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Greater positive schizotypy relates to reduced N100 activity during rejection scenes

Running head: Schizotypy and rejection sensitivity

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Abstract

Social anxiety due to rejection sensitivity (RS) exacerbates psychosis-like experiences in the general population. While reduced dorsal anterior cingulate cortex (dACC) activity during social rejection in high schizotypy has suggested self-distancing from rejection, earlier stages of mental processing such as feature encoding could also contribute to psychosis-like experiences. This study aimed to determine the stage of mental processing of social rejection that relates to positive schizotypy. Forty-one healthy participants were assessed for schizotypy and RS. Event-related potential amplitudes (ERPs) were measured at frontal, temporal and parieto-occipital sites and their cortical sources (dACC, temporal pole and lingual gyrus) at early (N100) and late (P300 and late slow wave, LSW) timeframes during rejection, acceptance and neutral scenes. ERPs were compared between social interaction types. Correlations were performed between positive schizotypy (defined as the presence of perceptual aberrations, hallucinatory experiences and magical thinking), RS and ERPs during rejection. Amplitude was greater during rejection than acceptance or neutral conditions at the dACC-P300, parieto-occipital-P300, dACC-LSW and frontal-LSW. RS correlated positively with positive schizotypy. Reduced dACC N100 activity during rejection correlated with greater positive schizotypy and RS. Reduced dACC N100 activity and greater RS independently predicted positive schizotypy. An N100 deficit that indicates reduced feature encoding of rejection scenes increases with greater positive schizotypy and RS. Higher RS shows that a greater tendency to misattribute ambiguous social situations as rejecting also increases with positive schizotypy. These two processes, namely primary bottom-up sensory processing and secondary misattribution of rejection, combine to increase psychosis-like experiences.

Key words: Dorsal anterior cingulate cortex, event-related potential, rejection sensitivity, schizotypy

Highlights

- Lower dorsal anterior cingulate N100 activity relates to more positive schizotypy
- Greater rejection sensitivity relates to greater positive schizotypy
- dACC N100 activity and rejection sensitivity separately predict positive schizotypy

Social anxiety is the expectation of being embarrassed or seen in a negative light by others (Lysaker et al., 2010) and is a common comorbidity of schizophrenia (Achim et al., 2011; American Psychiatric Association, 2013). In particular, rejection sensitivity (RS) is a type of social anxiety where the person believes he/she is being rejected in ambiguous interpersonal situations and overreacts to disengagement expressed by others (Downey & Feldman, 1996). The person then seeks reassurance, feels vulnerable about their relationships, and/or shows retaliation and aggression (Grant & Beck, 2009; Langens & Schuler, 2005; Lemay & Clark, 2008; Sinclair, Ladny, & Lyndon, 2011). Social anxiety can increase psychosis-like experiences (PLEs) in vulnerable populations (Bentall, Claridge, & Slade, 1989; Olin & Mednick, 1996; Raine et al., 1994) and exacerbate positive symptoms of psychosis, such as paranoia and delusions, via different pathways including avoidance (Achim et al., 2013; Lysaker et al., 2010). Likewise, RS increases with greater general psychopathology in individuals at risk for psychosis (A. P. Morrison et al., 2006) and is greater-than-normal in individuals with schizotypal personality disorder (Torgersen et al., 2002). Research clearly indicates that general anxiety (neuroticism) relates to schizotypy (Ettinger et al., 2005; Barrantes-Vidal et al., 2009), where the relation is influenced by both genetic and environmental factors (Macare et al., 2012). Furthermore, the presence of RS across the psychosis continuum (Kwapil, Brown, Silvia, Myin-Germeys, & Barrantes-Vidal, 2012; A. P. Morrison et al., 2006; Torgersen et al., 2002) might be such that the RS-positive schizotypy association is strengthened by anxiety (Kwapil et al., 2012). However, the relation between RS and positive schizotypy is the result of on-going social interaction rather than heritable familial traits (Torgersen et al., 2002).

If deficits in social cognition task performance can inform the relation between social anxiety and PLEs (Abbott & Green, 2013; Sergi et al., 2009; Shean, Bell, & Cameron, 2007), then social rejection tasks can also reveal the nature of the relation between RS and PLEs

(Premkumar et al., 2012). Social cognition in the form of facial affect recognition is severely impaired in schizophrenia patients (Kohler, Walker, Martin, Healey, & Moberg, 2010) and consistently impaired in schizotypal individuals (Brown & Cohen, 2010; Miller & Lenzenweger, 2012; S. C. Morrison, Brown, & Cohen, 2013). Poor facial affect recognition also relates to PLEs (Germine & Hooker, 2011; Roddy et al., 2012) and the social anxiety aspect of schizotypy in the non-clinical population (Abbott & Green, 2013). Equally, impaired understanding of relationships in vignettes is associated with more positive symptoms and poorer family and peer relationships in schizophrenia patients (Sergi et al., 2009). Poor recognition of others' body posture and verbal expressions is associated with positive schizotypy (Shean et al., 2007). Correspondingly, the presence of PLEs in the general community is associated with functional alterations in the prefrontal, cingulate and parieto-occipital cortices during performance of social cognition tasks (review, Ettinger et al., 2014).

However, the perception of scenes depicting rejecting interactions has not been studied in schizophrenia patients either behaviourally or neurally. The only study to investigate the relation between RS and psychometrically-defined risk for schizophrenia found that dorsal anterior cingulate cortex (dACC) activity was diminished during scenes depicting rejection than neutral interactions in individuals with high positive schizotypy (Premkumar et al., 2012), suggesting that there is avoidance of rejection due to social pain (Eisenberger, 2012). Here, dACC activity might be engaged at several stages of processing rejection, such as feature encoding, voluntary attention and top-down cognitive control. Event-related potentials (ERPs) are efficient measures of such contiguous mental processes (Luck, 2005). Specifically, the N100 relies on cortical sources originating predominantly from the primary sensory cortices, but also has generators in frontal regions, such as the dACC (Lu, Zhang, Hu, & Luo, 2011; Mulert et al., 2007; Vogel & Luck, 2000). The N100 indicates feature encoding when passively viewing unpleasant scenes (Jessen & Kotz, 2011; Lithari et al., 2010) and the frontal N100 that is evoked in affective priming tasks reflects anticipation of the primed emotion (Lu et al., 2011). Furthermore, diminished N100 following derogatory verbal feedback indicates that such primes disrupt conflict-detection during feature encoding (Wiswede, Munte, & Russeler, 2009). In schizophrenia patients, the visual P100 (parieto-occipital counterpart of N100) is reduced regardless of emotion type (Campanella, Montedoro, Streel, Verbanck, & Rosier, 2006). The auditory fronto-temporal N100 decreases with greater positive schizotypy (Sumich et al., 2008a; Sumich, Kumari, Gordon, Tunstall, & Brammer, 2008). Such a deficit in primary sensory processing across the psychosis continuum is similar to the kind of perceptual aberrations found in positive schizotypy (Mason, Claridge, & Jackson, 1995; Vollema & van den Bosch, 1995).

