An Exploration into the influence of Schizotypic Maternal Personality on Early Sensory Development.

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This thesis is submitted for the degree of Doctor of Philosophy

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November 2018

Declaration

This thesis has not been submitted in support of an application for another degree at this or any other university. It is the result of my own work and includes nothing that is the outcome of work done in collaboration except where specifically indicated. Many of the ideas in this thesis were the product of discussion with my supervisor.

Eleanor Smith 27th November 2018

Abstract

It has been known for some time that maternal personality is an influential factor in determining developmental and clinical outcomes in childhood risk for mental health. Current literature describes *schizotypy* as a multidimensional construct, representing a vulnerability to the schizophrenia-spectrum. This thesis investigates atypicalities observed throughout the spectrum aiming to determine whether these were present in mothers with sub-clinical schizotypy, and their offspring.

Chapter 2 explored sensory gating in infants at 6-months of age. Infants displayed intact sensory gating, and there was no difference between infants of schizotypic and those of control mothers. The mothers of the infants displayed significant differences between *Stimulus 1* and *Stimulus 2*, but also differences as a result of their schizotypy dimensionality; replicating prior literature. Similarly, in Chapter 3, schizotypic mothers displayed reduced oscillatory power towards *Stimulus 1* of the paired-tone paradigm, replicating prior literature. In contrast, their infants showed no group differences. This implies that having a mother with schizotypic traits does not influence the sensory gating ability of their 6-month-old infants.

Chapter 4 demonstrated that 6-month-old infants differentiated between happy and fearful emotional facial expressions, replicating prior literature. Maternal schizotypy, however, did not influence this ability. When exploring face processing in the maternal sample, schizotypic mothers exhibited greater amplitudes towards both facial expressions when contrasted with non-schizotypic mothers. In Chapter 5 we explored relationships between schizotypy and mother-child interactions in a free play session. We found that oscillatory power shown by infants in their left and right parietal regions was greater when their mother was talking to them, or when they were playing independently with a toy, compared to a baseline. No significant differences were observed between infants of schizotypic, and those of control mothers.

Despite a lack of infant group effects, it is important to explore schizotypal expression during adolescence and adulthood as a critical link to childhood risk markers, which confer a role of *developmental facilitators* on the road to psychosis proneness. This thesis concludes that schizotypy is linked to the schizophrenia-spectrum, as shown consistently by maternal electrophysiological data, but that maternal level of

schizotypy did not have an effect on infant markers.

Acknowledgements

Thank you with my whole heart **Vincent Reid**. It is safe to say that without your guidance and support, both professionally and personally, I would not have found my feet as a PhD Student and progressed on to my new position in Cambridge. You have given me the opportunity to acquire a unique skillset and also to develop myself on a personal level. **Trevor Crawford**, thank you for your guidance, care, and continued encouragement. Thanks for checking in to ensure I was attending to my work-life balance as well as my work. A warm thank you to **David Elliott**, for the friendly support through the highest and lowest of times, and your incredible hard work on our paper collaboration. Throughout my university experience you have been there and have helped me flourish into the person I am today! The biggest thank you to **Katharina Kaduk** for your on-going and endless support in so many areas: introducing me to EEG during my undergraduate degree, helping me find my place in the Babylab and providing any help I may have needed during the endless EEG analysis. Thank you for being such an amazing Babylab Manager – your friendship and humour got me through the toughest of days, and my PhD studies would not have come together the way they did without your drive and support.

I would like to thank **Gert Westermann** and the other members of the department who were involved in awarding me my Doctoral Scholarship. Many thanks to the **Leverhulme Trust** for providing me with this wonderful and unequivocally brilliant opportunity, which has allowed me to meet some superb people, visit places I never would have dreamt of visiting, and for simply allowing me to begin this journey within myself. I am extremely lucky to have been part of the Lancaster University **Babylab**; I feel so privileged to have come to work in such an inspiring and encouraging environment and be surrounded by such brilliant and motivated individuals.

A heartfelt thanks to my **family**. You were always there to proofread a draft, talk over a concept, or just be there when I needed you the most. **Mum**, you are the best proof-reader I know and were always up for a dog-walk, which helped me in more ways than you will ever understand. **Dad**, despite the physical distance, you were always engaged in my progress and there with me every step on my way to finishing this courageous task. Plus, the cards of wisdom made me smile everyday! And **James**, you always brought me back to planet earth, rather than planet PhD. You are so grounded and helped me see the bigger picture when I was so absorbed in all-things PhD. You probably didn't even realise how much I appreciated your support throughout the past 3-years. Thank you.

Perhaps the most ridiculous thanks, as she won't be able to read this for herself, but I know she understands the love I feel for her everyday. But, **Remi**, you shared my achievements and my stress, and were the person I went to to share my true feelings. You truly are my PhD Pup and I love you for that!

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Chapter 1: Literature Review

1.1 Introduction

From early in life it is clear that mothers have a direct impact on their infants' development. Maternal personality in particular has been highlighted as an influential factor for childhood risk for mental health, and determining their development and clinical outcomes (Wahlberg et al., 2004). In this thesis, I investigated atypicalities observed throughout the schizophrenia-spectrum with the umbrella hypothesis that these deficits previously observed in schizophrenic individuals may be present to some extent in those with sub-clinical schizotypy, and in their offspring; similarly to the manner in which first-degree relatives of those diagnosed with schizophrenia display abnormalities. This thesis explores how 6-month-old infants are able to gate out irrelevant repeated stimuli, known within the literature as *sensory gating*, process facial expressions, and how their neural frequencies differ during social and non-social interactions with their mother. More specifically, I examined the influence of maternal schizotypy on these abilities at 6-months of age.

1.2 What is Schizotypy?

Current conceptualisations indicate that schizotypy is a multidimensional construct that represents the underlying vulnerability to schizophrenia-spectrum psychopathology that is expressed across a broad range of personality, subclinical, and clinical phenomenology (Kwapil and Barrantes-Vidal, 2014). High levels of schizotypy are associated with behavioural, genetic, and neural patterns that are qualitatively similar to those reported in the schizophrenia-spectrum, albeit to a milder degree (Nelson et al., 2013; Ettinger et al., 2014), which are exhibited as specific atypicalities in comparison to the general population (Mohanty et al., 2005). The framework, within which schizotypy finds itself, is a continuum rather than discrete categories, describing schizotypy, and by extension, schizophrenia as heterogeneous (Kwapil and Barrantes-Vidal, 2012; 2014), which allows for the belief that vulnerability to schizophrenia-spectrum disorders can be expressed as a multidimensional personality organisation (Barrantes-Vidal et al., 2015). Schizotypy and schizophrenia appear to share a common multidimensional structure, with

numerous studies supporting the view that positive, negative, and disorganised dimensions underlie schizophrenia (Liddle, 1987; Lenzenweger and Dworkin, 1996; Rossi and Daneluzzo, 2002; Wuthrich and Bates, 2006), and these dimensions have been replicated in non-clinical schizotypy (Raine, 2006; Kwapil, Barrantes-Vidal, and Silvia, 2008). So, if we are able to demonstrate that both schizotypy and schizophrenia lie on continuums, is it possible that schizotypy lies at the furthest-most sub-clinical portion of this schizophrenia-spectrum?

1.3 A Brief Background in Schizotypy

Schizotypy was the term coined by Rado (1953) to describe the continuum of personality characteristics and experiences ranging from typical dissociative and imaginative states (e.g. magical thinking, perceptual abnormalities), to more extreme complaints relating to psychosis and schizophrenia (e.g. delusions, and negative symptoms). Meehl (1962) speculated that a single dominant 'schizogene' gave rise to a neurointegrative deficit, referred to as 'schizotaxia' that was necessary for the development of schizotypy. He described schizotypy as a personality organisation that culminated from schizotaxia and left the individual vulnerable to schizophrenia development. Meehl (1990) updated the original model by diminishing the role of anhedonia and developing the contribution of polygenic factors. He considered schizophrenia and schizotypy to be manifestations of the same underlying vulnerability, adding that schizotypy was taxonic in nature with approximately 10% of the population classed as schizotypic and that about 10% of schizotypes progressed into schizophrenia (corresponding with the 1% lifetime prevalence rate of schizophrenia).

The quasi-dimensional approach refers to levels of expression of symptomatology, but is otherwise described as categorical: an individual is considered to either possess a genetic vulnerability, or they do not. This approach is based on a disease model of mental illness, which postulates how schizotypy is a personality dimension specific only to a small group of individuals within the population (approximately 10%), who identify as schizotypes (Rado, 1953; Meehl, 1990; Lenzenweger, 1994; Beauchaine, Lenzenweger, and Waller, 2008). This specific personality organisation was said to exist in the form of a genetic predisposition, which manifests as an integrative neurological defect, known as *schizotaxia*. According to Meehl (1962), *schizotaxia* in

isolation is not sufficient to induce the development of schizophrenia, but it interacts with environmental influences throughout an individual's lifetime to determine the degree of symptomatology experienced (Lenzenweger, 2006). This perspective therefore suggests this genetic vulnerability towards developing psychotic symptoms to be 'taxonic', or categorical (Korfine and Lenzenweger, 1995; Waller et al., 2006). However, more recent models (Claridge and Beech, 1995) have been proposed that are, perhaps, more likely to reflect the reality of the situation.

The relationship between schizotypy and schizophrenia has been described using the fully dimensional approach (Claridge and Beech, 1995; Claridge and Davis, 2003; Rawlings et al., 2008a). This approach differs in that it suggests schizotypy represents 'natural central nervous system variations', which, in extreme cases, manifest as vulnerabilities to mental illness (Rawlings et al., 2008a).

The primary argument promoted by the fully dimensional approach is that the latent structure of schizotypy is on a continuum involving all members of the population. This continuum is considered to range from low psychological health, to dysfunction in the form of psychosis (Nelson, Seal, Pantelis and Phillips, 2013). Despite their differences, the fully dimensional approach is similar to the quasi-dimensional approach in that it does not assume that schizotypal traits are exclusively sufficient for an indication of the risk for psychopathology (Rawlings et al., 2008b). Instead, it is thought that high levels of schizotypy may be considered a predisposition for schizophrenia and other psychotic disorders only when in combination with other risk factors. If the two approaches are judged as rivals, it is only true insofar as the *fully dimensional model* is the more comprehensive: it included the features focused upon by the *quasi-dimensional model*, but also adds to them. Traits, which are commonly assumed to be observed in a fully-dimensional structure across the mid-range of a population, and symptoms, which could be viewed as more quasi-dimensional and in those further up the spectrum who are at high-risk of disorder development, certainly have different properties: the former are more continuous, follow normal distributions and are ego-syntonic; the latter are ego-dystonic and more often dichotomous and skewed in their distribution, but this does not mean that they are unable to lie on a continuum with one another.

The fully dimensional approach appears superior to the quasi-dimensional approach,

displaying consistency with current theories concerning schizophrenia, which consistently describe continuity between clinical and non-clinical populations (Linscott and van Os, 2010; Hengartner and Lehmann, 2017). The continuum hypothesis of psychosis (Allardyce et al., 2007) receives support from the fully dimensional approach. This illustrates the current dominant view that varying combinations of genes and environmental risk factors result in a different range of phenotypic expressions lying on a continuum from typical through to clinical psychosis. As such, it is possible to suggest that pre-dispositions are present across the population, but requires an *environmental facilitator* (for example, stress and trauma; Phillips et al., 2007; Varese et al., 2012) to act as a 'spring-board' for further development into mental illness. In this way, schizotypy acts as a sub-clinical manifestation of this pre-disposition within the population, but requires these *facilitators* in order to cross over into a diagnosable form of the schizophrenia-spectrum.

1.4 How can we measure Schizotypy?

As discussed by Kwapil and Barrantes-Vidal (2014), psychometric assessments of schizotypy provide a powerful tool for assessing schizophrenia-like symptoms and impairment. Numerous studies have reported psychometric schizotypy in non-disordered individuals associated with psychotic-like (Gooding, Tallent, and Matts, 2005), prodromal (e.g. Barrantes-Vidal, Chun, Myin-Germeys, and Kwapil, 2013), and schizophrenia-spectrum (e.g. Blanchard, Collins, Aghevli, Leung, and Cohen, 2011) symptoms. Schizotypy is associated with schizophrenia-like patterns of cognitive impairment (e.g. Tallent and Gooding, 1999), and social cognition (e.g. Morrison, Brown, and Cohen, 2013), neuroimaging (e.g. Modinos, et al., 2010), and typical personality traits (e.g. Kwapil, Barrantes-Vidal, and Silvia, 2008), impaired attachment (e.g. Sheinbaum, Bedoya, Ros-Morente, Kwapil, and Barrantes-Vidal, 2013), and schizophrenia-like symptoms and impairment in daily life (e.g. Barrantes-Vidal et al., 2013).

The *fully-dimensional* approach to characterising psychopathology illustrates that psychotic traits are normally distributed in the general population and, while still representative of psychosis proneness, are an aspect of typical variation in healthy personality. The Oxford-Liverpool Inventory of Feelings and Emotions (O-LIFE;

Mason, Claridge, and Jackson, 1996; Mason, Linney, and Claridge, 2005) is advantageous in that it measures schizotypy multidimensionally and allows for a broad screening of traits across the general population. For this reason, we chose to utilise the O-LIFE-Short Form in the succeeding research. The O-LIFE has firm psychometric properties and its validity is supported by numerous cross-sectional questionnaires (e.g. Goulding, 2004), psychophysiological (Mason, Claridge, and Clark, 1997), and neurocognitive (e.g. Burch, Hemsley, Corr, and Gwyer, 2006) studies. The O-LIFE scale has four factors: Unusual Experiences, Cognitive Disorganisation, Introvertive Anhedonia, and Impulsive Non-conformity. In addition to other measures of schizotypy, the O-LIFE scale contains a fourth factor, impulsive non-conformity, which is mostly ignored by those using the O-LIFE – presumably being regarded by them as a statistical aberration, a distraction from retaining the neat schizotypy structure traditionally supplied by the three other factors (Unusual Experiences, Cognitive Disorganisation, and Introvertive Anhedonia) which are generally accepted as comprehensibly defining schizotypy. For the sake of completeness, the present research has included all four dimensions in statistical analyses, but the impulsive non-conformity measure has been interpreted with caution as a result of its previous statistical inconsistencies.

There is evidence demonstrating how individuals with psychotic disorders tend to score highly on measures of schizotypy (Lenzenweger, 1994; Camisa et al., 2005); illustrating further support for the notion of a continuum between clinical and sub-clinical populations. In light of this, it should be remembered that although individuals may present with high levels of schizotypy, they are not necessarily dysfunctional and have control over their own life, can balance and cope with both positive and negative life events, and can maintain stability (Goulding, 2004).

Various atypicalities have been observed across the schizophrenia-spectrum, with first-degree relatives of those on the schizophrenia-spectrum not only displaying differential cognitive ‘traits’ in higher cognitive domains, but these also extend into information processing at the sensory and attentive level. As previously stated, this thesis explores sensory gating abilities, the processing of facial expressions, and how neural frequencies differ during social and non-social interactions. I will now go into more detail on each of these abilities specifically.

1.5 Sensory Gating

The P50 event-related potential (ERP) is strongly associated with *sensory gating*: the pre-attentional habituation of responses distinguishing between important and irrelevant information (Hall, Taylor, Salisbury, and Levy, 2011). *Sensory gating* is generally observed using the paired-tone paradigm: two identical auditory tones (Stimulus 1 (*S1*) and Stimulus 2 (*S2*)) are played 500ms apart, whereby participants hear a pair of single-sound stimuli within 50-milliseconds (ms) of each other. P50 suppression is assessed by measuring EEG responses to these auditory tones, with the reduction in the amplitude of the P50 response from the first to the second stimulus labeled "P50 suppression". The P50 sensory gating component is a passive psychophysiological measure and a putative adult schizophrenic endophenotype (Onitsuka et al., 2013; Ross and Freedman, 2015). The sensory gating ERP component, a potential biomarker of cognition, is often conceptualised as reflective of an individual's ability to automatically (Lijffijt et al., 2009) filter out irrelevant information (Kisley et al., 2004), and can be observed in the auditory P50, which is a positive ERP deflection observed 50ms after stimulus presentation, measured using a paired-tone paradigm. See Figure 1.1 for an example of the P50 event-related component. P50 sensory gating is a highly established biological trait of schizophrenia (Raine, 2006), observed in individuals with schizotypal personality disorder (Cadenhead, Light, Geyer, and Braff, 2000) and infants and children of parents with psychoses, or severe anxiety disorders (Ross and Freedman, 2015); supporting its potential as a biomarker for the general risk for psychopathology that potentially extends into infancy (Freedman et al., 2002). However, whether, and to what extent, these dimensions of schizotypy are related to the risk of developing psychosis is still unresolved (Debbané and Barrantes-Vidal, 2015).

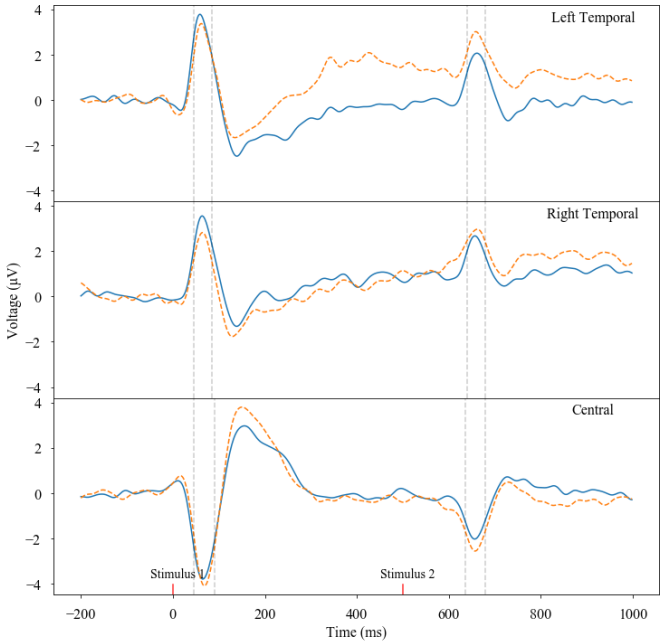


Figure 1.1. An example of the P50 event-related potential component.

Sensory gating efficacy can be measured using a ratio of the ERP amplitudes (*stimulus 2* (S2)/ *stimulus 1* (*S1*)), or by the difference between the mean amplitudes (*S1*-*S2*). A low ratio or large difference represents better sensory gating abilities (Freedman et al., 1983). Meta analyses support the relationship between P50 sensory gating and the schizophrenia-spectrum. Thus, studies employing spectral frequency analyses provide additional information about auditory sensory gating (Brenner et al., 2009), as it is understood that abnormal neural oscillations and synchrony are observed in the schizophrenic population (Uhlhaas and Singer, 2010). It has been proposed that less neural activity in the beta range (12-20Hz) is observed in schizophrenic patients (Brenner et al., 2009), with beta activity in response to *S1* of the paired-tones predicting stronger gating and P50 suppression to *S2* (Kisley and Cornwell, 2006; Hong et al., 2008). These suggestions are in agreement with work demonstrating how sensory gating abnormalities in the schizophrenia-spectrum extend to neural oscillations in gamma and beta frequency ranges (Hong et al., 2004; Hall et al., 2011).

The inhibitory mechanism we just outlined demonstrates parallels with a notion originally outlined by Venables (1964) who proposed that schizophrenia was essentially a problem of 'input dysfunction'. This outlines key features describing a deviation in inhibitory mechanisms in the brain, which has been extensively studied and has demonstrated that, to some extent, Venables was correct in his interpretation of inhibitory mechanisms. It is now further understood that in psychosis, all levels of

cognitive functioning may be subject to a weakened inhibitory control mechanism, resulting in the perceptual and attentional flooding that typifies the clinical state. This description outlines precisely the mechanisms that are involved in the sensory gating process, and fits Venables' suggestion that input dysfunction can lead to an excessive openness to the environment, or the inability to 'gate out' irrelevant information.

1.6 Facial Expression Perception

There is 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 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).

It is well established that individuals diagnosed with schizophrenia exhibit a variety of social deficits, the majority of which likely predate the onset of the illness by several years: possibly as early as childhood (Bearden et al., 2000; Tarbox and Pogue-Geile, 2008; Tsuji et al., 2013). Facial emotion tasks are used increasingly as a tool for exploring the underlying neurobiology of schizophrenia-spectrum disorders electrophysiological studies (Turetsky et al., 2007). Emotional impairments may be described as a central feature of schizophrenia (Aleman and Kahn, 2005; Versmissen et al., 2008; Mendoza et al., 2011), but these difficulties also appear to be present in vulnerable individuals before the onset of the disorder (Pinkham, 2003). Individuals with schizophrenia have displayed difficulty in recognising the emotions from faces (Aleman and Kahn, 2005) and are thought to show sensitivity to negative facial expressions, such as anger and fear (Evans et al., 2011), when compared to controls. The infancy literature generally observes the processing of facial expressions using the Negative-central (Nc) event-related potential. The Nc is a mid-latency component that is largely observed in young children around the frontal-central regions of the brain and has been observed consistently across several studies and in response to different visual stimuli (Hoehl, Wiese, and Striano, 2008; Striano, Reid, and Hoehl, 2006). In general the Nc is assumed to capture how much attention infants allocate when observing stimuli (Reynolds et al., 2014; Richards, 2003). Although the precise functional significance of the Nc component is still under debate, there is considerable

evidence suggesting it is amplified when stimuli are unexpected (Jeste et al., 2015; Kaduk, Elsner, and Reid, 2013). See Figure 1.2. for an example of the Nc component.

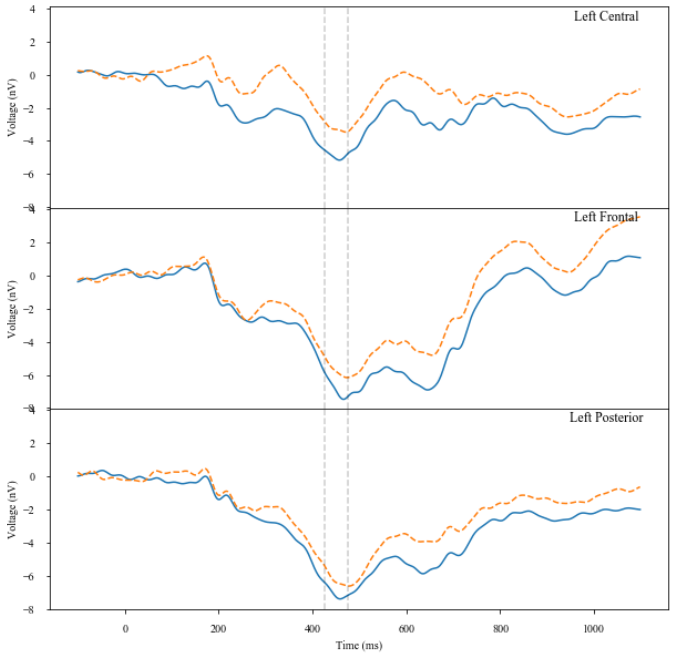


Figure 1.2. An example of the Nc event-related potential component.

1.7 Free-Play

Parents, who suffer with mental health disorders, or subclinical personality traits, not only transmit a genetic liability to their offspring but may also experience difficulty in providing optimal caregiving environments for these offspring. Previous literature into social-emotional development suggests that maternal sensitivity behaviours serve as a model for the child's emotional and social development (Mcelwain and Booth-LaForce, 2006), thus if the mothers' maternal sensitivity behaviours are altered, the caregiving environment may also be misrepresented. Psychopathology in parents is known to be a strong predictor of mental disorders in children (McLaughlin et al., 2012), with approximately 40% of children of depressed parents having one or more mental disorders (Angold and Costello, 1995). In line with previous research, Matijasevich et al. (2015) found that children of mothers assigned to a "high-chronic" maternal depressive symptomatology displayed the highest levels of psychiatric disorder at 6-years, as well as both internalising and externalising problems (Campbell et al., 2007; Cents et al., 2013). It is worth noting that it was also the case that children of mothers in the "moderate low" trajectory had more psychiatric problems than those belonging to the "low" maternal depression trajectory group. This effect has also been

observed by Cents et al. (2013), suggesting that chronic exposure to maternal depressive symptoms, even when the level of disorder is not that high, could have an effect on a child's development (Brennan et al., 2000).

Leppänen and colleagues (Leppänen and Nelson, 2009; Leppänen, 2011) proposed that infants exposure to parents' expressions of emotion during the daily parent-child interactions, which play an essential role in the neural fine-tuning of infants' emotional brain systems in typical development. Given this specific importance of environmental exposure for the development of emotional neural systems, Leppänen predicted that the influence of atypical emotional environments provided by mothers with either a predisposition to mental illness, or mental health difficulties, in the early years would be 'especially detrimental' for later development of emotion processing abilities (Leppänen, 2011, p.185). This may be particularly useful to detect early effects of exposure and risk for psychopathology in preverbal infants.

1.8 How are these atypicalities similar within families?

There is convincing evidence from family studies that the risk of developing schizophrenia increases with the degree of genetic relatedness within a family (Gottesman and Shields, 1982). Evidence from family, twin, and adoptive studies suggests that genetic transmission accounts for most of the familial aggregation of schizophrenia (Kendler and Diehl, 1993). For example, registry-based epidemiologic research supports the idea that risk of schizophrenia is associated not only with a family history of schizophrenia (Gottesman et al., 2010), but also with other categories of mental disorders in first-degree relatives (Dean et al., 2010; Mortensen et al., 2010). Both genetic and environmental factors have been associated with risk of psychosis, psychiatric disorders, and sub-clinical derivatives, but the latter presents more tangible markers for prevention and intervention strategies (Kirkbridge et al., 2010). Regardless of the biopsychological origins, increased interest is shown in understanding the psychosocial components of mental health and how these psychosocial components interact with biological liability processes. Ponizovsky, Nechamkin and Rosca (2007) proposed how attachment provides a diathesis for psychopathology in adulthood. Ainsworth (1985) proposes that attachment begins to take shape around 6-months of age with mother-infant attachment influencing the social-emotional development and competence of the child to be socially active and

successful throughout development (Kochanska, 2001). This illustrates how as soon as an infant is capable of attachment and interaction the effects of the mother-infant relationship on development will appear. Little is known about this process in early infancy, but it is essential to identify early atypicalities in our social-emotional development.

