The Influence of Maternal Schizotypy on the perception of Facial Emotional Expressions during Infancy: an Event-Related Potential Study.

[redacted]

Abstract

Parenting directly affects the developmental and clinical outcomes of children. How parental personality relates to perceptual and cognitive mechanisms during early development is not clear. For parents with traits of the personality dimension *schizotypy,* would their infant display brain responses similar to those on the schizophrenia-spectrum? This study investigates whether maternal personality influences early social-cognitive awareness during the first 6 postnatal months.

Schizotypy is a dimension of personality within the general population. If deficits contribute to the development of schizophrenia-spectrum disorders by influencing the development of symptom-like characteristics, they may be observable in neurotypical individuals with *schizotypal* characteristics. Parents and their infants were shown standardised positive and negative faces and event-related potential responses were assessed. It was hypothesised that the infants of *schizotypic* mothers would display differential Negative-central event-related potentials for the happy and fearful expressions when compared to infants of non-schizotypic mothers.

Results support prior literature; indicating 6-month-old infants allocate more attentional resources to fearful when contrasted to happy faces. The adult cohort displays this same ability. In addition, schizotypic mothers displayed comparable amplitudes for both expressions in comparison to the control mothers who exhibited larger amplitudes towards the fearful compared to the happy expression. Infants of schizotypic mothers did not show a greater sensitivity to facial expressions at 6-months, but schizotypic mothers showed a generalised response towards facial expressions compared to the typical *P600* response illustrated by the control mothers. The present study suggests that development in the higher cognitive domains, such as the allocation of attention to novel stimuli, are not affected at 6 months of age by maternal personality related to schizotypy when examined at the group level. Implications for personality development, maternal-infant interactions and cognitive neuroscience methodologies are discussed.

Key Words

EEG, Schizotypy, Event-related potential, Infancy, Facial Expression, Schizophrenia

Introduction

The influence of maternal personality on childhood risk factors for mental health is a widely acknowledged phenomenon, with a substantial amount of interest in the impact of early experiences on brain development in infancy (Belsky and de Haan, 2011). From this literature, it is suggested that the everyday experience of interacting with our parents will influence the processing of facial expressions, with atypical experience exposing infants to relatively frequent intensities of particular expressions (de Haan et al., 2004).

Faces provide preverbal infants with an early source of communicative information (Nelson, 2001) and we know that early in development, there is a preferences for configurations that facilitate early attention to face stimuli (Morton and Johnson, 1991; Reid et al., 2017). This mechanism drives early preferences and aids in the formation of the mother-infant relationship, which aids in the facilitation of social-emotional development (Bowlby, 1969; Blass and Camp, 2003). A window of vulnerability can therefore be observed during the earliest years of life (Andersen, 2003), whereby early adverse rearing, whether the result of personality traits, clinical diagnoses, or varying degrees of maltreatment, can have a lasting negative impact on the developing brain, increasing the risk for maladaptive outcomes (McLaughlin et al., 2014). This is driven by the knowledge that core neuropsychological dysfunctions of potential future psychopathologies may be present during childhood, which shape the development of the adult personality (Corr, 2010). It is consequently of fundamental interest to determine whether early exposure to atypical parenting or adverse developmental environments would result in long-term effects upon neural development (Bick et al., 2019).

Morton and Johnson (1991) suggest that from 2-months of age an infant's interest in faces is driven by an exposure-dependent, experience-based system. A mother's facial expressions are typically a factor to which the infant is extensively exposed (Montague and Walker-Andrews, 2002). As such, it makes sense that maternal emotional states and traits predict the social and emotional experiences that infants encounter during social interaction (Belsky and Barends, 2002). We can therefore propose that infant experiences are also shaped by parental psychological health. Supporting this, differences in maternal psychological health in a typical cohort have been found to affect infant face interest at 3.5-months (Jones, Slade, Pascalis, & Herbert, 2013) possibly due to mothers with a diagnosis of depression illustrating a withdrawn and muted style of interacting with their infants, with a diminished positive affective response (Field et al., 2009). Moreover, there is good evidence suggesting that at later stages of development emotional face processing is altered among children and adults with behavioural and affective disorders (Dolan & Fullam, 2006; Sinzig, Morsch, & Lehmkuhl, 2008): for example, individuals with high state anxiety respond stronger to fearful stimuli (Bishop, Duncan, & Lawrence, 2004), and high trait anxiety has been related to the altered processing of emotional information from both the face and voice (Koizumi et al., 2011).

Schizotypy refers to a dynamic continuum of symptomatology, impairments and personality traits (Kwapil and Barrantes-Vidal, 2012) that are similar to those experienced by the schizophrenia-spectrum (Fonseca-Pedrero et al., 2010). It has therefore been regarded as a predisposition to schizophrenia-spectrum psychopathology (Raine, 1991), which is observed as a personality dimension in the general population (Evans et al., 2017). Recent neuroimaging studies have shown schizotypy has a mild level of emotional deficit compared to the schizophrenia-

spectrum (see Jeong et al., 2017); it is therefore plausible that similar deficits may be observed in schizotypy within the general population.

Bick et al (2019) outline how exposure to atypical parenting or developmental environments may result in long-term effects on neural development, which may draw on the interactive process that children require in order to develop self-regulation through a mother-infant mirroring process. Thus, exposure to a parenting style, which is influenced by schizotypic traits, may somewhat influence the child's own emotion regulation practices and fundamental understanding. Considering the quantity of research supporting an implicit level of very early communication between mother-infant dyads and the idea that parental emotion regulation practices play a core role in supporting their own caregiving abilities (Rutherford et al, 2015), it is likely that similar elements of communication play a role in shaping the regulation and processing abilities of their infants. This will, in turn, contribute to determine their own personality and parenting styles as they continue to develop. This is supported by research indicating the role of early life experiences in shaping implicit neurophysiological processes (Lyons-Ruth et al., 2016) such as our processing of facial expressions. Maternal emotional states and personality traits have therefore already been shown to predict the social and emotional experiences displayed by infants (Belsky and Barends, 2002; de Haan et al., 2004; Prinzie, Stams, Dekovic, Reignties, and Belsky, 2009). This lack of stimulation, or over-exposure to particular expressions may therefore alter the developmental trajectory of the infant (Bick et al., 2019); thus creating a credible pathway for the general stability of atypical processing abilities across generations.

It is well established in the literature that individuals diagnosed with schizophrenia exhibit a variety of social deficits, the majority of which likely predate the onset of symptomatology by several years: possibly as early as childhood (Tarbox and Pogue-Geile, 2008; Tsuji et al., 2013). Emotional impairments may therefore be described as a central feature of schizophrenia (Silver et al., 2009; Mendoza et al., 2011), but these difficulties also appear to be present in vulnerable individuals before the onset of the disorder (Pinkham, 2003) and affect a broad range of domains of emotional functioning (Cedro et al., 2001; Edwards et al., 2002). Electrophysiological data indicates that deficits in early visual processing occur in the first-degree relatives of patients with schizophrenia (Yeap et al., 2006) and are also observed in high-risk groups (Pinkham et al., 2007; Bediou et al., 2007; Addington et al., 2008); proposing deficits in facial emotion processing as a potential endophenotype (Gur et al., 2007).

