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Neural responses to criticism and praise vary with schizotypy and perceived emotional support

Running head: Electroencephalography of criticism and praise in schizotypy

Preethi Premkumar[1*], Miguel Granja Espírito Santo[1,2], Juliana Onwumere[3], Martin Schürmann[2], Veena Kumari[4], Stephanie Blanco[1], Joshua Baker[1], Elizabeth Kuipers[3,5]

[1]Department of Psychology, Nottingham Trent University, Nottingham, UK

[2]School of Psychology, University of Nottingham, Nottingham, UK

[3]King's College London, Department of Psychology, Institute of Psychiatry, Psychology and Neuroscience, London, UK

[4]Centre for Cognitive Neuroscience, College of Life and Health Sciences, Brunel University London, Uxbridge, UK

[5]NIHR Biomedical Research Centre for Mental Health, South London and Maudsley NHS Foundation Trust, London, London, UK

*Correspondence address:

Department of Psychology

Nottingham Trent University

Burton Street

Nottingham

NG1 4BU

Tel: +44 (0)115 848 4511

Email: Preethi.premkumar@ntu.ac.uk

Abstract

Schizotypy is a latent organisation of a cluster of personality styles, such as magical thinking, disorganisation and anhedonia, which are in the normal range of the psychosis continuum. Schizotypy relates to an increased likelihood of perceiving expressed emotion (EE). EE is characterised by criticism, rejection, and emotional over-involvement and less warmth from a close relative. Neuroimaging studies have found normal frontal lobe activation to EE-criticism in people with high schizotypy. Alternatively, electroencephalography measures emotion processing, such as frontal theta power and occipital alpha. Frontal theta power responds to cognitive and affective processes and occipital alpha power denotes less consciousness and emotional attention. This study aimed to determine the relation of these electroencephalography responses during criticism and praise to perceived emotional support. Participants (n=32) representing the full (low-to-high) range of positive schizotypy listened to and rated the self-relevance of EE-like criticism and praise and affectively neutral comments while undergoing electroencephalography. Participants completed self-report measures of schizotypy, depression and anxiety. A subset of those with a high positive schizotypy score (n=22) completed a measure of perceived EE - lack of emotional support. Higher perceived EE - lack of emotional support correlated with lower frontal theta power and lower occipital alpha power during criticism and praise in schizotypal participants. The findings suggest that these neural responses may relate to less perceived emotional support in people with high schizotypy, of which a reduction of frontal theta power denotes less emotional arousal and lower occipital alpha power denotes more alertness to emotional information.

Keywords: anxiety; brain imaging, depression, family communication, schizotypy, social support

1 Introduction

Schizophrenia is a severe mental disorder characterised by hallucinations, delusions, disorganised speech and emotional disorders (Heckers et al., 2013). In a milder and non-clinical form, people have schizotypal traits which refer to personality traits in the healthy population that are similar to psychosis to some extent, but suggest vulnerability for psychosis (Barrantes-Vidal et al., 2013). Schizotypy is the overall latent personality organisation and a theoretical construct denoting this vulnerability, while schizotypal traits are its measurable facets (Premkumar et al., 2018). Positive schizotypy consists of perceptual aberrations, hallucinatory experiences and magical thinking (Mason, Claridge & Jackson, 2006), many of which increase under situations of social threat (Green & Phillips, 2004). Cognitive disorganisation consists of social anxiety, moodiness, difficulty maintaining attention and difficulty making decisions (Mason et al., 2006). Introvertive anhedonia refers to withdrawal and lack of pleasure from physical and social sources.

Family expressed emotion (EE) is a close relative's expression of criticism, hostility, emotional over-involvement and less warmth towards a person experiencing mental distress (Leff & Vaughn, 1985). Criticism could be threatening (Silk et al., 2017). Criticism, when perceived as such by the patient, could relate to more depression and anxiety in patients with schizophrenia (Docherty et al., 2011; Kuipers et al., 2006). People with schizotypy could encounter more EE-criticism than people without schizotypy (Premkumar et al., 2013), and so could perceive more threat at higher levels of schizotypy alongside depression and more irritability from a close relative (Premkumar et al., 2019). Criticism is defined as 'a statement which by the manner in which it is expressed, constitutes an unfavourable comment upon the behaviour or personality of the person to whom it refers' (Leff & Vaughn, 1985). A vigilance for criticism could increase self-criticism and subsequent depression (Bolton, Barrowclough & Calam, 2009; Mogg, Bradley, Miles & Dixon, 2004).

Another facet of EE is positive comments. A positive comment (referred to here as praise) is a positive remark which expresses 'approval or appreciation of the behaviour or personality of the person to whom it refers' (Leff & Vaughn, 1985). Warmth from a carer towards a person at high risk of psychosis or a person recently diagnosed with schizophrenia can improve the symptoms of the person (Lee, Barrowclough & Lobban, 2014; Meneghelli et al., 2011; O'Brien et al., 2006). However, people with schizotypy may respond less to praise (Premkumar et al., 2019) and so not perceive warmth, one reason being social anhedonia. Social anhedonia denotes less pleasure from social situations (Horan, Brown & Blanchard, 2007) which could diminish appraisal of praise. Another reason for less perceived praise in relation to schizotypy could be the amount of intrusiveness the person perceives from a close relative (Premkumar et al., 2019).

The neural responses to criticism and praise have been documented in relation to schizotypy. Listening to a carer's criticism can increase the blood oxygen-level dependent (BOLD) activation of the superior frontal gyrus and posterior cingulate cortex in people with a high level of schizotypy and people with schizophrenia

(Premkumar et al., 2013; Rylands, McKie, Elliott, Deakin & Tarrier, 2011). Activating these two brain regions signifies that there are different neural responses to criticism, one denoting emotional sensitivity (superior frontal gyrus activation) and the other denoting self-referential thinking (posterior cingulate activation). The amount of emotional support perceived could buffer the neural response to social threat. A selective review noted that having a supportive environment related to lower activation of the frontal lobe when participants were exposed to rejection (Eisenberger et al., 2007; Premkumar, 2012), which implies that emotional support can buffer the painful impact of social rejection. On the other hand, people with schizotypy may be unresponsive to such emotional support. The neural response to praise in people with high schizotypy, compared with people without schizotypy, is one of lower activation of the insula and putamen (Premkumar et al., 2013), which could denote less reward perceived from praise. People with schizotypy may respond less to social reward than people with low schizotypy if they experience social anhedonia (Horan, Brown & Blanchard, 2007).

