0.2	2.0	0.9	−8.44	<.01
BPRS: Positive[2]	1.1	0.2	1.8	0.7	−7.54	<.01

Note:

[1]Information is missing for two controls and seven patients.

[2]Information is missing for four patients.

BPRS = Brief Psychiatric Rating Scale; SAS-Brief = Social Anhedonia Scale-Brief

Table 2

Summary of Arousal and Valence Ratings and the Late Positive Potential (LPP)

	Controls		Patients	
	Mean	***SD***	***Mean***	***SD***
Arousal Ratings				
Pleasant	6.7	1.5	6.8	1.3
Neutral	5.4	1.2	5.5	1.1
Unpleasant	6.8	1.4	6.1	2.0
Valence Ratings				
Pleasant	7.2	1.4	7.1	1.1
Neutral	5.3	0.9	5.3	0.8
Unpleasant	2.8	1.0	2.7	1.1
LPP Amplitude (μV)				
Pleasant	2.7	3.1	1.6	2.4
Neutral	1.9	2.8	0.4	2.3
Unpleasant	2.2	2.9	0.9	2.6

Table 3

Regression Models Predicting Late Positive Potential (LPP) Amplitude

	Unpleasant LPP			Neutral LPP			Pleasant LPP		
	β	SE	*t*	β	SE	*t*	β	SE	*t*
SAS Total	−.15	0.06	−1.61	−.11	0.06	−1.18	−.21	0.06	−2.18*
Group	.12	0.40	0.89	.14	0.37	1.05	.12	0.39	0.92
SAS x Group	.10	0.06	0.68	.14	0.06	1.00	.02	0.06	0.12
BPRS Negative	−.07	0.96	−.22	.17	0.87	0.55	−.09	0.93	−.28
Group	.16	1.18	0.40	−.01	1.07	−.02	0.18	1.15	0.45
BPRS x Group	.03	0.96	0.06	.40	0.87	0.70	−.04	0.93	−.07
BPRS Positive	−.25	1.02	−.95	.14	0.92	0.56	−.09	0.98	−.33
Group	.39	1.22	0.96	−.19	1.11	−.48	.07	1.17	0.16
BPRS x Group	−.30	1.02	−.54	.58	0.92	1.07	.09	0.98	0.17

Note: BPRS = Brief Psychiatric Rating Scale; SAS-Brief = Social Anhedonia Scale-Brief.

* $p < .05$