A fundamental symptom associated with schizophrenia concerns deficits in emotion perception. Individuals diagnosed with schizophrenia have consistently been reported to display deficits in recognising emotions in facial expressions (Kosmidis et al., 2007; Morris et al., 2009), with observations of this deficit in both behavioural and electrophysiological studies (Wynn et al., 2008; Ramos-Loyo et al., 2009; Pinheiro et al., 2013). A recurrent finding is that those diagnosed with schizophrenia-spectrum disorders have difficulty in recognising negative compared to positive facial expressions (Edwards et al., 2001; Kohler et al., 2003; Bediou et al., 2005; Van't Wout et al., 2007), and the ability to process the emotional content of faces (Li et al., 2010). In contrast to previous findings, a greater sensitivity to negative emotions such as anger and fear have also been observed (Evans et al., 2011), with schizophrenia patients displaying increased aversion to angry faces (Evans et al., 2011), and a

disproportionate impairment in the identification of negative emotions, including fear, disgust, and sadness (Edwards et al., 2001; Kohler et al., 2003). Consistent findings indicating that recognition of happy expressions is more accurate and efficient than that of sad expressions aligns with how the general population detect happy faces more accurately and more quickly than negative emotions such as anger and fear (Juth et al., 2005); suggesting that this ability may be conceptualised along a typical-pathological continuum (Evans et al., 2017). The contrasting effects of schizophrenia-spectrum disorders resulting in difficulties in recognising negative emotional expressions, but also displaying greater sensitivities to negative emotions, is a controversy within the spectrum that should be further explored.

The present research explores responses to emotional faces in both infants and their mothers, a proportion of whom exhibit schizotypic traits. Similarly to the mixed findings of the schizophrenia literature, exploring schizotypy in relation to emotion perception, has also produced mixed findings as a result of differential tasks employed and measures utilised (Phillips and Seidman, 2008; Cohen et al., 2015); illustrating how specific facial emotion perception impairments have been associated with increased positive (Miller and Lenzenweger, 2012), negative (Shean, Bell, and Cameron, 2007; Morrison, Brown, and Cohen, 2013), and disorganised (Brown and Cohen, 2010) traits of schizotypy in independent studies. The controversy regarding sensitivity to facial expressions among the schizotypic and schizophrenia-spectrum literature provides motivation for the exploration of the maternal response to facial expressions, in addition to their infants' electrophysiological responses. Moreover, when examining the influence of emotional expressions on the P1 amplitude specifically, adults diagnosed with depression illustrate a main effect of P1 amplitude

for emotional expression stimuli, but no differences are observed between positive and negative emotions (Batty and Taylor, 2003; Eger et al., 2003). This was replicated by Zhao et al (2015) who illustrated no distinct bias on P1 amplitudes between the processing of happy and sad expressions for depressed individuals. This suggests a potential atypicality in the ability of these individuals to distinguish between positive and negative facial expressions, which supports the present hypothesis of a generalised sensitivity to facial expressions; demonstrated through a larger electrophysiological amplitude response, and promotes the exploration of ERP amplitudes among the maternal cohorts.

Outside the typical range of experience, infants of clinically depressed mothers have been shown to experience an atypical emotional environment characterized by a disproportionately high exposure to negative and neutral faces (Dawson et al., 2003). Moreover, Forssman et al. (2014) provide evidence of differential facial emotion processing in infants indicating that the symptoms of maternal depression were associated with decreased attentional disengagement from fearful facial expressions relative to happy or neutral expressions in infants. Furthermore, children who have experienced atypical parenting environments, either due to clinical or sub-clinical parental psychopathologies, have been shown to demonstrate faster recognition of anger and a delayed disengagement from angry stimuli (Pollak et al., 2009). For example, Taylor-Colls and Fearon (2015) examined the Nc magnitude in relation to objectively assessed parental sensitivity, with an association observed for happy, but not fearful, facial expressions. Moreover, infants of mothers who were more sensitive and responsive in their parenting actually shower larger Nc responses to happy faces, relative to neutral faces. This finding outlined by Taylor-Colls and Fearon (2015)

suggests that sensitive parental responses to infant cues help the infant brain to evaluate emotional expressions differently, perhaps attaching greater motivational value to them. In addition, there is evidence that repeated exposure can, under certain circumstances, heighten rather than diminish infant attention to stimuli (for example, Roder, Bushnell, & Sasseville, 2000). Taylor-Colls and Fearon (2015), however, demonstrated larger Nc amplitudes for fearful rather than the more familiar happy or neutral faces, with the Nc also being shown to be larger to the mother's face rather than a stranger's (de Haan & Nelson, 1997). This literature points towards the need for direct measurement of the frequency with which infants are exposed to different parental facial expressions of emotion as important information for disentangling these explanations.

The use of event-related potential (ERP) paradigms to measure neural activity during emotion processing has become a popular approach. Amongst other reasons, this is because this approach captures the exact time course of the emotional information-processing cascade from early to later processing stages with a millisecond-resolution (Luck et al., 2011). There is clear evidence that infants are able to distinguish between emotional expressions (Peltola et al., 2009) with the Negative-central (*Nc*) amplitude consistently observed to be greater in response to fearful expressions than positive or neutral emotions (Courchesne, 1977; Courchesne, Ganz, & Norcia, 1981; de Haan, Belsky, Reid, Volein, & Johnson, 2004; Leppänen, Moulson, Vogel-Farley, & Nelson, 2007). This links to behavioural performance, with longer engagement to fearful than happy faces by 7 months of age (de Haan and Nelson, 1998; Kotsoni, de Haan and Johnson, 2001). It is generally accepted that this greater *Nc* amplitude is a reflection of attention allocation toward the most novel stimuli, in this case a fearful

facial expression (de Haan et al., 2004). The *P600* has been proposed to reflect the recall of information, such as recalling whether a stimulus is familiar (Wilding, 2000; Taylor, Shehzad, and McCarthy, 2016) and is also thought to play a role in the recognition of faces (Eimer, 2000). It can therefore be predicted that the schizotypic mothers may show heightened amplitudes for both expressions in comparison to the controls. The *P1* is reliably elicited in response to visual stimuli in individuals of all ages and is influenced by manipulations of visual information (Taylor et al., 1999; Olofsson, Nordin, Sequeira, and Polich, 2008) including the encoding of face stimuli (Itier & Taylor, 2002). It was predicted that there would be little-to-no difference between amplitudes for the facial expressions in the control mothers, but the schizotypic mothers would display larger amplitudes for both facial expressions.

The notion that personality traits and clinical diagnoses are related constructs on the same continuum is not new (Eysenck, 1992; Corr, 2000), with the underlying vulnerability for schizophrenia-spectrum disorders and schizotypy, expressed across a dynamic continuum of symptoms and traits (Kwapil and Barrantes-Vidal, 2012). The implicit assumption is that exhibiting certain traits is not inevitably associated with the presence of a disorder, but can place these individuals at heightened risk for the development of mental disorders (Kwapil et al., 2013; Debbane et al., 2015). It has long been acknowledged that schizophrenia, as well as other severe psychiatric disorders, runs in families (Battaglia et al., 1991; Asarnow et al., 2001; Nicolson et al., 2003; Tarbox and Pogue-Geile, 2011; Roisko et al., 2015; Soler et al., 2017) and for that reason the study of young relatives at high-risk, such as the offspring of parents with a diagnosis, offers a valuable opportunity to potentially characterise premorbid psychopathology in schizophrenia-spectrum disorders.