Research utilizing schizotypic populations removes potential confounds associated with research with schizophrenic individuals, as participants should be able to report their feelings and experiences more accurately, non-smokers can be easily identified, and individuals with schizotypy traits in the general population generally do not take antipsychotic medication. The schizotypy construct can be measured using a psychometric approach, where individuals are given questionnaires to complete and is not to be confused with other more severe, schizophrenia-spectrum disorders, such as schizotypal personality disorder, which is a diagnosable, and clinical, disorder. The use of psychometric schizotypy does, however, make an assumption that it is related to the schizophrenia-spectrum. Psychometric schizotypy scores are thought to be representative of a schizophrenia-spectrum belief set, and there is good evidence in support of this (Duchene et al., 1998; Gruzelier et al., 1995). This is because these individuals exhibit parallel cognitive (Evans et al., 2007) and psychophysiological (Evans et al., 2005) deficits as those displayed in schizophrenia. The study of psychometric schizotypy, with support from the fully dimensional approach to schizotypy, provides a useful means of furthering our understanding of schizophrenia, as it avoids the confound of antipsychotic medication and also the restricted range of response and lack of self-awareness that can characterize schizophrenia (Light and Braff, 2000).

1.9 Concluding Remarks and Moving Forward

The symptoms, or traits, that define neurodevelopmental and neuropsychiatric disorders are best conceptualized as variations of quantitative dimensions of sensory, perceptual, and behavioural domains that are distributed throughout the general populations (Kotov et al., 2017; Hengartner and Lehmann, 2017; Evans et al., 2016; Evans et al., 2018). The ability to assess variation in such traits along a typical-pathological continuum, and across the lifespan, is a critical step for understanding and identifying possible risk factors associated with disorders in general. Psychiatric

morbidity is thought of more as a *shift* in the continuous distribution of neurodevelopmental traits toward greater impairment, whilst maintaining a clear overlap with the population distribution (van Os et al., 2009). For example, psychotic symptoms, such as hallucinations and delusions, are relatively common, appearing in some 12-40% of the general population (Simonoff et al., 2008; van Os et al., 2009), and for this reason do not necessarily indicate clinical psychiatric morbidity, but rather reflect the broad spectrum of human experiences (Mason and Claridge, 2006; Evans et al., 2016).

Decades of research have reported on the impact of the environment on personality development, including its role in influencing the development of certain traits, or strengthening the stability of traits (Briley and Tucker-Drob, 2017; Krzeczkowski and van Lieshout, 2018). It is understood that the relationship between personality and psychopathology is bi-directional (Widiger, 2011), therefore suggesting that certain personality traits can increase our risk for psychopathology (Boyce et al., 1991), and could even be present as a predisposition for mental illness in general. A developmental model of schizotypy holds the necessary ingredients to bring a developmental psychopathology account to psychotic disorders, which is a void that needs to be further understood. Schizotypal expression during adolescence is critically linked to childhood risk markers and endophenotype, which confer a role of a potential *developmental facilitator* on the road to psychosis proneness. For example, in this thesis, if the mothers who identify as schizotypic display abnormalities that associate with those experienced by individuals on the schizophrenia-spectrum then it suggests schizotypy supports a fully-dimensional approach, whereby the traits/symptoms are observable in a sub-clinical setting as well as a clinical one. Moreover, if their infants also demonstrate these abnormalities, to a lesser degree, then it suggests the strong possibility of a genetic predisposition to mental illness; however, if the infants do not show such an abnormality, then it is likely they have not been exposed to a *developmental/ environmental facilitator* to a sufficient degree in order to alter their electrophysiological development at 6-months.

There appears to be a void in the literature that requires further investigation into the relationship between processes indexed by event-related potential and event-related oscillations in parents with schizotypy, and the performance of their offspring in the same tasks. As previously outlined, the primary aim of this thesis is to investigate the

abnormalities previously illustrated within the clinical portion of the schizophrenia-spectrum and to observe whether they are also present to a milder degree in sub-clinical schizotypy.

Chapter 2

Is schizotypic maternal personality linked to sensory gating abilities during infancy?

Text accepted pending minor corrections by *Experimental Brain Research*.

Abstract

Schizotypy is a personality dimension within the general population elevated among schizophrenia-spectrum patients and their first-degree relatives. Sensory gating is the pre-attentional habituation of responses distinguishing between important and irrelevant information. This is measured by event-related potentials, which have been found to display abnormalities in schizophrenic disorders.

The current study investigated whether 6-month-old infants (n=35) of mothers with *schizotypic* traits display sensory gating abnormalities. The paired-tone paradigm was used to probe the selective activation of the brain during 15-minutes of sleep. Their mothers completed the Oxford and Liverpool Inventory of Feelings and Experiences-Short Form as an index of *schizotypy* dimensionality, categorized into: infants of control, and infants of *schizotypic,* mothers.

The findings revealed that although the infants' P50 components displayed significant differences between *S1* and *S2* in the paired-tone paradigm, there was no clear difference between infants of schizotypic and infants of control mothers. Moreover, the correlational relationships observed between the infants' event-related differences and suppression ratio measures and the maternal schizotypy measures suggests a potential emergence of individual differences, which could be observed to a greater degree as developmental trajectories continue. In contrast, the mothers displayed significant differences between *S1* and *S2*, as observed in the infants, but also significant differences between their sensory gating ability correlated with schizotypy dimensionality. These findings are consistent with sensory processes, such as sensory gating, evidencing impairment in schizophrenia-spectrum disorders. The present research supports the idea that first-degree relatives of individuals who identify on this spectrum, within the sub-clinical category, do not display the same deficit at 6

postnatal months of age.

2.1 Introduction

The influence of maternal personality on childhood risk factors for mental health is widely acknowledged with links identified between specific parental psychopathology and event-related potential (ERP) components. 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 maternal personality influences development during infancy.

The P50 ERP is strongly associated with *sensory gating:* the pre-attentional habituation of responses distinguishing between important and irrelevant information (Hall, Taylor, Salisbury, and Levy, 2011), a largely automatic process and an involuntary step in attentional mechanisms (Lijffijt et al., 2009). *Sensory gating* is generally observed using the paired-tone paradigm, whereby participants hear a pair of single-sound stimuli within 50-milliseconds (ms) of each other. P50 suppression is assessed by measuring EEG responses to these auditory tones, with the reduction in amplitude of the P50 response from the first to the second stimulus labeled "P50 suppression". Both tones have the same intensity, frequency and pitch, with sensory gating efficacy measured using a ratio of the ERP amplitudes (*S2/S1*), or by the difference between the mean amplitudes (*S1-S2*). A low ratio or large difference represents better sensory gating abilities (Freedman et al., 1983) and illustrates the P50 suppression ability of the participant cohort.

Atypical P50 sensory gating is a highly established biological trait of schizophrenia (Raine, 2006), observed in individuals with schizotypal personality disorder (Cadenhead, Light, Geyer, and Braff, 2000) and infants and children of parents with psychoses, or severe anxiety disorders (Ross and Freedman, 2015). This work supports its potential as a biomarker for the general risk for psychopathology that potentially extends into infancy (Freedman et al., 2002). However, whether, and to what extent, these dimensions of schizotypy are related to the risk of developing psychosis is still unresolved (Debbané and Barrantes-Vidal, 2015).

The notion that personality traits and clinical diagnoses lie on the same continuum is not new (Eysenck, 1992; Corr, 2000) and has stimulated research aimed at identifying core deficits shared by sub-clinical personality traits and clinical psychosis. *Schizotypy*

describes a dynamic continuum of symptomatology, impairments and personality traits (Kwapil and Barrantes-Vidal, 2012) that are cognitive, emotional and behavioural, and grouped into a multidimensional structure (i.e. positive, negative, and disorganised) similar to that in schizophrenia (Fonseca-Pedrero et al., 2010). *Schizotypy* is thought to mimic the subclinical expression of schizophrenia distributed along a continuum, rather than discrete categories, (Claridge, 1997), illustrating how vulnerability to mental illness can be expressed as a multidimensional personality organisation (Barrantes-Vidal, Grant, and Kwapil, 2015). *Schizotypy* traits are elevated in children *at-risk* for the development of schizophrenia during infancy, 2, 10, and 15 years of age (Carlson and Fish, 2005), and is therefore considered to be a sensitive predictor for the later development of schizophrenia-spectrum disorders (Tyrka et al., 1995). As it is not possible to reliably diagnose psychiatric disorders in infants, risk status is generally inferred from parental psychopathology (Keshavan et al., 2008).

Atypical sensory gating shows potential as a candidate endophenotype because the same deficit is observed in non-affected first-degree relatives of schizophrenic patients (Waldo et al., 2008), individuals at-risk of development (Cadenhead, Light, Shafer, and Braff, 2005), and in schizophrenia-spectrum disorders (Raine, 2006; Cadenhead et al., 2000). Importantly, from a developmental standpoint, *schizotypy* has been associated with endophenotypes and biomarkers whose dimensions can already be assessed during infancy.

The primary aim of the present study was to measure the electrical brain activity of 6-month-old infants (*Experiment 1*) and their mothers (*Experiment 2*) in auditory-gating tasks. Prior research suggests a development trajectory of sensory gating capacities, although the details of these abilities are not clear at 6-months. We therefore set out to explore whether measurable changes in sensory gating functions in the offspring of mothers with schizotypic traits could be detected. We hypothesised that abnormalities previously observed in individuals diagnosed with schizophrenia may be present to some extent in those with sub-clinical schizotypy, and to a lesser degree in their offspring; similarly to the manner in which first-degree relatives of those diagnosed with schizophrenia display sensory gating abnormalities. Specifically, we evaluated whether the 6-month-old infants of schizotypy mothers (iSZTm) display smaller

differences and larger suppression ratios in the *P50* component when explored using the paired-tone paradigm.

2.2 Methods and Materials

Experiment 1: Infant Cohort.

2.2.1 Participants

101 infants, aged 6-months (*M*=5.80 months; *SD*=9.23 days; 54 male) participated in the study. 66 infants were excluded from the final sample due to: no auditory data collected as the infant did not sleep (*n*=24), technical issues (*n*=4), the data not reaching the inclusion criteria: 20% good trials for each tone (*n*=27), and the Oxford-Liverpool Inventory of Feelings and Experiences – Short Form (sO-LIFE) scores not identifying with one of the two groups (*n*=10). 35 infants with a mean age of 5.88 months (*SD*=8.57 days; 18 male) were included in the final analysis. The final sample included 14-participants who identified as being an infant of a schizotypic mother (iSZTm) and the remaining 21-participants were infants of control mothers (iCONm). For one EEG experiment with infants, this is a typical sample size for similar studies with infants (e.g., Begus, Gliga, and Southgate, 2016) or substantially greater than the sample size for studies on schizotypy during development (Hunter, Gillow, and Ross, 2015). Recruitment was carried out using the Lancaster University Psychology Department of Infant and Child Development infant database. Ethical approval was obtained with the Lancaster University FST Ethics Board ("Understanding Sensory Processing in Early Development"), and the North West – Lancaster Research Ethics Committee for the NHS.

2.2.2 Materials and Stimuli

The participant experienced a pair of single-sound stimuli that was based on Park, Lim, Kirk, and Waldie (2015). A 500ms inter-tone interval was present between two tones and with a 10s inter-trial interval, repeated continuously for 15-minutes or until the infant woke. All electrophysiological signals were recorded using Electrical Geodesics Inc. amplifiers (input impedance=80KΩ; sampling rate=500 Hz) and ERPs were measured using an EGI Hydrocel GSN-128 electrode 1.0 net and analysed using Netstation 4.5.4.

EEG recordings were condensed to create epochs from 200ms before to 1000ms after stimulus-onset. Data were baseline corrected and ERPs visually edited offline to

remove artefacts. Epochs were excluded where a bad channel affected 80% of the recording, or if the segment contained more than 12 poor channels. Participants required a minimum of 20% good trials for each stimuli to be included in further analyses. Infants experienced a range of 57-141 paired-stimuli repetitions, dependent on how long they slept for, and contributed an average of 44.14 (*SD*=20.09) artefact-free trials (range: 28-105) for *S1*, and on average 33.22 (*SD*=22.78) artefact-free trials (range: 25-112) for *S2*. Following averaging, data were re-referenced to the average electrode and high-pass filtered at 0.3Hz, and low-pass filtered at 30 Hz. All infant ERPs computed a *mean amplitude* and *maximum amplitude* measure. Differences (*S1-S2*) and Suppression Ratios (*S2/S1*) were calculated and used for further analysis. All analyses were conducted blind to the participant group status.

Considerations for Infant ERP Analysis

In the first two years of life reduced synaptic efficiency results in greater slow wave activity rather than peaked activity, the latter being more typical of adult ERP's. Thus, the infant ERP does not show as many well-defined peaked responses when compared to adult responses. Because the distribution of activity across the scalp changes with age, we can infer that important changes are still taking place in the neural substrate generating the components of interest throughout development (see de Haan, 2007).

P50 – Stimulus 1

The P50 ERP *stimulus 1 (S1)* was measured over the central (the average of channels 6, 7, 31, 30, 55, 80, 106, 105, which are roughly similar to C1, C2, FCZ and other central electrodes), left-temporal (the average of channels 49, 50, 56, 57, 58, which are roughly similar to P7, TP7 and other left temporal-parietal electrodes), and right-temporal (the average of channels 113, 107, 100, 101, 96, which are roughly similar to P10, CP10 and other right temporal-parietal electrodes; Figure 2.1). A time window of 150-230ms was chosen for the left-temporal, 165-210ms for the right-temporal, and 80-210ms for the central electrodes, following inspection of the individual and grand averages.

P50 - Stimulus 2

The P50 ERP *stimulus 2 (S2)* was measured over the central (the average of channels 6, 7, 31, 30, 55, 80, 106, 105; yellow), left-temporal (the average of channels 49, 50, 56, 57, 58; green), and right-temporal (the average of channels 113, 107, 100, 101, 96; orange; Figure 2.1). A time window of 250-355ms was chosen for the left-temporal, 260-335ms for the right-temporal, and 260-355ms for the central electrodes, following inspection of the individual and grand averages.

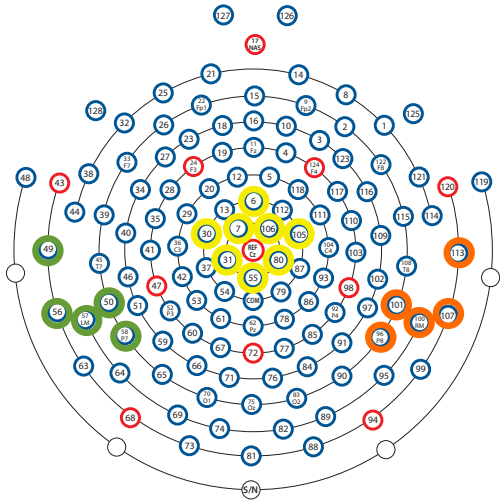


Figure 2.1. The *P50* electrode groupings for the infant cohort.

The time-windows chosen for the infant ERP's were chosen following inspection of the individual and grand averages, and as such a latency effect is observed within the infant cohort, which differs slightly from the existing infancy *P50* literature (Rodd et al., 2013; Hunter et al., 2015).

2.2.3 Questionnaires.

Schizotypy

The Oxford-Inventory of Feelings and Experiences- Short Form (sO-LIFE; Mason, Linney and Claridge, 2005) assessed schizotypy dimensionality and divided the participant cohort into iSZTm and iCONm. The mean across the population was calculated (*total M*=8.15, *total SD*=6.26). The iSZTm condition was determined by the *M*+.5*SD* (sO-LIFE Scores>11.28) and included 14-participants and the iCONm condition by the *M*-.5*SD* (sO-LIFE Scores 5.02>0.0), included 21-participants. The

sO-LIFE was chosen as the present measure of schizotypy dimensionality due to its fully dimensional approach, proposing that symptoms occurring in the schizophrenia-spectrum also occur in the typical population as well, with the sO-LIFE questionnaire measuring such symptoms. The reliability of the sO-LIFE, estimated with ordinal alpha, was disclosed to be above 0.78 (Fonseca-Pedrero et al., 2014). These levels of internal consistency are in line with the internal consistency values reported in previous studies; for example, previous work using ordinal alpha have found good reliability estimates (Lin et al., 2013; Sierra et al., 2013). The cronbach's alpha in the present cohort was 0.79, demonstrating the consistent reliability measure of the sO-LIFE. Moreover, the sO-LIFE scores showed good convergent and discriminant validity with the *Schizotypal Personality Questionnaire – brief revised* (Goulding, 2004; Mason, Claridge, and Clark, 1997; Burch, Helmsley, Corr, and Gwyer, 2006).

Additional Demographic Variables.

A general assessment questionnaire was used to gain an overall assessment of smoking habits, hearing deficits, birth complications, and whether they, or their family have experienced mental illness. Birth complications, and experience of mental health history was also noted. An Independent Samples T-test presented no significant differences between both iSZTm and iCONm groups (Table 2.1).

2.2.4 Procedure

Prior to participation, the caregiver completed a series of questionnaires.

The EEG cap was soaked in a warm water, sodium chloride solution and baby shampoo before fitting to the infant's head. Once fitted and following confirmation that each electrode responded to electrical activity, the trial procedure began. The auditory stimuli was presented 80-centimetres away, between 70-77dB (Wan, Friedman, Boutros and Crawford, 2008; Dalecki, Croft, and Johnstone, 2011) until the infant woke or became restless. The infant was then left to complete their natural sleep period. Throughout the testing period the infant's status was video-recorded to index activity.

Table 2.1. 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 and experienced no significant differences in mental heath experiences.

		Non-Schizotypy M(SD)	Schizotypy M(SD)	T-Test
Infant Age (days)		178.57 (8.07)	179.50 (9.70)	.693
Infant Gender	Female	*n*=12	*n*=6	.508
	Male	*n*=10	*n*=8	
Mother's Age (years)		32.76 (3.11)	33.09 (5.48)	.785
Maternal Mental Health Experiences		1.14 (.36)	1.43 (.51)	.061
Maternal Family History of Mental Health		1.52 (.51)	1.5 (.52)	.894
Birth Complications		1.64 (.79)	2.00 (.96)	.224

2.3 Results - *Experiment 1: Infant Cohort*

P50

A full factorial 2 (Group: iSZT or iCON) x2 (Paired-tone: *S1* or *S2*) x3 (Electrode Grouping: Central, Left-Temporal, or Right-Temporal) repeated-measures ANOVA with Bonferroni corrected for pairwise comparisons was carried out exploring both *mean amplitude* and *maximum amplitude* measures. This illustrated how a significant difference could be observed between the different regions of interest ($F(2,66)=12.467$, $p>.001$, $\eta^2=.274$), but particularly the central region *maximum amplitude*. A Paired-Samples T-test then demonstrated a significant difference between *S1* (*maximum amplitude: M*=5.45, *SD*=4.39) and *S2* (*maximum amplitude: M*=.18, *SD*=4.81) in the central region when examined using the *maximum amplitude* ($t(34)=2.062$, $p=.047$, $d=.05$) measures. No further significant effects were found with

only significant results reported in the present research. No significant group differences were observed between the infants of schizotypic and infants of control mothers.

A series of pearson correlations, corrected for multiple comparisons, were carried out to explore the relationship between the infants P50 ERP amplitude differences/suppression ratios and their mothers sO-LIFE scores. A significant relationship was observed between the *mean amplitude* suppression ratio in the right-temporal region and the sO-LIFE total score (r=-.347, p=.038), the Unusual Experiences dimension (r=-.410, p=.013), and the Cognitive Disorganisation dimension (r=-.362, p=.030).

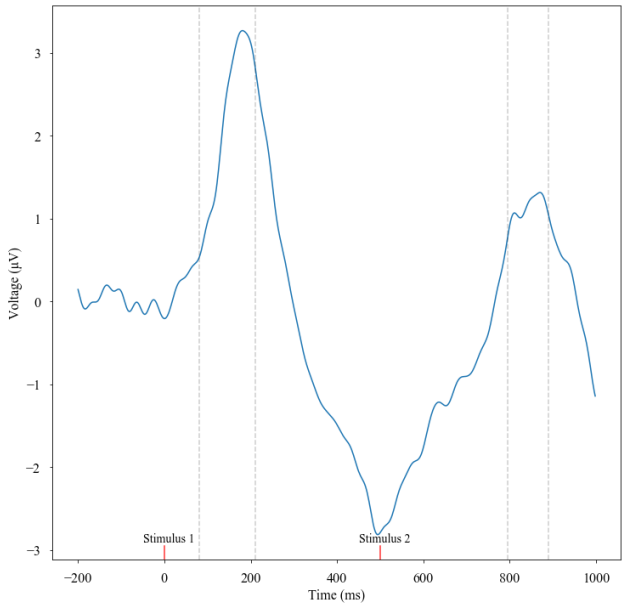


Figure 2.2. The P50 ERP component across the whole infant cohort in the central region.

A multivariate ANOVA illustrated how there was a statistically significant difference in sO-LIFE score between the SZT and CON infants ($F(1,33)=44.81$, $p<.001$, *Wilk's* $\Lambda=.14$, partial $\eta^2=.86$). A linear regression exploring the predictive value of the sO-LIFE total score, Unusual Experiences, Cognitive Disorganisation, Introvertive Anhedonia, and Impulsive Non-conformity dimensions, illustrated with a stepwise entry method how the sO-LIFE total score significantly predicted membership to the infants' SZT or CON groups ($F(1,33)=179.58$, $p<.001$), with the individual dimensions excluded from the model. Canonical correlation analyses were utilised to explore the relationship of the total score and the four individual dimensions further. Firstly, the sO-LIFE UE dimension significantly correlated with the sO-LIFE total

score (t=2.49, df=35, p=.02); a similar result was observed for the sO-LIFE total score and the sO-LIFE CD (t=5.42, df=35, p<.001), sO-LIFE IA (t=3.49, df=35, p<.001), and sO-LIFE IN (t=2.66, df=35, p=.01) dimensions; illustrating how all four individual dimensions correlated with the total score. However, to explore the relationship between the individual dimensions further, canonical correlations were explored, exhibiting relationships between the sO-LIFE UE and sO-LIFE IA dimensions (t=-6.48, df=35, p<.001), sO-LIFE UE and sO-LIFE IN (t=-.367, df=35, p<.001), and sO-LIFE CD and sO-LIFE IN (t=-6.70, df=35, p<.001). This suggested that both unusual experience and cognitive disorganisation share relationships with the impulsive non-conformity dimension in the present sample.

Experiment 2: Adult Cohort.

Experiment 1 showed no significant effects of maternal schizotypy status on sensory gating in infants although the infants did show significant differences between *S1* and *S2*. The principal aim of experiment 2 was to examine these effects of schizotypy status on the mother's themselves.

2.4 Methods and Materials

2.4.1 Participants

55 mothers of the 6 month-old infants (*M* age=32.90 years; *SD*=4.25) participated. 53 mothers were included in the final analysis following data editing, with exclusions due to sO-LIFE scores not identifying with one of the two groups (n=2). The final sample included 23-participants identified as schizotypic mothers (SZTm; *M* age =33.09 years, *SD*=5.48) and the remaining 30-participants were control mothers (CONm; *M* age = 32.76 years, *SD*=3.11). Recruitment and ethical approval was carried out using the same method as Experiment 1.

The same stimuli and materials, procedure, and EEG data reduction were used for Experiment 2 as per Experiment 1. Participants required a minimum of 20% good trials for each stimuli to be included in further analyses. The adult cohort experienced a range of 56-64 paired-stimuli repetitions and contributed an average of 44.96 (*SD*=7.11) artefact-free trials (range: 29-59) for *S1*, and on average 45.28 (*SD*=7.42)

artefact-free trials (range: 25-57) for S2. The data were bonferroni corrected for multiple comparisons.

2.4.2 Materials and Stimuli

P50 – Stimulus 1

The P50 *S1* was measured over the central (the average of channels 37, 31, 55, 80, 87, 104, 105, 106, 7, 30, 36, 6, which are roughly similar to C1, C2, FCZ and other central electrodes), left-temporal (the average of channels 44, 45, 50, 57, 56, 49, 58, which are roughly similar to P7, TP7 and other left temporal-parietal electrodes), and right-temporal (the average of channels 114, 108, 101, 96, 100, 107, 113, which are roughly similar to P10, CP10 and other right temporal-parietal electrodes; Figure 2.3). A time window of 45-85ms was chosen for the left-temporal, 50-80ms for the right-temporal, and 45-90ms for the central electrodes, following inspection of the individual and grand averages.

P50 - Stimulus 2

The P50 *S2* was measured over the central (the average of channels 37, 31, 55, 80, 87, 104, 105, 106, 7, 30, 36, 6; yellow) left-temporal (the average of channels 44, 45, 50, 57, 56, 49, 58; green), and right-temporal (the average of channels 114, 108, 101, 96, 100, 107, 113; orange; Figure 2.3). A time window of 100-145ms was chosen for the left-temporal, 105-140ms for the right-temporal, and 100-145ms for the central electrodes, following inspection of the individual and grand averages.

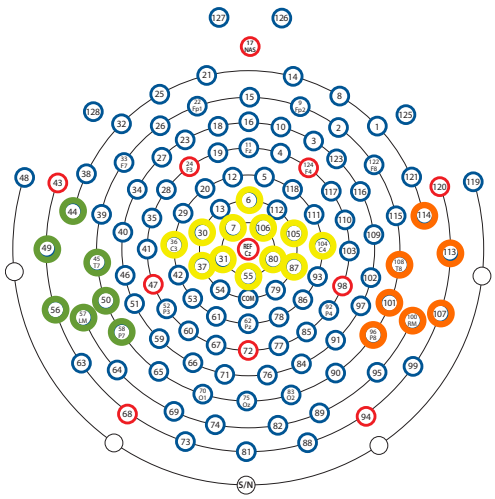


Figure 2.3. The *P50* electrode groupings for the maternal cohort.

2.4.3 Results

P50

A full factorial 2 (Group: iSZT or iCON) x2 (Paired-tone: *S1* or *S2*) x3 (Electrode Grouping: Central, Left-Temporal, or Right-Temporal) repeated-measures ANOVA with Bonferroni corrected for pairwise comparisons was carried out exploring both *mean amplitude* and *maximum amplitude* measures. A significant difference was observed between the paired-tones ($F(1,51)=4.28$, $p=.044$, $\eta^2= .077$), a paired-tone by group interaction ($F(1,51)=6.171$, $p=.016$, $\eta^2=.108$), region of interest ($F(2,102)=150.06$, $p<.001$, $\eta^2=.75$) and a paired-tone by region of interest interaction ($F(2,102)=2.01$, $p<.001$, $\eta^2=.038$).