Perception of rejecting interactions may relate to positive schizotypy at later components, because experiencing rejection increases parietal P300 and medial frontal LSW amplitudes, indicating greater anticipation and semantic processing of rejection respectively (Crowley, Wu, Molfese, & Mayes, 2010). The N300, P300 and late slow wave (LSW) index higher-order processes (Crowley et al., 2010; Sumich et al., 2008b; Zayas, Shoda, Mischel, Osterhout, & Takahashi, 2009) such as attention orientation, contextual updating/closure and response modulation (Castro & Diaz, 2001; Lu et al., 2011; Polich & Kok, 1995; Sumich et al., 2008a). The N300 (frontal maxima) in response to facial emotions is modulated by untrustworthiness of partners and unfairness during interaction (Lu et al., 2011; Ruz, Madrid, & Tudela, 2013). The P300 (parietal maxima) is evoked by salient information, such as target, novel or affect-laden stimuli (Olofsson, Nordin, Sequeira, & Polich, 2008). Reduced P300 during auditory attention indicates poor discrimination of innocuous auditory tones in recent-onset schizophrenia and positive schizotypy (Sumich et al., 2008a; Sumich et al., 2008b). The dACC is the neural generator of the frontal early P300 when processing personally-salient faces and detecting novelty in auditory odd-ball tasks (Dai, Zhai, Zhou, Gong, & Luo, 2013; Friedman, Cycowicz, & Gaeta, 2001; Merlotti et al., 2013). The LSW occurs at approximately 600 ms as a frontal negative potential and a centro-parietal positive potential (Bartholow, 2010; Foti, Hajcak, & Dien, 2009) and reflects evaluation of the motivational salience of affective stimuli and behavioural control in the context of emotions (Aguado, Dieguez-Risco, Mendez-Bertolo, Pozo, & Hinojosa, 2012; Gibbons, 2009).

Following on from our earlier finding of reduced dACC activation during rejection in high schizotypy (Premkumar et al., 2012), the current study aimed to determine the stage of mental processing of rejection at which the relation between positive schizotypy and altered perception of rejection occurs. Positive schizotypy relates to RS (Kwapil et al., 2012; Torgersen et al., 2002) and denotes perceptual aberrations in sensory processing and affect recognition (Campanella et al., 2006; Shean et al., 2007; Sumich et al., 2008b) . Therefore, it was hypothesized that positive schizotypy would relate to greater RS and reduced dACC N100 amplitude (a measure of early sensory processing) in anticipation of rejection (the scenes in the current study were preceded by 'rejection' primes). The study also sought to determine whether the P300 and LSW, which being indices of higher-order cognitive processes would also be sensitive neurophysiological measures of discriminating between rejecting and accepting social interactions.

2 Method

2.1 Participants

Forty-one participants were recruited from a student population through a University Psychology research credit scheme (Table 1). Inclusion criteria comprised being righthanded and aged between 18 and 45 years. Exclusion criteria included a history of mental disorder, brain injury, neurological disorder, learning disabilities, loss of consciousness for more than five minutes, and/or a history of alcohol or drug abuse within the last 12 months, and taking any kind of mood-altering prescribed medication. Ethical approval was obtained from the Nottingham Trent University School of Social Sciences Research Ethics Committee (No. 2012/55).

*** Insert Table 1 about here ***

2.2 Measures

2.2.1 Oxford-Liverpool Inventory of Feelings and Experiences.

The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE, Mason et al., 1995) is a 104-item schizotypy scale comprising four sub-scales, namely unusual experiences, cognitive disorganisation, introvertive anhedonia and impulsive nonconformity. Compared to the means reported by Mason and colleagues (1995) from an adult sample drawn from the general community (n=508), means in the present study sample were similar for unusual experiences, cognitive disorganisation and introvertive anhedonia (Cohen’s d=0.19, 0.64 and 0.26 and p=0.075, 0.059 and 0.422 respectively), but higher for impulsive nonconformity (Cohen’s d=1.07, p=0.002) (Table 1). The reliability (Cronbach’s alpha) was also good for most sub-scales in the present study (unusual experiences α=0.75, cognitive disorganisation α=0.87, introvertive anhedonia α=0.82 and impulsive nonconformity α=0.56).

2.2.2 Adult Rejection Sensitivity Questionnaire.

The Adult Rejection Sensitivity Questionnaire (Downey & Feldman, 1996) consists of nine hypothetical rejection scenarios concerning the participant and a family member or close friend, each scenario being followed by a negatively framed question about concern over being rejected and a positively framed question about confidence of being accepted. RS was the average of the product of 'concern' and 'acceptance' (reversed) responses to the nine scenarios. The mean (S.D.) in the present study sample was similar to an adult sample in an earlier study, where n=685 (Cohen's d=0.09, p=0.548) (Berenson et al., 2009) (Table 1). The scale had good reliability (α=0.80).

2.2.3 Social interactions pictures task.

The pictures from our earlier study (Premkumar et al., 2012) were used in the present study. However due to the larger number of stimuli needed for ERP studies, 15 additional pictures were selected for each condition (rejection, acceptance and neutral) resulting in thirty scenes for each condition controlling for the number, gender and ethnicity of people in the scene. The scenes depicting rejecting, accepting and neutral interactions were sourced from the International Affective Pictures System (Lang, Bradley, & Cuthbert, 1999) or purchased from a web-based company (www.jupiterimages.co.uk) supplying stock photographic images for professional use. The scenes had been rated on rejection (rejection-acceptance) and valence (negative-positive) as being more representative of the three types of interactions out of a set of 164 scenes by six doctoral or post-doctoral level Psychology researchers (Appendix A).

The EEG task employed affective priming, because affective primes lead to 'activation spreading' of a semantic context to a target stimulus and anticipation of the prime

(Bartholow, 2010; Hietanen & Astikainen, 2013; Lu et al., 2011). Rejection is a complex emotion (Çelik, Lammers, van Beest, Bekker, & Vonk, 2013; Power, 2005) requiring awareness of the circumstances that caused the emotion and therefore higher-order cognitive evaluation (JohnsonLaird & Oatley, Jun 1989). Furthermore, schizotypal individuals benefit from controlled processing of semantic primes (i.e. longer presentation time) during lexical decision-making (Morgan, Bedford, & Rossell, 2006). Therefore a prime, 'rejected' or 'sad', lasting for 500 ms was presented at the centre of the screen before the social interaction scene appeared for 3,000 ms (Figure 1). The two primes were used to provide two emotional contexts in which to process the scenes so as to determine the discriminant validity of the scenes in evoking rejection. This information was extracted through behavioural ratings of relevance or emotionality corresponding to each prime following each scene. Participants rated the scenes on 11-point Likert scales for relevance, 'How strongly did you relate to this scene?' ('Not at all' – 'Very strongly') for 'rejected' primes, and emotionality, 'How did this scene make you feel?' ('Sad' – 'Happy') for 'sad' primes. Scenes (size=800x530 pixels, horizontal angle 18° and vertical visual angle 14°) were presented twice in random order, preceded once by each prime. 180 trials [30 images per social interaction type x 3 conditions (rejection, acceptance and neutral) x 2 presentations (preceded by either a 'rejected' or 'sad' prime)] were split across two sessions to avoid fatigue (an eye-movement artefact correction task separated the two sessions).