On the basis of these two distinct literatures - infant emotion processing and schizotypy research – it can be suggested that schizotypic maternal personality may influence the development of facial expression perception in their infants. This research is drawn from previous literature illustrating the production of atypical emotional environments by parents with mental illness. It is thought that these atypical developmental environments expose infants to a disproportionately high experience of negative facial expressions. Prior literature has demonstrated how under specific conditions, schizophrenic patients are more sensitive to expressions than controls (Evans et al., 2011). We therefore suggest that the infants of schizotypic mothers would display greater amplitudes in the *Nc* component, than the infants of control mothers in both expression conditions. Additionally, we conducted the same experiment with the mothers of the infants with a view to examining the *P1* and *P600* ERP components, also aiming to observe the differential amplitudes of the mothers with schizotypy when compared to their control counterparts. Mothers with schizotypy may show greater sensitivity to facial expressions in the same way that this trait is observed in those further along the schizophrenia-spectrum. The literature outlines the ERPs we would expect to see in relation to positive and negative facial expressions in both the infant and adult cohorts, thus, hypotheses were developed following the mixed results of the literature in both schizophrenia and schizotypic populations; incorporating the potential maternal influence the infant cohort would have encountered in the first 6 postnatal months, suggesting the potential stability of electrophysiological deficits across these generations.

Method

Experiment 1: Infant Cohort

Participants.

One-hundred and one infants, aged 6-months (*M*=5.8 months; *SD*=9.23 days; Range=5.42-6.60 months; 54 male) participated in the study. Fifty-one infants (27 male, all white-Caucasian) were included in the final analysis following data editing. This sample reduction was due to insufficient trials completed for inclusion (*n*=31), sO-LIFE scores not identifying with either control or schizotypic groups (*n*=18), or technical difficulties with processing data (*n*=1). The final sample included twenty-one infants of schizotypic mothers (iSZTm; *M* age= 5.92 months; *SD*=8.69 days), and thirty infants of control mothers (iCONm; *M* age= 5.91 months; *SD*= 7.72 days). Recruitment was carried out using [redacted] infant database. Ethical approval for this research was obtained and complied with [redacted].

Materials and Stimuli

The stimuli were four black and white images of two female faces that posed both happy and fearful facial expressions. Two models were used to increase the generalizability of the results and their photographs were taken against a grey background, and their hair covered by a shower cap. The face stimuli were displayed 70-centimetres from the infant on the 17-inch stimulus monitor. This produced an approximate visual angle of 15.2 degrees (horizontal) and 12.7 degrees (vertical). The stimuli set-up was located in a lit room with a curtain drawn to restrict the distractions

available to the infant during the testing paradigm. These were the same happy and fearful face stimuli as those used by de Haan et al. (2004).

EEG Recordings

Electrophysiological signals were recorded using Electrical Geodesics Inc. amplifiers (input impedance of 80KΩ and sampling rate of 500 Hz). ERPs were measured using an EGI Hydrocel GSN 128 electrode 1.0 net and analysed using IBM Netstation 4.5.4.

For each facial expression stimuli, EEG recordings were condensed to create an epoch from 200ms before to 1000ms after stimulus-onset. Data were baseline corrected and visually edited offline to remove artefacts. For trials in which the segment contained more than 12 poor quality channels, that epoch was excluded. The data was also visually inspected and any channels that illustrated artefacts driven by muscular contractions, eye blinks, or a poor electrode connection were also rejected. An average was created for each of the two emotions, with the two fearful faces combined into a single group, and the same for the happy faces. Participants required a minimum of 15 ‘good trials’ (de Haan et al., 2004) for each face type to be included in further analysis. The average number of good trials was 26.37 (range =15-52) for fearful, and 24.81 (range =15-49) for happy. Following averaging, data were re-referenced to the average reference, and were digitally filtered (30Hz-0.3Hz).

EEG Analysis

We will explore the ERP morphology using full factorial repeated-measures ANOVAs. Corrections for multiple comparisons will be conducted using Bonferroni Post-Hoc tests if significant interactions are observed. If significant differences are

observed between the facial expressions in different regions of interest then paired-samples t-tests in those specific regions will be carried out to explore differences further. The correlational relationships between the ERP morphologies and maternal schizotypy dimensionality will also be explored, although any between-subjects comparisons related to infant ERP data will be interpreted with extreme caution.

Nc

A time window of 425-475ms after stimulus-onset was defined based on prior literature (Nelson & de Haan, 1996; de Haan & Nelson, 1998; de Haan et al., 2004; Kobiella et al., 2008) and inspection of the individual subjects and grand averages, focusing on the fronto-central electrode regions (Figure 1). The *mean amplitude* measure was computed for each facial expression within each region of interest.

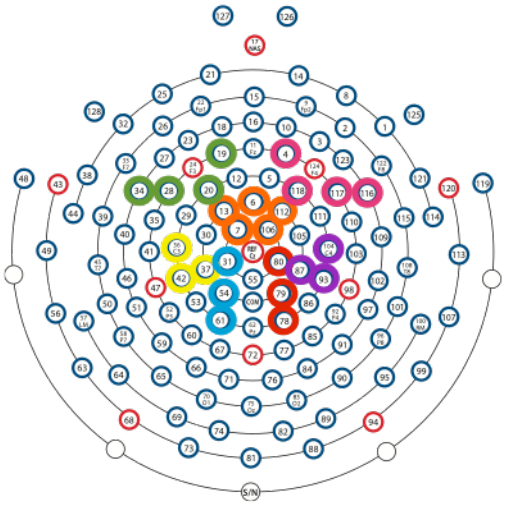

Figure 1. Infant ERP Nc Component Electrode Groupings (Central: 6, 7, 13, 106, 112; Left-Central: 36, 37, 42; Left-Frontal: 19, 20, 28, 34; Left-Posterior: 31, 54, 61; Right-Posterior: 78, 79, 80; Right-Central: 87, 93, 104; Right-Frontal: 4, 116, 117, 118).

Questionnaires.

Schizotypy Assessment.

The Oxford-Inventory of Feelings and Experiences – Short Form (sO-LIFE; Mason, Linney and Claridge, 2005) was used to assess schizotypy dimensionality and consists

of 43 self-reported 'yes/no' items loading onto four factors. This assessment was chosen as it is based on a 'fully dimensional' model, taking a personality-based approach (Claridge, 1997). The sO-LIFE was used to divide the participants into iSZTm and iCONm conditions. The mean sO-LIFE Total score (total mean = 8.091) and standard deviation for the entire population was calculated (total standard deviation = 5.999). The iSZTm group was determined by *M*+.5*SD* (sO-LIFE Scores >11.07) and included twenty-one participants. The remaining thirty-participants were categorized as iCONm and were determined by their score being below *M*-.5*SD* (sO-LIFE Scores < 5.11). This criterion was used as a result of its previous use in the schizotypy literature (for example, in Park, Lim, Kirk and Waldie, 2015).

Personality Assessment.

A shortened version of the EPQ-R personality questionnaire (Eysenck & Eysenck, 1992) was used as a measure of neuroticism in the mothers. There is a substantial overlap between schizotypy and neuroticism in typical participants (Ettinger et al., 2005; Kerns & Watson, 2006) with sizeable correlations observed, and higher levels of neuroticism in individuals diagnosed with schizophrenia (Gurrera, Nestor, & O'Donnell, 2000; Camisa et al., 2005). The shortened version of the EPQ-R includes 12 self-reported 'yes/no' items, with an affirmative answer contributing one point. The present study used only the neuroticism subscale of the Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck & Eysenck, 1992), which has good internal consistency (alpha=.85; Eysenck et al., 1985), and strong concurrent validity with related constructs (Stewart, Ebmeier, & Deary, 2005).