A paired-samples t-test was used to follow-up these significant effects, and illustrated a significant difference between *S1* (*mean amplitude: M*=2.92, *SD*=1.62; *maximum amplitude: M*=4.11, *SD*=1.73) and *S2* (*mean amplitude: M*=2.19, *SD*=2.38; *maximum amplitude: M*=3.12, *SD*=2.37) in the left-temporal region when examined using the *mean amplitude* ($t(52)=2.39$, $p=.02$, $d=0.47$) and *maximum amplitude* ($t(52)=3.24$, $p<.005$, $d=.64$) measures. Significant differences were also observed between *S1* (*mean amplitude: M*=-3.29, *SD*=1.66; *maximum amplitude: M*=-1.31, *SD*=1.38) and *S2* (*mean amplitude: M*=-1.92, *SD*=1.42; *maximum amplitude: M*=-.68, *SD*=1.27) in the central region when examined using the *mean amplitude* ($t(52)=-7.81$, $p<.001$, $d=-.55$) and *maximum amplitude* ($t(52)=-3.13$, $p<.005$, $d=-.62$) measures. See Table 2.2 for a breakdown of the means and standard deviations associated with these significant differences.

A 2 (Group: SZT or CON) x2 (Paired-tone: *S1* or *S2*) x3 (Electrode Grouping: Central, Left-Temporal, or Right-Temporal) Repeated-Measures ANOVA illustrated a series of significant effects (Figure 2.4) following correction for multiple comparisons. A significant difference between the amplitudes of *stimulus 1* and *stimulus 2* was observed in the *mean amplitude* measure in the left-temporal region ($F(1,52)=4.76$, $p=.03$, $\eta^2=.08$), with a trend towards a significant paired-tone by group interaction ($F(1,51)=3.69$, $p=.06$, $\eta^2=.07$). When bonferroni corrected only a significant difference was observed between the pairwise comparisons made for *S1* and *S2* in the Control group ($p<.005$). A significant difference was observed between the paired-tones in the *maximum amplitude* measure in the left-temporal region also

($F(1,51)=9.23$, $p<.005$, $\eta^2=.15$), with a trend towards a significant paired-tone by group interaction ($F(1,51)=8.42$, $p=.06$, $\eta^2=.14$). When bonferroni corrected only a significant difference was observed between the pairwise comparisons made for *S1* and *S2* in the CON group ($p>.001$). A significant difference was observed between the paired-tones in the *maximum amplitude* measure in the central region ($F(1,51)=8.56$, $p=.005$, $\eta^2=.14$), with a significant paired-tone by group interaction also observed ($F(1,51)=6.14$, $p=.02$, $\eta^2=.11$). When bonferroni corrected there was no significant pairwise comparisons between the two groups in *S1*, but a strong trend towards a difference between the two groups in *S2* was observed ($p=.08$). Additionally, only a significant difference was observed between *S1* and *S2* in the CON group ($p<.001$).

The maternal *P50* ERP observed in the central region illustrates a dipole difference that is observed across the regions that the present paper indexes. These dipole differences reflect a positive P50 peak in the temporal regions, but a negative peak at approximately 50ms post stimulus is observed in the central region surrounding CZ. Thus, the differences reflected in this central region among the adults cohort is reflective of this dipole.

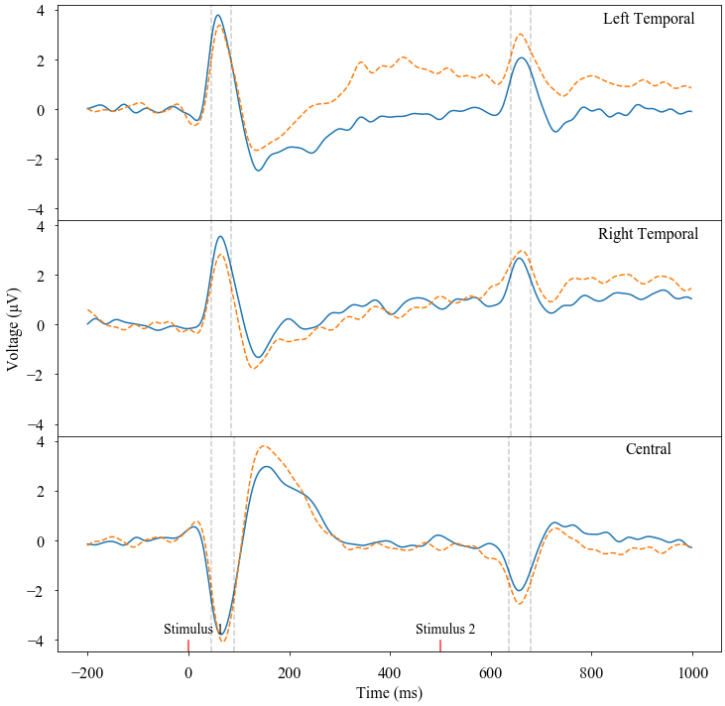


Figure 2.4. Maternal P50 mean amplitude paired-tone comparisons. Across the left-temporal, right-temporal, and central regions the SZTm *S1* and *S2* peaks show smaller differences than the CONm. Legend: SZTm – Orange, CONm – Blue.

Table 2.2. Mean and Standard Deviations in relation to the Independent Samples t-test significant differences between SZTm and CONm groups.

Electrode Region	Measure	Group (*n*)	*M*	*SD*
Central	*Maximum Amplitude* Difference	SZTm (23)	-.084	1.60
		CONm (30)	-1.03	1.19

A series of correlational analyses were conducted, corrected for multiple comaprisons, demonstrated significant relationships between the *maximum amplitude* difference measure in the combined-temporal regions and the impulsive non-conformity dimension (r=-.31, p=.03), the *maximum amplitude* suppression measure also in the combined-temporal regions and the sO-LIFE total score (r=.29, p=.04), the introvertive anhedonia dimension (r=.319, p=.02), and the impulsive non-conformity dimension (r=.29, p=.04). A significant relationship was also observed between the *mean amplitude* difference measure in the combined-temporal regions and the impulsive non-conformity dimension (r=-.32, p=.02). Moreover, a significant association was observed between the *maximum amplitude* difference measure in the central region and the sO-LIFE total score (r=.33, p=.02), and the cognitive disorganisation dimension (r=.29, p=.03). A significant correlation was observed in the central region between both the *mean amplitude* difference (r=.29, p=.03) and suppression ratio (r=-.55, p<.001) measures and the introvertive anhedonia dimension. A significant relationship was observed in the *mean amplitude* difference measure in the right-temporal region and in the unusual experiences dimension (r=-.28, p=.04), with the *maximum amplitude* difference measure in the same region displaying a significant association with the impulsive non-conformity dimension (r=-.29, p=.03). Canonical correlation analyses were utilised to explore the relationship of the mothers' total score and the four individual dimensions further. Firstly, the sO-LIFE UE dimension significantly correlated with the sO-LIFE total score (t=12.80, df=52, p<.001); a similar result was observed for the sO-LIFE total score and the sO-LIFE CD (t=17.23, df=52, p<.001), sO-LIFE IA (t=9.53, df=52, p<.001), and sO-LIFE IN (t=5.48, df=52, p<.001) dimensions; illustrating how all four individual dimensions correlated with the total score. However, to explore the relationship between the individual dimensions further, canonical correlations were explored, exhibiting

relationships between the sO-LIFE CD and sO-LIFE IA dimension (t=3.93, df=52, p=.001), the sO-LIFE CD and sO-LIFE UE (t=5.77, df=52, p<.001), and the sO-LIFE UE and sO-LIFE IN (t=2.51, df=52, p=.02) dimensions. This demonstrates similarities with the infant cohort in that both the unusual experiences and Cognitive Disorganisation dimensions illustrate relationships with the other dimensions.

To further understand the relationship between infant and maternal sensory gating ability, a series of correlations (corrected for multiple comparisons) were undertaken between the infants' and mothers' suppression ratio and differences measures. These analyses illustrated only a significant relationship between the infant and maternal left-temporal suppression ratio measure (r=.52, p<.001), with the infant and maternal left-temporal difference measure nearing significance (r=-.28, p=.08). The left-temporal suppression ratio association indicates that both infant and maternal suppression measures increase in synchrony with each other; suggesting that those mothers illustrating larger suppression ratios, which are indicative of poorer sensory gating, are also observed among the infant cohort.

2.5 General Discussion

The present research investigated whether measurable changes in sensory gating function in the offspring of mothers with schizotypic traits could be detected in comparison to their control counterparts. Specifically it was hypothesised that these mothers and their offspring would display smaller differences and larger ratios in the P50 event-related potential component. We have demonstrated two important findings in this research. Firstly, that sensory gating can be detected in infants as early as 6-months-of age. Data revealed that although the 6-month-old infants' P50 components displayed significant differences between *S1* and *S2*, there was no clear difference between infants of schizotypic and infants of control mothers. Therefore, the infants of mothers presenting with schizotypic traits appear not to be at higher risk than normal, at least at 6-months-of age.

Despite a lack of clear group differences in the 6-month cohort, a series of significant correlations were observed between suppression ratio/ difference measures and the maternal sO-LIFE dimensions. This could be perceived as the beginning of differences between groups at this age. It is possible to conclude that these deficits are just not present at 6-months of age, or that maternal personality impacts the development of sensory gating, but this influence is not yet robust enough to illustrate clear group differences. Schizotypic traits are present in the general population and can go undetected by the unaided eye; thus, at 6-months it is likely that maternal schizotypy has not been extensively experienced enough to influence a measure as sensitive as sensory gating. Moreover, the event-related potential analysis utilised in this sensory gating paradigm may be hindered by the neuronal development of the 6-month-old infant. At this age we have a quantity of neuronal and synaptic connections which we then prune throughout development to adulthood to gain maximum efficiency (Singer et al., 1995; Huttenlocher, 2002). Thus, with increased neuronal connectivity, the EEG data collected and analysed is more 'noisy' than that collected by an adult cohort.

A second key finding was a clear dissociation in the brain activity of the SZTm and CONm mothers. The Bonferroni corrected pairwise comparisons illustrated how the CONm mothers had significant differences between *S1* and *S2*, illustrating typical sensory gating ability, whereas the lack of significant difference between the *S1* and

S2 for SZTm mothers illustrates the sensory gating deficit observed across the schizophrenia-spectrum. This suggests that experiencing schizotypic traits, as characterised through the sO-LIFE, also influences sensory gating ability; whereby a smaller difference or larger suppression ratio is observed between *S1* and *S2*. This supports prior literature (for example, Wan et al., 2017); whereby individuals who exhibit schizotypic traits also illustrate a reduced inability to inhibit, or 'gate out', the second tone in a paired-tone paradigm. The mothers experiencing schizotypic traits, may feel as though they would benefit from follow-up guidance, additional family support and education to assist them in mitigating any potential and future impact of their schizotypy status on their parenting skills.

Schizotypal expression during adolescence and adulthood is critically linked to childhood risk markers, which confer a role of potential developmental facilitators on the road to psychosis proneness (Debbané, 2015, pp. 88), thus establishing brain-behaviour links in both clinically significant behaviours and those of typical development is an important step in further understanding the continuities and discontinuities that exist between typical and pathological behaviour (Hentgartner and Lehmann, 2017). Prior literature focuses on deficits observed in schizophrenic patients and their biological relatives (for example, Ross and Freedman, 2015), but a more recent shift in the literature explores the same deficits, albeit to a milder degree, in individuals who identify with schizotypic traits, but are part of the general population (for example, Debbané and Barrantes-Vidal, 2015; Ross and Freedman, 2015). These deficits can be described as endophenotypes and the continuous nature of these endophenotypes make it difficult to escape the conclusion that there is considerable overlap between the clinical schizophrenia-spectrum and sub-clinical schizotypy, as represented by the fully-dimensional approach (Claridge and Beech, 1995; Claridge and Davis, 2003). Exploring endophenotypes among the sub-clinical realm of the spectrum is advantageous as it removes the difficulties associated with schizophrenic cohorts, for example, medication. If schizotypic traits are present in the general population then it is also an important step to understand the influence these traits have on the people surrounding them; hence the focus of the present research. Moreover, the successful adaptation of tasks for use in early infancy will therefore increase our understanding of the developmental timeline of these disorders and perhaps allow for the development of novel prevention strategies.

In order to primarily focus on the continuities and discontinuities that exist between typical and pathological behaviour (i.e. the continuous nature of schizotypic traits in conjunction with the rest of the schizophrenia spectrum), perhaps a focus on the individual sub-dimensions would 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 entire spectrum; as it is largely understood that these traits/symptoms underlie schizophrenia (e.g., Lenzenweger and Dworkin, 1996) and have been replicated in non-clinically ascertained schizotypy (Kwapil, Barrantes-Vidal, and Silvia, 2008). A limitation of this is, however, the lack of reliability in these measures throughout the schizophrenia-spectrum (for example, Cochrane, Petch, and Pickering, 2010). In contrast, the use of the combined dimensions total-score, although it does not provide a segregated reflection on the differential elements of schizotypy, does nevertheless provide a way of 'grouping' those individuals who exhibit generalised schizotypic traits. For the present research, with a small sub-sample of the general population, this was 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 the individual sub-dimensions of the schizotypic personality may well be a more profitable approach.

Further to the prior point, it should be clearly articulated that schizotypy, for the purpose of the present research, was defined using the sO-LIFE measurement, with mothers classed as schizotypic if their sO-LIFE score, averaged across the four dimensions, was half a standard deviation above the total participant population mean (as outlined previously). This was the same approach adopted by Park et al. (2015) and weighs in favour of the fully-dimensional approach, describing how schizotypic features are observed in the general population and linked with typical development and atypical clinical disorders (Claridge et al., 1996). However, this could be limited in its ability to fully understand schizotypy as a personality construct. There is much evidence that schizotypy is a construct with separable and well-identified components (Kwapil, Barrantes-Vidal, and Silvia, 2008); thus, these dimensions in combination with each other do not present a clear and distinguishable reflection of positive,

negative, or disorganised schizotypy. However, the present experiment attempts to control for this limitation through the use of correlational analyses with the four separate dimensions; providing an additional measure of the four scales separately. Moving forward in the schizotypy literature, this is an important element to consider.

The sensory gating literature is unclear (Dalecki, Croft, and Johnstone, 2011) with respect to the best method of suppression presentation and as such, the inclusion of both measures in the present study provides comparable clarity for understanding infant sensory gating. The current experiment includes the differences and suppression ratios within the analysis, in contrast to previous work that has relied on a single suppression parameter. Here significant effects were observed in the suppression ratio scores in the infant population, and in both the difference and suppression ratio measures in the maternal cohort. In additional strength, multiple electrode sites were utilised for analysis when contrasted with prior research, which have used limited recording sites. The ability to select a number of electrodes for each regional analysis provides a broader understanding of the neural activity experienced during sensory gating. Previous literature explored sensory gating in the central regions, specifically CZ, and utilised a mastoid or earlobe reference (Toyomaki et al., 2015; Hunter et al., 2015; Thoma et al., 2017). However, an advantage of the current research is the quantity of electrodes in the electrode high-density array. Upon visual inspection of both individual and grand averages, a clear P50 component could be observed both in the central regions (Park et al., 2015), as we predicted from prior literature, but also in the temporal regions as would be expected in concordance with prior auditory paradigms (Korzyukov et al., 2007). The current study also highlighted the complexity of recording electrical activity during sleep. During sleep, infants produce unpredictable movements, increasing quantities of artefacts, leading to a reduced number of infants being included in the final analysis when contrasted to the sample taking part in the study. A future exploration could track, alongside the EEG P50 recordings, the sleep cycles of the infants, similarly to Hunter et al. (2015), to explore, for example, whether sensory gating is more efficient during the different types of sleep.

Key strengths to the present study include the recruitment of only non-smoking mothers to eliminate any potential confounding effects of nicotine, as smoking has been shown to diminish sensory gating ability (Wan, Crawford, and Boutros, 2006)

and the overall sO-LIFE score was used as a global measure of schizotypy dimensionality in the two groups. Capturing the typical-pathological continuum in the expression of schizotypal traits presents significant measurement challenges. The assessment tools chosen therefore needed to be sufficiently sensitive to register subtle variation across the whole continuum in order 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 (Dembińska-Krajewska, and Rybakowski, 2012).

A further strength of this work was the non-specific differences in the demographic, social and clinical factors associated with the mothers. As shown in Table 1 the mothers and infants themselves were matched across a range of demographic and clinical factors. This supports the hypothesis that the critical explanatory factor was the specific schizotypy status of the mother, rather than generalised or non-specific factors. Additionally, lack of specificity in the questionnaire responses restricted the analyses carried out to further understand the influence of prior mental illness on sensory gating ability. Perhaps a future replication could explore more detailed histories of mental illness in the adult populations to address whether schizotypy was more prevalent among those with a history of mental illness, as would be expected.

Our study extends the existing scope of the links between maternal personality influence and the development of their 6-month-old infant; furthering our knowledge into the extent to which these issues are present in the general population, and how we universally imprint on infants' early development (de Haan et al., 2004). Schizophrenia, other psychiatric disorders, and sub-clinical expressions of such disorders, is inherent in families (Roisko, Wahlberg, Hakko, and Tienari, 2015). The characteristics that define neurodevelopment and neuropsychiatric disorders may be best conceptualised as variations of quantitative dimensions of domains distributed throughout the general population (Hengartner and Lehmann, 2017). The ability to assess variation in such traits along a continuum, and across the lifespan, is critical in understanding and identifying risk and protective factors associated with personality dimensions and clinical disorders alike.

In summary, 6-month-old infants, in general, display the ability to gate out irrelevant stimuli. It is known that core neuropsychological dysfunctions for the potential

development of clinical disorders are present during childhood and shape adult personality (Corr, 2010), however these relationships between the ERP differences and suppression ratio measures in the infants and the maternal sO-LIFE measures suggests a potential emergence of differences, which may be observed to a greater degree with continued developmental change.

Prelude to Chapter 3

If we know *sensory gating* deficits are observable in schizotypic mothers, then are they also observable in the form of reduced oscillatory power?

The preceding work demonstrated two important findings. First, we have demonstrated that sensory gating can be detected in infants as early as 6-months-of age. A second key finding was a clear dissociation in the brain activity of the schizotypic mothers and those in the control condition. Despite a lack of clear group differences in the 6-month cohort, a series of significant correlations were observed between suppression ratio/ difference measures and the sO-LIFE dimensions. These correlations may be interpreted as the beginning of differences between groups at this age. As such, it is possible to suggest that maternal personality is related to the development of sensory gating, but thus far in this thesis, it is not robust enough to illustrate clear group differences.

This inhibitory process, which we have observed in the mothers, is an essential cognitive ability for humans in everyday life (Cheng et al., 2016). It has also been suggested, however, that this P50 ERP component has a subcomponent that is exposed as a low-frequency oscillatory response occupying the 1-20Hz range (Clementz and Blumenfeld, 2001). This 1-20Hz bandwidth can also be analysed in the paired-tone paradigm to facilitate the spectral power of the frequencies in this band (Clementz and Blumenfeld, 2001), which provides a broader assessment of auditory gating dysfunction (Brenner et al., 2009) and the oscillatory frequencies that underpin the P50 ERP gating component. The overlap between this sensory gating phenomenon in the event-related potential and oscillation literature drives further exploration of oscillations and their relationship with their ERP component counterpart.

This finding observed in the mothers, and the correlation observed in the infants, supports the notion originally outlined by Venables (1964) who proposed that schizophrenia was essentially a problem of ‘input dysfunction’. A key feature of this proposal is the idea that it involves some deviation in inhibitory mechanisms in the brain, which has been extensively studied and has demonstrated that, to some extent, Venables was correct in his interpretation of inhibitory mechanisms (Claridge, 2009). It is now further understood that in psychosis, all levels of cognitive functioning may

be subject to a weakened inhibitory control mechanism, resulting in the perceptual and attentional flooding, or cognitive 'over inclusion', that typifies the clinical state (Claridge, 2009). This description outlines the mechanisms that are involved in the sensory gating process, and aligns with Venables' suggestion that input dysfunction can lead to an excessive openness to the environment, or the inability to 'gate out' irrelevant information.

It has been proposed that reduced neural activity in the beta range (12-20Hz) is observed in schizophrenic patients when contrasted with non schizophrenics (Brenner et al., 2009), with beta activity in response to *S1* of the paired-tones predicting stronger gating and P50 suppression (Kisley and Cornwell, 2006; Hong et al., 2008). These suggestions are in agreement with work demonstrating how sensory gating abnormalities in the schizophrenia-spectrum extend to neural oscillations in gamma and beta frequency ranges (Hall et al., 2011). As such, we consequently asked the question: could a similar oscillatory deficit be observed in the traits of schizotypy when observed in a non-clinical population? Schizotypy is acknowledged as a sub-clinical dimension that shares traits with the diagnosable schizophrenia-spectrum. Deficits in sensory gating ability are observed throughout this spectrum, including schizotypy, when observe using ERPS. ERPs are a far more common method of exploring sensory gating and as such, it is important to explore the oscillatory element of sensory gating and to aim for a deeper understanding of the differences between event-related potential and oscillation processing.

Hong et al. (2008) demonstrated how the presence of typical gamma and beta gating in relatives of individuals with schizophrenia suggests that the underlying cognitive functions measured by the event-related oscillation gating responses may differ from those tapped by a P50 suppression task. As such, the following chapter aims to observe whether mothers who identify as schizotypic demonstrate reduced evoked power in their neuro-oscillatory responses during sensory gating, and whether these responses have similar manifestations in their 6-month-old offspring, or whether we observe the same finding as Hong et al. (2008), whereby the offspring of schizotypic mothers would show no difference from their control counterparts.

Chapter 3

The influence of Schizotypy on Event-Related Oscillations in Sensory Gating.

Text under revision in Frontiers in Psychiatry.

Abstract

Schizotypy is a personality dimension within the general population elevated among schizophrenia-spectrum patients and their first-degree relatives. Neuro-oscillatory deficits have been observed in individuals diagnosed with schizophrenia. More specifically, reduced gamma and beta activity is observed towards *S1* in a paired-tone paradigm. However, the relatives of schizophrenic patients do not always show these deficits.

The current study investigated whether schizotypic mothers demonstrate reduced evoked oscillatory activity during sensory gating, and whether these deficits are replicated in their 6-month-old offspring. The paired-tone paradigm was used to probe the oscillatory activity of 37 infants during 15 minutes of sleep, and 33 of their mothers whilst at rest. Their mothers completed the Oxford and Liverpool Inventory of Feelings and Experiences-Short Form as an index of *schizotypy* dimensionality, categorized into: infants of control, and infants of *schizotypic* mothers.

The findings revealed that although the infants' evoked-oscillations displayed differences between *S1* and *S2*, there was no difference in power between the infants of schizotypic and the infants of control mothers, replicating previous work and supporting our hypothesis. The mothers, however, displayed significant differences, with reduced power toward *S1* observed in the schizotypic mothers between 13-30Hz, supporting prior literature. These findings are consistent with surrounding evidence that early sensory processes, such as sensory gating are impaired in schizophrenia-spectrum disorders. The present research supports the idea that relatives do not display the same deficit as patients; event-related oscillation gating differs from the cognitive functions indexed by P50 event-related suppression.

3.1 Introduction

Maternal personality is known to have a direct influence on childhood risk factors for mental health with prior links made between specific parental psychopathology and P50 event-related potential sensory gating abilities (Ross and Freedman, 2015). Core neuropsychological, and neuro-oscillatory dysfunctions of potential future psychopathologies may be present during childhood, which shape the development of adult personality (Corr, 2010). Studies employing spectral frequency analyses provide additional information about auditory sensory gating within the schizophrenia-spectrum. It is therefore of fundamental interest to understand the spectral frequencies involved in the sensory gating process.

Neuro-oscillatory deficits are observed in the first-degree relatives of individuals diagnosed with schizophrenia who also present with schizophrenia-spectrum personality disorder traits, but who are not on antipsychotic medication (Hong et al., 2004b). The shared experience of these deficits raises the possibility that oscillatory abnormalities may present a neurobiological endophenotype for schizophrenia-spectrum disorders in general (Gottesman and Gould, 2003). If atypical event-related oscillations are observed across the schizophrenia-spectrum (Gur et al., 2004; Seidman et al., 2006), then could these abnormalities be observed, to a lesser degree, in sub-clinical schizotypy? The literature is mixed in this instance, with Hong et al. (2008) suggesting that the typical first-degree relatives of those diagnosed with schizophrenia display no difference in their event-related oscillation gating responses when compared to controls. No research, as far as we are aware, has looked at the oscillatory power of sensory gating among mothers and their 6-month-old infants, thus the basis of the present research originates from the schizophrenia literature.

The inhibition of responses to irrelevant stimuli is an essential cognitive ability for humans in everyday life. The ability to ‘gate out’ these irrelevant stimuli is known as *sensory gating*. This is an attenuated neural response to the second identical stimulus in a paired-tone paradigm, which is considered an automatic inhibition function (Freedman et al., 1987). In the auditory modality, the paired-tone paradigm, in which two stimuli are presented in close succession, have been widely applied across the literature and across the schizophrenia-spectrum (Patterson et al., 2008). The P50 auditory event-related potential (ERP) response to the second stimuli (S2) is typically

reduced compared with that of the first stimulus (*S1*). This suppression, termed P50 gating, is thought to serve as a protective mechanism against flooding of the higher-order cortical centres with unnecessary information (Turetsky et al., 2007; Braff et al., 2007). Individuals diagnosed with schizophrenia and a significant proportion of their clinically unaffected relatives exhibit reduced P50 ERP suppression. This suggests that the compromised ability of the brain to filter this irrelevant information is associated with mental health difficulties.

It has previously been proposed that a sub-component of the event-related brain potential to paired-tones, the P50 gating component, is a low-frequency response that occupies the 1-20Hz range (Clementz and Blumenfeld, 2001). This low-frequency range spans the theta band, associated with new information and encoding (Klimesch, 1999), and the beta band, associated with the detection of salient changes in sensory stimuli (Haenschel et al., 2000), which is therefore thought to signify attentional engagement to task-relevant features of stimulus processing. This 1-20Hz bandwidth has also previously been employed in the paired-tone procedure to facilitate the spectral power of the frequencies in the band (Clementz, Barber, and Dzau, 2002; Johannesen et al., 2005; Clementz and Blumenfeld, 2001; Blumenfeld and Clementz, 2001), which are putative indices of selective attention. As such, the separation of the auditory P50 ERP into low-frequency response bands provides a broader assessment of auditory gating dysfunction (Johannesen et al., 2005).