*** Insert Figure 1 about here ***

2.2.4 EEG recording and pre-processing.

Participants were positioned 50 cm away from the computer screen while performing the Social interactions pictures task. EEG data were collected using a BioSemi Active-two system. A standard set of 64 Ag/AgCl electrodes was fitted using an electrode cap. Four electrodes were additionally placed (F9, F10, F11 and F12) using the International 10-10 system. The brain electrical activity was sampled at 2,048 Hz and digitized at 24 bits.

2.3 Analysis

2.3.1 Relation between schizotypy, RS and behavioural task performance.

Pearson correlations (one-tailed) were performed between RS and schizotypy subscales. To determine whether relevance ratings of rejection scenes on the pictures task specifically gauged RS, the correlation between RS and rejection scenes' relevance was compared with the correlation between RS and rejection scenes' emotionality using Fisher's z transformation. To determine the validity of the task, the difference in the relevance of social interaction types (rejection, acceptance and neutral) was examined using analysis of variance (ANOVA), followed by *post hoc* Bonferroni pairwise comparisons. The difference in emotional distance (difference between emotionality of the neutral and emotional scenes) between rejection and acceptance scenes was also tested using a pairwise t-test.

2.3.2 EEG processing and analysis.

Channels were re-referenced to average. High-pass (frequency=0.53 Hz, low cut-off slope=6db/oc) and low-pass filters (frequency=35 Hz, high cut-off slope=24bd/oc, zero phase) were applied to the data prior to averaging topographical waveforms within conditions. Eye-blink and horizontal eye-movement artefact corrections were performed using established methods (Picton et al., 2000; Scherg, Ille, Bornfleth, & Berg, 2002). Data were segmented into -200 to 1,999 ms epochs, such that epochs were baseline corrected for the first 200 ms. Trials with artefacts exceeding 120µV were removed automatically [mean % (S.D.) of included trials for rejection=96.42% (6.13), acceptance=95.47% (6.87) and neutral=96.50% (5.49)].

The grand average waveforms indicated the following components: frontal N100/parieto-occipital P100 (70-160 ms), a frontal N300/parieto-occipital P300 (200-400 ms) and a frontal/parieto-occipital LSW (600-900 ms) with maximal activity in frontal, temporal and parieto-occipital sites (Figure 2). These components were comparable with those of another affective priming pictures task (Lu et al., 2011). Therefore frontal right and left amplitudes were measured as the average amplitude at F2, F4, FC4 and F1, F3, FC3 sites respectively. Temporal right and left amplitudes were measured as the average amplitude at FT8, T8 and T10 and FT7, T7, T9 sites respectively. Parieto-occipital right and left amplitudes were measured as the average amplitude at P2, P4, PO4 and P1, P3, PO3 sites respectively. ANOVAs were performed with component (N100/P100, N300/P300 and LSW), social interaction type (rejection, acceptance and neutral), hemisphere (right and left) and region (frontal, temporal and parieto-occipital) as the within-subjects factors and mean amplitude as the dependent variable (the Greenhouse-Geisser estimate was used if the Mauchley's sphericity assumption was violated), followed by *post hoc* Bonferroni pairwise comparisons between types of social interaction.

Dipole modelling was performed using Brain Electrical Source Analysis (BESA, version 5.37) to locate the cortical sources of the components. High-pass (frequency=0.53 Hz, low cut-off slope=6db/oc) and low-pass filters (frequency=35 Hz, high cut-off slope=24bd/oc, zero phase) were again applied to the grand average data prior to modelling. Dipoles were fitted based on the regions of maximal amplitude observed in the topographical maps (Figures 2b and 3). dACC dipole location (Talairach coordinates: x=0, y=16, z=32) was taken from the averaged co-ordinates of dACC activation in different rejection paradigms across different studies (review, Premkumar, 2012). Symmetrical dipoles were fitted in the lingual gyrus (x=±7, y=-79, z=5), because left lingual gyrus activation is increased during rejection than acceptance scenes (Premkumar et al., 2012) and posterior P1 amplitude is sourced to the lingual gyrus during face processing in young adolescents (Wong et al., 2009). Symmetrical dipoles were fitted in the temporal pole (x=±36, y=14, z=-26), because the temporal pole is activated during evaluation of social feedback as rejection from others and when imputing other people's emotional states (Beeney et al., 2011; Jimura et al., 2010; Korn et al., 2012). The best fit (residual variance) of the model solution for each condition at each time frame was good: rejection N100=7.96 (20.56), acceptance N100=8.10 (16.49) and neutral N100=8.17 (16.53), rejection P300=2.62 (4.31), acceptance P300=2.88 (5.27) and neutral P300=2.34 (4.21), and rejection LSW=2.96 (4.77), acceptance LSW=2.41 (4.66) and neutral LSW=4.83 (7.12). ANOVAs were performed with component, social interaction type, hemisphere (for temporal pole and lingual gyrus only) and region (dACC, temporal pole and lingual gyrus) as within-subjects factors and mean dipole moment (nAmp) as the dependent variable (the Greenhouse-Geisser estimate was used if the Mauchley's sphericity assumption was violated), followed by *post hoc* Bonferroni pairwise comparisons between types of social interaction.

*** Insert Figures 2 and 3 about here ***

2.3.3 Association between positive schizotypy, RS and ERP amplitude/dipole moment during rejection.

Pearson correlations (one-tailed) were performed between positive schizotypy (O-LIFE unusual experiences subscale), RS and amplitude during the rejection condition for those ERP components for which there was a main effect of social interaction type. If both ERP amplitude and RS were found to correlate with positive schizotypy, then a hierarchical regression analysis was performed to determine the independent contributions of the rejection-related amplitude/dipole moment at that ERP component and RS to schizotypy variance. The alpha-level for the correlation between schizotypy, RS and ERP amplitude/dipole moment was not adjusted for multiple comparisons due to the exploratory nature of the study and schizotypy and RS in the current sample were mild.

3 Results

3.1 Relation Between Schizotypy, RS and Behavioural Task Performance

RS correlated with all schizotypal sub-scales: cognitive disorganisation ($r=0.68$, $p<0.001$), introvertive anhedonia ($r=0.52$, $p<0.001$), unusual experiences ($r=0.44$, $p=0.003$) and impulsive nonconformity ($r=0.44$, $p=0.003$). In addition, RS tended to correlate more strongly with relevance ($r=0.46$, $p=0.001$) than emotionality ($r=-0.14$, $p=0.191$) ratings of rejection scenes ($z=1.52$, $p=0.06$), indicating that the relevance ratings measured rejection. On the pictures task, rejecting and accepting interactions were more relevant than neutral scenes, $F=19.97$, d.f.=2,78, $p<0.001$ (rejection vs. neutral, mean difference=1.33, $p<0.001$, and acceptance vs. neutral, mean difference=1.79, $p<0.001$, and rejection vs. acceptance, mean difference=-0.46, $p=0.589$) (Table 1). Finally, the emotional distance between rejecting and neutral interactions was smaller than between accepting and neutral interactions, $t=3.561$, d.f.=39, $p=0.001$.