Procedure

The EEG cap was soaked in a warm water sodium chloride and baby shampoo solution before fitting to the infant's head, in order to improve EEG sensitivity. Once

fitted and following confirmation that each electrode responded to electrical activity, the trial procedure began. The infant was seated in the caregiver's lap 70cm from a computer monitor. For each trial, a small, static, black fixation cross was presented in the centre of the screen for a random duration between 800 and 1200ms, followed by one of the four facial expression stimuli, which were presented at the centre of the screen for a duration of 500ms, followed by 600ms with a uniform grey screen. The facial stimuli were presented in a random order with two constraints: (a) each of the stimuli was presented with equal probabilities, and (b) the same emotion was not presented more than three times consecutively. There were 112-trials in total. The participant's demeanor was monitored online throughout the test session by video camera. If the infant became fussy or disinterested in the stimuli, the experimenter triggered the presentation of a moving stimulus with sound to attract the infant's attention back to the monitor, or gave the infant a short break. The testing session ended when the infant's attention could no longer be attracted to the screen or upon completion of the programmed stimuli set. EEG was recorded continuously throughout the session, and the infants were also video-recorded throughout to allow for the video to be coded off-line, eliminating trials in which the infant was not looking at the stimuli or looked away from the screen. The maternal cohort were invited to take part in the same paradigm on a separate occasion.

Results

Nc

A full factorial 2 (group: iSZTm or iCONm) x2 (expression: happy or fear) x7 (electrode region: Central, Left-Central, Left-Frontal, Left-Posterior, Right-Posterior, Right-Central, Right-Frontal) repeated-measures ANOVA with Bonferroni corrections for pairwise comparisons was carried out to explore the mean amplitude

Nc measure. This indicated a significant difference could be observed between the facial expressions ($F(1,49)=4.727$, $p=.035$, $\eta_p^2=.08$), and the regions of interest ($F(6,294)=21.835$, $p>.001$, $\eta_p^2=.31$). No significant interactions were observed. A paired-samples t-test then demonstrated a significant difference between the fearful and happy expressions in the left-frontal ($t(50)=-2.307$, $p=.025$), left-central ($t(50)=-2.959$, $p=.005$), and left-posterior ($t(50)=-2.495$, $p=.016$), regions. No further significant effects were observed. See Table 1 for the means and standard deviations for the infant Nc mean amplitude in the significant regions of interest. No significant group differences were observed between the infants of schizotypic and those of control mothers.

Table 1. Means and Standard Deviations for the infant *Nc* component mean amplitude in left-central, left-frontal, and left-posterior regions ($n=51$).

Electrode Region	Condition	Mean	Standard Deviation	Paired-samples t-test sig.	Group Mean*(SD)* iSZTm	Group Mean*(SD)* iCONm
Left-Central	Fearful	-10.75	5.00	.005	-11.12(4.87)	-10.48(5.16)
	Happy	-8.28	5.71		-9.21(5.29)	-7.63(5.98)
Left-Frontal	Fearful	-5.89	6.25	.025	-6.98(5.34)	-5.14(6.80)
	Happy	-4.14	5.94		-5.47(4.55)	-3.21(6.67)
Left-Posterior	Fearful	-11.94	5.71	.016	-11.56(5.57)	-12.21(5.89)
	Happy	-9.77	5.31		-9.74(4.51)	-9.79(5.89)

A negative correlational relationship was observed between the maternal sO-LIFE introvertive anhedonia dimension and the infants Nc mean amplitude in the right-posterior ($n=57$; $r=-.29$, $p=.03$) and right-central ($n=57$; $r=-.37$, $p=.005$) locations in response to the fearful expression. See Figure 3 for these correlational relationships.

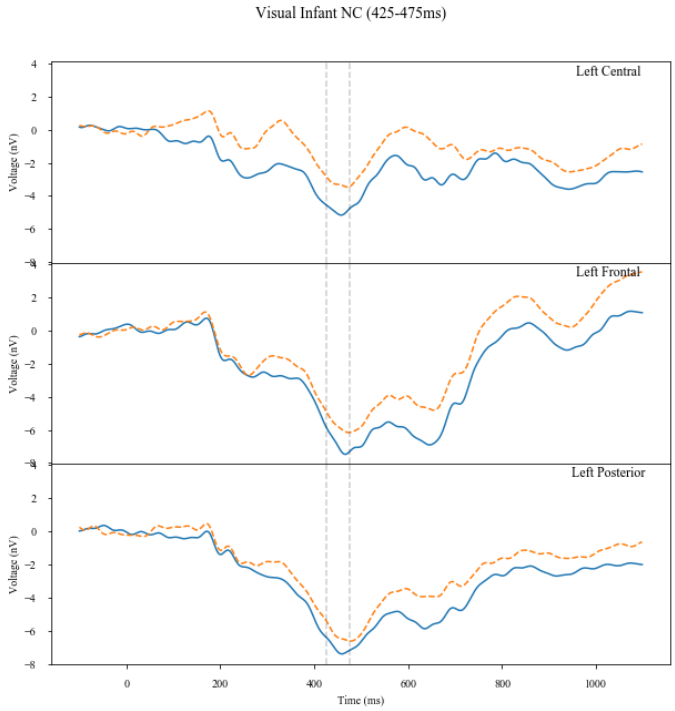

Figure 2. The *Nc* component in the left-central, -frontal, and –posterior regions across the infant cohort. Note how the fearful amplitudes are more negative than that of the happy expression. Legend – complete line=Fearful Expression, dotted line= Happy Expression.

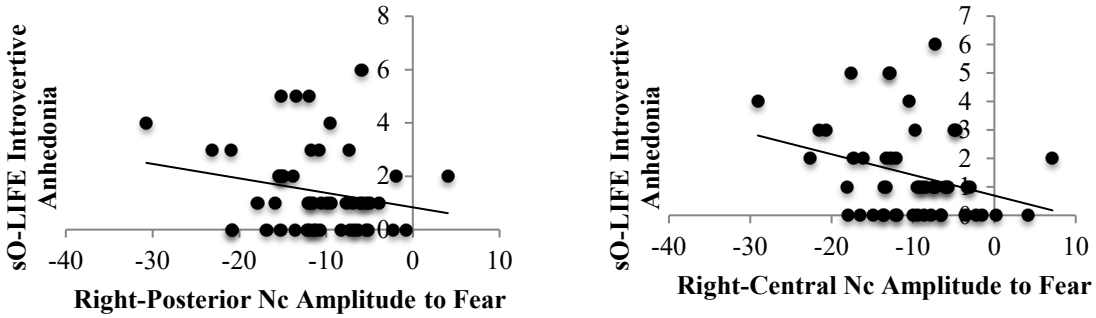

Figure 3. Correlational analyses illustrating negative relationships between maternal sO-LIFE introvertive anhedonia and infant Nc mean amplitudes towards fearful stimuli. Note how decreased Nc amplitudes were observed towards fearful stimuli among those infants with a greater maternal sO-LIFE score.

Experiment 1: Discussion

The aim of this study was to examine the potential influence of maternal schizotypy on infants' responses to facial expressions of emotion. The results demonstrate overall effects for the entire sample whereby the infant cohort display differential amplitudes

between the happy and fearful faces, but differences between the groups were not observed. The present research found significant generalised within-subject effects of facial expression across different regions, illustrating how the total infant cohort allocated differential attentional mechanisms to each facial expression; supporting the prior literature (de Haan et al., 2004). The results demonstrate that maternal schizotypy does not influence the infants' *Nc* ERP responses to facial expressions at 6-months of age.

Nc

Significant differences were observed in Left-Central, Left-Frontal, and Left-Posterior regions, illustrating how 6-month-old infants allocate more attentional resources towards fearful faces than happy faces. It is generally interpreted that this additional allocation is due to the novelty of the fearful expression (de Haan et al., 2004). It can therefore be suggested that at 6-months the allocation of attentional resources to novel stimuli is not influenced by maternal schizotypy.