Complementing BOLD activation is electroencephalography (EEG) which is another measure of neural response. Spectral power is an EEG response that arises from the synchronised oscillation of a limited set of neuronal generators within a defined brain region (e.g. frontal and occipital cortices) and so could denote a specific cognitive function (Başar, 2012, review; Güntekin & Başar, 2014). Spectral power is a single value of electrical potential (square of amplitude) measured within a specific frequency band over the duration of a trial. This single value of electrical potential is averaged across many such trials to obtain the spectral power value. The frontal theta rhythm (4-7 Hz) is a slow wave that has been linked to sources from the medial frontal cortex, the anterior cingulate, the hippocampus and the thalamus (Karakaş, Erzengin & Başar, 2000; Mitchell, McNaughton, Flanagan & Kirk, 2008). Frontal theta activity is thought to increase alongside an increase in cerebral metabolism in the anterior cingulate (Pizzagalli et al., 2011). Frontal theta power denotes emotional arousal besides other cognitive functions (Karakaş et al. 2000). Midfrontal theta may serve as a gating function on the information processing flow in limbic regions (Knyazev, Slobodskoj-Plusnin & Bocharov, 2010; Pizzagalli, Oakes, & Davidson, 2003). Frontal theta power plays a role in detecting conflict and unexpected social rejection (Cristofori et al., 2013; van der Molen et al., 2017). In picture arousal paradigms, fronto-lateral theta power increases during both pleasant and unpleasant pictures and it relates to high scores on the behavioural motivation system in healthy participants (Balconi, Brambilla & Falbo, 2009). Contrastingly in dysphoric individuals, theta power at fronto-central sites (FC3 and FC4) is lower during the imagery of pleasant stimuli than unpleasant stimuli (Messerotti, Mennella, Buodo & Palomba, 2017), which could suggest that the frontal theta rhythm is susceptible to emotional blunting in people with affective disorders. Likewise, frontal theta power was found to be reduced during facial emotional processing in particular cases of schizophrenia (Ramos-Loyo et al., 2009), one explanation of which is less emotional arousal. However, an improvement in anxiety and depression following music therapy sees an increase in fronto-lateral theta power (Fachner, Gold &

Erkkilä, 2013), and so frontal theta power denotes an improvement in emotional arousal to positive emotions in patients with depression. Thus, the frontal theta system responds to positive and negative emotional induction, but it may be less responsive in people experiencing emotional blunting.

Occipital alpha power (8-12 Hz) is another EEG measure that reflects wakefulness and consciousness (Başar, 2012, review). Alpha power across the scalp increases when the eyes are closed and it reflects an idling state, a relaxed awareness without having to concentrate, as well as mental imagery of internally generated information in the absence of external stimulation (Bartsch et al., 2015. Conversely, occipital alpha power decreases upon sensory stimulation and visual attention, and it denotes higher cortical activation. Occipital alpha power is thought to originate from the visual cortex among other neural generators, especially when evoked by visual stimuli (Başar, 2012, review). The occipital cortex contains several small generators of the alpha rhythm that largely oscillate in synchrony (Başar, 2012). This rhythm is age-dependent, such that young adults elicit lower occipital alpha power in response to visual stimuli than young children and middle-aged adults. Occipital alpha power decreases when watching arousing pictures, when listening to emotional music and when having emotional dreams, findings which are consistent with the role of occipital alpha power in conscious processing of external information (Baumgartner, Esslen & Jäncke, 2006; Daoust, Lusignan, Braun, Mottron & Godbout, 2008). Conversely, alpha power increases across the parietal and occipital cortices during mental imagery of previously presented pleasant and unpleasant words more than during neutral words, because the scenes depicting the emotional words are imagined more and are more arousing than neutral words (Bartsch et al., 2015). The change in alpha power during mental imagery spans the left and right-lateral sites of the parietal and occipital cortices, e.g. CP3/CP4, P3/P4 and O1/O2 (Bartsch et al., 2015; Baumgartner et al., 2015; Daoust et al., 2008). Occipital alpha power reduces when a facial emotional expression changes from a neutral expression to any type of emotional expression, implying attention to any emotion (Campagnoli et al., 2019). Thus, lower occipital alpha power implies alertness and attention to ongoing visual emotional stimuli, but increased occipital alpha power implies internally generated mental imagery of emotions.

1.1 Current study

The current study aimed to determine whether the neural and behavioural responses to criticism and praise would relate to self-reported perceived EE – lack of emotional support in people with high positive schizotypy. Out of the LEE subscales, we chose to only examine EE-lack of support in relation to the neural response to criticism and praise because (1) lack of emotional support denotes less warmth from a close relative, (2) the positive reward system is diminished in schizotypy (Premkumar et al., 2013; Horan et al., 2007), meaning that people with schizotypy may not perceive emotional support, (3) greater perceived emotional support can buffer the neural response to social rejection, which is a type of EE (Eisenberger et al., 2007), and

(4) people with high schizotypy being exposed to high EE due to hostility would suggest that they lack emotional support (Premkumar et al., 2013; 2019). The primary hypothesis was that higher frontal theta power and lower occipital alpha power during EE-like criticism and praise would relate to greater perceived EE – lack of emotional support in people with high schizotypy. A further aim was to determine whether the neural and behavioural responses to criticism and praise would relate to greater schizotypy, depression and anxiety in people representing the normal to high range of schizotypy. The second hypothesis was that the neural responses and behavioural appraisal (self-relevance) of criticism and praise would relate to schizotypy, depression, anxiety and perceived EE, because people with schizotypy encounter high EE-criticism (Premkumar et al., 2013; 2019). Vigilance for threat could turn into self-criticism and depression (Bolton, Barrowclough & Calam, 2009; Mogg, Bradley, Miles & Dixon, 2004), and so increase perceived criticism. Social anhedonia in schizotypy could diminish an interest in social reward (Horan, Brown & Blanchard, 2007), such as praise.

2 Method

2.1 Participants

Thirty-two participants [mean age (S.D.) = 26.6 (7.4), % female = 52.4)] representing the full range of positive schizotypy were recruited from the general population through adverts placed on social networking websites for University students and through adverts in the local newspaper and community centres. Further adverts were placed on websites for people with spiritual or paranormal beliefs, and we attended a local wellbeing event that offered psychic communication and spiritual remedies to people. People from these communities were recruited because people from new religious movements score highly on positive schizotypy (Day & Peters, 1999). Positive schizotypy was measured by the unusual experiences subscale of the Oxford and Liverpool Inventory of Feelings and Experiences (O-LIFE) (Mason, Claridge & Jackson, 1995; Mason & Claridge, 2006). Twenty-two participants (68%) had high positive schizotypy, defined as a scored above 15 denoting the 75% percentile of the unusual experiences (positive schizotypy) subscale of the O-LIFE according to the scale norms (Mason and Claridge, 2006). The current sample (68%) had a higher percentage of participants with high positive schizotypy (68%) than a large healthy sample (n=318; 36%) (Premkumar et al., 2018). The current sample also had a lower percentage of participants with low positive schizotypy (12%), defined as a score below 4 denoting the 25th percentile of positive schizotypy, than the other healthy sample mentioned above (n=318; Premkumar et al., 2018; 29%). The high schizotypy group (n=22) had a similar age to the rest of the sample (n=10), 25.2 and 26.4 respectively, $t(30) = .43$, $p = .668$, and gender distribution (female:male), 11:11 and 7:3 respectively, Chi-square = 1.1, $p = .290$. All participants were chosen for this study because they spent at least 10 hours a week in contact with a family member (a parent, sibling or partner), either face-to-face or by phone. Other inclusion criteria were being aged between 18 and 45 years and not

having a current diagnosis of psychosis, neurological disorder, or a loss of consciousness for more than 5 minutes.