3.2 ERP Analysis

3.2.1 Topographical analysis.

At the parieto-occipital P100, there was a social interaction-by-hemisphere interaction (Table 2, Figure 4); however, pairwise comparisons did not reveal any difference between social interactions. At the frontal N300, there was a main effect of social interaction, such that frontal amplitude was greater during accepting than neutral interactions, mean difference=0.31, p=0.011. At the parieto-occipital P300, there was a main effect of social interaction where there was greater amplitude during rejecting than neutral interactions, mean difference=0.27, p=0.012, and a main effect of hemisphere indicated larger right-than-left amplitude. At the frontal LSW there was a main effect of social interaction, such that amplitude was greater during rejecting than accepting interactions, mean difference=0.32, p=0.007, and during rejecting than neutral interactions, mean difference=0.21, p=0.036. At the temporal LSW there was a main effect of social interaction such that amplitude was greater during neutral than rejecting interactions, mean difference=0.21, p=0.011. An effect of hemisphere in the parieto-occipital LSW indicated greater right-than-left amplitude.

3.2.2 Source analysis.

At the dACC N100 there was a main effect of social interaction type (Table 2, Figure 4), such that there was greater moment during neutral than accepting interactions, mean difference=8.89, p=0.03. At the dACC N300 there was a main effect of social interaction type, such that there was greater moment during rejecting than accepting interactions, mean difference=8.13, p=0.012 and neutral than accepting interactions, mean difference=12.20, p<0.001. At the dACC LSW there was a main effect of social interaction type, such that there was greater moment during rejecting than neutral interactions, mean difference=6.868, p=0.032.

In the temporal pole, an effect of hemisphere at the N300/P300 and LSW indicated polarity reversal between hemispheres and although there was a main effect of social interaction at the N300/P300, no pairwise comparison was significant. In the lingual gyrus an effect of hemisphere at P100, P300 and LSW indicated greater right-than-left moment.

*** Insert Table 2 and Figure 4 about here ***

3.3 Association Between Positive Schizotypy, RS and ERP Amplitude/Dipole Moment During Rejection

Lower dACC N100 moment during rejection correlated with greater positive schizotypy (O-LIFE unusual experiences) and greater RS (Table 3 and Figure 5). Greater left temporal pole moment during rejection correlated with greater RS.

A hierarchical regression analysis was performed with positive schizotypy as the criterion variable and dACC N100 moment during rejection as the first predictor and RS as the second predictor. In the first step, dACC N100 moment during rejection explained 19.6% of the variance (R=0.44, adjusted R^2=0.17). The model was significant, F (1,37)=8.781, p=0.005. In the second step, dACC N100 moment during rejection and RS explained 30.6% of the model variance (R=0.55, adjusted R^2=0.27, R^2 change=0.11, F-change=5.56, p-change=0.024). The model was significant, F (2,35)=7.73, p=0.002, as were the standardized beta coefficients (β) for the two predictors, dACC N100 β=0.35, p=0.024, partial r=0.37 and RS β=0.35, p=0.024, partial r=0.37.

*** Insert Table 3 and Figure 5 about here ***

4 Discussion

The study aimed to determine at what stage of mental processing the relation is found between positive schizotypy and ERP amplitude during perceived rejection. Firstly as hypothesized, RS was related to positive schizotypy, which implies that RS aggravates PLEs (Kwapil et al., 2012). Additionally, RS related to all other schizotypy subs-scales, but its association was strongest with cognitive-disorganisation. Cognitive disorganisation reflects social anxiety and difficulty with attention, concentration and decision-making (Bentall et al., 1989; Mason et al., 1995; Vollema & van den Bosch, 1995). This suggests that RS relates to an increased risk of social anxiety, thought disorder and attentional difficulties within schizotypy.

4.1 Relation Between Positive Schizotypy, RS and dACC N100 Activity

As hypothesized, reduced N100 dACC moment during rejecting interactions related to positive schizotypy indicating that encoding of rejection scenes diminishes as the level of positive schizotypy increases (Lithari et al., 2010; Lu et al., 2011). Given that the task used a semantic prime to facilitate anticipation of the primed emotion (Lu et al., 2011) and primes in the form of derogatory verbal feedback diminish N100 during error monitoring (Wiswede et al., 2009), the anticipation of rejection may have partly contributed to the inhibited feature encoding of rejection scenes in those with more PLEs, because anxiety moderates the association between RS and positive schizotypy (Kwapil et al., 2012). However, this interpretation is tentative since both ‘rejected’ and ‘sad’ primes were used. Nevertheless, the fact that RS related specifically to ratings of rejection scenes following the ‘rejected’ prime, but not ratings following the ‘sad’ prime, suggests that the scenes did induce rejection when preceded by the ‘rejected’ prime. Moreover in the context of perceiving social interaction, rejection is a more complex emotion (Çelik et al., 2013; Power, 2005) and difficult to induce as indicated by the lower emotional distance relative to neutral scenes for rejection than acceptance in the current study. Therefore, the inverse association between N100 dACC moment during rejection and positive schizotypy might even suggest that with increasing PLEs there is an impaired ability to encode complex emotions in general while anticipating rejection. Evidence does suggest a generalised early visual processing deficit in schizophrenia patients, who show reduced N80 and N100 amplitude to visual stimuli that excite the magnocellular visual pathway (Butler et al., 2007; Nunez et al., 2013) and lower N170 amplitude to faces regardless of type of emotion (Campanella et al., 2006; Lynn & Salisbury, 2008; Turetsky et al., 2007).

Lower dACC N100 moment was also associated with greater RS. The dACC is involved in experiencing social pain due to rejection across multiple paradigms (Eisenberger, 2012; Premkumar 2012), such that greater distress is associated with lower dACC activity during rejection scenes in high RS individuals (Kross, Egner, Ochsner, Hirsch, & Downey, 2007). Furthermore, the increased rejection-related dACC activity when participants are subjected to direct aggression is moderated by poorer Stroop performance (Chester et al., 2013), suggesting that poor early attention increases the effect that rejection-induced pain has on subsequent social pain. Moreover, N100 modulation by Stroop performance indicates early selective attention (David et al., 2011). Thus, the relation between RS and dACC activity could mean that feature encoding of rejection scenes decreases as anticipation of rejection increases. In the present study, dACC N100 moment during rejection (19.6%) and

RS (11%) contributed independently to positive schizotypy. Therefore, it is inferred that difficulty with encoding rejecting interactions, which is a primary bottom-up process, and a greater tendency to misattribute ambiguous social interactions as rejecting, which is a secondary appraisal process, individually contribute towards PLEs.

4.2 Greater dACC N300/parieto-occipital P300 and frontal/dACC LSW Activity During Rejection

Greater dACC N300 moment and parieto-occipital P300 during rejecting than accepting or neutral scenes suggests a visual attentional bias towards rejection. Larger amplitude in the mid-latency period (225 to 400ms) denotes attention to rejection, since higher parieto-occipital N2pc during rejection-themed distracters among low self-esteem individuals (Li et al., 2012), larger parietal P300 amplitude when children are excluded from a ball-tossing game (Crowley et al., 2010), and larger N400 amplitude when listening to partner-related statements primed by rejection than acceptance cues (Zayas et al., 2009) all imply vigilance for rejection. Given the dACC's role in attachment salience (Dai et al., 2013), greater dACC N300 activity during rejection would suggest vigilance for rejecting interactions because of attributing greater personal salience when relating rejection to the self. Although the dACC P300 amplitude differed between rejecting and accepting scenes, it did not differ between rejection and neutral scenes. Such findings may reflect the fact that the emotional distance relative to neutral scenes was shorter for rejection than acceptance and therefore neutral interactions tend to be seen more negatively. Furthermore, the absence of a relation between dACC N300 and schizotypy suggests that dACC N300 during vigilance for rejection maybe resilient to schizotypy.