An additional correlation illustrated a negative relationship between the mean amplitude measure of the fearful expression and the introvertive anhedonia measure; indicating that a large sO-LIFE score, which is indicative of schizotypy, can be associated with reduced Nc amplitude towards fearful expressions. This correlation highlights a potential relationship that supports our hypotheses that over-exposure to a more withdrawn or negative parenting style may result in reduced attentional resources allocated to fearful faces when compared to happy faces. With respect to the sO-LIFE dimension and the infant ERP data, any between-subjects comparisons related to infant ERP data should be treated with extreme caution due to large inter-individual variability (Thierry, 2005).

The current study divided the participants into iSZTm and iCONm using the overall sO-LIFE score. This questionnaire favours the fully dimensional approach, describing how the features of schizotypy are observed in the general population and link typical personality traits to atypical clinical disorders (Claridge et al., 1996). It is possible that the lack of significance in some regions is due to larger standard deviations observed, causing the groups to overlap. In summary, the results illustrated support for prior literature demonstrating how 6-month-old infants allocate greater attentional mechanisms towards fearful expressions when compared to happy expressions. These data suggests that maternal schizotypy does not influence the infants' ability to differentially process these emotions at 6-months of age when explored at the group level. However, the correlational analyses, which may be argued to be the more suitable, suggests the emergence of individual differences, highlighting the infants of schizotypic mothers as exhibiting greater amplitudes towards the fearful stimuli.

Experiment 2: Adult Cohort

Experiment 1 showed that infants at 6-months are able to differentiate between happy and fearful faces, but that maternal schizotypy did not influence the overall cohort's ability to do this. The principal aim of *Experiment 2* was to examine the effects of schizotypy status on the mothers themselves in the *P1*, and *P600* components.

Participants

Fifty-seven mothers of the previously tested 6-month-old infants (*M*=32.8 years; *SD*=7.33 years; Range=23-44 years) participated. Forty-three mothers were included in the final analysis following data editing: exclusions due to technical difficulties

(n=1), data not reaching the inclusion criteria described below (*n*=1), and sO-LIFE scores not identifying with either the control or the schizotypy group (*n*=12). The final sample included twenty-three participants who identified as schizotypic mothers (SZTm; *M*=32.7 years, *SD*=5.27 years) and twenty control mothers (CONm; *M*=32.9 years, *SD*=2.05 years). Recruitment was carried out in the same manner as *Experiment 1*. The same stimuli and materials were used as in *Experiment 1*.

An independent samples t-test was used to address the demographic variables associated with the adult cohort for *Experiment 2*, and the infant's age in *Experiment 1*. Chi- squared was used to observe the effect of gender on the infant cohort. See Table 2 for the non-specific differences in the demographic, social and clinical factors associated with the mothers. The mothers and infants themselves were matched across a range of demographic and clinical factors. A significant difference was observed in the mothers' mental health experiences, with chi-squared analysis demonstrating a greater incidence of mental illness of some kind experienced by those mothers identifying as schizotypic. The assessment scale used is not a standardised or validated clinical assessment tool; instead it was a self-report measure on the mothers' previous experience of mental illness.

Table 2. A Table to illustrate the demographic variables across both Infant and Adult Cohorts. Note how the non-schizotypy and schizotypy groups in both infants and adults were age-matched.

		Non-Schizotypy M(*SD*)		Schizotypy M(*SD*)		T-Test	Chi-Squared
Infant Age (days)		179.90(*7.72*)		180(*8.69*)		.901	
Infant Gender	Female	*n*=16		*n*=8			.283
	Male	*n*=14		*n*=13			
Mother's Age (years)		32.50(*2.67*)		32.60(*5.32*)		.945	
Mother's Mental Health Experiences (n=48)		No History *n*=24	History *n*=4	No History *n*=9	History *n*=11	.002	
Family History of Mental Health		1.64(*.49*)		1.45(*.51*)		.192	
Birth Complications		1.66(*.86*)		2.05(*.99*)		.145	

P1

A time window of 75-105ms after stimulus-onset was defined. The *P1* analysis focused on occipital-left, and occipital-right regions (Figure 4). The mean amplitude was computed for each facial expression within each electrode group.

P600

A time window of 590-650ms after stimulus-onset was defined and analysis focused on the occipital-left, and occipital-right regions (Figure 4). The mean amplitude was computed for each facial expression within each electrode group.

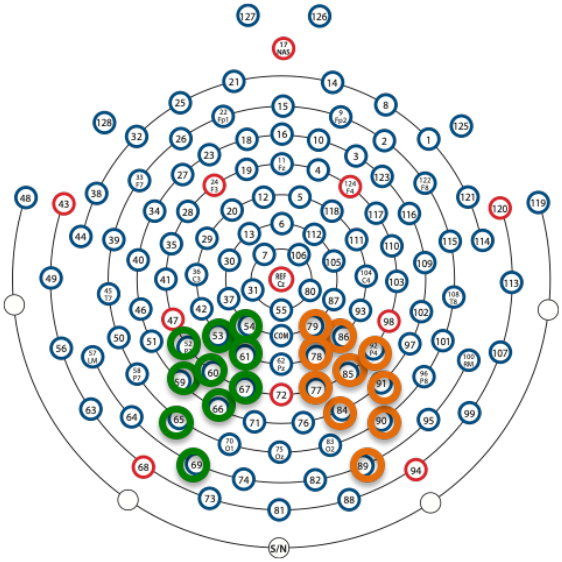

Figure 4. Adult Electrode Groupings. Occipital-Left (green; 52, 53, 54, 59, 60, 61, 65, 66, 67, 69) and Occipital-Right (orange; 77, 78, 79, 84, 85, 86, 89, 90, 91, 92).

Procedure

The same procedure was utilised in *Experiment 2* as was employed in *Experiment 1*.

Results

P1

A 2 (group: SZTm or CONm) x2 (expression: fear or happy) x2 (electrode group: occipital-left or occipital-right) repeated-measures ANOVA with Bonferroni corrections for pairwise comparisons was utilised to explore the P1 component in the maternal cohort. This found a main effect of emotional expression ($F(1, 41)=6.97$, $p=.012$, $\eta_p^2=.15$) and a main effect of region of interest ($F(1,41)=4.43$, $p=.041$, $\eta_p^2=.09$; see Figure 5). No further comparisons were found to be significant.

A significant positive relationship was observed between the maternal neuroticism measure ($n=43$, $r=.34$, $p=.03$) and the P1 posterior-left mean amplitude measure for the fearful expression. A significant association was also observed between the maternal sO-LIFE Cognitive Disorganisation dimension and the P1 posterior-left

mean amplitude measure for the fearful expression (*n*=54, *r*=.31, *p*=.03). This suggests that greater neuroticism and larger schizotypy cognitive disorganisation dimensionality was observed in those displaying greater amplitudes across the facial expression stimuli. No further significant relationships were observed (See Figure 6).