Ethical approval for the study was provided by the University's School of Social Sciences Research Ethics Committee (No. 2015/44). All participants provided written informed consent to their participation and were reimbursed for their time.

2.2 Assessments

2.2.1 Oxford-Liverpool Inventory of Feelings and Experiences

Positive schizotypy was measured with the unusual experiences subscale of the O-LIFE (Mason, Claridge & Jackson, 2006). The other schizotypal subscales were introvertive anhedonia (solitude and lack of enjoyment from general activity), cognitive disorganisation (social anxiety and difficulty focusing attention), and impulsive nonconformity (reckless behaviour). The scale has 104 items to which participants respond 'Yes' or 'No', e.g., 'Do your thoughts sometimes seem as real as actual events in your life?' The subscales had acceptable (0.7) to excellent (0.9) internal consistency (Cronbach's alpha).

2.2.2 Level of Expressed Emotion (LEE) scale

Perceived expressed emotion – lack of emotional support was measured from the 38-item version of the LEE scale (Cole & Kazarian, 1988; Gerlsma & Hale, 1997). The scale measures a person's perception of EE from a significant other towards the person in the last three months in terms of lack of emotional support, intrusiveness, irritability and criticism. The LEE - lack of emotional support subscale measures perceived empathy, tolerance and warmth from a close relative when the respondent is distressed, unwell or when things go wrong. The 19 items of the LEE - lack of emotional support subscale were rated on a 4-point Likert scale, that ranged from 'Untrue', 'More or less untrue', 'More or less true' to 'True'. Internal consistency of the subscales was acceptable (0.7) to excellent (0.9). The high schizotypy subset (n=22, as explained in section 2.1) completed the scale due to the decision to include the LEE as a measure at a later stage of data collection.

2.2.3 Depression, Stress and Anxiety scale (short form) (DASS-21)

Self-reported depression and anxiety were measured from the DASS. The depression subscale measures hopelessness and devaluation of life (Lovibond & Lovibond, 1995). The anxiety subscale measures physiological arousal and situational anxiety. Participants rated 21 items on a 4-point Likert scale, that ranged from 'Did not apply to me', 'Applied to me to some degree, or some of the time', 'Applied to me to a considerable degree, or a good part of time', to 'Applied to me very much, or most of the time'. Participants

referred to their past week when responding to the items. Internal consistency of the subscales was excellent in the present sample, Cronbach's alpha=0.9.

2.3 Criticism and praise appraisal task

The criticism and praise appraisal task consisted of listening to 40 standard criticisms, 40 standard praises and 40 standard neutral comments, each lasting from 5 to 10 seconds and delivered through headphones (Sennheiser HD-205) (Figure 1). Standard criticism and standard praise resembled EE-like remarks that a carer would make about the participant during the Camberwell Family Interview (Leff & Vaughn, 1985; Premkumar et al., 2013). The Camberwell Family Interview is the gold standard measure of carer EE-criticism. Neutral comments were about the weather, science and arts. The standard comments were developed in an earlier standardisation study (Premkumar et al., 2013). Criticism and praise were chosen as being those above the 60th percentile, while neutral comments were those below the 40th percentile of a larger set of comments that had been rated for arousal and relevance (Supplementary data). Although the number of words in each comment were equivalent between types of comments (ranging from 20-22), the duration of the spoken comments differed between comment type, Welch's $F(2,74)=85$, $p<.001$. The duration of criticism (mean duration=5.8s ± .9s) was shorter than the duration of praise (mean duration=6.4s ± .8s), $t(78)=2.71$, $p=0.02$, and shorter than the duration of neutral comments (mean duration=7.8s ± .5s), $t(78)=11.56$, $p<.001$. The duration of praise was also shorter than the duration of neutral comments, $t(78)=9.17$, $p<.001$.

EEG data were collected during the playing of the comments. After each comment, participants rated the self-relevance of each comment on an 11-point Likert scale ranging from 'Not at all relevant' to 'Very relevant' while attempting to imagine that those comments were passed by a close relative. EEG data were not collected during the self-rating of the comment. Participants responded by using a mouse to select a point on the Likert scale that was displayed on the computer screen. 120 trials were based on the 40 comments in each category, and were presented in a random order. Comments were separated by a three-second inter-trial interval. Half of the comments were spoken by a female and the other half by a male. Comments were spoken in a male or female voice, to consider gender differences in emotional prosody (Lattner, Meyer & Friederici, 2005). The gender in which the comments were spoken was switched between two stimulus sets, so that a comment that was spoken by a female in one stimulus set was spoken by a male in the other stimulus set. The two stimulus sets were counterbalanced between participants.

*** Insert Figure 1 about here ***

2.3.1 EEG recording

Participants' EEG response was recorded on a high-density (64-channel) BioSemi Active-Two amplifier (sampling rate=2,048 hertz; digitisation=24 bits). Electrode offsets (difference in microvolts of each channel from the Common Mode Sense electrode) were examined after electrode application and addressed if the absolute value was more than 20 microvolts. EEG data were analysed in EEGLAB (Delorme & Makeig, 2004). After resampling the data to 256 Hz and filtering the data (high pass >0.5 Hz and low pass <50 Hz), channels were re-referenced to average. Removal of artefacts in the EEG data took place in three stages of EEG data pre-processing. Firstly, atypical artefacts in continuous (un-epoched) data, such as segments of the EEG signals with high frequency spikes seen across many channels, were removed manually by visual inspection. Further, channels with abnormal activity patterns, based on the kurtosis of the signal amplitudes across all timepoints in any channel, were automatically rejected. Next, the data were epoched into time-limited and condition-wise trials (criticism, praise and neutral conditions). The EEG trial length was fixed at 7 s, beginning with a 2 s pre-stimulus interval before the onset of the comment, followed by 5 s listening (see further explanation of the selection of this trial duration below). Secondly, typical artefacts were removed after epoching. These bad trials had typical artefact waveforms that denoted eye-blinks, eye movements and spontaneous muscle activity and were identified by visual inspection following standard criteria and removed manually (Delorme & Makeig, 2004; Hari & Puce 2017, chapter 8). Next, an independent components analysis was performed on each participant's dataset. Here, epoched trials were submitted to independent components analysis decomposition using the algorithm runica (see Makeig et al., 1996, 1997), allowing for blind separation of the underlying component topographies. Thirdly, artefacts were moved after independent components analysis. Here, independent components denoting eye movement artefacts and spontaneous muscle activity were identified using standard criteria and removed (see examples in Jung et al. 2000a,b).