Underlying mechanisms that are involved in stimulus-evoked oscillations seem to also be impaired in individuals diagnosed with schizophrenia. Abnormalities in the power of gamma oscillations suggest that the neural mechanisms that mediate gamma activity may be atypical. Abnormalities have been reported in gamma activity related to early auditory processing (Clementz, Blumenfeld, and Cobb, 1997; Hong et al., 2004b), such as sensory gating. Poor gating may, in part, reflect attenuated neural activation in response to S1 (‘gating in’ deficits) between 1-20Hz (Blumenfeld and Clementz, 2001; Johannesen et al., 2005). Moreover, the auditory P50 ERP overlaps morphologically with the evoked gamma frequency (approximately 40 Hz; Muller et al., 2001) and additionally responses to *S1* stimuli in the low beta frequency range (approximately 16 Hz) have been shown to be negatively associated with the P50

response to S2 stimuli (Hong et al., 2008). Beta (~13-29 Hz) oscillations are associated with encoding and consolidating sensory information and may be correlated with stimulus salience (Haenschel et al., 2000; Bibbig et al., 2001). Further, both gamma and beta responses to *S1* stimuli have been correlated with P50 *S1* amplitudes (Kisley and Cornwell, 2006). This literature suggests that gamma band (35-45Hz) and beta band oscillations (13-30Hz) may contribute to auditory P50 ERP responses, although the precise mechanisms involved remain to be determined. Based on the proposed role(s) of activity in these frequency ranges for stimulus processing, it is possible that sensory flooding is associated with the inability to reduce beta and gamma oscillatory power in order to reduce stimulus salience following repetitive stimulation.

Several findings (Leicht et al., 2010; Brenner et al., 2009, for example) have suggested a dysfunction in the detection and encoding of salient sensory information in individuals diagnosed with schizophrenia. Using the paired-stimulus paradigm, individuals diagnosed with schizophrenia have shown a decreased beta activity to *S1* stimuli (Brenner et al., 2009) and reduced activity at low frequencies that included beta oscillations and smaller gamma power to the *S1* stimulus compared to controls in fronto-central regions (Johannesen et al., 2005). This reduced activity is thought to be a predisposition to misperceiving environmental stimuli in individuals diagnosed with schizophrenia. Moreover, reduced gamma activity to *S1* stimuli has been observed in some samples of schizophrenic individuals (Johannesen et al., 2005**),** but not all (Clementz and Blumenfeld, 2001); suggesting a disrupted or inefficient formation of neural assemblies for registering sensory input. Alternatively, this could reflect how the sensitivity of this measure is not consistently robust. Additionally, increasing quantities of studies have found that electrophysiological abnormalities associated with the schizophrenia-spectrum are evident in clinical high-risk patients (Bodatsch et al., 2011; Perez et al., 2013; Ross and Freedman, 2015). Gamma phase synchrony and associated reductions in evoked gamma power are present early in the course of the disorder, and possible even prior to the onset of behavioural symptoms during the prodromal period. If these reduced evoked oscillations are present in this precursor stage then is may be possible to observe similar patterns of activation in the sub-clinical portion of the schizophrenia-spectrum.

Across the literature, neural oscillatory activity in the gamma and beta ranges is thought to reflect the differential aspects of early sensory information processing (Kopell et al., 2000; Traub et al., 1999; Basar-Eroglu et al., 1996), with gamma and beta event-related oscillations described as major contributors to the auditory P50 sensory gating response (see Ulhaas and Singer, 2010, for a review). Previous literature has studied individuals diagnosed with schizophrenia and their relatives (Hong et al., 2008), reporting no differences observed between the clinically unaffected relatives and healthy controls in either beta or gamma gating responses.

Reduced gamma power and synchrony deficits have been positively correlated with the negative symptomatology of schizophrenia (Lee, Williams, Haig, and Gordon, 2003). Could a similar oscillatory deficit be observed in the traits of schizotypy when observed in a non-clinical population? However, Hong et al. (2008) demonstrated how the presence of typical gamma and beta gating in relatives suggests that the underlying cognitive functions measured by the event-related oscillation gating responses may differ from those tapped by P50 suppression. As such, the current research aims to observe whether mothers who identify as schizotypic demonstrate reduced evoked power in their neuro-oscillatory responses during sensory gating, and whether these responses have similar manifestations in their 6-month-old offspring, or whether we observe the same finding as Hong et al. (2008).

3.2 Method

Experiment 1: Infant Cohort.

3.2.1 Participants

101 infants, aged 6-months (*M*=5.80 months; *SD*=9.23 days; 54 male) participated in the study. A further 64 were excluded from the final sample due to: poor data quality (*n*=18), no auditory data collected due to the infants not sleeping (*n*=26), sO-LIFE score did not identify with either control or schizotypic groups (n=10), or the participant did not produce over 20% good epochs (*n*=10). Thirty-seven (20 male) infants were included in the final analysis. The final sample included 15-participants who identified as an infant of a schizotypic mother (iSZTm) and the remaining 22-participants were infants of control mothers (iCONm). All participants were from a non-clinical population. Recruitment was carried out using the Lancaster University Department of infant and child development infant database. Ethical approval was obtained with the Lancaster University Ethics Board and the North West – Lancaster Research Ethics Committee for the NHS.

3.2.2 Materials and Stimuli

The participant experienced a paired-tone paradigm that was based on Park, Lim, Kirk, and Waldie (2015). The auditory stimuli was presented 80-centimetres away from the participant, between 70-77dB (Wan, Friedman, Boutros and Crawford, 2008; Dalecki, Croft, and Johnstone, 2011), and for approximately 100-trials, or until the infant woke or became restless. A 500ms inter-tone interval was present between two tones and with a 10s inter-trial interval, repeated continuously for 15-minutes or until the infant woke. All electrophysiological signals were recorded using Electrical Geodesics Inc. amplifiers (input impedance=80KΩ; sampling rate=500 Hz) and event-related oscillations were measured using an EGI Hydrocel GSN-128 electrode 1.0 net and analysed using Netstation 4.5.4.

The data was 0.5-65Hz bandpass filtered and segmented to create epochs from 400ms before to 1200ms after stimulus-onset for each trial. The data was visually inspected and edited offline to remove artefacts. Epochs were excluded if the channel segment contained more than 12 poor channels. Participants required a minimum of 20% good

trials for each stimuli to be included in further analyses. Infants experienced a range of 63-140 paired-stimuli repetitions, dependent on how long they slept for, and contributed an average of 51.62% artefact-free trials (range: 23-90.7%) for *S1*, and on average 52.04% artefact-free trials (range: 24.5-94%) for S2.

The artefact-free segments were subjected to time-frequency analysis to examine stimulus-induced oscillatory responses. The epochs were imported into Matlab® using the free toolbox EEGLAB (v. 9.0.5.6b) and re-referenced to the average reference. Using a custom-made scripts collection named 'WTools" (see Parise, Csibra, and Becchio, 2013, for reference) we computed complex Mortlet wavelets for the frequencies 10-90Hz with 1Hz resolution. We calculated total-induced oscillations performing a continuous wavelet transformation of all the epochs by means of convolution with each wavelet and taking the absolute value (i.e., the amplitude, not the power) of the results (see Csibra et al, 2000). Transformed epochs were then averaged for each condition separately. To remove the distortion introduced by the convolution, we edited out 200ms at the edges of the epochs, resulting in 1200ms long segments, including 200ms before and 1000ms after stimulus onset. We used the average amplitude of the 200ms pre-stimulus window as baseline, subtracting it from the whole epoch at each frequency (see Parise, Csibra, and Becchio, 2013, for reference).

Based on previous literature (Smith et al., 1994; Roach and Mathalon, 2008; Smith et al., 2010; Popov et al., 2011) and visual inspection of the grand and individual means, we selected the scalp area, time window and frequency band. Gamma and Beta induced frequencies were measured over the left-temporal (the average of channels 47, 51, 52; green), right-temporal (the average of channels 115, 116; yellow), and left-frontal (the average of channels 12, 20, 24; orange) regions, in the 100 to 325 ms time window (Figure 3.1). Beta activity was analysed between 10-20Hz and gamma between 30-50Hz.

All analyses were conducted blind to the participant group status.

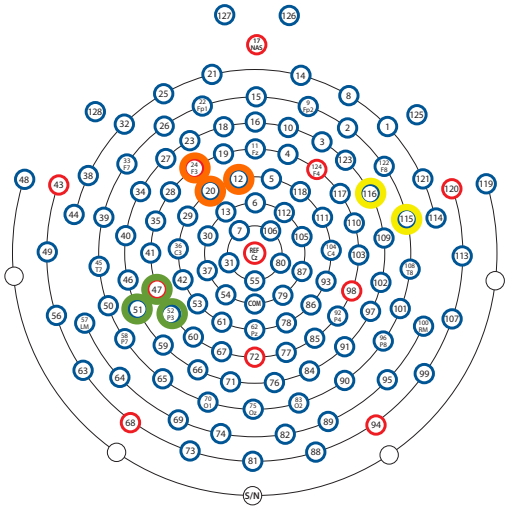


Figure 3.1. Infant electrode groupings which were averaged in the 100 to 325ms time window.

3.3 Questionnaires

3.3.1 Schizotypy

The Oxford-Inventory of Feelings and Experiences- Short Form (sO-LIFE; Mason, Linney and Claridge, 2005) assessed schizotypy dimensionality and divided the participant cohort into iSZTm and iCONm. The mean across the population was calculated (total *M*=8.15, total *SD*=6.26). The iSZTm condition was determined by the M+.5SD (sO-LIFE Scores>11.28) and included 15-participants and the iCONm condition by the *M*-.5*SD* (sO-LIFE Scores 5.02>0.00), included 22-participants. The sO-LIFE was chosen as the present measure of schizotypy dimensionality due to its fully dimensional approach, proposing that symptoms occurring in the schizophrenia-spectrum also occur in the typical population as well, with the sO-LIFE questionnaire measuring such symptoms. The reliability of the sO-LIFE, estimated with ordinal alpha, was disclosed to be above 0.78 (Fonseca-Pedrero et al., 2014). These levels of internal consistency are in line with the internal consistency values reported in previous studies; for example, previous work using ordinal alpha have found good reliability estimates (Lin et al., 2013; Sierra et al., 2013). The cronbach's alpha in the present cohort was .79, demonstrating the consistent reliability measure of the sO-LIFE. Moreover, the sO-LIFE scores showed good convergent and discriminant validity with the *Schizotypal Personality Questionnaire – brief revised* (Goulding, 2004; Mason, Claridge, and Clark, 1997; Burch, Helmsley, Corr, and Gwyer, 2006).

3.3.2 Personality Assessment.

A shortened version of the EPQ-R personality questionnaire (Eysenck and Eysenck, 1992et al., 1985) 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 and Watson, 2006) with sizeable correlations observed, and higher levels of neuroticism in individuals diagnosed with schizophrenia (Gurrera, Nestor, and 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 and Eysenck, 1992), which has good internal consistency (alpha=.85; Eysenck et al., 1985), and strong concurrent validity with related constructs (Stewart, Ebmeier, and Deary, 2005).

3.3.3 *Additional Demographic Variables.*

A general assessment questionnaire was used to gain an overall assessment of smoking habits, hearing deficits, birth complications, and whether they, or their family have experienced mental illness. Birth complications, and experience of mental health history was also noted. An Independent Samples T-test presented no significant differences between both iSZTm and iCONm groups (Table 3.1).

3.4 Procedure

Prior to participation, the caregiver completed a series of questionnaires.

The EEG cap was soaked in a warm water, sodium chloride solution and baby shampoo before fitting to the infant's head. Once fitted and following confirmation that each electrode responded to electrical activity, the trial procedure began. The auditory stimuli was presented 80-centimetres away and for 100-trials, or until the infant woke or became restless. The infant was then left to complete their natural sleep period. Throughout the testing period the infant's status was video-recorded to index activity.

Table 3.1. Table indicating similarities between the iSZTm and iCONm groups in their demographic information, as collected using a general information questionnaire.

		Schizotypy (infant *n*=15)	Non-Schizotypy (infant *n*=22)	T-Test
Infant Age (days)		179.27 (9.51)	178.52 (7.77)	.793
Infant Gender	Female	*n*= 6	*n*= 12	.476
	Male	*n*= 9	*n*= 11	
Mothers Age (years)		*n*= 20	*n*= 13	.914
		32.53 (5.21)	32.69 (2.06)	
Mothers Mental Health Experiences		1.60 (.51)	1.86 (.35)	.070
Family History of Mental Health		1.53 (.52)	1.59 (.50)	.737
Birth Complications		2.00 (1.00)	1.57 (.84)	.158

3.5 Results

A paired-samples t-test illustrated a significant difference between the frequencies observed in the right region ($t(37)=2.82$, $p=.01$, 95% CI [.022, .133], $d=.66$); illustrating decreased activity in *S2* compared to *S1* (Figure 2). A one-way ANOVA and repeated-measures ANOVA showed no significant differences between the iSZTm and iCONm (all p values >0.05). No further significant effects were observed.

Z-scores were calculated for the Total sO-LIFE score, and the four sO-LIFE dimensions (Unusual Experiences, Cognitive Disorganisation, Introvertive Anhedonia, Impulsive Nonconformity) and underwent a correlational analysis corrected for multiple comparisons. No significant relationships were observed between these dimensions and the infant oscillatory power in the left-temporal, right-temporal, or left-frontal regions. A significant positive relationship was observed between the neuroticism score and the sO-LIFE Total score ($r=.76$, $p<.001$); suggesting the larger an individual's schizotypy score, the higher their neuroticism score.

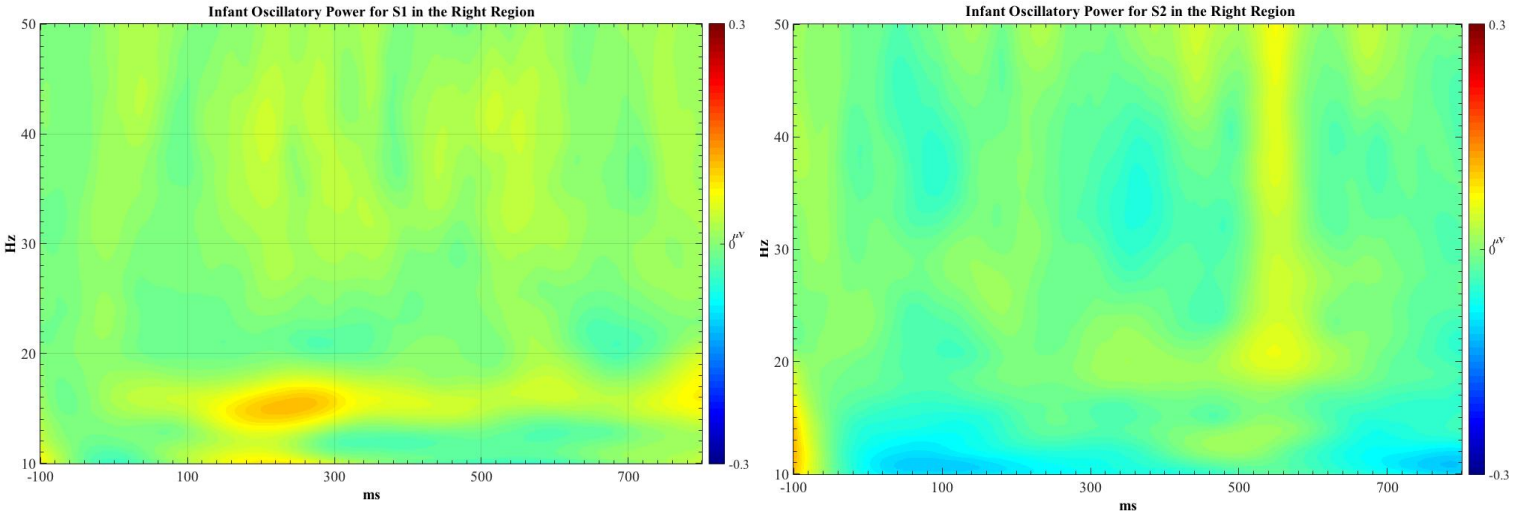


Figure 3.2. Topographical Plot of *S1* and *S2* across the entire infant cohort. Note how the power related to S1 is greater in comparison to that of *S2*. A greater power can be observed between 10-20Hz across the time-window of *S1*.

Experiment 2: Adult Cohort

3.6 Participants

43 mothers of the previously tested infants participated in the study. These mothers were recruited through the same database as their infants. A further 10 were excluded from the final sample due to: poor data quality (*n*=1), and sO-LIFE score did not identify with either control of schizotypic groups (*n*=9). 33 mothers were included in the final analysis. The mothers contributed on average 88.2% artefact-free trials (*M*=49.48 trials, *SD*=5.35 trials, range: 42-61 trials) for *S1* and on average 88.3% artefact-free trials (*M*=49.58 trials, *SD*=5.12 trials, range: 41-62 trials) for S2.

The final sample included 20-participants who identified as a schizotypic mother (SZTm) and the remaining 13-participants were control mothers (CONm). The mean of the sO-LIFE total score across the population was calculated (total *M*=10.07, total *SD*=6.77). The SZTm condition was determined by the *M*+.5*SD* (sO-LIFE Scores>13.46) and included 20-participants and the CONm condition by the M-.5SD (sO-LIFE Scores 6.68>0.0), included 13-participants.

3.7 Materials and Stimuli

The materials, stimuli, and analysis utilised were the same as for Experiment 1 with the exception of the scalp regions for analysis. The scalp regions, time window, and frequency bands were determined by prior literature (Roach and Mathalon, 2008; Smith et al., 2010; Popov et al., 2011) and the visual inspection of the grand and individual means for the maternal cohort. Gamma and Beta induced frequencies were measured over the left-frontal (the average of channels 12, 18, 19, 20, 22, 23, 24, 26, 27; yellow), and right-frontal (the average of channels 3, 4, 5, 9, 10, 11, 118, 123, 124; orange) regions, in the 50 to 250 ms time window (Figure 3.3). Beta activity was analysed between 13-20Hz and gamma between 35-50Hz. All analyses were conducted blind to the participant group status.

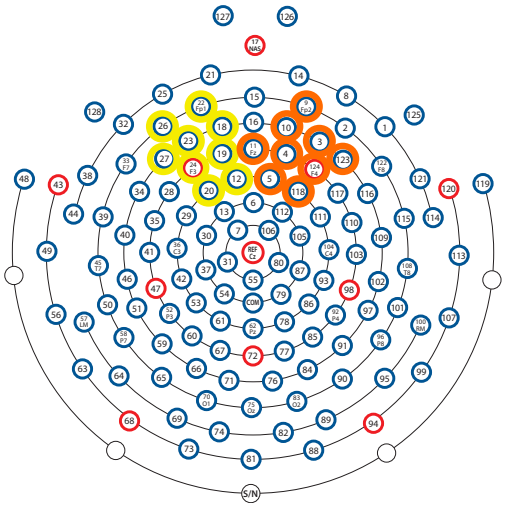


Figure 3.3. Maternal electrode groupings which were averaged across the 50 to 250ms time window.

3.8 Results

A paired-samples t-test illustrated a significant result in the right region ($t(32)=2.45$, $p=.020$, 95% CI [.007, .079], $d=.62$); suggesting more negativity in S2 as observed in the mother cohort (Figure 3.4).

A one-way ANOVA, corrected for multiple comparisons, displayed a significant group difference in the right region ($F(1,31)=11.06$, $p=.002$, $\eta p^2 =0.26$), indicating that mothers with schizotypy ($M=.03$, $SD=.06$) displayed reduced power in *S1* compared to control mothers ($M=.11$, $SD=.07$), replicating previous literature (Johannesen et al., 2005; Brenner et al., 2009). A 2 (condition: SZT or CON) x2 (paired-tone: *S1* or *S2*) x2 (channel region: right, left) repeated-measures ANOVA

displayed a significant difference between the *S1* stimuli in the right region ($F(1,32)=8.19$, $p=.01$, $\eta p^2=.21$), in addition to a between-subjects group effect in the same stimuli and region ($F(1,32)=10.92$, $p=.002$, $\eta p^2=.26$). This supports the hypothesis that schizotypic mothers show decreased activity in *S1* compared to control mothers between 13-20Hz (beta) range (Figure 3.5).

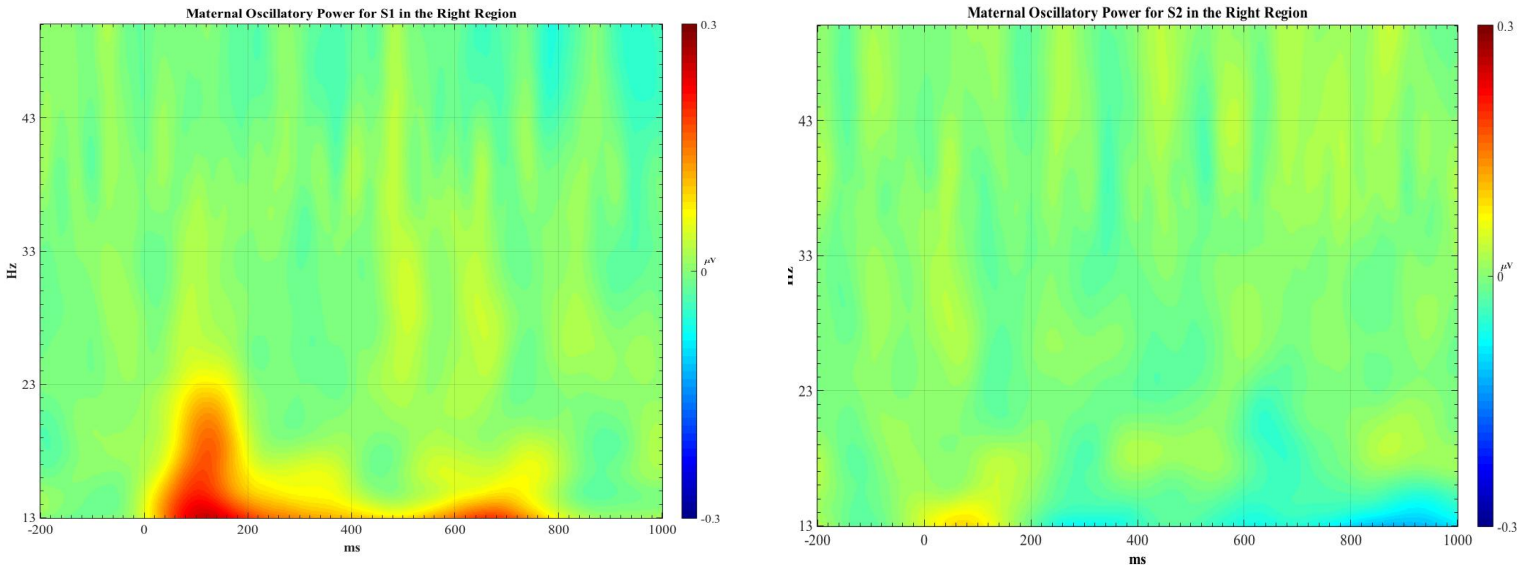


Figure 3.4. Topographical Plot of the *S1* and *S2* stimuli responses across the entire maternal cohort. Note how the power related to *S1* is greater in comparison to that of S2.

Z-scores were calculated for the Total sO-LIFE score, and the four sO-LIFE dimensions (Unusual Experiences, Cognitive Disorganisation, Introvertive Anhedonia, Impulsive Nonconformity) and underwent a correlational analysis with correction for multiple comparisons. Significant negative relationships were observed between the Maternal *S1* power in the right region and the sO-LIFE Total Score ($r=-.47$, $p=.01$), the Unusual Experiences ($r=-.46$, $p=.01$), and the Cognitive Disorganisation ($r=-.43$, $p=.01$) dimensions. These findings are indicative that the greater the sO-LIFE score, which is an indicator or schizotypy dimensionality, the lower the oscillatory power towards *S1*. This supports prior literature previously outlined. No significant correlations were observed for the Introvertive Anhedonia or Impulsive Nonconformity dimensions.

In addition, a significant negative correlation was also observed between the Maternal *S1* power in the right region and the Neuroticism score of the mothers as indexed by a shortened version of the EPQ-R personality questionnaire (Eysenck et al., 1985; $r=-$

.53, *p*=.01). This suggests that the larger the Neuroticism score, the lower the oscillatory power towards *S1*. This finding supports prior schizophrenia research suggesting that the emergence of neuroticism is greater among those who identify with schizotypic traits (Ettinger et al., 2005; Kerns and Watson, 2006).

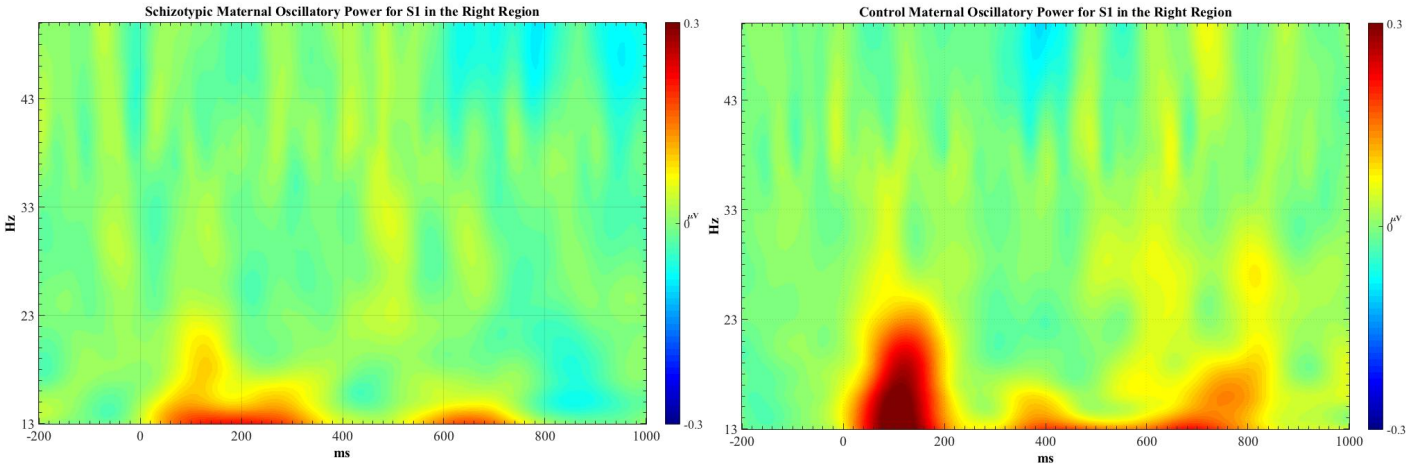


Figure 3.5. Topographical Plot of the *S1* stimuli of SZTm and CONm in the right region between 13-20Hz . Note how the CONm demonstrate greater oscillatory power when compared to their SZTm counterparts whom demonstrate a similar pattern of activation but to a lesser degree.