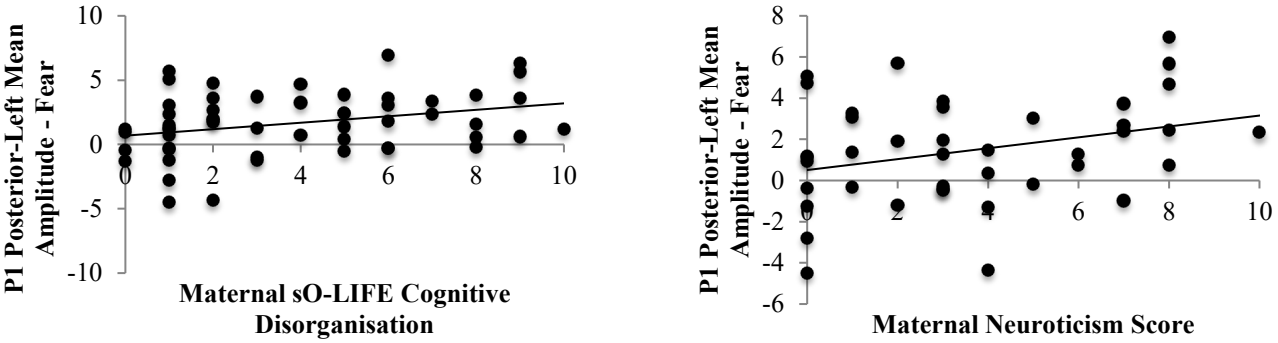

Figure 6. Correlational analyses illustrating relationships between maternal sO-LIFE cognitive disorganisation and neuroticism scores and the maternal P1 mean amplitudes towards fearful stimuli. Note how increased P1 amplitudes were observed towards fearful stimuli among those mothers with a greater maternal neurotic or sO-LIFE score.

P600

A 2 (groups: SZTm or CONm) x2 (expression: fear or happy) x2 (region of interest: occipital-left or occipital-right) repeated-measures ANOVA with Bonferroni corrections for pairwise comparisons explores the maternal P600 component. There was a significant main effect of emotional expression (F(1,41)=8.89, p=.005, η_p^2=.18). Overall there was no significant between-group differences were found in the ANOVA (F(1,41)=.26, p=.61, η_p^2=.01) and post-hoc multivariate ANOVA analyses confirmed no significant group differences between the amplitudes exhibited towards the fearful expression (F(1,41)=.14, p=.71, η_p^2=.003) and those towards the happy expression (F(1,41)=1.17, p=.29, η_p^2=.028) in the right-occipital region, but the expression*group interaction was found to be significant (F(1,41)=5.01, p=.03, η_p^2=.11), which were Bonferroni corrected for multiple comparisons (See Figure 7 for representation of the reported effects). In order to locate the effects of this interaction

we conducted post-hoc comparison using a paired t-test. These revealed that there was no significant difference in expression for the SZTm, (t(22)=.57, p=.57), however there was a significant difference between expression for the CONm group (t(19)=3.39, p=.003). To further explore the smaller difference in amplitudes in the SZTm, a difference score was calculated (Fear Expression Amplitude – Happy Expression Amplitude), which was utilised in a Multivariate ANOVA. This analysis highlighted a significant group difference in the occipital-left mean amplitude difference (F(1,41)=5.74, p=.02, η_p^2=.12; see Table 3). No further comparisons were found to be significant. No significant relationships were observed between the maternal P600 component and the sO-LIFE dimensions or neuroticism tendencies.

Table 3. Means and Standard Deviations for the maternal P600 component mean amplitude in occipital-left and occipital-right regions (*n*=43).

Electrode Region	Condition	Mean(SD)	Group Mean(SD) SZTm	Group Mean(SD) CONm		Multivariate ANOVA sig.	Mean(SD) Amplitude Difference SZTm	Mean(SD) Amplitude Difference CONm
Occipital - Left	Fearful	2.24(1.49)	1.99(1.38)	2.52(1.61)	Mean Amplitude Occipital-Left Difference	.02	-.08(1.05)	.93(1.69)
	Happy	1.86(1.39)	2.08(1.29)	1.59(1.49)				
Occipital - Right	Fearful	2.27(1.66)	2.36(1.59)	2.17(1.76)	Mean Amplitude Occipital-Right Difference	.26	.32(1.23)	.69(.89)
	Happy	1.78(1.73)	2.04(1.55)	1.47(1.90)				

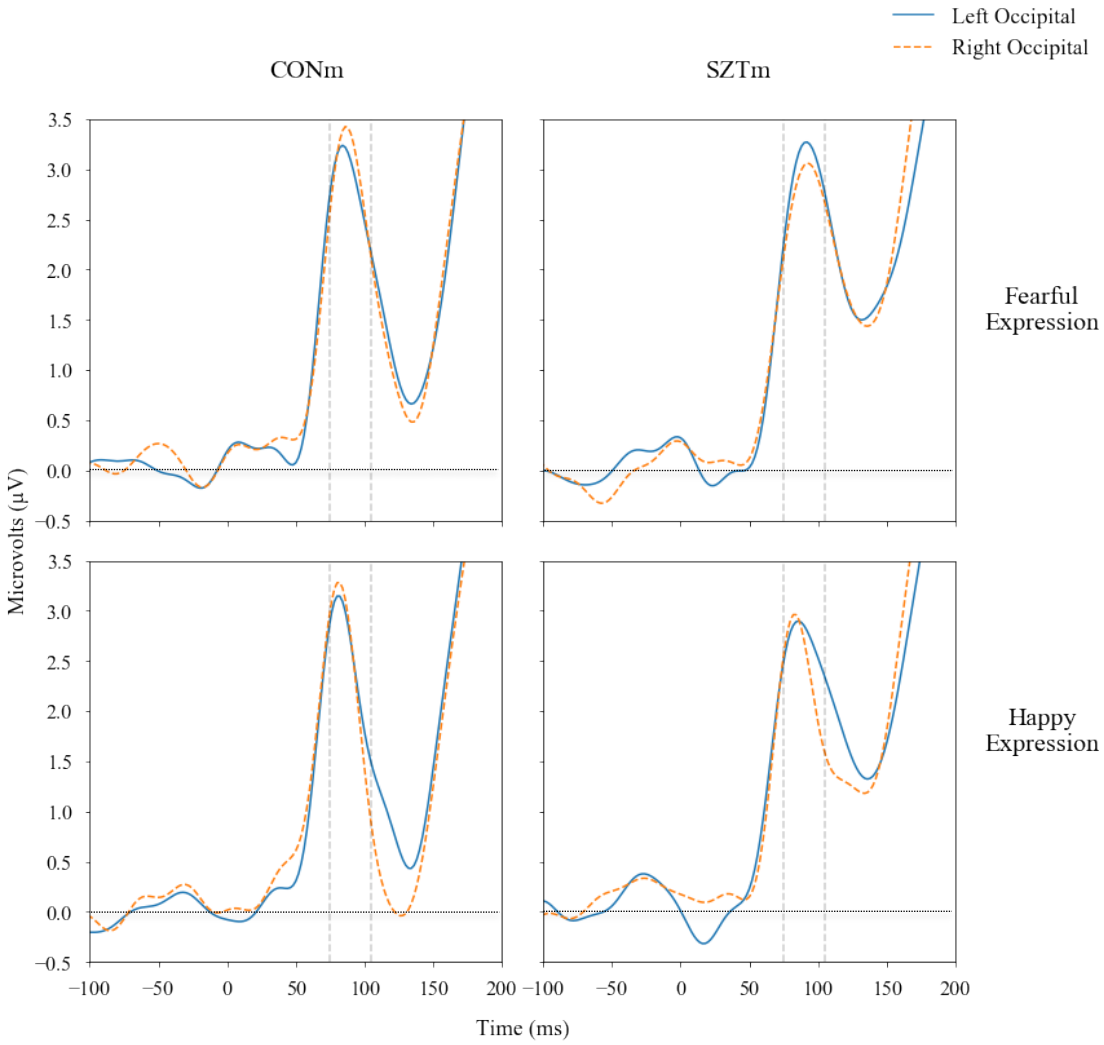

Figure 5. The Maternal *P1* event-related component. Despite no significant group differences reported, note the SZTm amplitudes for fearful (*M*=2.28; *SD*=2.30) and happy (*M*=1.80; *SD*=2.29) expressions compared to the fearful (*M*=1.01; *SD*=2.39) and happy (*M*=.83; *SD*=2.93) expressions in the control mothers.