The comments were played in full to the participants, but the spectral power measurement of participants' neural response to the comments was restricted to a 2 s baseline and the first 5 s across all comments. This time-limited spectral power measurement was performed to avoid including a part of the spectral power response when no comment was being played at the end of the comments, as would have been the case for shorter comments. Measuring spectral power after the comment could introduce confounding variables related to processing silence. Another reason for fixing the spectral power response at 5 s of the comments was that the duration of the comments varied by condition, with criticisms lasting 5 s, praises lasting 6 s and neutral comments lasting 7 s (see section 2.3). Most of the information was presented in the first 5 s of the comments by when most meaning and the decision about the type of comment would have been made. Figure 1 presents a sample criticism and praise where it is easy to detect whether the comment was a praise or a criticism at the end of the first sentence. Further, delivering 40 such comments in each condition may have

acclimatised participants to recognise the comment type within the first 5 s of the comment and evoke an emotional response across comments of a certain type that was consistent with the affect of that comment type. To test whether the comment type was recognised within 5 s, 14 additional healthy University students took part in a brief experiment where they were asked to recognise a subset of 30 comments from the original set of comments (10 criticism, 10 praises and 10 neutral comments) as quickly as possible. Within-subjects analysis of variance revealed that recognition time as below 5 s and it differed by comment type, $F(2, 26) = 20.3$, $p < 0.001$. Recognition time was shorter for criticism, mean recognition time (S.D.) = 2.2 s (2.7) than praises, mean recognition time (S.D.) = 2.7 s (4.8), $t(13) = 7.9$, $p < 0.001$, and neutral comments, mean recognition time (S.D.) = 3 s (3.2), $t(13) = 2.9$, $p = 0.039$. Neutral comments were recognised quicker than praises, $t(13) = 3.1$, $p = 0.025$.

A fast Fourier transform (FFT) was applied to each artefact-free trial. The resulting spectral power was log-transformed to ensure Gaussian distribution (Marosi et al., 2001). Spectral power within each frequency band (theta, 4-7 Hz, and alpha, 8-12 Hz) was averaged across all trials within each emotion. Frontal theta power was measured at F3/FC3 and F4/FC4 sites consistent with evidence of increased theta power at these sites during mood induction (Balconi et al., 2009; Fachner et al., 2013; Messerotti et al., 2017) (Figure 2). Occipital alpha power was measured at P3/PO3 and P4/PO4 sites consistent with evidence of altered alpha power at these lateral sites of the parieto-occipital cortex during emotional stimulation (Bartsch et al., 2015; Baumgartner et al., 2006). Spectral power during the comment was calculated relative to a 2 s baseline. The pre-stimulus decrease in alpha amplitude could be due to the fixed 3-second interval between trial-end rating and stimulus onset of the following trial, with participants anticipating stimulus onset.

*** Insert Figure 2 about here ***

2.3.2 General Procedure

After giving informed consent, participants completed the O-LIFE in an initial meeting aimed for recruitment. In a subsequent visit, participants appraised the criticism, praise and neutral comments during which their EEG response was measured. Participants completed the self-report questionnaires on depression, anxiety and perceived EE at the end of the experiment.

2.4 Statistical analysis

To test the fidelity of the criticism and praise appraisal task, a within-subjects ANOVA was performed, with emotion (criticism, praise and neutral comments) as the independent variable and behavioural appraisal

(self-relevance) as the dependent variable. *Post hoc* Bonferroni-corrected t-tests compared the comments' self-relevance between pairs of emotions.

Several two-tailed Pearson correlational tests were performed. This correlational test was chosen because data for each variable were normally distributed, that is skewness ranged from -1.18 (standard error = 0.44) to 0.69 (standard error = 0.44), and kurtosis ranged from -1.30 (standard error = 0.86) to 1.29 (0.86). The neural responses, frontal theta power and occipital alpha power, were correlated against behavioural appraisal (self-relevance) during criticism and praise and self-reported questionnaire measures of perceived EE, schizotypy, depression, and anxiety. Behavioural appraisals (self-relevance) during criticism and praise were correlated against self-reported questionnaire measures of perceived EE, schizotypy, depression and anxiety. Statistical significance was set at $p \leq 0.05$ for all tests.

3 Results

3.1 Criticism and praise appraisal task

There was a significant main effect of emotion in the criticism and praise appraisal task [$F(2,60)=66.6$, $p<.001$]. Criticism was more relevant than neutral comments, [$t=9.0$, $p<.001$], and praise was more relevant than neutral comments, [$t=11.7$, $p<.001$]. The self-relevance ratings did not differ between criticism and praise, [$t=1.4$, $p=.545$].

3.2 Correlations of responses (neural and behavioural) of criticism and praise with measures of perceived EE, schizotypy, depression and anxiety

3.2.1 Neural response

In participants with high positive schizotypy (n=22), there was a significant correlation of perceived EE - lack of emotional support with lower frontal theta power during criticism and praise (Table 1). Perceived EE - lack of emotional support also correlated with lower occipital alpha power during criticism and praise. As denoted by the coefficient of determination, R^2, frontal theta power during criticism and frontal theta power during praise each explained 37% of the variance in perceived EE – lack of emotional support (Figure 3). Occipital alpha power during criticism explained 21% of the variance in perceived EE – lack of emotional support. Occipital alpha power during praise explained 19% of the variance in perceived EE - lack of emotional support. Frontal theta power during criticism and praise also correlated positively with occipital alpha power during criticism and praise, $r > 0.49$, $p < .001$. In the full sample (n=32), greater frontal theta power during criticism and praise correlated with greater overall schizotypy (O-LIFE total). This relationship was absent in the high schizotypy subgroup (n=22), $r < .19$, $p < .2$.

A Pearson correlation was performed between the neural responses, frontal theta power and occipital alpha power, during neutral comments and perceived EE - lack of emotional support to check whether the association extended to the non-emotional condition. Perceived EE – lack of emotional support correlated with lower frontal theta power during neutral comments, $r = .57$, $p = .007$, but not with lower occipital alpha power during neutral comments, $r = -.41$, $p = .064$.

3.2.2 Behavioural appraisals

In the full sample (n=32), there was a correlation of greater relevance of criticism with greater O-LIFE impulsive non-conformity, O-LIFE total, DASS depression, and DASS anxiety, and at trend level with O-LIFE cognitive disorganisation and O-LIFE introvertive anhedonia. There was a correlation of greater relevance of praise with lower O-LIFE unusual experiences, O-LIFE cognitive disorganisation, O-LIFE impulsive non-conformity, O-LIFE total, DASS depression, DASS anxiety, and at a trend level with O-LIFE introvertive anhedonia (Table 1). Neither the relevance of criticism nor praise correlated with LEE-lack of emotional support.

*** Insert Table 1 and Figure 3 about here ***

4 Discussion

EE is considered an important risk factor in the relapse of psychosis (Bebbington & Kuipers, 1994; López et al., 2004). Yet, the neural and behavioural responses to perceived EE and their relation to schizotypy and social distress have seldom been addressed. Warmth could alleviate social distress, and so reduce the risk of psychosis relapse (Lee, Barrowclough & Lobban, 2014; O'Brien et al., 2006). Our first hypothesis was that a greater neural response to criticism and praise (i.e. higher frontal theta power and lower occipital alpha power) would relate to a greater level of perceived EE – lack of emotional support. As hypothesised, lower occipital alpha power related to perceived EE – lack of emotional support. However, lower, rather than greater, frontal theta power during criticism and praise related to perceived EE – lack of emotional support.