3.9 General Discussion

The present research, which aimed to observe whether schizotypic mothers demonstrate reduced evoked oscillatory activity during sensory gating, and whether these deficits are replicated in their 6-month-old offspring. Our results demonstrated how mothers with schizotypy displayed reduced activity towards *S1* between 13-20Hz, replicating previous literature (Johannesen et al., 2005; Brenner et al., 2009; Hall et al., 2011). In contrast, the infants of the previously reported mothers showed no significant differences between groups. This illustrated how having a mother with schizotypy did not influence the infants' oscillations in relation to sensory gating processing. These findings support our hypotheses stating whether these deficits are observed to a lesser degree in sub-clinical schizotypy, and whether the first-degree relatives of those on the spectrum display no difference in their event-related oscillation gating responses when compared to controls.

Psychiatric disorders, such as schizophrenia, may be thought of as a 'shift' in the continuous distributions of neurodevelopmental traits towards greater impairment, whilst maintaining an overlap with the population distribution (Hengartner and Lehmann, 2017). Establishing brain-behaviour links in both clinically significant behaviours and those of typical development is an important step in further understanding the continuities and discontinuities that exist between typical and pathological behaviour. Despite some literature finding low reliability (Luck et al., 2011), meta-analysis supports the relationship between P50 sensory gating and schizophrenia (Patterson et al., 2008) and the method for measuring P50 sensory gating in infants has been established (Kisley et al., 2003). The successful adaptation of tasks for use in early infancy therefore increases our understanding of the developmental timeline of these disorders and will perhaps allow for the development of novel prevention strategies.

Individuals diagnosed with schizophrenia and a significant proportion of their clinically unaffected relatives exhibit reduced P50 event-related potential suppression. P50 sensory gating is a passive psychophysiological measure and a putative adult schizophrenic endophenotype (Campanella and Guerat, 2009; Onitsuka et al, 2013), which suggests that the compromised ability of the brain to filter this irrelevant repeated information is associated with mental health difficulties. Despite the

differences in heritability of these deficits among first-degree relatives, the separation of the auditory P50 ERP into low-frequency response bands provides a broader assessment of auditory gating dysfunction (Johannesen et al., 2005), with beta band oscillations (13-30Hz) contributing to auditory P50 ERP responses, although the precise mechanisms involved remain to be determined.

Multiple electrode sites were analysed when contrasted to prior research, which used limited recording sites, or singular electrodes (for example, electrode CZ, Hong et al., 2008). This ability to select a number of electrodes for each regional analysis provides a broader and more thorough understanding of the neuro-oscillatory activity experienced during sensory gating in terms of the morphology of the effect over the surface of the scalp. There is growing research into schizotypy and its involvement in the schizophrenia-spectrum. Exploration into the oscillatory frequencies of first-degree relatives of those individuals on this spectrum, in the form of their 6-month-old offspring, is an integral step forward in the literature, which holds the necessary ingredients to bring a developmental psychopathology account to psychotic disorders. This is the first time this has been demonstrated, to our knowledge, and for this reason, the methodology was based on Park et al (2015) and Ross et al (2015).

A key strength of the present study includes the recruitment of only non-smoking mothers to eliminate any potential confounding effects of nicotine (Wan, Crawford, and Boutros, 2006). In addition, the total sO-LIFE score was used as a global measure of schizotypy dimensionality in the two groups. Capturing the typical-pathological continuum in the expression of schizotypal traits presents significant measurement challenges. The assessment tools chosen therefore needed to be sufficiently sensitive to register subtle variation across the whole continuum. The concept of schizotypy is a significant phenomenon in current psychiatry and the sO-LIFE is an important tool in this respect (Dembińska-Krajewska and Rybakowski, 2014).

A strength of the present research is the inclusion of correlational analyses between z-score sO-LIFE Total and dimension scores in comparison to the oscillatory power toward *S1*. This found that those mothers who scored greater on the sO-LIFE questionnaire, which is an indicator or schizotypy dimensionality, the lower their oscillatory power towards *S1*. This was not, however, also observed in their infants, which supports prior literature. The inclusion of this analysis aims to treat schizotypy

as a more continuous variable within the general population. Moreover, the participant cohorts' *Introvertive Anhedonia* dimension describes a lack of enjoyment from social sources of pleasure, as well as avoidance of intimacy, and is one of the four dimensions included in the sO-LIFE questionnaire. It can be seen to reflect a weakened form of the negative symptoms of the schizophrenia-spectrum, so-called negative-schizotypy. A small quantity of previous literature (Smucny et al., 2013) has found that reduced stimulus evoked beta oscillations in sensory gating was related to the negative symptoms of schizophrenia. However, the present work did not replicate this finding. More specifically, no correlation was found between the introvertive anhedonia score, as a reflection of negative schizotypy, and the beta range evoked power scores. The current study highlighted the complexity of recording electrical activity during sleep. During sleep, infants produce unpredictable movements, increasing quantities of artefacts, leading to a reduced number of infants being included in the final analysis when contrasted to the sample taking part in the study.

A limitation of the present study is the lack of previous literature looking at sensory gating related time-frequency oscillations with infants. This is the first time this has been demonstrated, to our knowledge. For this reason, there is little literature on which to base our predictions, or via which to have apriori topographical hypotheses; prior work used very few electrodes whereas we used a 128-electrode EEG cap. All topographical predictions and outcomes must therefore be made with caution.

Neural oscillatory activity in the beta range is thought to reflect the different aspects of early sensory information processing (Kopell et al., 2000; Traub et al., 1999; Basar-Eroglu et al., 1996), with hypotheses that beta oscillations may contribute to sensory gating (Hong et al., 2004a). The presence of normal gamma and beta gating in first-degree relatives (Hong et al., 2008) suggests that the underlying cognitive functions measured by the event-related oscillation gating responses may differ from those tapped by P50 suppression. Although, some neuro-oscillatory deficits have been observed in the first-degree relatives of individuals diagnosed with schizophrenia who present with personality disorder traits but who are not on antipsychotic medications (Hong et al., 2004a). The present research supports the notion that those individuals who display traits from the schizophrenia-spectrum also display differences in oscillatory function when contrasted with controls, however, the first-degree relatives of these individuals do not present the same deficit.

Prelude to Chapter 4

If cognitive abnormalities are observable at the sensory and pre-attentive level, then could these deficits also be observed in measures of higher cognitive function?

The preceding chapter demonstrated how mothers who identified as experiencing schizotypic traits displayed reduced beta- oscillatory power towards *stimulus 1* of the paired-tone paradigm between 13-20Hz. In contrast, the infants of the previously reported mothers showed no differences in their oscillatory activity between infants of schizotypic and those of control mothers. This suggests that having a mother with schizotypic traits does not influence the oscillatory activity of their 6-month-old infants in relation to sensory gating processing when measured via frequency oscillations.

On reflection, with the paired-tone paradigm utilised in the past two chapters, a natural comparison can be made between these two findings. When analysed as both ERP and ERO components this inhibitory deficit is observed in the maternal cohort, but not their infants. In the previous chapter I briefly discuss how these cohort inconsistencies may be the result of maternal personality not producing a robust enough effect to illustrate clear group differences among the infants and their mothers, despite correlational analyses suggesting an influence that may come into fruition in the future. We can see from the present data that 6-month-old infants are able to 'gate out' the repeated stimuli in the paired-tone paradigm; displaying an intact sensory gating ability, however, the presence of correlational results implying a correlational relationship between maternal schizotypy dimensions and the infants' sensory gating ability at 6-months suggests a potential emergence of individual differences, which is perhaps more complex than originally hypothesised.

It is perfectly acceptable to assume that this sensory gating deficit is just not shown in the 6-month-old offspring, but in order to make conclusions, replication, and further extensions would be necessary. For example, investigating the same paradigm in a longitudinal style; examining ERPs and EROs at different ages throughout infancy and childhood to see whether they develop a deficit later in life following exposure to more environmental situations.

In contrast to Chapter 2 and 3 and the pre-attentive inhibitory paradigms previously used, the research presented in Chapter 4 explores the question of whether these deficits could also be observed in the higher cognitive domains. The following chapter assesses this question: does maternal schizotypy influence the Nc, P600, and slow wave components in relation to facial expression perception in their 6-month-old offspring?

Parenting environments and parental psychopathology have been related to social information processing atypicalities and biases in young childhood (Aktar and Bögels, 2017). Atypical experience in the form of parental personality, or mental health, is presumed to expose infants to particularly frequent level of specific facial expressions in the course of their everyday interactions. Maternal emotional states and traits have been proposed to predict the social and emotional experiences that infants have in the course of interacting with their mothers (Belsky and Barends, 2002). For this reason, we felt that the following experiment was an inquisitive and natural step to address a more 'exposure-based' element of our neural development.

Chapter 4

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

Text under revision in Special Issue on Brain Imaging in Infant Behavior and Development.

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. Mothers (n=43) and their infants (n=51) 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, P600, and Slow Wave 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 demonstrated larger amplitudes overall in central-posterior regions. Infants of schizotypic mothers did not show a greater sensitivity to facial expressions at 6-months, but schizotypic mothers showed a general increased amplitude to both expressions. 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. Implications for personality development, maternal-infant interactions and cognitive neuroscience methodologies are discussed.

4.1 Introduction

Faces provide preverbal infants with an early source of communicative information (Nelson, 2001). We know that infants possess preferences for configurations that facilitate early attention to face stimuli (Morton and Johnson, 1991). This mechanism drives early preferences and aids in the formation of mother-infant relationships, which facilitates social-emotional development (Bowlby, 1969; Blass and Camp, 2003).

Morton and Johnson (1991) suggest that from 2-months of age an infant's interest in faces is driven by an experience-based system, which is dependent upon exposure. A mother's facial expressions are typically the first infant experience and the ones experienced in the greatest numbers (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 the experiences an infant has are also shaped by parental psychological health. Supporting this, differences in maternal psychological health have been found to affect infant face interest at 3.5-months (Jones, Slade, Pascalis, and Herbert, 2013) possibly due to a withdrawn and muted style of interacting with their infants, with 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 and Fullam, 2006; Sinzig, Morsch, and Lehmkuhl, 2008).

Individual differences in neural responses to emotional stimuli can contribute to a better understanding of developmental disorders in social-emotion processing (de Haan and Gunnar, 2009). These neural responses can be measured using an electroencephalogram (EEG), which is a method by which we can measure the spontaneous electrical activity of the brain. Scalp electrodes are used to detect variations in electrical activity, which are produced by neurons as electrical signals are transferred along the synapse (Teplan, 2002). An advantage of electroencephalographic reading is the completely non-invasive procedure, which can be applied repeatedly to patients, typical adults, and children with virtually no risk

(Teplan, 2002). A well explored technique for using EEG is to use the method of evoked event-related potentials (ERP), as in the present research. With this method the evoked neural responses to an event, in this case the facial stimuli, is measured and repeated. The neural response is thus measured for each trial and averaged, giving a more reliable electrical signature. The advantage of the ERP measure is that it can immediately time the event of activation of a particular brain region and is a more direct measure of stimulus-elicited brain activity. A major disadvantage of the EEG technique is the lack of spatial acuity represented by this method since the electrical activity is diffusely represented once the signal is received via the electrodes (Hoehl and Wahl, 2012).

EEG research with infants is not without its methodological issues. There are a number of inconsistencies experienced across the EEG literature, which make direct comparisons between research difficult if these details are not disclosed. These issues include the electrode montage, filtering mechanism, and the reference electrode used. Further from the lack of spatial acuity in the EEG technique, the variety of electrode montages used across the literature makes it difficult to directly compare the electrophysiological activity being observed. This is a difficulty experienced across the entire EEG literature with inconsistencies observed as a result of the mixture of low- and high-density electrode montages. In addition to these complexities, data editing and processing is required prior to the statistical analysis of EEG data. Issues in subjectivity are encountered throughout the visual editing process, with researchers displaying different perceptions of 'noisy' data and what should be excluded from the analysed data set. This is a highly subjective process, which is not outlined in the literature and will differ from study to study. This is an element of EEG processing that is difficult to compare between studies.

Although all filters distort time-domain data to some extent, filtering is beneficial by removing frequency components that are likely to be artefact thereby improving signal-to-noise in the data and thus statistical power (Kappenman and Luck, 2010). In other words, the benefits of filtering outweigh the costs when appropriate filter parameters are used, however, it is important to consider how some filter settings may lead to significant distortion of the ERP waveforms, thus resulting in misleading conclusions (Tanner, Morgan-Short, and Luck, 2015). In addition, the choice of reference electrode differs among the EEG literature, with difference paradigms

utilizing different reference electrodes, for example a mastoid or average reference, which can affect the overall outcome of the research (see Lei and Liao, 2017 for reference).

The use of 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 greater in response to fearful expressions than positive or neutral emotions (De Haan, Belsky, Reid, Volein, and Johnson, 2004; Leppänen, Moulson, Vogel-Farley, and 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).

There is a substantial amount of interest in the impact of early experiences on brain development in infancy (Belsky and de Haan, 2011). From this literature, everyday experience of interacting with 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). 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. Further, 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).

A substantial growth in interest has been observed surrounding impairments in identifying emotions from facial stimuli in the schizophrenia-spectrum (Kohler et al., 2010; Mendoza et al., 2011). 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 this finding observed 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). A greater sensitivity to negative emotions such as anger and fear have 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 are 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).

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). Moreover, deficits in facial emotion processing have been proposed as a potential endophenotype (Gur et al., 2007), given

that they are also observed in high-risk groups (Pinkham et al., 2007; Bediou et al., 2007; Addington et al., 2008).

Schizotypy refers to a multidimensional construct representing an underlying predisposition to schizophrenia-spectrum expressed across a broad range of personality, subclinical, and clinical phenomenology (Raine, 1991; Kwapil and Barrantes-Vidal, 2014). which is observed as a personality dimension in the general population (Evans et al., 2017). Recent neuroimaging studies (for example, Papousek et al., 2014; Jeong et al., 2017) have shown schizotypy has a mild level of emotional deficits compared to the schizophrenia-spectrum. For this reason it is plausible that similar deficits may be observed in schizotypy within the general population. Thus, a parent who presents with schizotypy traits may provide an altered developmental environment, potentially changing the social perceptions of that infant. Maternal emotional states and personality traits have already been shown to predict the social and emotional experiences that infants display (Belsky and Barends, 2002). This lack of stimulation, or over-exposure to particular expressions may therefore alter the developmental trajectory of the infant. Along these lines, de Haan et al (2004) selected maternal personality as an indirect marker for the infant's exposure to different patterns of parental care in light of the extensive evidence that personality influences parenting (Prinzie, Stams, Dekovic, Reigntjes, and Belsky, 2009).

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, schizotypy, expressed across a dynamic continuum of symptoms and traits (Kwapil and Barrantes-Vidal, 2012). The implicit assumption is that experiencing certain traits is not inevitably associated with the presence of a disorder, but can place these individuals at heightened risk for 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 (Roisko et al., 2015) and for that reason the study of young relatives at high-risk, such as the offspring of parents with a diagnosis, offer 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 for 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, P600, and slow wave components, 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. The P1 is reliably elicited in response to visual stimuli in individuals of all ages and has been shown to be influenced by manipulations of visual (Taylor et al., 1999) information including the encoding of face stimuli (Itier and Taylor, 2002). Moreover the present study also aims 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 it is observed further along the schizophrenia-spectrum.

4.2 Methods

Experiment 1: Infant Cohort

4.2.1 Participants.

101 infants, aged 6-months (*M*=5.80 months; *SD*=9.23 days; Range=5.42-6.60 months; 54 male) participated in the study. 51 infants 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), and thirty infants of control mothers (iCONm). Recruitment was carried out using the Lancaster University Department of infant and child development infant database. Ethical approval for this research was obtained and complied with Lancaster University Ethics Board Guidelines and the North West – Lancaster Research Ethics Committee for the NHS.

4.2.2 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 80-centimetres from the infant on the stimulus monitor. These were the same happy and fearful face stimuli as those used by de Haan et al. (2004).

4.2.3 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. An average was created

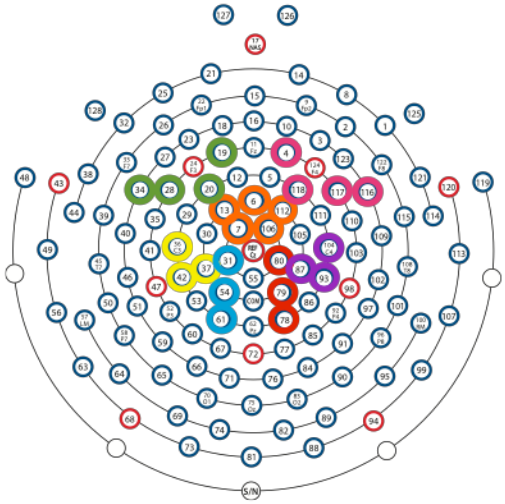
for each of the two emotions, with the two fearful faces combined into a single group, and the same for the happy faces. Participants required a minimum of 15 'good trials' (de Haan et al., 2004) for each face type to be included in further analysis. The average number of good trials was 26.37 (range =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).

4.2.4 EEG Analysis

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 4.1). The *mean amplitude* measure was computed for each facial expression within each region of interest.

Figure 4.1. 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).

4.2.5 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 = 8.09) and standard deviation for the entire population was calculated (total standard deviation = 5.99). The iSZTm group was determined by M+.5SD (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-.5SD (sO-LIFE Scores < 5.11). This criterium 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).

4.3 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 to eliminate 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.

4.4 Results

4.4.1 *Nc*

A full factorial 2 (group: iSZTm or iCONm) x2 (expression: happy or fear) x6 (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 illustrated how a significant difference could be observed between the facial expressions ($F(1,49)=4.72$, $p=.04$, $\eta^2=.08$), the regions of interest ($F(6,24)=21.84$, $p>.001$, $\eta^2=.85$). No significant mean amplitude differences were observed between the two groups when Bonferroni corrected ($p=.95$). A paired-samples t-test then demonstrated a significant difference between the fearful and happy expressions in the left-frontal ($t(50)=-2.31$, $p=.03$, $d=-.47$), left-central ($t(50)=-2.95$, $p=.01$, $d=-.59$), and left-posterior ($t(50)=-2.49$, $p=.02$, $d=-.50$), regions, as highlighted from the repeated-

measures ANOVA. See Figure 4.2. No further significant effects were observed. See Table 4.1 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 4.1. 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
Left-Central	Fearful Expression	-10.75	5.00
	Happy Expression	-8.28	5.71
Left-Frontal	Fearful Expression	-5.89	6.25
	Happy Expression	-4.14	5.94
Left-Posterior	Fearful Expression	-11.94	5.71
	Happy Expression	-9.77	5.31

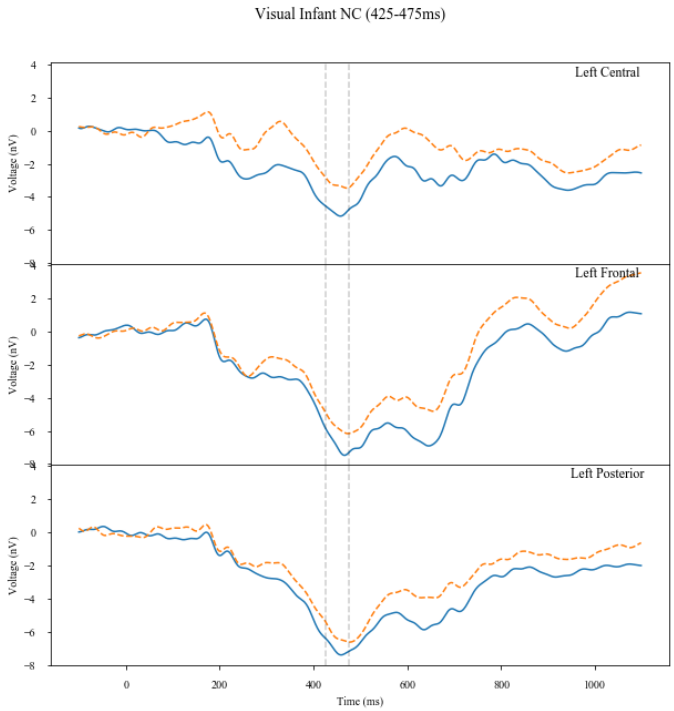


Figure 4.2. The *Nc* component in the left-central, -frontal, and –posterior regions across the infant cohort. Note how the fearful amplitudes are more negative than that of the happy expression. Legend – complete line=Fearful Expression, dotted line= Happy Expression

4.5 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. This data suggests that maternal schizotypy does not influence the infants' ability to differentially process these emotions at 6-months of age.

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.

4.6 Methods

4.6.1 Participants

Fifty-seven mothers of the previously tested 6-month-old infants (*M*=32.80 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 schizotypic mothers (SZTm) (*M*=32.70 years, *SD*=5.27 years) and the twenty control mothers (CONm; *M*=32.90 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*.

P1

A time window of 75-105ms after stimulus-onset was defined. The *P1* analysis focused on occipital-left, and occipital-right regions (Figure 4.4). The mean amplitude was computed for each facial expression within each electrode group.

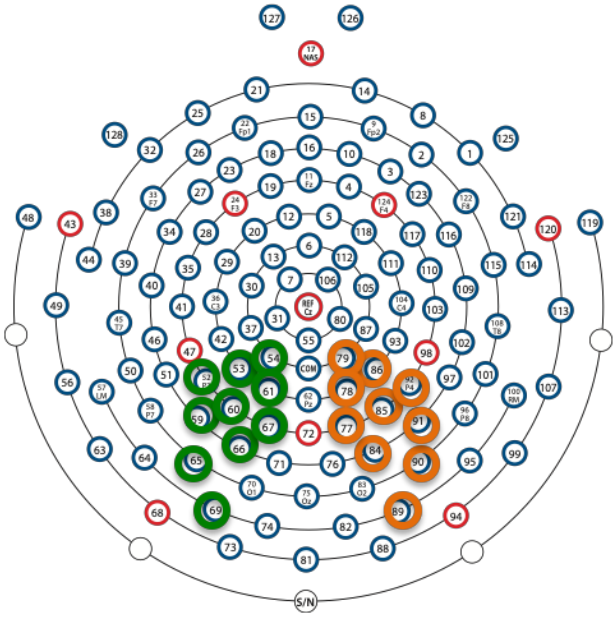


Figure 4.4. Adult Electrode Groupings. Occipital-Left (green; 52, 53, 54, 59, 60, 61, 65, 66, 67, 69) and Occipital-Right (orange; 77, 78, 79, 84, 85, 86, 89, 90, 91, 92).

P600

A time window of 590-650ms after stimulus-onset was defined and analysis focused on the occipital-left, and occipital-right regions (Figure 4.4). The mean amplitude was computed for each facial expression within each electrode group.

4.7 Procedure

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

4.8 Results

P1

A 2(group: SZTm or CONm) x2 (expression: fear or happy) x2 (electrode group: occipital-left or occipital-right) repeated-measures ANOVA illustrated a significant effect of expression in the occipital-left mean amplitude measure ($F(1,41)=5.91$, $p=.02$, $\eta^2=.13$), but no significant group difference was observed. Once Bonferroni corrected a significant difference can be observed between the expressions ($p=.01$), a trend towards significance in the groups ($p=.08$), and a significant difference between the regions of interest ($p=.04$). When exploring the descriptive statistics, it can be observed that the schizotypic mothers displayed larger amplitudes for both fearful ($M=2.28$; $SD=2.30$) and happy ($M=1.80$; $SD=2.29$) expressions when compared to the fearful ($M=1.01$; $SD=2.39$) and happy ($M=.83$; $SD=2.93$) expressions in the control mothers; although no significant between-group differences can be reported in the left-occipital region ($F(1,41)=2.60$, $p=.11$, $\eta^2=.06$). Exploration of the means and standard deviations suggest 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. No significant differences were observed in the occipital-right region, with a trend towards a within-subjects effect of expression ($F(1,41)=3.17$, $p=.08$, $\eta^2=.07$), and a trend towards a group-effect ($F(1,41)=2.86$, $p=.09$, $\eta^2=.07$).

A significant positive relationship was observed between the parents' neuroticism measure (SZTm $M=6.27$, $SD=2.79$; CONm $M=2.47$, $SD=2.99$) and the central-posterior mean amplitude measure for the fearful ($r=.42$, $p<.05$) and happy expression

(r=.39, p<.05) following correction for multiple comparisons. This suggests that greater neuroticism was observed in those displaying greater amplitudes across the facial expression stimuli.