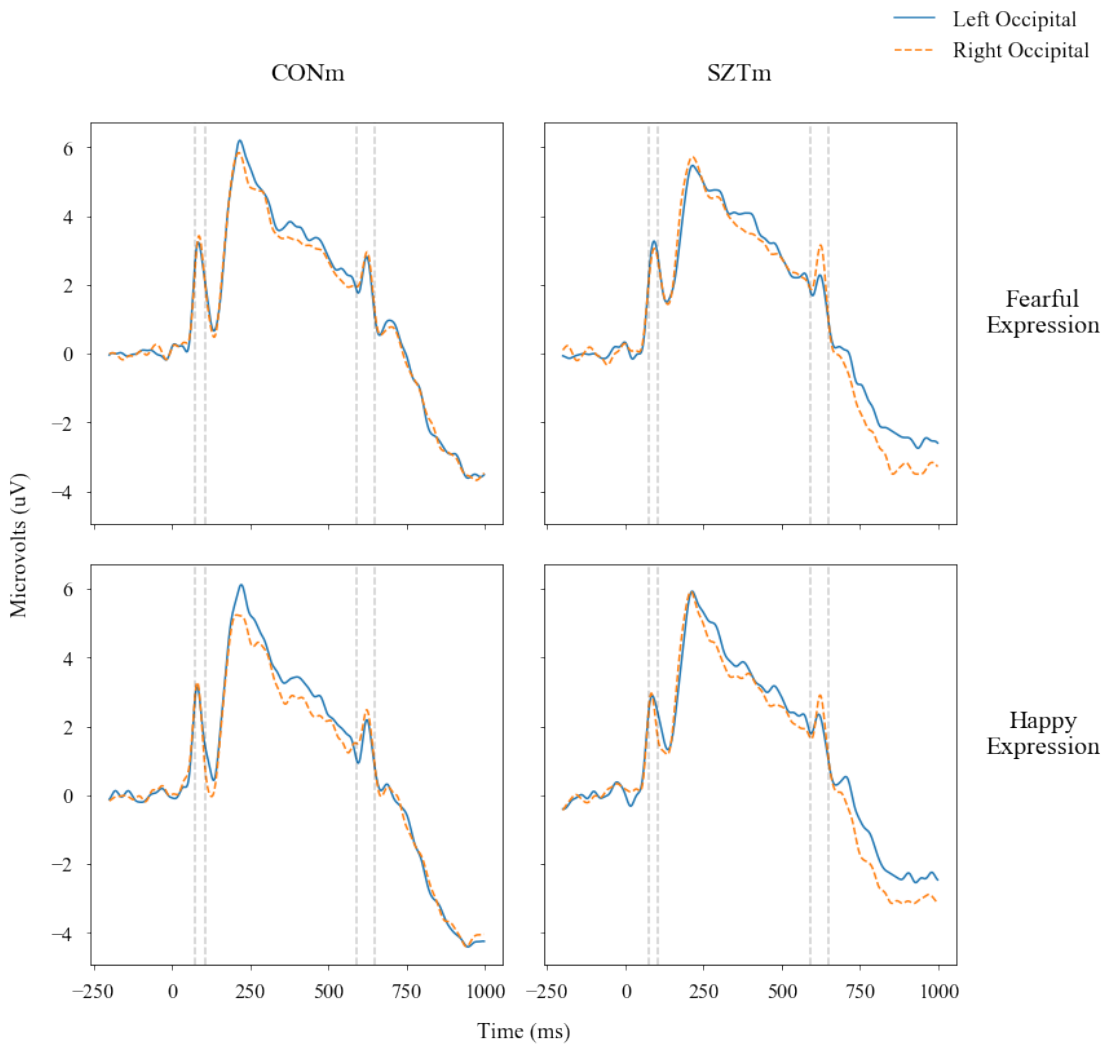

Figure 7. The Maternal ERP amplitudes. For the P600 ERP, note how in the left-occipital region (blue line) the SZTm illustrate similar amplitudes for both fearful (*M*=1.99; *SD*=1.38) and happy (*M*=2.08; *SD*=1.30) expressions, in comparison to the CONm who display a larger amplitude towards the fearful (*M*=2.52; *SD*=1.61) compared to the happy (*M*=1.60; *SD*=1.49) expression.

Experiment 2: Discussion

The present research highlighted a significant difference between amplitudes exhibited towards the facial expressions across the maternal cohort. The left-occipital region in the *P600* demonstrated a significant difference between the SZTm and CONm groups. These effects in the *P600* illustrated how those who identified as schizotypic demonstrated comparable amplitudes for both facial expressions

compared to the control group. This suggests a sensitivity to facial expressions, in support of Morris et al (2009) and Strauss et al. (2011). In contrast, the *P1* illustrated no significant group differences, but significant differences were observed between the facial expression amplitudes.

P1

A significant main effect of expression (happy versus fearful) and region of interest was observed in the P1 amplitudes. Upon exploration of the descriptive statistics, it was observed that the schizotypic mothers exhibited larger P1 amplitudes for both expressions in comparison to their control counterparts, although these differences were not large enough to drive significance at the group level. The *P1* has been described to index attentional responses to visual stimuli in individuals of all ages; but in relation to facial expressions it could be predicted that adults would show no difference between attentional allocations to different facial expressions as they are exposed to different facial expressions regularly. Due to the dimensional nature of the schizophrenia-spectrum, and thus the degree of deficit, a more practical statistical approach may be to explore correlational relationships. Thus, when taking this approach, significant positive associations were observed between the cognitive disorganisation dimension and P1 mean amplitude in the poster-left region for the fearful expression, suggesting that those mothers exhibiting schizotypic traits, in the form of cognitive disorganisation, also displayed greater amplitudes in the facial expression stimuli.

P600

A significant main effect of expression and an expression*group interaction was found in the maternal P600 component. When exploring the descriptive statistics, the data indicated a smaller difference in amplitude between the happy and fearful

expressions in the schizotypic mothers compared to the corresponding amplitudes exhibited by the control mothers. Thus it is possible to suggest that schizotypic mothers display a general electrophysiological response to facial expressions in contrast to the typical response demonstrated by the control mothers. No significant correlational relationships were observed between the maternal P600 component and the sO-LIFE dimensions or neuroticism tendencies.

General Discussion

To better understand the relationship between maternal schizotypy and facial emotion perception, an ERP study was carried out with 6-month-old infants and their mothers. Considering the notion that elements of communication between mother-infant dyads play a role in shaping the regulation and processing abilities of these infants, the present research explored whether the perception of facial expressions exhibited by schizotypic mothers would influence the perception of their 6-month-old infants.

It was found that the 6-month-old infants were able to differentiate between fearful and happy expressions, but that maternal schizotypy did not influence this ability at 6-months. The maternal cohort illustrated a main effect of expression in both *P1* and *P600* components; illustrating similar amplitudes for both happy and fearful expressions when contrasted with the control mothers. Thus, it is possible that schizotypic mothers display a generalised response towards facial expressions in comparison to the typical response illustrated by the control mothers, although no significant group differences were observed at the group level. The present research provides further exploration of facial expressions among schizophrenia-spectrum traits/symptoms; do these individuals illustrate a greater sensitivity towards facial expressions or generalized amplitudes towards facial expressions, which contrasts with those exhibited by controls?