Larger frontal (topographical) and dACC (source) LSW amplitude during rejection compared to neutral scenes suggests sustained processing of rejection following voluntary orientation because of deeper semantic processing, in terms of resolving semantic conflict (Bartholow, 2010; Herbert, Herbert, Ethofer, & Pauli, 2011) and preference for motivationally salient scenes (Foti et al., 2009; Franz, Schaefer, Schneider, Sitte, & Bachor, 2004). The LSW may also respond to minimizing social pain, because larger medial frontal LSW amplitude during exclusion from a ball-tossing game was associated with lower ostracism-related distress (Crowley et al., 2010). Taken together, the larger frontal/dACC LSW activity during rejection may indicate evaluation of rejection that may facilitate subsequent behavioural adaptation.

4.3 Limitations

One limitation of the study was to use a small, predominantly university student sample where RS due to close relationships may not be comparable to that of the general population because 93% were single and it is common for students to live away from home. Future research could replicate this study's findings in a larger community-based sample in the context of participants' close relationships, since hostility as rejection from carers increases psychopathology in at-risk individuals (Schlosser et al., 2010). Secondly, the task did not differentiate between complex (rejection and acceptance) and basic emotions (sad and happy); therefore the specificity of the reduced dACC N100-schizotypy association to complex scenes could not be ascertained. Thirdly, a difference was not found between rejection and acceptance/neutral conditions [rejection (mean=-20.91, S.E.=5.85) vs. acceptance (mean=-16.22, S.E.=5.40), Cohen's d=0.13; rejection (mean=-20.91, S.E.=6.85) vs. neutral (mean=-24.71, S.E.=5.24), Cohen's d=0.11], whereas N100 amplitude was significantly lower for acceptance than neutral conditions (Cohen's d=0.25). However, the grand average maps in Figure 2a suggest that N100 amplitudes of neutral and rejection conditions were similar and that they were higher than that of acceptance. The amplitude difference between rejection and acceptance may not have been statistically significant partly because of insufficient power, but also because amplitude during rejection was intermediate between neutral and acceptance. Early feature processing of rejection may have been slightly more difficult to process than acceptance, but not significantly so. What the findings do show is that the N100 is able to discriminate between emotions, such that there is greater difficulty processing features of neutral scenes than acceptance scenes. Studies do tend to find higher N100 amplitude during neutral than emotional scenes (Jessen & Kotz, 2011), but also higher amplitude for highly than weakly arousing scenes (Lithari et al., 2010).

4.4 Conclusion

To conclude, the inverse relation between dACC N100 activity and positive schizotypy suggests that this neural response may be a very early indicator of PLEs. A greater tendency to misattribute social situations as rejecting may compound experiences of social anxiety in vulnerable groups. There is recent evidence that RS is higher in certain ethnic minorities than others (Tsai & Lau, 2013). Therefore, future research could investigate how ethnicity contributes to RS and vulnerability for psychosis. Diminished encoding of rejecting interactions followed by greater attribution of social interactions as rejecting may accentuate poor interpersonal functioning. In turn, this might exacerbate the poor outcome of clinical groups such as patients with psychosis who have poor family relationships (Kuipers, Onwumere, & Bebbington, 2010).

Conflict of interest

No competing financial interests exist.

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Table 1. Participant (N=41) demographic and behavioural response characteristics

Measure	Mean (S.D.)	Mean (S.D.) in other studies
Age	21.1 (1.8)	
Gender (M/F)	15/26	
Marital status (single/married or living together/not known)	38/2/1	
Ethnicity (White British/White Other/Asian/Black-Caribbean heritage)	33/3/4/1	
†Schizotypy - total	39.3 (13.9)	
†Schizotypy – unusual experiences	8.4 (4.5)	9.7 (6.7)‡
†Schizotypy – cognitive disorganisation	13.4 (5.8)	11.6 (5.8)‡
†Schizotypy – introvertive anhedonia	6.7 (4.8)	6.1 (4.6)‡
†Schizotypy – impulsive nonconformity	10.8 (3.2)	9.1 (4.3)‡
†Rejection sensitivity	9.0 (3.9)	8.6 (3.6)!!

Table 1 continued.

Social interactions pictures task ratings	Rejection	Acceptance	Neutral
‘How relevant is this scene to you?’ (‘Not at all’=0; ‘Very relevant’=10)	5.2 (1.4)	5.6 (1.6)	3.9 (1.2)
‘How does this scene make you feel?’ (‘Sad’=-5; ‘Happy’=5)	-1.9 (0.8)	2.7 (1.3)	-0.4 (0.6)

†n=38, as schizotypy and rejection sensitivity data were missing for three participants; ‡mean (S.D.) taken from Mason et al. (1995) where n=508; ‼mean (S.D.) taken from Berenson et al (2009) where n=689.

Table 2. Effects of social interaction and hemisphere on N100, P300 and LSW amplitude and dipole moment

Region or Source	Social interaction F (d.f.)	p-value	Hemisphere F (d.f.)	p-value	Hemisphere-by-social interaction F (d.f.)	p-value
TOPOGRAPHICAL ANALYSIS						
N100/P100						
Frontal	1.90 (2,80)	0.164	1.12 (1,40)	0.296	2.84 (2,80)	0.064
Temporal	2.26 (2,80)	0.111	0.88 (1,40)	0.354	0.64 (2,80)	0.531
Parieto-occipital	1.43 (2,80)	0.245	0.44 (1,40)	0.511	**3.73** (2,80)	0.028

Table 2 continued.

Region or Source	Social interaction F (d.f.)	p-value	Hemisphere F (d.f.)	p-value	Hemisphere-by-social interaction F (d.f.)	p-value
N300/P300						
Frontal	**4.60** (2,80)	0.013	0.96 (1,40)	0.333	1.00 (2,80)	0.374
Temporal	0.59 (2,80)	0.556	0.31 (1,40)	0.583	2.43 (2,80)	0.095
Parieto-occipital	**3.98** (2,80)	0.023	**6.63** (1,40)	0.014	2.33 (2,80)	0.104
LSW						
Frontal	**6.48** (2,80)	0.002	0.11 (1,40)	0.736	2.08 (2,80)	0.141
Temporal	**3.80** (2,80)	0.039	0.04 (1,40)	0.841	0.86 (2,80)	0.428
Parieto-occipital	1.32 (2,80)	0.271	**6.99** (1,40)	0.012	2.48 (2,80)	0.090

Table 2 continued.