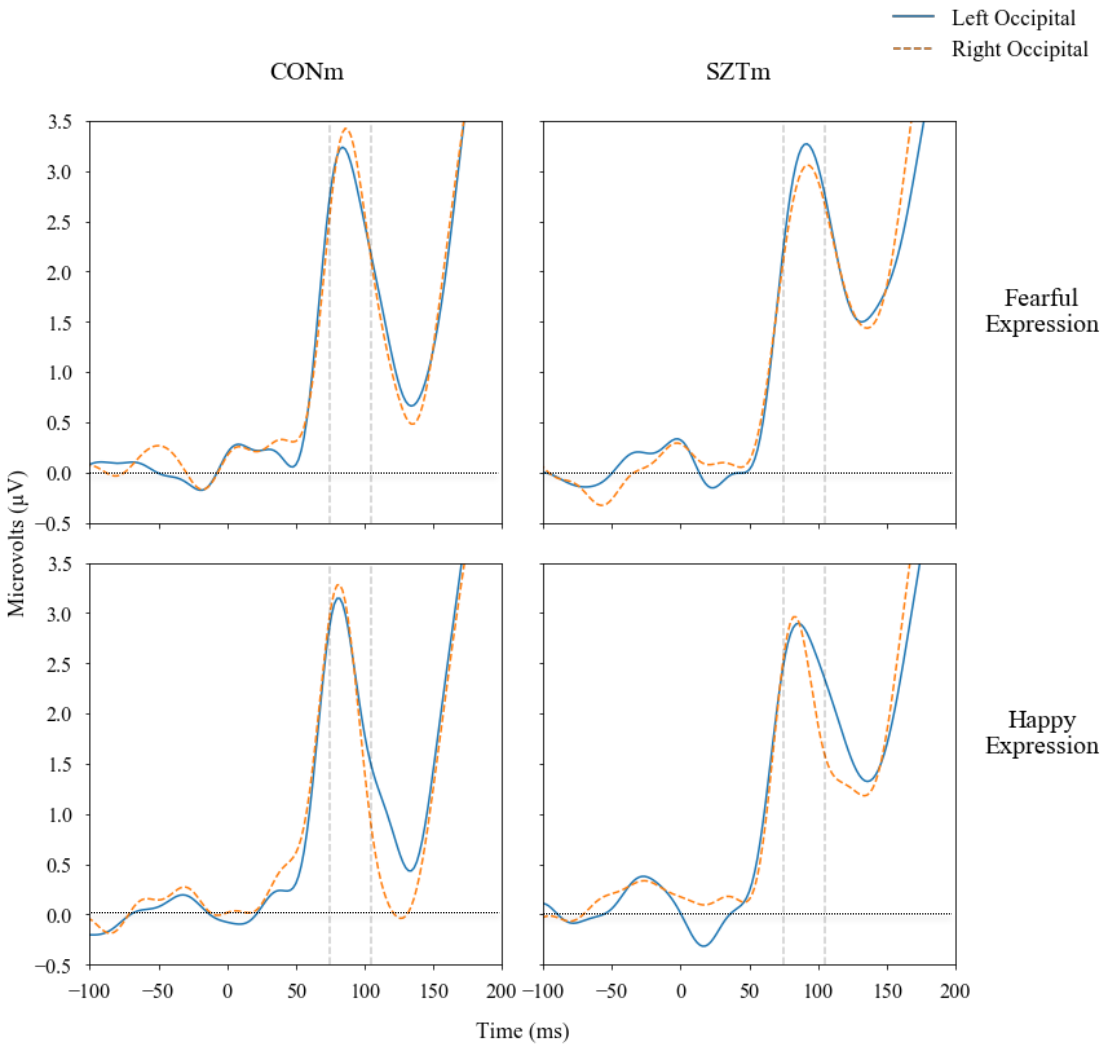


Figure 4.5. The Maternal *P1* event-related component. Despite no significant group differences reported, it is possible to note how the SZTm display larger amplitudes for both fearful (M=2.28; SD=2.30) and happy (M=1.80; SD=2.29) expressions when compared to the fearful (M=1.01; SD=2.39) and happy (M=.83; SD=2.93) expressions in the control mothers. Dotted line horizontally from 0μV represents baseline level.

P600

A 2 (groups: SZTm or CONm) x2 (expression: fear or happy) x2 (electrode group: occipital-left or occipital-right) repeated-measures ANOVA illustrated a strong trend

towards a significant effect of expression ($F(1,41)=3.97$, $p=.05$, $\eta^2=.09$) and a significant expression by group interaction ($F(1,41)=5.75$, $p=.02$, $\eta^2=.12$) in the left-occipital region. Once Bonferroni corrected a significant effect was observed for expression ($p=.01$), and an expression by group interaction ($p<.005$). A significant effect of expression was observed in the right-occipital region ($F(1,41)=9.30$, $p<.005$, $\eta^2=.18$), but no further significant effects were observed in this region. When exploring the descriptive statistics from the left-occipital region, it can be observed that the schizotypic mothers display a dulled amplitude for both fearful ($M=1.99$; $SD=1.38$) and happy ($M=2.08$; $SD=1.30$) expressions in comparison to the control mothers who exhibited a much larger amplitude towards the fearful ($M=2.52$; $SD=1.61$) compared to the happy ($M=1.60$; $SD=1.49$) expression. Thus, it is possible to suggest that schizotypic mothers display a dulled generalised sensitivity towards facial expressions compared to the typical *P600* response illustrated by the control mothers.

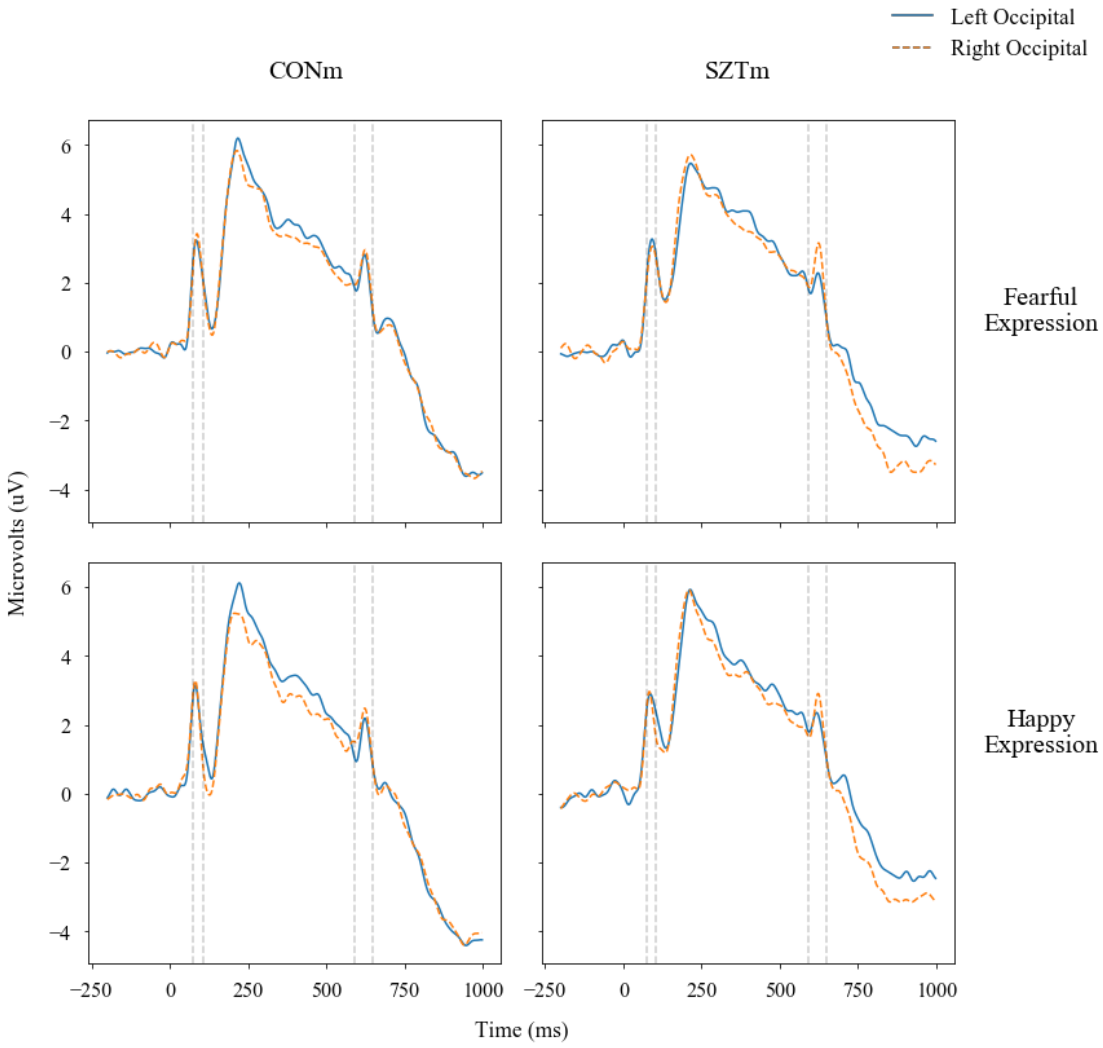


Figure 4.6. The Maternal ERP amplitudes. For the P600 ERP, note how in the left-occipital region (blue line) the SZTm illustrate similar amplitudes for both fearful (*M*=1.99; *SD*=1.38) and happy (*M*=2.08; *SD*=1.30) expressions, in comparison to the CONm who display a larger amplitude towards the fearful (*M*=2.52; *SD*=1.61) compared to the happy (*M*=1.60; *SD*=1.49) expression.

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 4.2. 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*)		*p*-values
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

4.9 Experiment 2: Discussion

The present research highlighted a generalized significant difference between facial expressions across the adult 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 dulled amplitudes towards both happy and fearful faces when 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 difference between mean amplitudes observed for fearful vs happy expressions were observed in the occipital-left region of interest, but no significant group differences were observed. Exploration of the means and standard deviations suggest 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. 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 allocation to different facial expressions as they are exposed to different facial expressions regularly.

P600

A strong trend was observed towards a significant difference between amplitudes observed for the facial expressions, with a significant expression by group interaction also observed. When exploring the descriptive statistics, schizotypic mothers displayed a dulled amplitude for both fearful and happy expressions in comparison to the control mothers who exhibited a much larger amplitude towards the fearful compared to the happy expression. Thus, it is possible to suggest that schizotypic mothers display a dulled generalised sensitivity towards facial expressions compared to the typical *P600* response illustrated by the control mothers.

4.10 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. 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 *P600* component which illustrated how schizotypic mothers displayed a dulled amplitude for both expressions in comparison to the control mothers who exhibited a much larger amplitude towards the fearful compared to the happy expression. Thus, it is possible to suggest that schizotypic mothers display a dulled generalised sensitivity towards facial expressions compared to the typical *P600* response illustrated by the control mothers, adding further controversy in the exploration of facial expressions among schizophrenia-spectrum traits/symptoms; do these individuals illustrate a greater sensitivity towards facial expressions or a generalized amplitude towards facial expressions, which could be exhibited in a dulled amplitude compared to controls?

A negative relationship was also observed between the mean amplitude measure of the fearful expression in the infant cohort and the introvertive anhedonia measure; denoting that a large sO-LIFE score, which is indicative of schizotypy, can be associated with reduced Nc amplitudes towards fearful expressions. This correlation highlights a potential relationship that supports the hypotheses that over-exposure to a specific parenting style over time may result in reduced attentional resources allocated to fearful faces when compared to happy faces. 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 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 dulled amplitudes towards fearful 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 dulled 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 correlational degree at 6-months, but they are only just emerging.

Prelude to Chapter 5

If we observe atypical facial expression perception among mothers with schizotypy traits, then how do these influence oscillatory frequencies during free-play interactions between mother-infant dyads?

The preceding work illustrates how 6-month-old infants are able to differentiate between happy and fearful expressions, with greater event-related amplitudes observed towards fearful expressions. Our results showed, however, that having a mother who experienced schizotypic traits did not influence this ability at 6 postnatal months. In contrast, the mothers who experienced schizotypic traits observed greater event-related amplitudes towards both facial expressions when compared to control mothers. We therefore concluded that maternal schizotypy does not influence this ability at 6-months of age, but a heightened sensitivity to facial expressions may be a trait observed continuously along this schizophrenia-spectrum.

By employing the stimuli used by de Haan et al. (2004), it was hypothesised that those infants of schizotypic mothers would display a preference for the happy expressions due to increased exposure to negative emotions, when compared to their control counterparts. This is supported by previous literature that highlights the processing of emotionality in faces as an aspect of cognition that is significantly impaired in those diagnosed with schizophrenia. In addition to impairments in emotion recognition, it has been proposed that parents with clinical diagnoses, such as depression or schizophrenia produce atypical emotional environments for their offspring, ultimately exposing infants to disproportionately high experiences of particular facial expressions (Eley et al., 2015; Nivard et al., 2015).

If atypical emotion perception is demonstrated through maternal ERP components, then could related oscillatory abnormalities also be observed during free-play interactions between mother-infant dyads? Event-related potentials are widely used with infant populations, but in order to further understand the functional neural activity while infants are engaged in social interactions it is important to measure this electrophysiological activity during social interactions, for example between mother-infant dyads. By furthering our understanding of how patterns of neural activation differ across social and non-social contexts, and how maternal personality has the

potential to alter these neural patterns, we can begin to disentangle the neural bases of social and non-social interactions.

During periods of free-play, interactions occur that may focus on the caregiver's ability to read the child's behaviour with reference to the likely internal states that govern the specific actions carried out. This is known as *mind-mindedness*. It has been proposed that in an atypical developmental environment, low mind-mindedness and maternal stimulation may be a factor accounting for the development of later psychopathology. For example, mothers with mood or anxiety disorders often display difficulties in responding appropriately to infant cues (Arteche et al., 2011). Negative interactions between mother-infant dyads as a result of these difficulties may ensue, subsequently perpetuating maternal depression and anxiety, impacting infant attachment and resulting in issues with infant behaviour, neurophysiology, and subsequent cognitive development (Cornish et al. 2005; Poobalan et al. 2007; Tronick and Beeghly 2011). Maternal mood and anxiety traits have been associated with mental health, as well as interpersonal difficulties later in life for the offspring (Turney 2011); suggesting an influence of deficient early maternal interactions on the offspring developing mental health deficits.

Little is known about the neural frequencies that occur during these periods of free-play; thus the following chapter will explore this area. We know that social interactions are an essential component involved in infant development, but the neural underpinnings of social engagement during infancy, however, are not fully understood. For that reason the following experiment aims to observe the oscillatory electrophysiological activity of 6-month-old infants during social, and non-social, interactions with their mother.

Chapter 5

Social vs. Non-Social: How do infants' oscillatory frequencies change during Free-Play Interactions.

Abstract

Social interactions are known to be an essential component of infant development. For this reason, exploring the functional neural activity while infants are engaged in social interactions will enable the better understanding of the infant *social brain*. By furthering this understanding, we can begin to disentangle the neural basis of social and non-social interaction in addition to the influence maternal engagement has on infant brain development. The current research aimed to observe the oscillatory electrophysiological activity of 6-month-old infants during free-play social and non-social interactions with their mother.

Previous literature proposes that maternal sensitivity serves as a model for socio-emotional development during infancy; this poses the question: do interactions between parents with mental disorders, or at risk for disorders, and their offspring differ in comparison to typical population interactions? The discourse used by mothers with predisposition to mental illness has previously indicated a more withdrawn engagement style and reduced amount of social interactions overall when contrasted with mothers with no mental health issues.

A 5-minute free-play session was recorded between infant-mother dyads with EEG recordings taken from the 6-month-old infant (n=65). During the recording, social and non-social behaviours were observed. Results suggested that the behavioural conditions *SPOK* and *PLAY* displayed a greater difference in oscillatory power between themselves and the baseline. More specifically, the oscillatory power exhibited by the infants was greater when their mother was talking to them (*SPOK*), or when they were playing with a toy independently (*PLAY*), than compared to the baseline measure where they were not exposed to any form of interaction. In contrast, in the same regions, dyadic and mind-minded interactions showed an equal difference between themselves and the baseline. Moreover, the oscillatory power exhibited by the infants during the *dyadic*, *mind-minded*, and *baseline* behavioural classifications

showed no significant differences. No significant differences were observed between infants of schizotypic, and infants of control mothers.

It was hypothesised that infants of schizotypic mothers may illustrate atypical oscillatory activity compared to control infants; this was not the case. Nonetheless, a significant difference was observed between the behaviours explored and the baseline activity. It is important to note that these results should be interpreted with caution due to imbalance in behavioural classifications, and the matter of characteristically noisy data collected from a free-play infant environment.

5.1 Introduction

Social interactions are known to be essential for infant development. It has already been observed that infants who experience social/environmental deprivation of some kind demonstrate neural, social, and emotional deficits (Marshall et al., 2008; Tarullo et al., 2011). The neural underpinnings of social engagement during infancy, however, are not well understood and for that reason the current research aimed to observe the functional oscillatory electrophysiological activity of 6-month-old infants during free-play, social and non-social, interactions with their mother.

Baseline measures of neural activity are widely used with infant populations, but less research has explored the functional neural activity while infants are engaged in free-play social interactions. In order to better understand the development of what is termed the *social brain* (Grossmann, 2015), it is important to measure the functional electrophysiological activity as infants interact socially. By furthering our understanding of how patterns of neural activation differ across various social and non-social contexts, we can begin to disentangle the neural bases of social and non-social interaction in addition to the influence maternal interactions may have on neural development.

The growing development of modern brain imaging techniques have enabled the literature to appreciate the remarkable plasticity of the developing brain, especially during the first years of life, which can be characterised by the over-production of synapses followed by a period of gradual pruning (Huttenlocher, 2002). Experience and exposure is considered to determine to a large degree which synaptic connections persist and are strengthened by frequent use, or selectively eliminated as a result of inactivity (Singer, 1995). In this context, there is a substantial window for environmental input to influence the developing brain (Kold et al., 2012), with observations proposing that early caregiving relationships should be centrally implicated in infant's/children's neural development (Nelson, 2000; Cicchetti, 2002; Belsky and de Haan, 2011).

It is agreed that one of the earliest, most intense and enduring experiences of both infanthood and childhood is the parent-infant caregiving relationship: a prime candidate to account for those individual differences in brain development driven by the environment. Decades of empirical research have provided overwhelming support

for the classic notion that early parent-infant relationships exert an exceptional influence on development; illustrated through longitudinal explorations from infancy to early adulthood (e.g., Fraley, Roisman, and Haltigan, 2013), meta-analytic reviews (e.g., Pallini et al., 2014), and experimental studies (e.g., Kochanska, Kim, Boldt, and Nordling, 2013; Guttentag et al., 2014).

Research employing environmental indicators such as stressful life events in the family (Luby et al., 2013), or maternal mental illness, depression (Ashman, Dawson, and Panagiotides, 2008; Diego, Jones, and Field, 2010; Lupien et al., 2011) for example, converge to suggest that such indices of familial risk predict non-optimal brain development during infant/childhood, whether considering structure or function (Bernier, Calkins, and Bell, 2016). More importantly, these authors argue that such environmental factors have the power to impact neural development because they are likely to influence the overall quality of parent-child interactions, which in turn are presumed to be the key factor influencing infant/child neural development.

Research into social-emotional development suggests that maternal sensitivity behaviours serve as a model for the child's emotional and social development (Mcelwain and Booth-LaForce, 2006). Thus, infants born to mothers with personality traits that may be classed as a predisposition to mental illness, such as schizotypy, not only inherit a genetic vulnerability that predisposes them, but they may also be exposed to socio-emotional environments marked by alterations in parents' emotional expressions (Eley et al., 2015; Nivard et al., 2015). Schizotypy can be defined as a multidimensional construct that represents the underlying vulnerability to schizophrenia-spectrum psychopathology, which is expressed across a broad range of personality, sub-clinical, and clinical phenomenology (Kwapil and Barrantes-Vidal, 2014). Despite the significant hereditary predisposition surrounding mental illness, children with parents who display predispositions to mental illness do not always develop mental health issues themselves (Aktar and Bogels, 2017).

Developmental models of parent-to-child transmission of mental illness, such as depression and anxiety (Goodman and Gotlib, 1999; Murray et al., 2009), propose that children's repeated exposure to parent's negative moods is a potential mechanism that contributes to risk for the development of psychopathology. For example, Schmid et al. (2011) provided longitudinal evidence that was indicative of less maternal

stimulation during mother-infant interactions at 3-months predicting a higher rate of depressive symptoms in the offspring at 19-years. The acknowledgement that poor infantile stimulation emerges later in childhood proposes a continuous influence of deficient early maternal interaction behaviour on the offspring's mental health (Aktar and Bogels, 2017). This poses the question as to whether interactions between parents with mental disorders, or at-risk for disorders, and their offspring differ in comparison to typical population interactions.

Leppänen and colleagues (Leppänen and Nelson, 2009; Leppänen, 2011) support the previously stated notion that infant exposure to parent's expressions of emotion during daily parent-child interactions plays an essential role in the neural fine-tuning of the infant emotional brain system in typical development. Given this specific importance of environmental exposure for the development of emotional brain systems, Leppänen predicted that the influence of atypical emotional environments provided by mothers with either a predisposition to mental illness, or mental health difficulties, in the early years would be 'especially detrimental' for later development of emotion processing abilities (Leppänen, 2011, p.185). This may be particularly useful to detect early effects of exposure and risk for psychopathology in preverbal infants. In triadic parent-infant-object interactions, which emerge at the second half of the first year, the parent and infant communicate affective states about external environmental conditions. The emotional expressions demonstrated by the parent during these interactions serve as a basis for infant expression and regulation of emotional and behavioural reactions to novelty.

A major point, which is crucial to make at this stage of the present research is the varying possibilities of influence a mother with atypical sub-clinical personality traits could have on their infant at 6-months of age. It is possible that with repeated exposure to flat or withdrawn interaction styles in maternal-infant engagements, this contributes to the transmission of a similar interaction style in the infant, constituting a risk for the potential development of similar traits in the future. Likewise, as mentioned previously, repeated exposure to fearful and anxious interaction styles in triadic parent-infant-object engagements may contribute to infants learning of fear and contribute to the risk for early intergenerational transmission of anxious reactivity patterns. In turn, enhanced attention to parents' negative emotions in infants of mothers who exhibit schizotypic traits, whether these are simply negative in nature or

more similar to symptoms of anxiety, mothers may be putting certain children at risk for later psychopathology.

Given the lack of research in the area of infant development, adult studies can help to inform which brain regions may be important during infant social interaction. Adult neural activation measured with EEG (Lachat et al., 2012) demonstrates the involvement of frontal (Redcay et al., 2012; Williams et al., 2005), temporal (Lachat et al., 2012; Redcay et al., 2012; Williams et al., 2005), and parietal (Lachat et al., 2012; Redcay et al., 2012) regions during joint attention. Frontal regions have been involved in orienting and shifts of attention (Petersen and Posner, 2012), suggesting that frontal activation may also be important for joint attention. Temporal regions are involved in facial processing, including the direction of another individual's gaze (Emery, 2000); indicating temporal regions could be involved in face-to-face social interaction in general and in joint attention specifically. Parietal regions are involved in orienting spatial attention and gaze following (Emery, 2000; Petersen and Posner, 2012); suggesting that parietal activation could be required for joint attention as opposed to other forms of social engagement. This prior literature does not compare joint attention with other aspects of social interaction, however this work suggests the likely involvement of frontal, temporal, and parietal regions in infant social engagement.

The current research aims to explore frequency oscillations involved in social and non-social interactions demonstrated by 6-month-old infants. Spontaneous electroencephalogram (EEG) can be decomposed into different frequency bands, which have been associated with different functional correlates. There is evidence that both the theta (≈4 to 6Hz) and alpha (≈6 to 9Hz) bands may be sensitive to aspects of the social brain in infancy. Theta rhythm is thought to support species-relevant behaviours (Orekhova et al., 2006), whereby in human infants greater theta power is observed during social interactions and exploratory activity (Jones et al., 2015). For example, theta power increases when 5-month-old infants look at a face with a neutral expression versus a smiling face during a period of interaction (Bazhenova et al., 2007), moreover greater theta power is observed in response to child-directed speech and toy play (Orekhova et al., 2006). It would therefore be hypothesised that greater theta activity would be observed during periods when the mother was speaking directly to the infant, or while the infant was playing with a toy.

Despite the importance of social interaction, to our knowledge this is the first study to observe EEG oscillations during free-play interactions between a mother-infant dyad. By comparing infant EEG power in non-social conditions with various social conditions such as hearing language, mind-minded language, and direct eye-contact dyadic interactions, it is possible to begin to elucidate the neural bases of social engagement during infancy. *Mind-mindedness (MM)* has been defined as: the caregiver's ability to read the child's behaviour with reference to the likely internal states that might be governing that specific action (Meins et al., 1998). Infant neural activation has be shown throughout the literature to be sensitive to environmental factors observed during the EEG recording paradigm, for example, maternal depression has already been linked to right frontal EEG asymmetry during infancy across different recording contexts (Lusby et al., 2014). This prior literature illustrates how infant EEG is sensitive to broader environment factors (i.e. maternal depression; Diego et al., 2006).

Diego et al (2006) further reported that infants of depressed mothers exhibiting a withdrawn interactive style at 6-months show greater right frontal asymmetry in EEG recordings at 3 to 6 months of age. Moreover, Hane and Fox (2006) assessed mother-infant home interactions when infants were aged 9-months, and found relations to infants' concurrent resting frontal EEG asymmetry when considering extreme groups of maternal behaviour: infants exposed to very low-quality maternal behaviour were more likely to show right frontal asymmetry. Conversely, in a subsequent study with the same sample, Hane et al (2010) found no significant association between the quality of 9-month maternal behaviour and subsequent resting frontal asymmetry at 3-years of age, when considering the whole distribution of maternal behaviour scores (an analysis not reported in Hane and Fox, 2006); however, relations were observed between 3-year frontal EEG asymmetry and the extremes of maternal behaviour, similar to that found when infants were aged 9 months. It is therefore unclear whether the 3-year results held above the previously documented associations at 9 months. Despite inconsistencies, these studies are noteworthy in that they provide rare evidence that direct and objective measures of the quality of parent-child relationships may, in some circumstances, relate to an important aspect of infant brain functioning.

Research previously outlined suggests that there are emerging differences in infant EEG power across various social contexts; however, the specific role of various environmental inputs, such as face-to-face interaction and language, still remains unclear. To our knowledge, no studies have directly compared EEG power during a free-play live session comparing social vs. non-social interactive elements. Making a comparison between EEG frequency power recorded during non-social vs. social interactions would help elucidate how infant brain oscillations vary during social engagement.

Parents with psychopathologies, whether these are diagnosable mental health disorders, or subclinical personality traits, not only transmit genetic information to their offspring, but they may also provide an altered developmental environment. The current research therefore aimed to address two main questions: 1) What neural oscillatory patterns are observed in 6-month-old infants during social vs. non-social interactions? 2) Do infants of mothers with schizotypy display altered neural frequencies when compared to controls?