The second hypothesis was that a greater neural response to, and behavioural appraisal of criticism and praise would relate to perceived EE, schizotypy, depression and anxiety. Greater frontal theta power during criticism and praise related to greater overall schizotypy. Greater self-relevance of criticism related to the schizotypal trait of impulsive non-conformity, overall schizotypy, depression and anxiety. Greater self-relevance of praise related to a lower level of all schizotypal traits (except introvertive anhedonia), depression, and anxiety. The behavioural appraisal of criticism and praise did not relate to perceived EE.

4.1 Appraisal of criticism and praise, and its relation to schizotypy, depression, and anxiety

4.1.1 Neural response to criticism and praise (EEG results)

The relation of greater frontal theta power during criticism and praise to greater overall schizotypy across the whole sample could suggest that schizotypy relates to greater emotional arousal during criticism and praise when schizotypy is within the normal range. One explanation for the relation of lower frontal theta power during criticism and praise, to perceived EE-lack of emotional support could be reduced emotional arousal due to EE (Balconi, Brambilla & Falbo, 2009). Perceived EE-lack of emotional support denotes less perceived warmth, reassurance and empathy from a close relative. Frontal theta power decreases when visualising pleasant stimuli among people with dysphoria (Messerotti et al., 2017), implying that people with dysphoria have less affective reactivity to positive emotion. The frontal theta rhythm is linked to sources arising from the anterior cingulate (Mitchell et al., 2008) and it increases with an increase in cerebral metabolism in the anterior cingulate derived from positron emission tomography (Pizzagalli et al., 2011). People with depression fail to show a BOLD increase in the anterior cingulate during criticism (Hooley et al., 2008). The current study's findings supports all of this evidence linking lower frontal theta power to a lower level of emotional arousal. Without adequate warmth, people with schizotypy may not engage the frontal theta system, which suggests that emotional arousal may be blunted during verbal communication in the absence of warmth in this group.

The relation of lower frontal theta power to perceived lack of emotional support also extended to frontal theta power during neutral comments. Increased frontal theta power is typically associated with increased emotional arousal, but it is also observed during non-arousing scenes (Balconi et al. 2009). Regardless of emotional valence, the frontal theta power system may be susceptible to emotional distress arising from lack of social support. Frontal theta power was reduced during facial emotional processing regardless of emotional valence in schizophrenia (Ramos-Loyo et al., 2009), which could imply less emotional arousal in general. Resting-state frontal theta power increases after three months of remission from anxiety symptoms in patients with depression receiving music therapy, further suggesting that the frontal theta power system in a non-emotional context is responsive to long-term positive emotional induction (Fachner, Gold & Erkkilä, 2013).

On the other hand, lower occipital alpha power during criticism and praise related to greater perceived EE-lack of emotional support from a significant other. Lower occipital alpha power denotes greater cortical activation, and so denotes greater alertness and emotional attention (Başar, 2012, review). Visualising emotional words and sounds is another explanation of lower occipital alpha power (Baumgartner, Esslen & Jäncke, 2006). The relation between lower occipital alpha power and perceived EE-lack of emotional support in this sample could mean that people with schizotypy are alert to criticism and praise (the latter of which may be disbelieved) when their close relative is not supportive.

The findings concerning the direct relation between lower frontal theta power and lower occipital alpha power, and in turn and their relation to perceived lack of emotional support are seemingly contradictory, because lower frontal theta power denotes less emotional arousal, while lower occipital alpha power denotes greater emotional attention. Frontal theta power increases when viewing arousing pictures (Balconi, Brambilla & Falbo, 2009) and it is reduced during the imagery of arousing stimuli in people with dysphoria and patients with schizophrenia (Messerotti, Mennella, Buodo & Palomba, 2017; Ramos-Loyo et al., 2009). Lower occipital alpha power denotes greater emotional attention, because occipital alpha power decreases when watching arousing pictures, when listening to emotional music and when having emotional dreams, (Baumgartner, Esslen & Jäncke, 2006; Daoust, Lusignan, Braun, Mottron & Godbout, 2008) and when a facial emotional expression changes from a neutral expression to another emotional expression, implying attention to any emotion (Campagnoli et al., 2019). These opposing correlations, lower frontal theta power and its relation with perceived lack of emotional support on the one hand and lower occipital alpha power and its relation with perceived lack of emotional support on the other, suggest that the alpha and theta spectral power rhythms are dissociable and relate to different mental processes when evaluating criticism and praise, and so relate differently to perceived EE. Perceived lack of emotional support may relate to diminished emotional arousal underlying frontal theta power, whilst also relating to increased attention to emotional words and sounds underlying occipital alpha power.

4.1.2 Behavioural appraisal of criticism and praise

Lower behavioural appraisal of praise related to a higher level of positive schizotypy, cognitive disorganisation and overall schizotypy. The findings support earlier neuroimaging evidence of a diminished neural response to praise in people with high schizotypy (Premkumar et al., 2013) and recent evidence of a relation between less perceived praise and greater schizotypy due to greater perceived intrusiveness from a close relative (Premkumar et al., 2019). People with schizotypy tend to avoid social situations because they find them unrewarding (Horan, Brown & Blanchard, 2007). Appraisals of praise and criticism play a role in relational situations, such as emotional adjustment and relationship satisfaction (Renshaw, 2008). Greater warmth from family carers can reduce the likelihood of the initial onset of psychosis and subsequent relapse to psychotic state (Lee, Barrowclough & Lobban, 2014; O'Brien et al., 2006). Greater activation of the amygdala during maternal praise relates to less anxiety (Aupperle et al., 2016), which suggests that greater neural response to praise can relate to lower distress. These findings emphasise the relation between perceived EE – warmth and vulnerability for psychosis.

In this study, greater behavioural appraisal of criticism related to overall schizotypy and impulsivity, the latter of which denotes hostile and reckless behaviour (Ramírez & Andreu, 2006). Schizophrenia patients

make three times as many criticisms when interacting with a high EE relative and display more anxious/agitated and hostile/unusual behaviour during these exchanges (Miklowitz et al. 1989). This relationship between EE and hostility in schizophrenia may extend to the people with schizotypy. Greater behavioural appraisal of criticism on the one hand, and lower behavioural appraisal of praise on the other, related to depression and anxiety. Schizotypy, depression and anxiety are closely related (Premkumar et al., 2019; Rey, Jouvent & Dubal, 2009), because maladaptive meta-cognitive beliefs feature in schizotypy, depression and anxiety (Debbané et al., 2012). Greater perceived criticism relates to depression in married couples (Gerlsma & Hale, 1997; Peterson-Post, Rhoades, Stanley & Markman, 2014). Maternal criticism in adolescence may relate to greater perceived criticism and self-criticism, which in turn increases the likelihood of subsequent depression and anxiety, such as feeling hopeless and devalued (Bolton, Barrowclough & Calam, 2009; Nelemans et al., 2014; Yamaguchi & Kim, 2013). The findings suggest that perceived criticism, schizotypy, depression and anxiety are inter-related.