Region or Source	Social interaction F (d.f.)	p-value	Hemisphere F (d.f.)	p-value	Hemisphere-by-social interaction F (d.f.)	p-value
SOURCE ANALYSIS						
N100/P100						
dACC	**3.57** (2,80)	0.033	-	-	-	-
Temporal pole	1.80 (2,80)	0.173	1.25 (1,40)	0.269	1.14 (2,80)	0.325
Lingual gyrus	2.78 (2,80)	0.068	**6.74** (1,40)	0.013	0.78 (2,80)	0.463
N300/P300						
dACC	**10.22** (2,80)	<0.001	-	-	-	-
Temporal pole	**5.67** (2,80)	0.005	**44.29** (1,40)	<0.001	2.29 (2,80)	0.108

Table 2 continued.

Region or Source	Social interaction F (d.f.)	p-value	Hemisphere F (d.f.)	p-value	Hemisphere-by-social interaction F (d.f.)	p-value
Lingual gyrus	0.28 (2,80)	0.758	**46.14** (1,40)	<0.001	1.36 (2,80)	0.262
LSW						
dACC	**3.94** (2,80)	0.023	-	-	-	-
Temporal pole	2.22 (2,80)	0.115	**34.80** (1,40)	<0.001	0.06 (2,80)	0.941
Lingual gyrus	0.49 (2,80)	0.611	**96.74** (1,40)	<0.001	2.40 (2,80)	0.097

Values in bold are statistically significant

Table 3. Correlation (p-value) between positive schizotypy (O-LIFE unusual experiences), rejection sensitivity and ERP amplitude/dipole moment during rejection scenes

	Positive schizotypy	Rejection sensitivity
Topographical amplitude during rejection scenes		
Left frontal N300	-.025 (.440)	.170 (.154)
Right frontal N300	.029 (.431)	.143 (.196)
Left parieto-occipital P300	.246 (.068)	.106 (.263)
Right parieto-occipital P300	.150 (.184)	.191 (.126)
Left frontal LSW	.059 (.363)	.120 (.237)
Right frontal LSW	.129 (.219)	.080 (.316)
Left temporal LSW	.029 (.431)	.122 (.233)
Right temporal LSW	-.113 (.251)	.013 (.469)
Dipole moment during rejection scenes		
dACC N100	**.443 (.003)**	**.278 (.045)**
dACC N300	.127 (.224)	.113 (.250)
dACC LSW	-.010 (.476)	-.107 (.262)
Left temporal pole P300	.078 (.321)	**.331 (.021)**
Right temporal pole P300	-.145 (.193)	-.176 (.145)

Values in bold are statistically significant

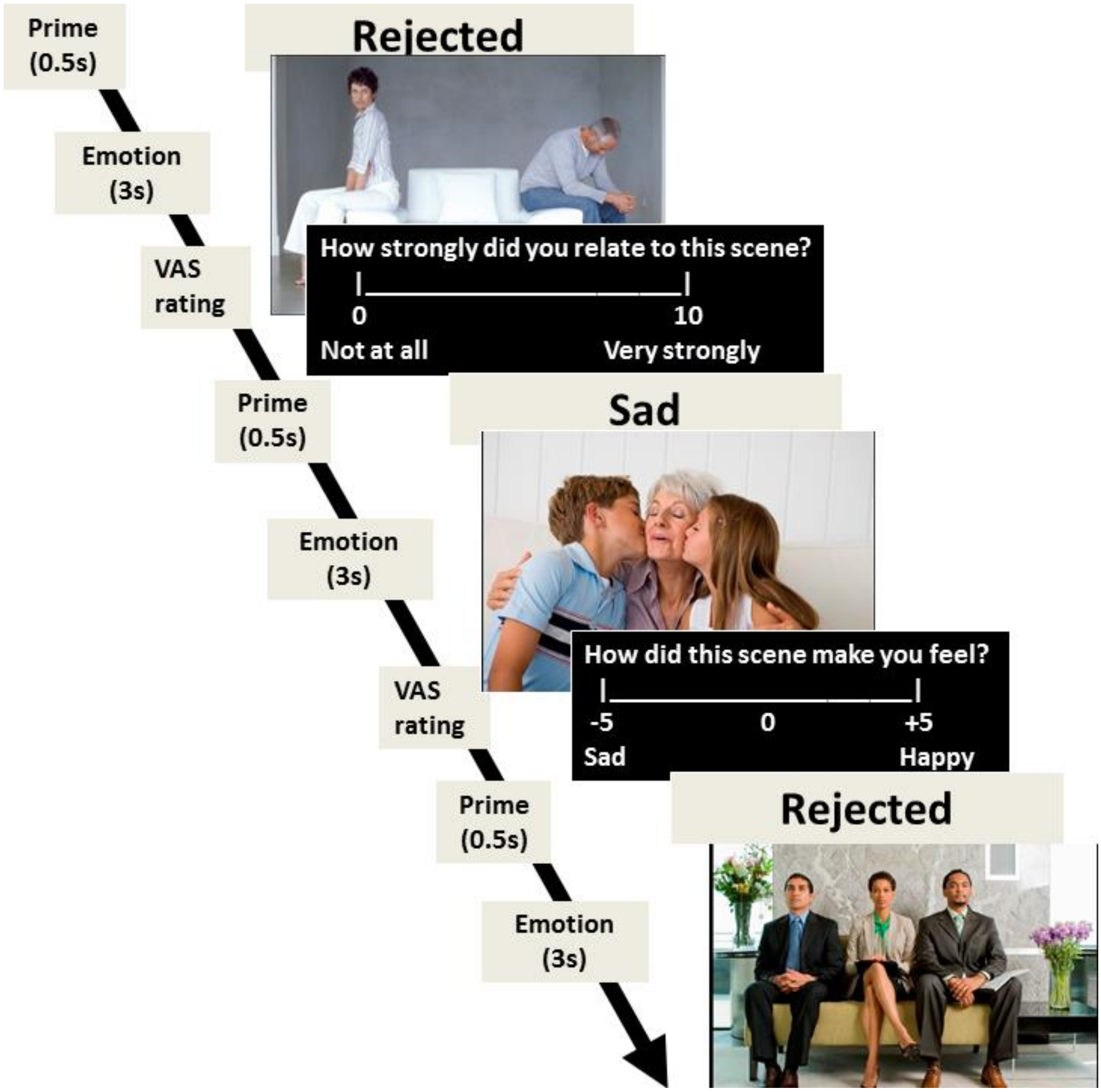
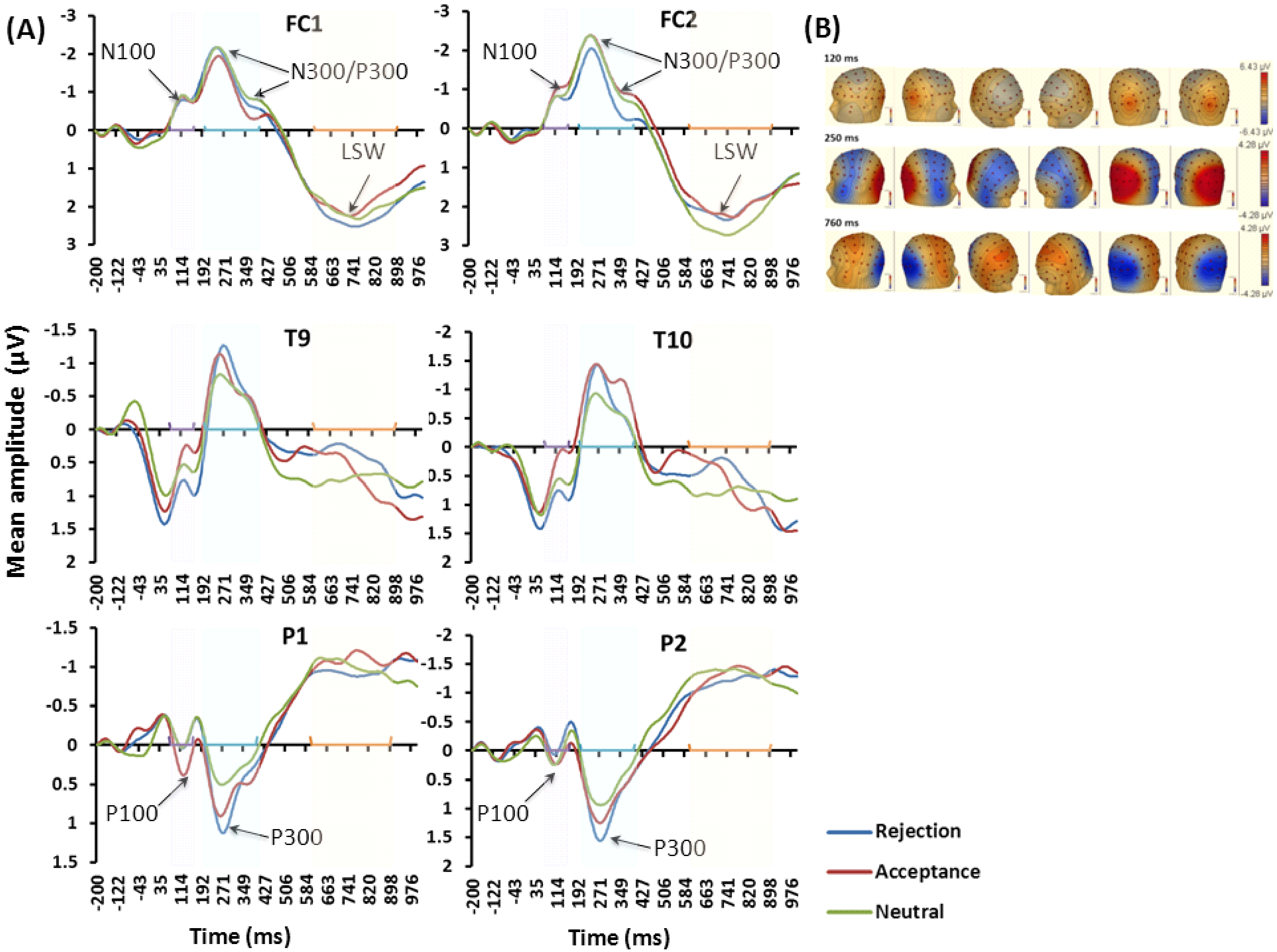