5.2 Method

5.2.1 Participants

101 infants, aged 6-months-old (*M*=5.80 months; *SD*=9.23 days; Range=5.42-6.50 months) participated in the study. 65 infants (Male=37, Female=28) were included in the final analysis following data editing, with 6 excluded due to technical difficulties (*n*=6), the use of a foreign language during interactions (*n*=2), interactions with a second parent during the 5-minute session (*n*=4), less than 5-minutes of EEG recorded (*n*=5), no data collected due to infant fussiness (*n*=4), and infants who demonstrated particularly motion-artifact-filled data (*n*=15), for example blink, jaw and movement artifacts. Recruitment was carried out using the Lancaster University Department of infant and child development infant database. Ethical approval for this research was obtained and complied with Lancaster University's Ethics Board Guidelines and the North West – Lancaster Research Ethics Committee for the NHS.

5.2.2 Procedure

Prior to participation, the caregiver completed a questionnaire measuring their schizotypy dimensionality: the Oxford-Inventory of Feelings and Experiences- Short Form (sO-LIFE; Mason, Linney and Claridge, 2005). The EEG cap was soaked in a warm water, sodium chloride solution and baby shampoo before fitting to the infant's head. Once fitted and following confirmation that each electrode responded to electrical activity, the caregiver and infant were given a number of age-appropriate toys and were left to play freely for a 5-minute period. The caregiver was given the instruction to *'Please play with your baby as you would if you had some free-time together at home'*. During this time, they were both video and voice-recorded, and the infant's EEG activity recorded. Throughout the testing period the mother-infant dyad's status was video and voice-recorded to index social and non-social activity.

Prior to data analysis, the video recordings were time-coded for the content of each second of behavior. The behaviours coded for were divided into social and non-social components, with social behaviours including (a) a mind-related comment made by the parent (*MM*), (b) the mother speaking to the infant (*SPOK*), and (c) a dyadic interaction between the mother and the infant (*DYD*), defined as a clear eye-to-eye contact interaction. A non-social behaviour included, (a) the infant playing

independently with a toy (*PLAY*), with no presence of the mother or the mother's hands, or (b) the infant independently looking at objects in the room (*BASE*). The 5-minute audio and visual recording was taken during the testing period and transcribed into written form so observations could be made. The recordings were behaviorally coded second-by-second for the full 5-minute EEG recording. Each event type was identified using both the visual and auditory behaviours transcribed and observed. For example, the mother-infant dyads making direct eye-contact would have been transcribed as a *DYADIC* interaction, whereas the infant playing with a toy independently of their mother would have been identified as infant *PLAY*. 20% of video recordings were coded by a second independent coder to assess the inter-rater reliability, producing a mean Cohen Kappa of 0.67.

One of the social interactions examined was *mind-mindedness (MM)*: the caregiver's ability to read the child's behaviour with reference to the likely internal states that might be governing that specific action. This has been operationalized in terms of the caregiver's tendency to, (a), describe their infants with reference to mentality characteristics (Meins et al., 1998), (b) attribute meaning to infants' early utterances (Meins, 1998), or (c) to comment appropriately on their infant's internal states during play interactions (Meins et al., 2001). This notion has primarily been investigated as an interaction between caregivers and their infants, where it provides a measure of the caregiver's tendency to treat the infant as an individual with their own mind, rather than an entity with means that must be satisfied (Meins, 1997). It has been proposed that *MM* grew out of the notion of maternal sensitivity and social referencing within infancy and childhood. This reflects the importance of the mother responding in an appropriate manner to the child's cues. As such, interactional measures of *MM* are deemed as appropriate for assessing *MM* with infants in the first year of life, with longitudinal research displaying how early observational measures relate to later representational measures of *MM* (Meins et al., 2003).

5.2.3 Schizotypy Questionnaire

The Oxford-Inventory of Feelings and Experiences- Short Form (sO-LIFE; Mason, Linney and Claridge, 2005) assessed schizotypy dimensionality and divided the participant cohort into infants of schizotypic mothers (iSZTm) and infants of control mothers (iCONm). The mean across the population was calculated (total M=8.15, total

SD=6.26). The iSZTm condition was determined by the *M*+.5*SD* (sO-LIFE Scores>11.28) and included 19-participants and the iCONm condition by the *M*-.5*SD* (sO-LIFE Scores 5.02>0.0), included 31-participants. The remaining 15 participants were labeled as 'no group' as their sO-LIFE scores failed to identify with either of the iSZTm or iCONm.

The sO-LIFE was chosen as the present measure of schizotypy dimensionality due to its fully dimensional approach, proposing that symptoms occurring in the schizophrenia-spectrum also occur in the typical population as well, with the sO-LIFE questionnaire measuring such symptoms. The reliability of the sO-LIFE, estimated with ordinal alpha, was disclosed to be above 0.78 (Fonseca-Pedrero et al., 2014). The cronbach's alpha in the present cohort was .79, demonstrating the consistent reliability measure of the sO-LIFE. These levels of internal consistency are in line with the internal consistency values reported in previous studies; for example, previous work using ordinal alpha have found good reliability estimates (Lin et al., 2013). Moreover, the sO-LIFE scores showed good convergent and discriminant validity with the *Schizotypal Personality Questionnaire – brief revised* (Goulding, 2004; Mason, Claridge, and Clark, 1997; Burch, Helmsley, Corr, and Gwyer, 2006).

5.2.4 EEG Analysis

EEG data was recorded with 124 Ag–AgCl electrodes in a HydroCel Geodesic Sensor Net, referenced to Cz and arranged in the 10-20 layout, and an EGI GES 300 amplifier with an online 500Hz Butterworth software filter applied. Raw txt files were extracted from NetStation (*4.5.4)*; with data preparation conducted using Jupyter notebooks (*5.5.0*) running Python (*3.6.5*). The event codes were synchronized to the EEG data, with analysis only focusing on portions of the data coded for its content. MNE-Python (*0.16.1*; Gramfort et al., 2014) was firstly used to visualise the data to manually identify 'bad' channels, which produced drifts in the raw signal and high, variable decibel values across the frequency range in power spectral density plots. These channels were identified as 'bad' by manually observing large quantities of blink, jaw, or motion artifacts. One-second epochs of behaviourally coded EEG data were rejected if the root mean square of the EEG voltage exceeded 175μV in more than 20 channels (John et al., 2016*)*. In each participant, data associated with a behavioural code that had less than 3 occurrences were removed. These procedures lead to 9782

seconds (41.05%) of epoched data being coded as Artefactual and 84 seconds (0.35%) being removed due to being under the occurrence threshold. 5578 seconds (23.41%) were coded as *SPOK*, 3292 seconds (13.81%) as *PLAY*, 233 seconds (0.98%) as *MM*, 141 seconds (0.59%) as *DYADIC,* 129 seconds (0.54%) as *BASE*, and *4592* seconds were not given a behavioural code (19.62%).

Data was down-sampled to 125Hz to allow for a continuous wavelet transformation, using a Daubechies 4 (db4) wavelet family, to decompose the spectral components of the entire EEG signal into the frequency bands, described in Table 5.1. These bands were chosen to reflect typical frequencies of interest in EEG, with down sampling ensuring the lower bands had less boundary coefficients at the start and end of the signal. Wavelets decompose data on a multi-scale basis (frequency and time) by projecting multiple oscillatory kernel-based waves and enable frequency components to be analysed in respect to their scale (Kiymik et al., 2005; Sakkalis et al., 2008; Sakkalis, Zervakis, and Micheloyannis, 2006). Wavelets give accurate results with data containing discontinuities and sharp spikes (Kiymik et al., 2005) and can be used to analyse time series with non-stationary power at different frequency bands (Sakkalis et al., 2006). The db4 wavelet is specifically used to smooth the frequency, filtering enough to characterise EEG data well, but is also computationally efficient (Kjær et al., 2017; Subasi, 2007). The resulting detail coefficients from the wavelet transform were squared to give an estimate of the periodogram/spectrum.

A Tukey Fence (Tukey, 1977) threshold with parameter 1.5 was applied to the spectral data in each frequency band for each participant to remove outlier values resulting from artefacts (see Tukey, 1977 or Quitadamo et al., 2018, for example). The channels on the edges of the cap were most commonly rejected across participants for containing artefacts, so were removed from all participants. See Supplementary Figures 1-5 for topographical plots showing the influence channel removal had on the frequencies observed across the entire scalp. Remaining channels were assigned a hemispheric channel region depending on the location on the scalp; these being frontal, central, temporal, or parietal (See Figure 5.1). Attempts were made to ensure each group had a similar number of channels, whilst still reflecting the channel topography.

Table 5.1. Corresponding frequencies of different decomposition levels for the Daubechies 4 filter wavelet with a sampling frequency of 125Hz.

Decomposition level	Frequency Range (Hz)	Associated Frequency Band
D1	31.25 - 62.5	Gamma
D2	15.63 - 31.25	Beta
D3	7.81 - 15.63	Alpha
D4	3.91 - 7.81	Theta
A4	>3.91	Delta/DC

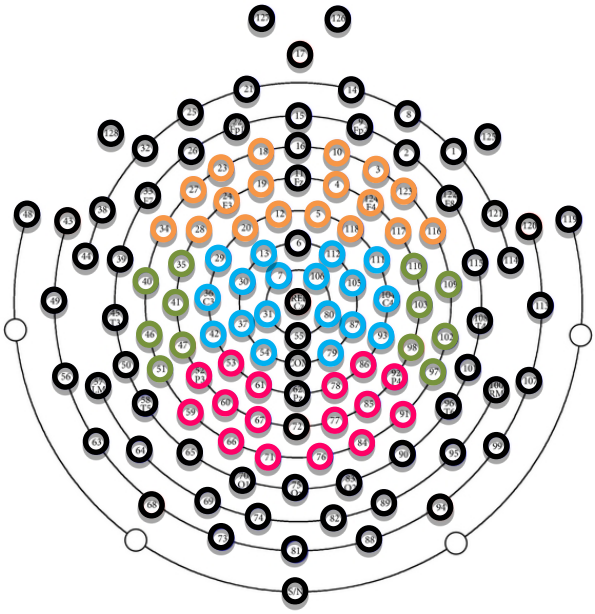


Figure 5.1. Channel locations used in the analysis.

Black: Excluded; Orange: Frontal; Blue: Central; Green: Temporal; Pink: Parietal

Linear Mixed Models (LMMs; Gałecki and Burzykowski, 2013) were used to model the mean spectral power for each epoch as a linear combination of fixed and random effects. A linear mixed model is a combination of a linear regression model with random effects. The linear model predicts the *i*th participants' power at electrode *j* using explanatory variables e.g., Frequency band. As we are combining information across participants, we would expect that different participants may have different baseline EEG. To account for this we introduce a 'random effect' term to give separate intercepts for each participant. This accounts for the inherent differences between individuals. A model just including Frequency as a covariate would be:

$$\text{Power}_{ij} = (b_0 + u_i) + b_1\text{Frequency}_{ij} + \varepsilon_{ij}$$

Here the component u_i is a participant specific component of the intercept, with $(b_0 + u_{0j})$ therefore the overall intercept for each person. We can thus condense the model to:

$$\text{Power}_{ij} = b_{0i} + b_1\text{Frequency}_{ij} + \varepsilon_{ij}$$

This model can be extended to include further explanatory variables. Indeed, we consider the following explanatory variables: frequency band, electrode location, behavioral event, schizotypy maternal group, and gender.

The order of the levels within a variable, as well as the type of variable, affects the outcome of a model. Frequency band was treated as a numeric variable with the Hz in the center of a band given to represent the Gamma (46.88Hz), Beta (23.44Hz), Alpha (11.72Hz) and Theta (5.86Hz) bands. As the frontal channels have previously been demonstrated to be involved in orienting and shifts of attention (Petersen and Posner, 2012), channels were ordered moving from the front to the back of the electrode array, with each group ordered left and right (see Table 3). Behavioral events were ordered first with *BASE*, as our baseline variable, with *SPOK* and *PLAY* following, as these represented the largest distinguishing groups, followed by *MM, DYADIC,* and *NONE.* Group was ordered iCONm, iSZTm and no group.

Different methods can be used to find the variables that contribute to the most statistically appropriate model. One method is to add fixed effects to a model sequentially and compare the models using measures such as Akaike information criterion (AIC; Akaike, 1974) or Bayesian information criterion (BIC; Schwarz, 1978). This process is repeated by sequentially adding interactions of the fixed effects that significantly improve the model fit. Another method is to use step-wise backward elimination of predictors from a model, removing predictors that do not significantly improve the model. One such method is outlined by Kuznetsova et al. (2017), where the fixed-effects structure is simplified by first creating an ANOVA table from a model, calculating *F* statistics and *p*-values for each fixed-effects term using Satterthwaite's approximation (Giesbrecht and Burns, 1985; Fai and Cornelius, 1996). Higher order interaction effects are then considered, and a model is constructed without the fixed effect with the highest *p*-value. This process is repeated until the highest *p*-value is below a specified significance level or there are no more fixed effects.

5.3 Results

All data analysis was conducted using R (*3.4.1*; Team, R. C., 2014), with lme4 (*1.1.18.1;* Bates, Mächler, Bolker, and Walker, 2014) and lmerTest (*3.0.1;* Kuznetsova, Brockhoff and Christensen, 2017) statistical packages. We first checked that a mixed effect model was required, by comparing a model with only the intercept and a model with only a random intercept. For our data, spectral power was shown to have significant variance in intercepts across participants, 2352, $p < .0001$; showing that accounting for participant variation is helpful in modelling the structure in the data. The most statistically appropriate model was found using the stepdown model building approach, as implemented in lmerTest. The first model included Frequency, Location, Event, Group, and Gender as fixed effect variables, with estimates of the parameter values estimated using maximum likelihood. The variable Group, $F(2) = 0.54$, $p = .058$, was first removed from the model, followed by Gender, $F(1) = 2.22$, $p = 0.14$. All other fixed effects were found to significantly improve the model. Model 2 added all two-way interactions between the previously significant fixed effects. As all two-way interactions were found to significantly improve the model, model 3 added a three-way interaction between the variables; finding this also significantly improved the model. The final model, was then fitted with Restricted Maximum Likelihood Estimation used to estimate variance components.

Table 5.2. Type III ANOVA on the Final Model

	F- value	Df	Pr(>F)
Frequency (Numeric)	8.89	1	< 0.01
Location (Factor)	10.85	7	< 0.01
Event (Factor)	8.26	5	< 0.01
Frequency* Location	5.65	7	< 0.01
Frequency* Event	5.40	5	< 0.01
Location* Event	3.17	35	< 0.01
Frequency* Location* Event	1.69	35	< 0.01

A Type III ANOVA was run on the final model to assess the contributions of the fixed-effects, as Type III allows for hypothesis testing on unbalanced datasets and does not depend on the order in which the effects are entered in the model. The significant interactions were further examined using Satterthwaites's method for calculating degrees-of-freedom and t-statistics (see Table 5.3 and Supplementary Table S 5.1 for the full model estimates and t-tests).

Table 5.3. Significant three-way interactions of the linear mixed model analysis fit with the restricted maximum likelihood (REML) approach. The variables in the final model are alongside their estimates and t-tests using Satterthwaite's method.

	Estimate	*t* value	Pr(>|t|)
Frequency*Right Parietal*SPOK	-0.0027	-2.1570	0.0310
Frequency*Left Parietal*PLAY	-0.0026	-2.0850	0.0371
Frequency*Right Parietal*PLAY	-0.0030	-2.3510	0.0187
Frequency*Left Parietal* NONE	-0.0025	-2.0300	0.0423
Frequency*Right Parietal*NONE	-0.0030	-2.4280	0.0152

Significant t-tests between the frequency bands in the Parietal regions (Right and Left) during *SPOK*, *PLAY*, and *NONE* behavioural conditions in comparison to the *Baseline* condition in the Left Frontal regions, indicated that as the frequency decreases from the Gamma to Alpha bands, the power during these events, also decreases significantly in comparison to the Left Frontal region during the baseline condition. Indeed Figure 5.2 and 5.3 demonstrate the differences between the *BASE* event and these variables, as they generally are predicted to have steeper regression slopes. The marginal effects shown in this figure, measure the expected change in a dependent variable as a function of changes in an explanatory variable, while keeping all other covariates constant.

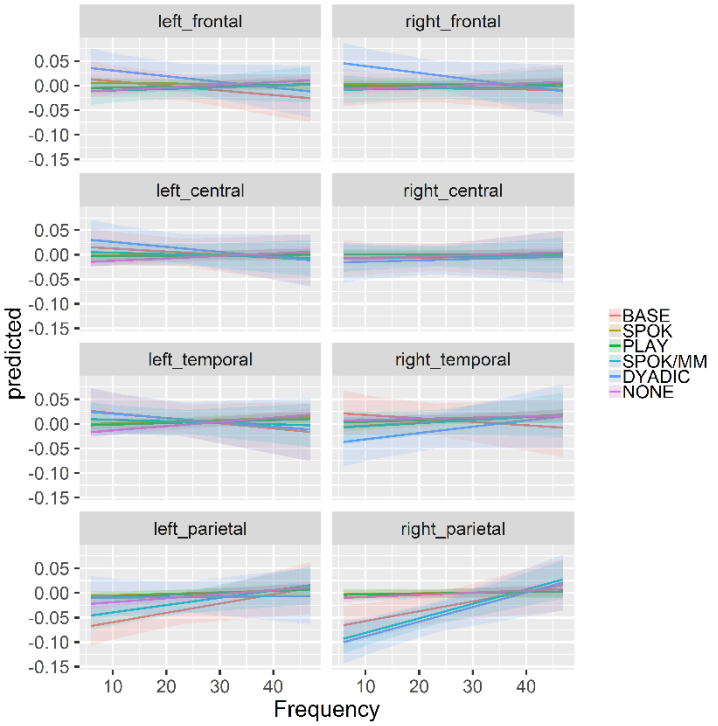


Figure 5.2. The differences between the *BASE* event and the behavioural variables.

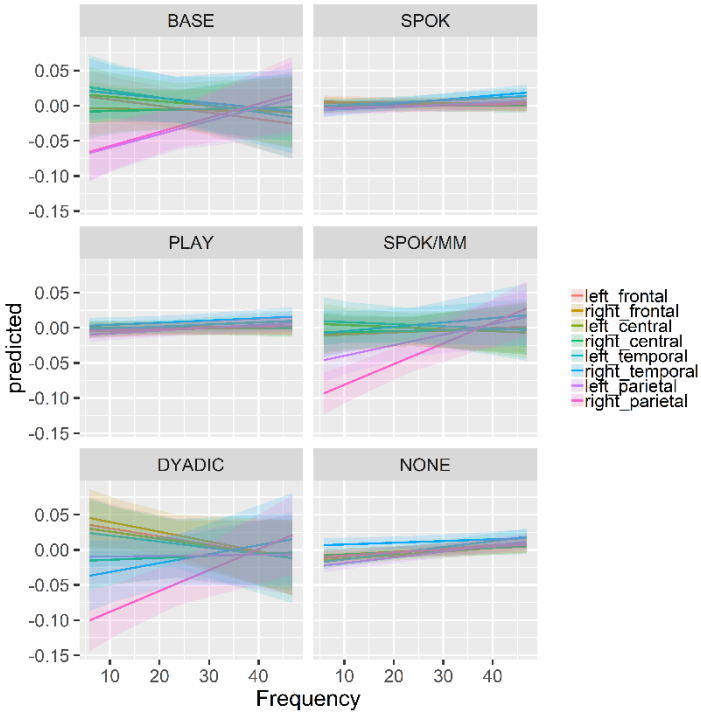


Figure 5.3. The differences between the *BASE* event and the behavioural variables.

See Figure 5.4 and 5.5 for a graphical representation of the distribution of the current dataset. This showed that following the removal of particularly noisy electrode channels; the distribution of the data was normal. See Supplementary Materials (Supplementary Figures S 5.1-5.5) for topographical plots showing the influence

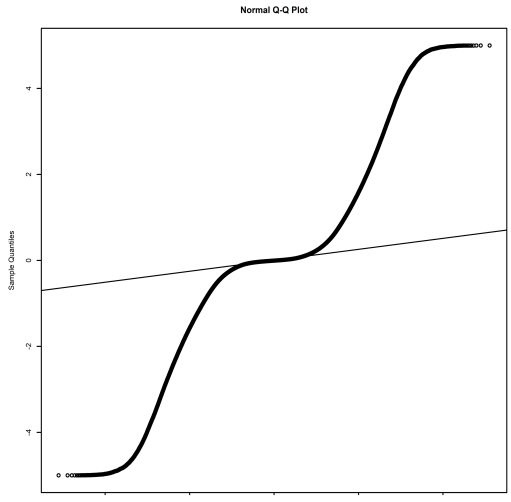


Figure 5.4. A Q-Qplot displaying the normative distribution of the current dataset.

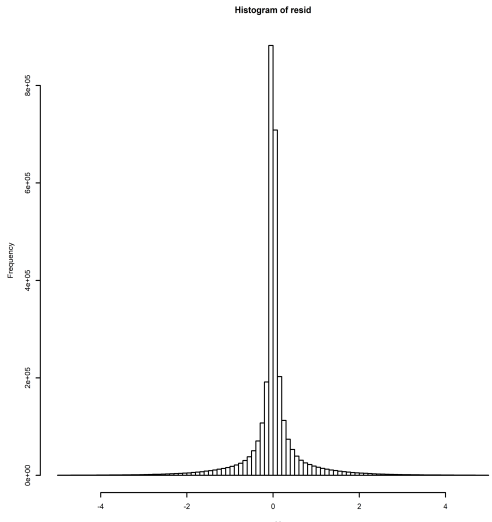


Figure 5.5. Histogram of Residuals When the model residuals are plotted limited to the range of -4 to 4, as seen here, they are relatively normally distributed.

channel removal has on the frequencies observed across the entire scalp.

In summary, the primary finding of the present research illustrated how in the right and left parietal regions, the behavioural conditions *SPOK* and *PLAY* display a greater predicted difference in oscillatory power between themselves and the baseline. In contrast, in the same regions, dyadic and mind-minded interactions showed an equal predicted difference between themselves and the baseline. This suggests that the oscillatory power exhibited by the infants was greater when their mother was talking to them (*SPOK*), or when they were playing with a toy independently (*PLAY*), than compared to the baseline measure (*BASE*) where they were not exposed to any form of interaction.

5.4 Discussion

The present research aimed to address two main questions: 1) What neural oscillatory patterns are observed in 6-month-old infants during social vs. non-social interactions? 2) Do infants of mothers with schizotypy display altered neural frequencies when compared to controls?

It was illustrated that frequency, electrode location, and coded behavioural events, all significantly predicted spectral power, with a significant three-way interaction observed between these factors. Significant t-tests between the frequency bands in the Left Frontal region during the baseline event with the frequency in the Parietal regions (Right and Left) during *spoken*, *play*, and *no event* conditions; indicating that as the frequency decreases from the gamma to alpha bands, power in these areas during the events decreases significantly comparative to the *baseline* in the left-frontal region. From Figure 3 it is possible to see that the greatest amount of oscillatory change occurs in the left and right parietal regions, as supported by these t-tests.

As shown in Figures 2 and 3, in the right and left parietal regions, the behavioural conditions *SPOK* and *PLAY* display a greater predicted difference in oscillatory power between themselves and the baseline (*BASE).* More specifically, the oscillatory power exhibited by the infants was greater when their mother was talking to them (*SPOK*), or when they were playing with a toy independently (*PLAY*), than compared to the baseline measure (*BASE*) where they were not exposed to any form of interaction. In addition, the *NONE* behavioural classification also showed, in the right and left parietal regions, a greater predicted difference in oscillatory power between itself and the baseline (*BASE*). This significance is likely due to the classification *NONE* including mother-infant-object triadic interactions, among other interactive behaviours, despite these not being a primary focus of the present research. In contrast, in the right and left parietal regions, dyadic (*DYADIC*) and mind-minded (*MM*) interactions showed an equal predicted difference between themselves and the baseline (*BASE*). Moreover, the oscillatory power exhibited by the infants during the *dyadic*, *mind-minded*, and *baseline* behavioural classifications showed no significant differences; however, this may be the result of analytical limitations outlined later in the discussion. No significant differences were observed between infants of schizotypic, and infants of control mothers.

To our knowledge, no research has directly compared EEG power during a free-play live session comparing social vs. non-social interactive elements. As a result of this, there are a series of limitations for the present study that could be eliminated through the repetition, and development, of a similar procedure. A series of artificial constraints were met, resulting from a relatively restricted *baseline* period to compare with the experimental conditions. The current paradigm was recorded live and as such the *baseline* period was identified when the infant sat independently with no interactions. This was experienced in the smallest quantity of seconds of all the coded behaviours; only being identified 0.54% of the time. For future research, ensuring an adequate baseline number of seconds would be crucial to balance the number of behavioural classifications and comparisons made.

The present study hypothesized that the iSZTm would exhibit atypical oscillatory activity compared to iCONm: this was not observed in the current participant sample. The literature has previously proposed that increased negative emotional expressions, or interactions, among anxious parents and those with a predisposition to mental illness in general, may not be perceptible during the first 6-months of life (Kaitz, 2010), but are exposed in the second half of the first year during triadic interactions. This is due, in part, to the atypical maternal affective states displayed towards environmental circumstances not being visible during the everyday mother-infant interactions (Kaitz, 2010), such as those analysed during the present research. In addition, it is recognized that the infant brain demonstrates remarkable plasticity, characterised by the over-production of synapses followed by a period of gradual pruning (Huttenlocher, 2002). Environmental exposure is considered a major factor in determining which synaptic connections persist, or are selectively eliminated, or pruned, as a result of frequent use or inactivity (Singer et al., 1995). There is therefore a substantial window for environmental factors to influence the developing brain (Kolb et al., 2012). It is however, possible that at 6-months maternal schizotypy does not influence our oscillatory power, but these results should be interpreted with caution, as there are a number of methodological issues that could account for both the significant and non-significant results stated. I will go on to detail these further.

Firstly, EEG data collected from infants in the first instance is noisy in nature, but during a live paradigm this increases the noisiness and limits, somewhat, the

techniques employed to reduce this noise. Multilevel models have assumptions alike to standard regression models. The variability of the data should be approximately equal to the deviation of the model's predicated values. In this case the model was predicting lower values than observed in the data, suggesting it is unable to account for larger values. The effects of these values can be seen in Figure 4, which suggests the model violates the assumption of normality. However, in general linear models are relatively robust against this violation (Winter, 2013) and, as can be seen in Figure 5, when the model residuals are plotted limited to the range of -4 to 4, they are relatively normally distributed. Using cooks' distance (Cook, 1979), we also found no influential participants who would change the results if their inclusion was altered, and the Variance Inflation Factor (VIF) was 1.000, suggesting that fixed effects were not collinear. This would cause an unstable interpretation of the significance of any correlated effects (Winter, 2013).