4.2 Outlook and implications

A limitation of the study was that the LEE was only administered to a subset of participants, namely those scoring above the 75th percentile of positive schizotypy, due to the decision to include the LEE as a measure at a later stage of data collection. The relation of the neural response to criticism and praise with perceived EE along the full continuum of schizotypy needs to be determined. Also, participants were not screened for any psychiatric diagnosis using a structured interview, e.g. Structured Clinical Interview for DSM-5 (First, Williams, Karg & Spitzer, 2015). Having a psychiatric disorder can increase the likelihood of perceived criticism and social distress (Butzlaff & Hooley, 1998; review). Besides age and gender, other demographic characteristics that could have covaried with schizotypy, such as the level of education, ethnicity and drug usage (Fergusson, Horwood & Swain-Campbell, 2003), were not ascertained. The link of the neural response to criticism and praise with perceived EE did not extend to the behavioural appraisal of criticism and praise. The ecological validity of the criticism and praise appraisal task could be further tested. The analyses did not correct for multiple comparisons in the level of statistical significance because the correlations of the neural responses with other measures of schizotypy, depression and anxiety were exploratory. Finally, the restricted range of schizotypy in the current sample may exaggerate the relation of the appraisals of criticism and praise to schizotypy.

In summary, the neural responses from the frontal theta and occipital alpha frequency bands to criticism and praise have opposing links to perceived EE-lack of emotional support in people with high schizotypy, which suggests that the two spectral power systems are dissociable. Further, the behavioural appraisal of criticism and praise is associated with social distress and schizotypy. These findings support

evidence for a link between schizotypy and perceived EE. These findings have theoretical implications for the mechanisms of family-based psychological interventions, which are recommended treatments in schizophrenia (e.g. Galletly et al., 2016; National Institute of Health and Clinical Excellence, 2014). Family and individual intervention can help people at a high risk of psychosis to think less self-referentially about criticism and be more alert to praise. These findings support the evidence that family-based interventions for psychosis are effective when they include a focus on improving supportive communication (Bird et al., 2010; Claxton, Onwumere & Fornells-Ambrojo, 2017).

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Figure legends

Figure 1. Schematic diagram of the order of events per trial

Figure 2. Grand average (n = 32 participants) event-related spectral power in decibels (dB). Frontal theta power (4-7 Hz) at the (a) F3/FC3 and (b) F4/FC4 electrode sites and occipital alpha (8-12 Hz) power at the (c) P3/PO3 and (d) P4/PO4 electrode sites. The dB scale is relative to baseline of -2 to 0 s

Figure 3. Scatterplot of frontal theta power (4-7 Hz) in log-transformed microvolts [$10*\log_{10}(\mu V^2/Hz)$] during (a) criticism and (b) praise, and occipital alpha power (8-12 Hz) during (c) criticism and (d) praise, against Level of Expressed Emotion scale – lack of emotion support in participants with high schizotypy (n=22). Theta and alpha power averaged across hemispheres. The Level of expressed emotion scale measures the participant's perception of poor communication from a significant other, including their lack of emotional support. A high score indicates poor communication. The negative slopes are the line of best fit of the data points and they indicate that lower frontal theta power and lower occipital alpha power relate to a lack of emotional support from a significant other. The coefficient of determination, R^2, indicates the amount of variance in perceived EE - lack of emotional support that was explained by frontal theta power and occipital alpha power during criticism and praise.

Table 1. Pearson correlations, r (two-tailed p), between self-relevance ratings, frontal theta power (4-7 Hz) and occipital alpha power (8-12 Hz) of criticism and praise, and self-report measures (LEE – lack of emotional support, O-LIFE, and DASS)

	LEE-Lack of emotional support	Relevance of criticism	Relevance of praise	O-LIFE unusual experiences	O-LIFE cognitive disorganisation	O-LIFE introvertive anhedonia	O-LIFE impulsive non-conformity	O-LIFE total	DASS depression	DASS anxiety
	(n=22) †	---------- (n=32) ----------								
Mean (S.D.)	41.15 (11.91)	5.28 (1.92)	5.92 (1.26)	16.94 (9.74)	15.56 (6.83)	9.09 (5.89)	11.81 (4.25)	53.6 (21.7)	14.25 (11.11)	12.41 (10.40)
Spectral power (neural appraisals)										
Frontal theta power (Criticism)	**-.61 (.003)**	-.05 (.780)	-.15 (.396)	.32 (.078)	.20 (.259)	.24 (.171)	.19 (.29)	**.33 (.030)**	.14 (.443)	.19 (.303)
Frontal theta power (Praise)	**-.60 (.003)**	-.03 (.868)	-.18 (.324)	.33 (.066)	.21 (.245)	.26 (.157)	.22 (.23)	**.35 (.025)**	.15 (.413)	.18 (.323)
Occipital alpha power (Criticism)	**-.45 (.035)**	-.08 (.765)	-.18 (.314)	<.01 (.984)	.04 (.843)	-.01 (.937)	.07 (.70)	.02 (.449)	-.14 (.455)	-.10 (.592)
Occipital alpha power (Praise)	**-.43 (.050)**	-.05 (.789)	-.18 (.336)	.03 (.867)	.05 (.783)	<.01 (.997)	.07 (.71)	.04 (.414)	-.08 (.660)	-.07 (.688)
Relevance of comments (behavioural appraisals)										
Relevance of criticism	.03 (.891)	-	.15 (.426)	.16 (.369)	.33 (.061)	.34 (.058)	**.45 (.01)**	**.31 (.040)**	**.48 (.005)**	**.42 (.018)**
Relevance of praise	-.06 (.781)	.15 (.426)	-	**-.36 (.043)**	**-.40 (.022)**	-.34 (.054)	**-.40 (.03)**	**-.43 (.007)**	**-.42 (.017)**	**-.47 (.007)**

Bold text indicates correlation is significant at 0.05 level of significance; †only those scoring above the 75th percentile of positive schizotypy were administered the LEE; frontal theta power and occipital alpha power were calculated as average of spectral power at left and right hemispheres; DASS - Depression, Anxiety and Stress scale; O-LIFE – Oxford-Liverpool Inventory of Feelings and Experiences.

Supplementary data. Ratings of the arousal and relevance of 100 criticisms, 100 praises and 100 neutral comments by an independent sample of 24 healthy participants

In an earlier standardisation study, 24 Psychology lecturers or post-graduate students (12 males and 12 females who had little or no anxiety) rated the arousal and relevance of 100 criticisms, 100 praises and 100 neutral comments. The criticism and praise in the top 40th percentile and neutral comments in the bottom 40th percentile were selected for the family communication evaluation task in the present study. Out of the 100 comments in each comment type, criticism and praise in the top 40th percentile were more arousing and relevant than neutral comments in the bottom 40th percentile, while praise were more relevant than criticism (Table A.1).