Moreover, due to the dimensional nature of the schizophrenia-spectrum it could be argued that a more pragmatic statistical approach may have been to explore the correlational relationships between maternal schizotypy and the electrophysiological responses to emotive stimuli. Thus, when taking this approach, the infants of

schizotypic mothers highlight a potential relationship that supports our hypotheses that over-exposure to a more withdrawn or negative parenting style may result in reduced attentional resources allocated to fearful faces when compared to happy faces. Whereas, the maternal cohorts suggest that those mothers exhibiting schizotypic traits, in the form of cognitive disorganisation, also displayed greater amplitudes in the facial expression stimuli. Notwithstanding, with respect to the sO-LIFE dimension and the infant ERP data, any between-subjects comparisons related to infant ERP data should be treated with extreme caution due to large inter-individual variability (Thierry, 2005).

It is possible to speculate on the potential reasons for the null group effect in the infant cohort. It is, of course, entirely possible that the atypical perception of facial expressions is not an ability that is altered by having a mother with schizotypic traits, but there are potential reasons why the infants of schizotypic mothers may have not displayed significant differences at 6-months. For example, the perception of facial expressions and the attentional mechanisms oriented towards them are a complex cognitive process and as such, is not influenced by such a specific personality trait; thus, there isn't an effect at 6-months, but there may be later in development as significant correlations were observed. Additionally, it is possible that the mothers over-compensate and are overly positive with their infants at this age; thus, their more 'negative' traits aren't expressed in their true manner to the infants until later on in development when they are more routinely exposed to a more representative pattern of traits. Kaitz (2010) suggested that the increase in negative emotion expression among anxious parents may not be visible during everyday dyadic parent-infant interactions and may instead be specific to particular circumstances. This could

explain the null group effect in the infant cohort in the present paper, although further exploration would be required.

The current findings of *Experiment 2* display how *P1* differences were observed between the facial expressions, but no direct significant group differences were observed. Exploration of the means and standard deviations suggested that the schizotypic mothers had a tendency to produce greater amplitudes towards both facial expressions, whereas the control mothers displayed a slightly greater amplitude towards the fearful expression, although these differences were not large enough to drive significance. However, the present *P600* results support prior findings illustrating how schizophrenia-spectrum individuals display comparable amplitudes, that is a smaller difference in amplitudes, towards facial expressions (e.g. Morris et al. (2009) and Strauss et al. (2011)).

The study of individual differences utilising infant EEG is a very small subfield, which requires further understanding of the parameters of infant analyses within neuroscience methods. The present research has therefore begun to pave the way for future infant EEG parameters. The current infancy literature utilising EEG and ERP measures demonstrates a wide variety of methods; this suggests that for an effective level of comparison across all literature, for example, specific norms should be identified for data editing processes and the use of reference electrodes. A more obvious issue across the literature is the variation in electrophysiological data collection systems and their variation in montage type, quantity, location, and placement. These systems can be identified as low- (ranging from 3-32 electrodes) and high-density (ranging from 32-256 electrodes) montages.

The main advantage of using a high-density montage is the increased opportunity for source localisation, use of the average reference, and the relative increased ability to detect subcortical electrical activity. The low-density montages typically follow the 10-20 system of electrode placement, whereas the arrangement of electrodes for the high-density montages does not typically follow this international 10-20 system due to the fact that the tension structure conforms to the geometry of each individual's head, but ensures that each electrode is equidistant from one another. The ability to precisely map the topographical location of the equivalent electrodes is vital for consistency throughout the literature and something that is still not done accurately across all electrophysiological measurement systems. In relation to this, the present research references to the average reference, which is the more commonly utilised procedure (for example, de Haan et al., 2004), although other references can be used, such as a mastoid reference (see Lei & Liao, 2017 for a discussion of the influence reference has on EEG analysis).

Key strengths to the current study include the use of the overall sO-LIFE score as a global measure of schizotypy dimensionality across the two groups. Capturing this typical-pathological continuum in the expression of schizotypal traits presents significant measurement challenges and as such the assessment tools needed to be sufficiently sensitive to register subtle variation across the whole continuum to avoid floor/ceiling effects. The concept of schizotypy is a significant phenomenon in current psychiatry and the sO-LIFE is an important tool in this respect (Dembinska-Krajewska & Rybakowski, 2014). To focus on the continuous nature of schizotypic traits in conjunction with the rest of the schizophrenia spectrum, a focus on the individual sub-dimensions of the sO-LIFE may have provided a more accurate

reflection of the relationship schizotypy has with the clinical portion of the continuum. This is a potential limitation of the present work: focusing on individual sub-dimensions would have allowed for a direct mapping of the 'positive', 'negative' and 'disorganised' traits\symptoms outlined across the schizophrenia-spectrum, which underlie schizophrenia (e.g., Lenzenweger and Dworkin, 1996) and are replicated in the non-clinically ascertained schizotypy (Kwapil, Barrantes-Vidal, and Silvia, 2008). Nevertheless, the lack of reliability in these measures across the schizophrenia-spectrum (for example, Cochrane, Petch, and Pickering, 2010) is a limitation of this proposition. In contrast, however, the use of a combined dimensions total-score, as used in the present research, although not providing a segregated reflection of the different elements of schizotypy, does nevertheless provide a way of grouping individuals who exhibit generalized traits. If schizotypy can be described as a loose collection of relatively independent vulnerabilities (Davidson et al., 2018), segregating participants into separate groupings may obscure their observable, and measurable, vulnerabilities. For example, some of the characteristics that traditionally define schizotypy, for example 'negative' schizotypal characteristics such as social anhedonia, and 'positive' characteristics such as suspiciousness are suggestive of a general impairment in social cognition (Davidson et al., 2018). It is clear that the definition of schizotypy assimilates multiple dimensions of the schizotypic personality state. The proposed 'solution' to this issue is to take a more dimensional approach (Premkumar et al., 2014; Premkumar et al., 2015, for example); perhaps within-group correlational design structures that display sensitivities to individual differences. But there are limitations to this 'solution' too. This approach does not allow the comparison of specific abnormalities between the general population, schizotypy, and schizophrenia-associated disorders. The present research utilized a

small sub-sample of the general population, and was thus an accurate way of segregating those with schizotypic traits from those who show little-to-no schizotypic traits. For future analyses, where exploring the continuity of endophenotypic traits/symptoms is a primary focus, addressing individual sub-dimensions of schizotypic personality may well be a more profitable approach. A strength of the current work, however, was the non-specific difference in demographic, social and clinical factors associated with the mothers. As shown in Table 2, the mothers and infants themselves were matched across a range of demographic and clinical factors. This supports, however, the hypothesis that the critical explanatory factor was the specific schizotypy status of the mother, rather than generalised or non-specific factors.

In summary, the key findings of the current study are that 6-month-old infants are able to differentiate between happy and fearful facial expressions and allocate their attentional resources according to their novelty. At 6-months, maternal schizotypy is not a prominent factor in influencing this ability and as such no clear differentiation was observed between the two infant groups. Mothers with schizotypy display sensitivities to facial expressions with similar amplitudes generally displayed across both expressions when compared to controls.

The current study enhances our understanding of parental influence on development, demonstrating how the offspring of mothers with schizotypy do not display distinct cognitive deficits in higher cognitive domains at 6-months even when maternal processing of the same stimuli indicates differences between groups by adulthood. However, it is possible to argue that the correlational analyses show that individual

differences are observable to a dimensional degree at 6-months, but they are only just beginning to emerge.

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