Figure 1. Social interaction pictures task



(A)
(B)
FC1
FC2
T9
T10
P1
P2
N100
N300/P300
LSW
P100
P300
Mean amplitude (μV)
Time (ms)
120 ms
250 ms
760 ms
Rejection
Acceptance
Neutral

Figure 2. (A) ERP waveforms at frontal, temporal and parietal sites and (B) topographical maps displaying areas of maximal positive (red) and negative (blue) amplitude at discrete time points. Polarities are reversed to fit the conventions of labelling components as positive (mean amplitude is negative) and negative (mean amplitude is positive).

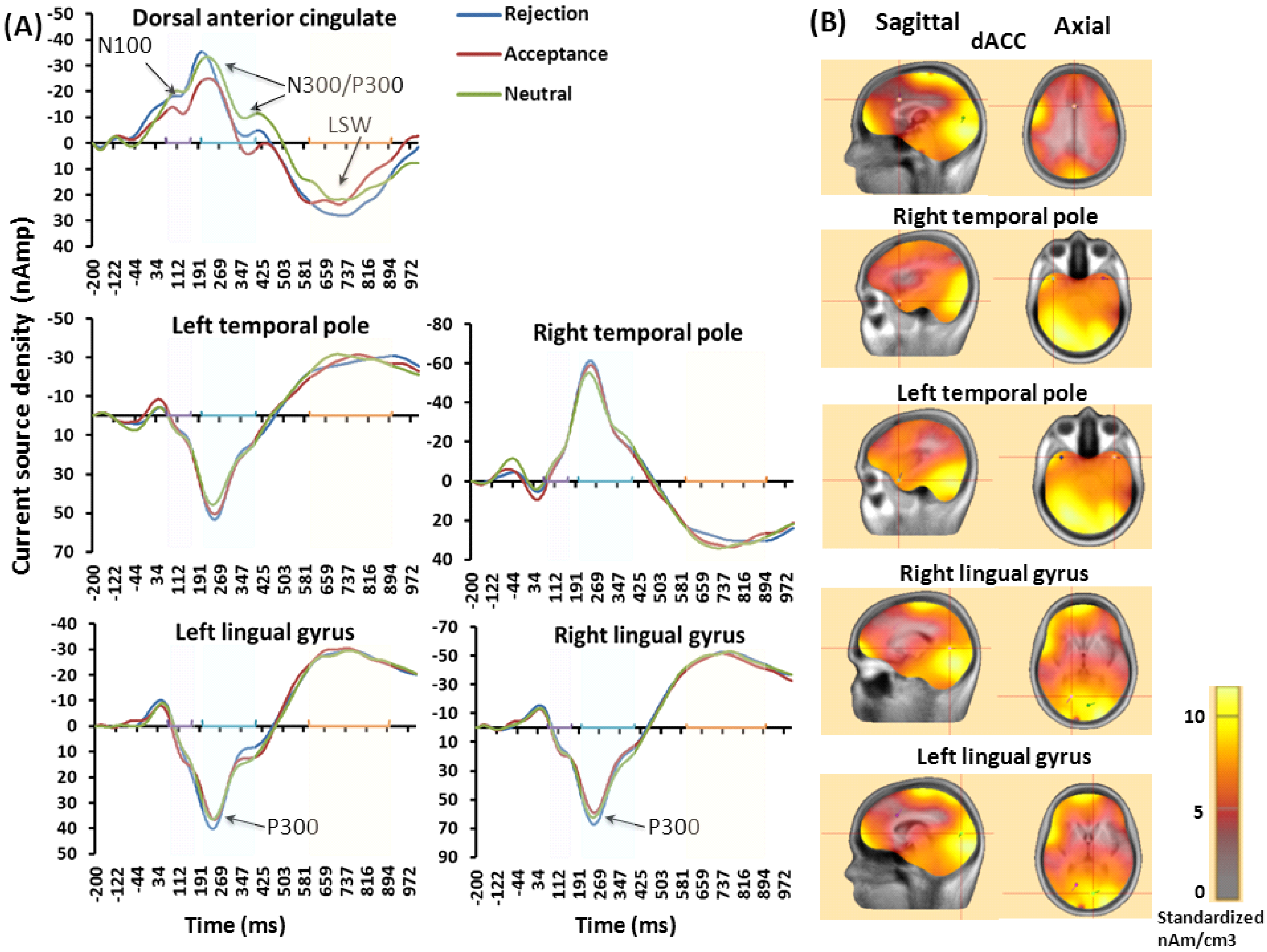

(A)
Dorsal anterior cingulate
Rejection
Acceptance
Neutral
N100
N300/P300
LSW
Current source density (nAmp)
Left temporal pole
Right temporal pole
Left lingual gyrus
Right lingual gyrus
P300
Time (ms)
(B)
Sagittal
dACC
Axial
Right temporal pole
Left temporal pole
Right lingual gyrus
Left lingual gyrus
10
5
0
Standardized nAm/cm3

Figure 3. (A) Dipole moment waveforms of the dACC, temporal pole and lingual gyrus and (B) location of the dipoles in three-dimensional brain space. Polarities are reversed to fit the conventions of labelling components as positive (mean amplitude is negative) and negative (mean amplitude is positive).