Table A.1. Arousal and relevance ratings of 40 criticisms, 40 praises and 40 neutral comments by 24 raters in the standardisation study

	Mean (S.D.)	Criticism vs. neutral mean difference (*p*)	Praise vs. neutral mean difference (*p*)	Criticism vs. praise mean difference (*p*)
Criticism				
Arousal	5.67 (1.89)	3.36 (<0.001)		-0.81 (0.161)
Relevance	4.33 (1.85)	2.44 (0.001)		-1.94 (0.002)
Praise				
Arousal	6.48 (1.58)		4.17 (<0.001)	
Relevance	6.27 (1.79)		4.38 (<0.001)	
Neutral comment				
Arousal	2.31 (1.87)			
Relevance	1.89 (1.87)			

Arousal rated as 'How arousing is this comment?', 0='Not at all' and 10='Very Relevant'; Relevance rated as 'How strongly do you relate to this comment?', 0='Not at all' and 10='Very Strongly'.

Figure 1

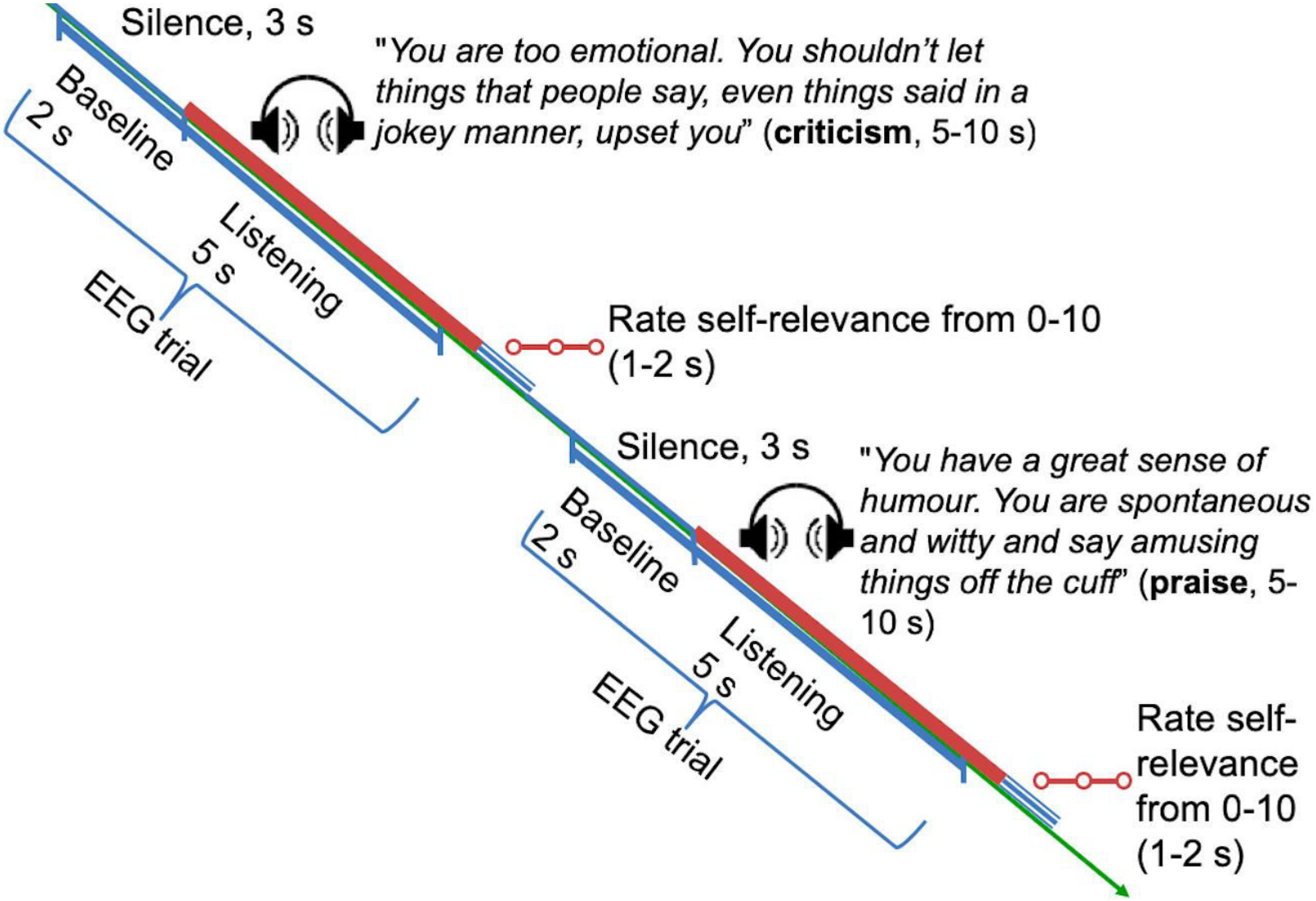

Silence, 3 s
"You are too emotional. You shouldn't let things that people say, even things said in a jokey manner, upset you" (criticism, 5-10 s)
Baseline 2 s
Listening 5 s
EEG trial
Rate self-relevance from 0-10 (1-2 s)
Silence, 3 s
"You have a great sense of humour. You are spontaneous and witty and say amusing things off the cuff" (praise, 5-10 s)
Baseline 2 s
Listening 5 s
EEG trial
Rate self-relevance from 0-10 (1-2 s)

Figure 2

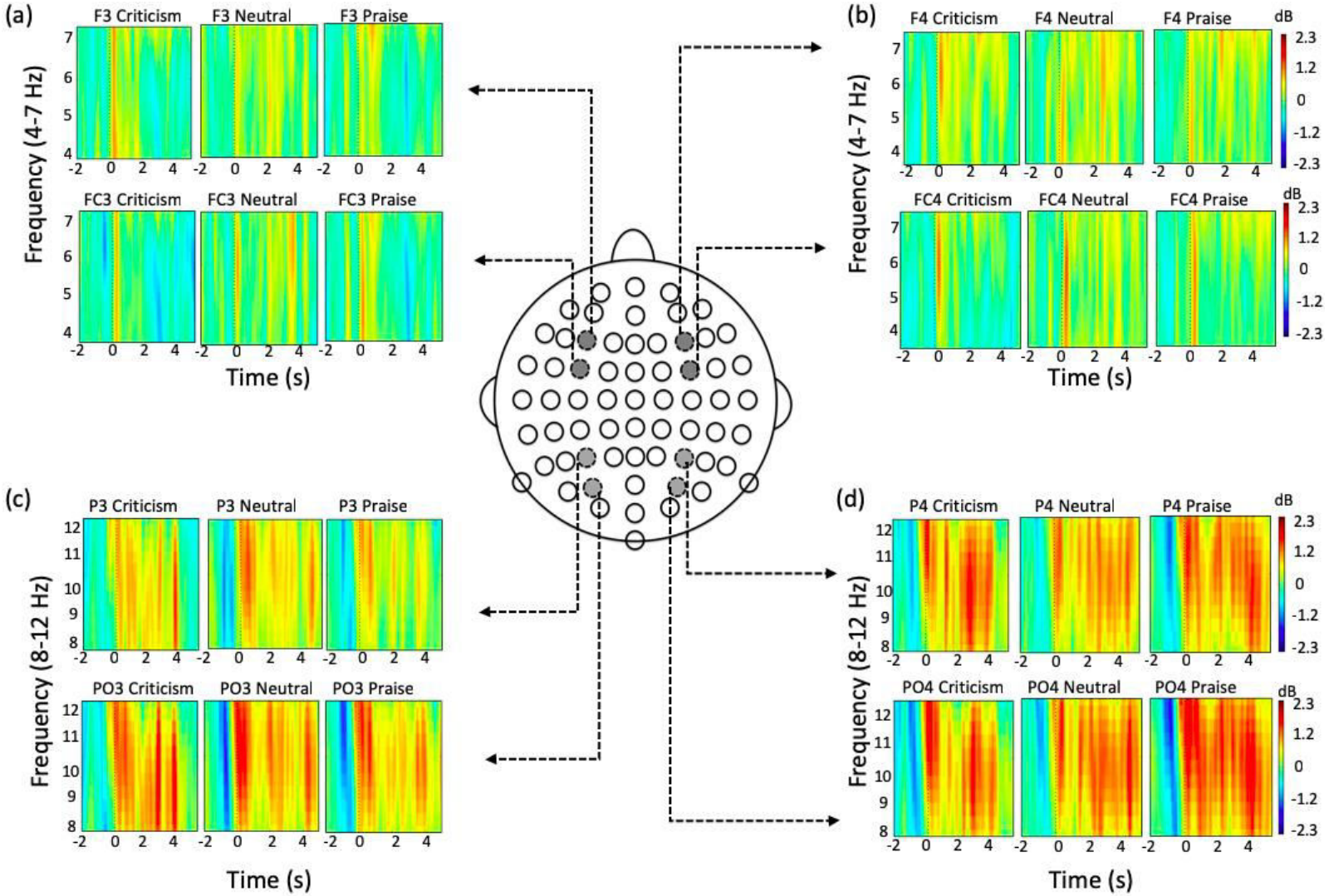
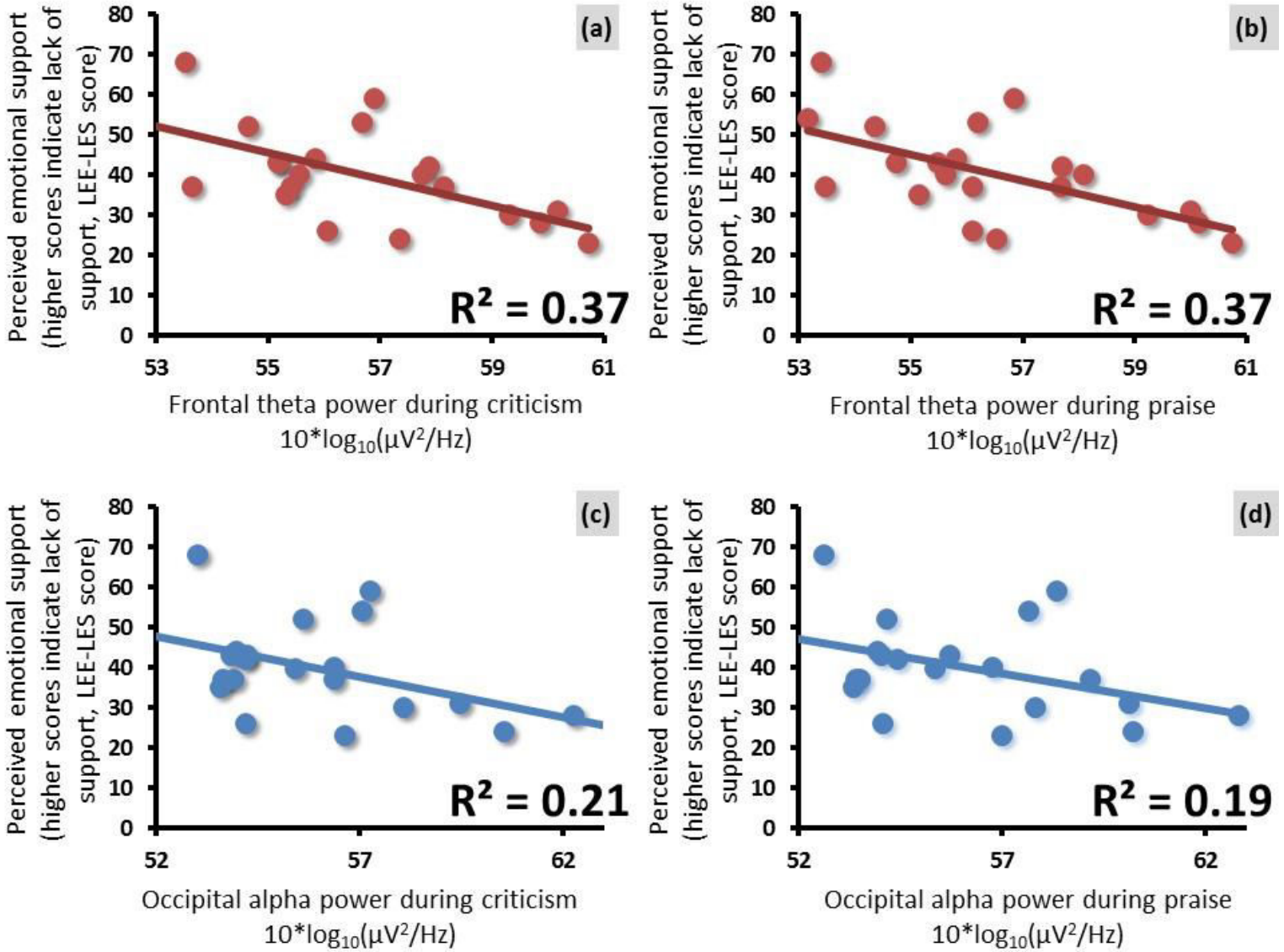

(a)
F3 Criticism
F3 Neutral
F3 Praise
FC3 Criticism
FC3 Neutral
FC3 Praise
Frequency (4-7 Hz)
Time (s)
(b)
F4 Criticism
F4 Neutral
F4 Praise
FC4 Criticism
FC4 Neutral
FC4 Praise
dB
2.3
1.2
0
-1.2
-2.3
(c)
P3 Criticism
P3 Neutral
P3 Praise
PO3 Criticism
PO3 Neutral
PO3 Praise
Frequency (8-12 Hz)
(d)
P4 Criticism
P4 Neutral
P4 Praise
PO4 Criticism
PO4 Neutral
PO4 Praise

Figure 3


(a)
Perceived emotional support (higher scores indicate lack of support, LEE-LES score)
80
70
60
50
40
30
20
10
0
53
55
57
59
61
R² = 0.37
Frontal theta power during criticism
10*log10(μV²/Hz)
(b)
Perceived emotional support (higher scores indicate lack of support, LEE-LES score)
R² = 0.37
Frontal theta power during praise
10*log10(μV²/Hz)
(c)
Perceived emotional support (higher scores indicate lack of support, LEE-LES score)
52
57
62
R² = 0.21
Occipital alpha power during criticism
10*log10(μV²/Hz)
(d)
Perceived emotional support (higher scores indicate lack of support, LEE-LES score)
R² = 0.19
Occipital alpha power during praise
10*log10(μV²/Hz)