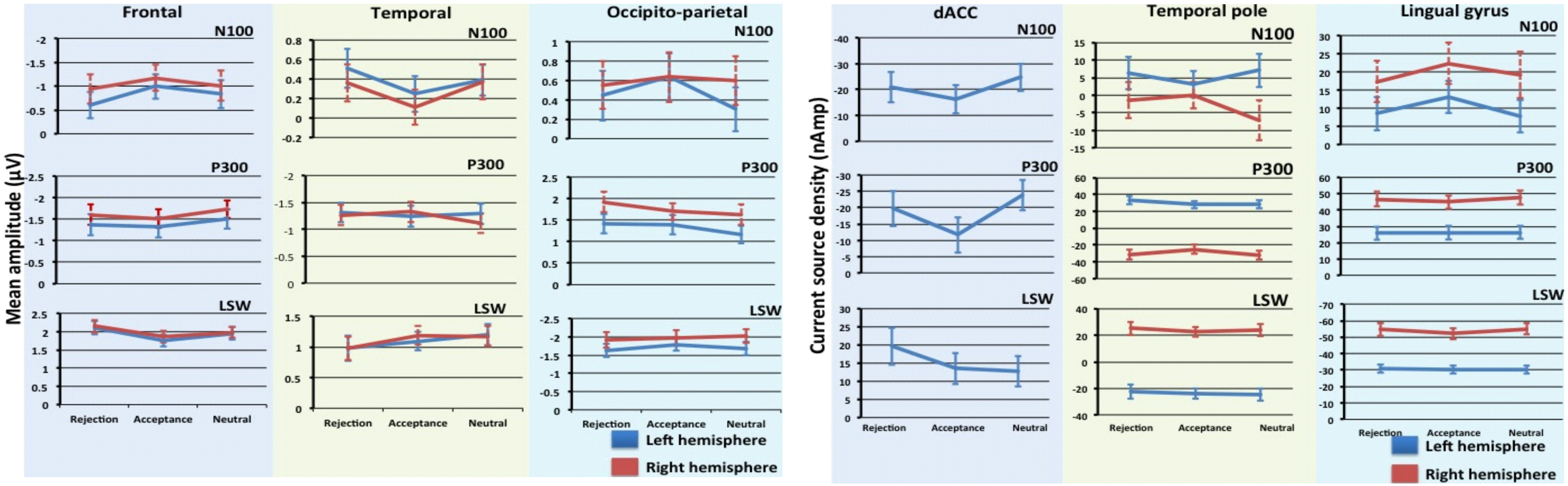


Figure 4. Plot of social interaction-by-hemisphere effects at N100, P300 and LSW based on mean amplitudes at frontal, temporal and parietal sites (left panel) and dipole moment at the dACC, temporal pole and lingual gyrus (right panel). Error bars represent standard error.

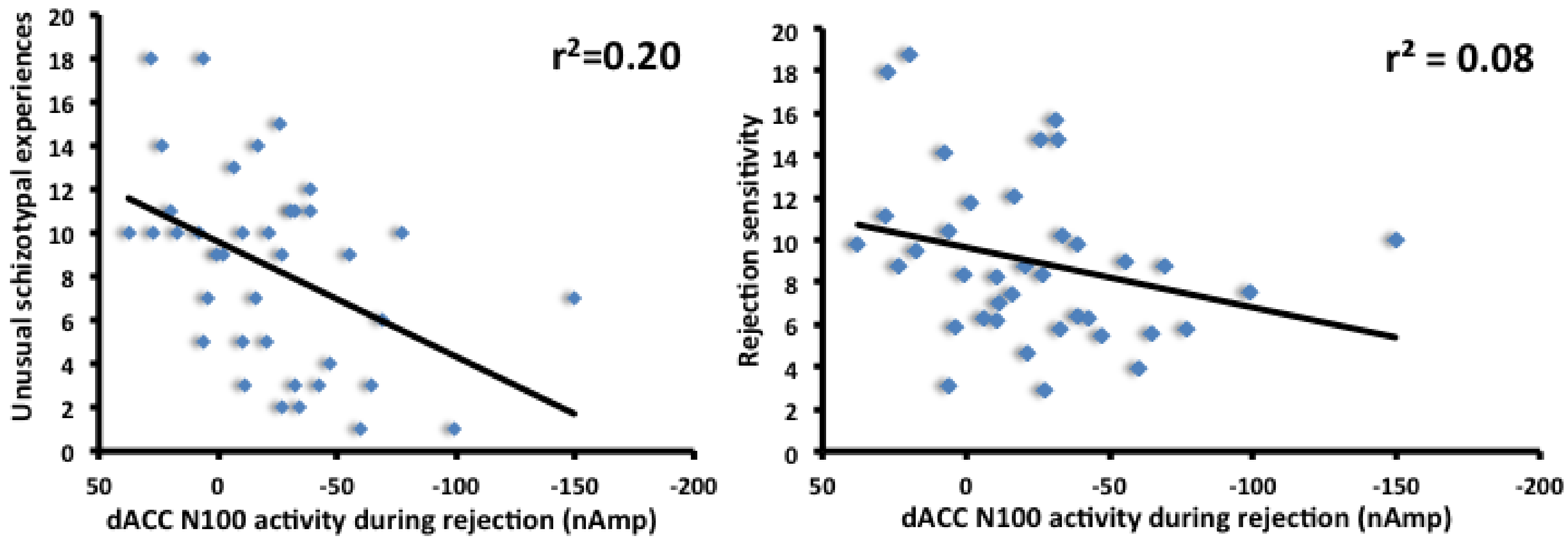


Figure 5. Scatterplot of dorsal anterior cingulate cortex N100 moment during rejection scenes and (a) O-LIFE unusual experiences and (b) rejection

Appendix A. Mean (S.D.) of 30 rejection, 30 acceptance and 30 neutral images ratings on rejection and valence provided by six doctoral or post-doctoral researchers

Interaction type	Rejection (-5=rejection to +5=acceptance)	Valence (-5=negative to +5=positive)
Rejection	-2.3 (0.6)	-2.0 (0.6)
Acceptance	3.9 (0.3)	3.7 (0.3)
Neutral	0.1 (0.3)	0.1 (0.3)