The difficulty in removing effects of noise from the data is, in part, due to a lack of standardised specifications in the literature. There are no current norms for a reasonable quantity of data required for this type of frequency analysis, or how many epochs would be viewed as reasonable. Infancy work in general encounters greater issues with noisy data when contrasted with adult EEG data. Adult data has had Independent Components Analysis applied to it for removing noise (see Pontifex et al., 2017 for a discussion on how ICA can affect EEG data), but it also alters the data when decomposing it into a smaller subspace, for which, again the number of components required to carry out this process is lacking reasonable guidelines. For future research, clustering methods, such as Icasso (Himberg and Hyvarinen, 2003) may provide more guidance for dimensionality reduction in neuroimaging research techniques.

There was no significant benefit from including the Schizotypic grouping into the model as no significant differences could be observed between the iSZTm and iCONm. This could be due to outliers and general noise skewing the final results, or it is entirely possible that schizotypy is too sensitive a measure to be detected and to have influence on the oscillatory activity of infants at 6-months of age. Perhaps further along these infants' developmental trajectories an altered oscillatory behaviour could be observed, however, future research should employ parallel EEG recording from the

infant-mother dyad in order to make a direct comparison during interactions to determine whether this would display similar activity between the dyads and be a more sensitive measure of individual differences. Despite the lack of significant group effects, the use of the O-LIFE score to divide the groups captures the typical-pathological continuum in the expression of schizotypal traits, which presents significant measurement challenges. The assessment tools chosen therefore needed to be sufficiently sensitive to register subtle variation across the whole continuum to avoid floor/ceiling effects.

The behavioural conditions explored, as they were coded following the testing session, were variable in number and no control could be given over the quantity of each behavioural classification for each child. As such, a major imbalance was observed between behavioural classifications. This is something that could skew the results and potentially create interactions; for this reason, Chapter 5 should be interpreted as a novel piece of research, which provides a good basis for future free-play research, but requires further progression and replication in its methodology. An imbalance was observed between the behavioural classifications: 23.41% were coded as *SPOK*, 13.81% as *PLAY*, 0.98% as *MM*, 0.59% as *DYADIC*, and 0.54% as *BASE.* This is a major limitation to the present research and for future development would require bootstrapping and resampling to try to balance out these classifications more equally. Perhaps upon replication of the current paradigm, the free-play recording could also be lengthened. Rather than 5-minutes long, 10- or 15-minutes would allow for a greater number of behaviours to be coded in general; which could allow for the repeated bootstrapping of random subsamples of the data to balance out class distribution, whilst still allowing a suitable sample size to endure. Furthermore, the results of the present research should be interpreted very carefully, and provide indication for future research rather than a clear-cut finding in itself.

A strength of the present study, and a strength that should be carried forward in the methodology is the use of multiple electrode channel groupings, which contrasts the most similar methodological research (interpersonal neural synchronisation; for example, Leong et al., 2017) who predominantly focus on two EEG channels in central locations (for example, C3 and C4 in Leong et al., 2017), whereby it is difficult to make inferences about the potential neural sources of effects. Although the present research should be interpreted with caution, from a methodological standpoint,

the use of electrode channel grouping that are relatively balanced in number on both the left and right hemispheres forms a good base from which future free play paradigms can be developed.

The present research aimed to observe the oscillatory activity of 6-month-old infants during free-play social and non-social interactions with their mother. The primary findings indicated that as oscillatory frequency decreases, from the gamma to alpha bands, power in these areas during the *spoken and play* events decreases significantly comparative to the *baseline* in the left-frontal region. Previous literature drove a secondary hypothesis asking whether interactions between parents with mental disorders, or at risk for disorders, and their offspring differ in comparison to typical population interactions. In the current study, this was not the case for the reasons outlined previously. An important element of the current study to consider is the methodological nuance illustrated and the analytical exploration taken forward. A number of limitations have been highlighted, but it should be observed that these limitations have been outlined in order for replication and future free-play paradigms to have an analytical starting point to further develop.

Chapter 6 – General Discussion

Interest in the connection of mental disorders, such as schizophrenia, to elements of personality are predicated on the notion that features recognizable as 'psychotic' can be observed in many people who do not, and will never, meet the clinical criteria for psychosis of any kind. The present thesis finds its basis in theories of healthy, typical individual differences and their application to the future understanding of mental illness. In this Chapter, I recap the main findings of the four experiments outlined already and discuss how they contribute to our current understanding, and explore the implications that they have on the main emerging theoretical issues surrounding the schizotypy literature.

6.1 Summary of the Findings

This thesis presents four empirical studies that encompass the umbrella hypothesis that deficits observed among the clinical portion of the schizophrenia-spectrum may be present to some extent in those who identify with sub-clinical schizotypy, and in their 6-month-old offspring; similarly to the way in which the first-degree relatives of those with schizophrenia also display neurological deficits.

In the study described in Chapter 2, I investigated whether measurable changes in sensory gating function in the offspring of mothers with schizotypic traits could be detected in comparison to their control counterparts. Specifically we hypothesised that mothers with schizotypic traits, and their 6-month-old offspring would display smaller differences and larger ratios in the P50 event-related potential component. In a paired-tone paradigm, participants were exposed to paired auditory tones, which were played every 10-seconds for approximately 15-minutes while the infants slept and while the mothers rested in a darkened room. Electroencephalography was measured throughout with event-related amplitudes measured specifically for *stimulus 1 (S1)* and *stimulus 2 (S2)* of the paired-tone paradigm. Data revealed that although the 6-month-old infants' P50 components displayed significant differences between *S1* and *S2*, there was no clear difference between infants of schizotypic and infants of control mothers. The significant correlational relationships observed between the infants' event-related differences/ suppression ratio measures and the maternal schizotypy measure (sO-LIFE), however, suggested a potential emergence of individual differences;

illustrating how a greater maternal schizotypy score was associated with a smaller amplitude difference or a larger suppression ratio. In contrast, the mothers displayed significant differences between *S1* and *S2*, as observed in the infants, but also significant differences between their sensory gating ability as a result of their schizotypy dimensionality. This suggests that experiencing schizotypic traits, as characterised through the sO-LIFE, also influences sensory gating ability; whereby a smaller difference or larger suppression ratio is observed between *S1* and *S2.* This supports prior literature (for example, Wan et al., 2017); whereby individuals who exhibit schizotypic traits also illustrate a reduced ability to inhibit, or 'gate out', the second tone in a paired-tone paradigm.

Research across the literature claims that the electrophysiological P50 response to paired auditory stimuli is a pre-attenive, automatic process, which is therefore unaffected by attentional manipulations (for example, Boutros et al., 2004; Braff and Light, 2004). Other research, however, has proposed that components as early as the P50, either the gating ratio/ differences or amplitudes, could be influenced by altering the capacity for sustained attention, or by directing attention towards the stimuli (Rosburg et al., 2009; Yee et al., 2010; Gjini et al., 2011). These potential effects of attention may reflect top-down processing of sensory stimuli working simultaneously with bottom-up processes (Posner, 2004). Support for these top-down processing hypotheses come from research utilising patients and animals with pre-frontal cortex lesions; demonstrating that pre-frontal cortex damage impairs the ability to inhibit sensory information, specifically the ability to attend to relevant over irrelevant stimuli (Knight et al., 1989; Rosenkranz and Grace, 2001). Furthermore, support for this top-down theoretical mechansism for P50 sensory gating has emerged from ERP studies which have found significant relationships between measures of frontal lobe dysfunction and sensory gating (Boutros et al., 2009), and P50 generators within the frontal lobes (Mears et al., 2006; Korzyukov et al., 2007; Liu et al., 2011). Moreover, Jones et al. (2016) report a significant relationship between sensory gating, latent inhibition, and the continuous performance task (CPT; Nestor et al., 1990), which directly measures sustained attention. They therefore concluded that sensory gating was associated with specific aspects of attentional control, underpinned by both top-down and bottom-up processes occuring at the initial encoding stage of stimulus processing. Additionally, sensory gating enables resistance to interference as well as

early cognitive inhibition at the encoding stage compared to other inhibition tasks that arguably involve more cognitive and behavioural inhibition at the output/response stage. The present research illustrates a consistent pattern of sensory gating deficit among mothers experiencing schizotypic traits, presented through a smaller amplitude difference between stimulus 1 and stimulus 2 or larger suppression ratios, as expressed in Chapter 2. The extent to which, and the influence of sensory gating deficits alter our day-to-day functioning is not fully understood, but it is worth asking whether it is possible that these individuals experience a 'less inhibited' social experience; whether this be a difficulty in filtering out noise, or a more specific function of inhibition. The precise theoretical cognitive mechanism associated with sensory gating in everyday functioning is something worth exploring further as the paired-tone paradigm and sensory gating deficits are a well-utilised paradigm and well-known endophenotype of the schizophrenia-spectrum, but we do not understand the extent to which this deficit may alter our day to day experience.

In the study presented in Chapter 3, I examined whether evoked beta-oscillatory activity is reduced during sensory gating among mothers who identify with schizotypic traits, and whether these deficits are also manifested among their 6-month-old offspring, or whether no oscillatory difference is observed between the infant cohorts. An identical paired-tone paradigm to the one outlined previously was utilised with electroencephalography measured once again but analyses focused on the event-related oscillations associated with the paired-tones: more specifically beta- (10-20Hz) and gamma-frequencies (30-50Hz). This is a novel approach to exploring the sensory gating paradigm. Although it is typically an event-related potential paradigm, here I also explore other aspects of psychophysiology. The data demonstrated how mothers who identified as experiencing schizotypic traits displayed reduced oscillatory power towards *S1* of the paired-tone paradigm between 13-20Hz in the beta frequency band; supporting prior literature (for example, Hong et al., 2008; Brenner et al., 2009). In contrast, the infants of the previously reported mothers showed no differences in their oscillatory activity between infants of schizotypic and infants of control mothers. This suggests that having a mother with schizotypic traits does not influence the oscillatory activity of their 6-month-old infants in relation to sensory gating processing. This may simply be due to possibility that 6-months of age may be too early to detect these effects during development.

In the experiment described in Chapter 4, I investigated whether infants of schizotypic mothers, and the schizotypic mothers themselves, would display greater event-related amplitudes to facial expressions in general, when compared to controls. 6-month-old infants and their mothers were shown a series of happy and fearful facial expressions while their event-related potentials were examined for each facial expression. The data revealed that the 6-month-old infant population were able to differentiate between happy and fearful expressions, with greater amplitudes observed towards the fearful expression in general; previously shown by de Haan et al (2004). Maternal schizotypy, however, was found not to influence this ability at 6-months. In contrast, schizotypic mothers when compared to the control mothers observed greater amplitudes towards both facial expressions. It was therefore reasonable to assume that maternal schizotypy does not influence this ability at 6-months of age.

In the study described in Chapter 5, we addressed two main questions: 1) what neural oscillatory patterns are observed in 6-month-old infants during social vs. non-social interactions, and 2) do infants of mothers with schizotypy display altered neural frequencies when compared to controls? During the experiment the infant had their neural activity measured while the mother was given the instruction to *'Please play with your baby as you would if you had some free-time together at home'*. A 5-minute free-play session was recorded between infant-mother dyads with EEG recordings taken from the 6-month-old infant. During the recording, social and non-social behaviours were observed. The results demonstrated that frequency, electrode location, and the coded behavioural event (social vs. non-social) all significantly predicted spectral power, with a significant three-way interaction observed between these factors. Frequency bands in the Parietal regions (Right and Left) during *SPOK*, *PLAY*, and *NONE* behavioural conditions in comparison to the *Baseline* condition in the Left Frontal region, indicated that as the frequency decreases from the Gamma to Alpha bands, the oscillatory power during these events also decreases significantly in comparison to the Left Frontal region during the baseline condition. In summary, the primary finding of Chapter 5 illustrated how in the right and left parietal regions, the behavioural conditions *SPOK* and *PLAY* display a greater predicted difference in oscillatory power between themselves and the baseline. In contrast, in the same regions, dyadic and mind-minded interactions showed an equal predicted difference between themselves and the baseline. This suggests that the oscillatory power

exhibited by the infants was greater when their mother was talking to them (*SPOK*), or when they were playing with a toy independently (*PLAY*), than compared to the baseline measure (*BASE*) where they were not exposed to any form of interaction. No significant differences were observed between infants of schizotypic, and infants of control mothers. It is important to note that these results should be interpreted with caution due to imbalance in the behavioural classifications and due to the amount of noise in the data, given that this was recorded in a free play environment. For this reason, there is a chance that the presented results are due to noise and this imbalance, however, for future free-play live paradigms this paper provides a good basis for methodological and paradigm design for free-play paradigm analysis.

To summarise these findings, throughout Chapter 2, 3, and 4, the findings were consistent in their illustrations of how mothers who demonstrated schizotypic traits displayed similar deficits to those demonstrated by individuals on the schizophrenia-spectrum. This consistency among the maternal participant group suggests that sub-clinical schizotypy has the potential to be linked to the schizophrenia-spectrum somewhat but the extent to which we currently understand this relationship will be discussed below. The infants' results were equally consistent, with the infants presenting significant differences in their electrophysiological activity between stimuli (*S1* vs. *S2*, or Fearful vs. Happy, for example) although no significant group differences were observed as a result of their mothers' schizotypy dimensionality. No significant group difference was observed in Chapter 5 between the infants of schizotypic mothers (iSZTm) and infants of control mothers (iCONm), although the imbalance among the behavioural classifications may be a reason for this, alongside the noisiness of the data. It is, once again, reasonable to assume that at 6-months postnatal such sensitive differences in electrophysiological activity are not yet discernable. So what can we take from this? An important element to first consider is: Where do these findings stand in terms of the fully-/quasi-dimensional approaches (Rado, 1953; Claridge and Beech, 1995) outlined earlier?

The two perspectives regarding how sub-clinical personality could possibly be linked to clinical symptomatology labelled *quasi-dimensional* and *fully dimensional (*Rado, 1953; Claridge and Beech, 1995, offer different evaluations of the literature. The former perspective, which assumes psychotic features, when observed in the general population in the absence of overt mental illness, nevertheless represents an attenuated

form of clinical symptomatology. It can therefore be assumed that 'dimensionality' in that model refers to continuity only in the sense of an attenuated manifestation of mental illness. In contrast, the *fully dimensional* perspective assumes that as with other traits (for example, trait anxiety and anxiety disorder are a case in point; Claridge, 2015, pp.224), characteristics of psychosis form a part of our typical personality structure, and similarly double-up as a predisposition to mental illness. To consider my previous question again: do these findings present themselves as being simply linked to the spectrum in the deficits observed, or is it possible they are a precursor to mental illness?

The results of the paired-tone paradigm imply that sensory gating is a pre-attentive, stable ability that can be measured across the lifespan, the deficit of which has already been proposed as an endophenotype for schizophrenia (Waldo et al., 2000; Freedman et al., 2002). In Chapter 2 and Chapter 3, the mothers illustrated the expected deficit, which supports the fully dimensional perspective in that sensory gating is clearly part of our typical personality structure, but the literature has also shown the stability of the deficit throughout the spectrum. The infants, who were exposed to the paired-tone paradigm, although they showed the ability to 'gate out' the repeated stimuli, were not influenced by their mother's schizotypy dimensionality. The facial expression paradigm outlined in Chapter 4 also illustrated no significant difference between the infants of schizotypic or control mothers; this is consistent with the view that neither group experienced an atypical balance of exposure to positive and negative facial expressions during the first 6-months of life in order to alter their attentional mechanisms towards novel stimuli. It is important to state that correlational analyses in both Chapter 2 and Chapter 4 illustrated significant relationships between the infants' event-related potentials and the maternal schizotypy measure (sO-LIFE), which is suggestive of a potential emergence of individual differences; illustrating how a greater maternal schizotypy score was associated with a sensory gating deficit. Conversely, these individual differences are not clearly observed in the 6-month-old infants, but may be manifested later in development. Current infant literature investigating the influence of schizotypy is sparse; preventing the extent to which we can state that schizotypy could be considered as a precursor to mental illness, but it is undeniable that there are parallels running between the clinical and sub-clinical elements of this schizophrenia-spectrum.

Across several studies this work has found a consistent pattern that maternal schizotypy did not influence these abilities at 6-months. I will systematically outline suggestions as to why this may have been the case, although it is perfectly acceptable to assume that these deficits are just not present at 6 postnatal months of age. In reference to both Chapter 2 and 3 it is possible that maternal personality impacts the development of sensory gating, but this influence is not robust enough to illustrate clear group differences at 6-months-old. Moreover, the ERP and ERO analyses utilised in these sensory gating paradigms may be hindered by the neuronal development of the 6-month-old infant. At 6-months-old we have a quantity of neuronal and synaptic connections that are much greater than those we possess during adulthood, which we then prune throughout development to gain maximum efficiency (Singer et al., 1995; Huttenlocher, 2002). Thus, with increased neuronal connectivity, the EEG data collected and analysed is more 'noisy' than that collected by an adult cohort. In reference to Chapter 4 there are a number of reasons why this may be the case: 1). 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 as mentioned beforehand, and 2). 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 Chapter 4, although further exploration would be required.

In Chapter 5 it was hypothesised that iSZTm would exhibit atypical oscillatory activity compared to iCONm, in a similar way to those infants of depressed mothers (for examples see, Diego et al., 2006; Hane and Fox, 2006). It was not observed to be the case in the current sample, which may be due to a number of factors. 1). If it is the case that negative interactional expression is not observed during everyday parent-infant interactions, but is specific to circumstance (Kaitz, 2010), then during parent-infant-object interactions (which are not observed until the second half of the first

year), by 6-months the infants would not have been exposed to a representative sample of affective states towards environmental conditions. Future research employing an older infant sample would enable the exploration of this idea further. 2). As outlined in the discussion of Chapter 5, it is clear that the results have been interpreted with caution, as there are a number of methodological issues that could account for both the significant and non-significant results stated. Firstly, EEG data collected from infants in the first instance is noisy in nature, but during a live paradigm this increases the noisiness, and limits somewhat, the techniques employed to reduce this noise. The behavioural conditions explored, as they were coded following the testing session, were variable in number and no control could be given over the quantity of each behavioural classification for each child. This is something that could skew the results and potentially create interactions; for this reason, Chapter 5 should be interpreted as a novel piece of work, which provides a good basis for future free-play research, but requires further progression and replication.

The fully dimensional approach refers to the attenuated manifestations of mental illness, and makes the distinction between 'traits' and 'symptoms'; recognising that the shift into illness does involve varying degrees of discontinuity implied by the notion of the schizophrenia-spectrum (Claridge and Davis, 2003). The consistent findings derived from the data by the mothers in my samples support this description of continuity. It is important to discuss how traits become disadvantageous or even detrimental to our everyday living, and how they have the potential to develop into mental illness rather than remain as a defined personality difference. Following exploration of the literature, interpretation of the presented findings, and convergence of diagnosed patients scoring highly on scales specifically designed to measure schizotypy (Heron et al., 2003, for example), it is difficult to escape the conclusion that there is considerable overlap between the schizophrenic, the borderline, the affective, and the schizotypal.

6.2 Difficulties in Schizotypy Research

The conventional structure of an infancy experiment would be to contrast groups of participants who are subject to different environmental factors; in this case, groups of schizotypal and non-schizotypal individuals. However, this approach is problematic within the schizophrenia-spectrum and, consequently, schizotypy research, which is a

widely recognised and long-known problem (e.g. Novic, Luchins, and Perline, 1984; Miller et al., 1995). If schizotypy can be described as a loose collection of relatively independent vulnerabilities (Davidson et al., 2018), segregating participants into separate groupings may obscure these 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). Previous literature proposes that positive schizotypy overlaps substantially with the positive symptoms of schizophrenia, but the links to negative disorganisation, and cognitive symptoms of schizophrenia may be weaker (Cochrane, Petch, and Pickering, 2010). Given this complexity, the more recent literature pursues the potential links between the different dimensions of the schizotypy continuum and more endophenotype constructs related to psychosis (Debbané, 2015; Owens et al., 2016). 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. Such an abundance of quantitative evidence observed over the past few decades stimulates the use of continuous measures to assess *phenotypic* manifestations of schizotypy, but this should not be taken to confirm that the underlying latent schizotypy construct is fully quantitative or uniformly graded by degree. Whether or not schizotypy is fully quantitative at the latent levels is an empirical question and can only be answered with proper statistical methods with probative value (Lenzenweger, 2018b).

It is worthwhile exploring whether a focus on the sub-dimensions of schizotypy, rather than using the combined-dimensions total score as a whole, would have been a more profitable approach. This overlaps with the previously outlined notion; reflecting on whether a between- or within-subjects approach would provide a more reliable interpretation. In order to primarily focus on the continuous nature of schizotypic traits in conjunction with the rest of the schizophrenia-spectrum, perhaps a focus on the individual sub-dimensions would be a more accurate reflection. This would allow

for a direct mapping of the 'positive', 'negative', and 'disorganised' traits/symptoms outlined across the entire spectrum; it is largely understood that these traits/symptoms underlie schizophrenia (e.g., Lenzenweger and Dworkin, 1996) and have been replicated in non-clinically ascertained schizotypy (Kwapil, Barrantes-Vidal, and Silvia, 2008). A limitation of this is, however, the lack of reliability in these measures throughout the schizophrenia-spectrum (for example, Cochrane, Petch, and Pickering, 2010). In contrast, the use of the combined dimensions total-score, although it does not provide a segregated reflection on the differential elements of schizotypy, does nevertheless provide a way of 'grouping' those individuals in the general population who exhibit generalised schizotypic traits. For the present research, with a small sub-sample of the general population, this was 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 the individual sub-dimensions of the schizotypic personality may well be a more profitable approach.

The present research combined between- and within-subjects analyses to explore all potential aspects of the data. This was then subjected to correlational within-subjects analyses to maintain the continuous nature of schizotypy, but I also felt it beneficial to observe the effect this individual difference measure has on specific processing abilities that are already recognised within schizophrenic patients. Despite within-subjects analyses being proposed as the 'solution' to this issue (Davidson et al., 2018), at this stage in the literature there is value in taking conventional experimental approaches alongside continuous measures to identify links between schizotypic characteristics and processing abnormalities within the general population (e.g. Salokangas et al., 2013; Lin et al., 2013; Fluckiger et al., 2016).

The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE; Mason, Claridge, and Jackson, 1995) takes a fully dimensional approach, measuring schizotypy multidimensionally, which allows for the broad screening of traits across the general population. The O-LIFE has solid psychometric properties and its validity is supported by numerous cross-sectional questionnaire (e.g. Goulding, 2004), psychophysiological (Mason, Claridge, and Clark, 1997), and neurocognitive (e.g. Burch, Hemsley, Corr, and Gwyer, 2006) studies. The O-LIFE Short form (sO-LIFE;

Mason, Linney, and Claridge, 2005) aims to measure the same constructs reliably in an efficient manner, which is why it was chosen for the present experiments.

As our understanding of the schizophrenia-spectrum expands, new aspects of schizotypy and related constructs continue to be included in its *nomological network*, whether this be at clinical levels of extremity, recognised as schizotypal personality disorder, although they are not exclusive to the schizophrenia-spectrum (Dinsdale et al., 2013), or at more moderate levels, viewed as a source of variance in personal and social functioning (e.g., Fonseca-Pedrero et al., 2010a), vulnerability or prodromal factor for psychosis (e.g., Horan et al., 2008), and a stable trait-like feature of schizophrenia (e.g. Lenzenweger, 2011; Nelson et al., 2013). In this way, any future progression of the current work could incorporate multiple measures of schizotypy, exploring the previously defined 'positive', 'negative', and 'disorganised' traits, represented in their equivalent symptoms. Although schizotypy is often thought of as a unitary construct, self-reported schizotypy has not been explained effectively by a single dimension (Fonseca-Pedrero et al., 2014), thus, these equivalent traits/symptoms throughout the spectrum are important to our continued understanding of their continuous relationship. It is also important to explore the different structures utilised for partitioning the dimensions of schizotypy, which differ depending on instrument and version, analytic approach, and purpose for dimensional reduction (Fonseca-Pedrero et al., 2010b; Fonseca-Pedrero et al., 2014). A broad range of research has demonstrated reliable differences related to psychometrically-defined schizotypy (Brown and Cohen, 2010), including the differences in clinical presentation, clinical and genetic risk for mental illness, social cognitive abilities, and general functioning (McCleery et al., 2012; Morrison et al., 2013; Fervaha et al., 2014).

Thereby, the O-LIFE was chosen due to its basis in the sub-clinical, general population and its reliability among prior psychophysiological (Mason, Claridge, and Clark, 1997), and neurocognitive (e.g. Burch, Hemsley, Corr, and Gwyer, 2006) studies throughout the spectrum.

As mentioned previously, the research outlined in this thesis utilised a combination of conventional within-subjects analyses and continuous correlations in order to partake in the continual schizotypy debate. It should be clearly articulated that schizotypy for

the purpose of this thesis was defined using the sO-LIFE measurement, with individuals classed as *schizotypic* if their sO-LIFE score, averaged across the four dimensions, was half a standard deviation above the total participant population mean (as outlined in each preceding Chapter). This was the same approach adopted by Park et al. (2015) and could be argued to have confines in its ability to fully understand schizotypy as a personality construct. There is much evidence, as outlined in this thesis, that schizotypy is a construct with separable and well-identified components; thus, these dimensions in combination with each other do not present a clear and distinguishable reflection of positive, negative, or disorganised schizotypy. However, the preceding experiments attempt to control for this limitation through the use of correlational analyses with the four separate dimensions; providing an additional measure of the four scales separately. Moving forward in the schizotypy literature, this is an important element to consider. It has been proposed that Unusual Experiences is a factor associated with the positive dimension of psychosis, while Cognitive Disorganisation is associated with symptoms of depression, anxiety and anhedonia (Lin et al., 2013), which supports literature outlining how schizotypic individuals display similar deficits to those found in patients with schizophrenia and individuals at high-risk for psychosis (Ettinger et al., 2014; Cohen et al., 2015). Moreover, Dembińska-Krajewska and Rybakowski (2014) suggested that the impulsive non-conformity dimension should be interpreted with caution when utilising the sO-LIFE. This is because significant correlations were found between the unusual experiences, cognitive disorganisation, introvertive anhedonia, and psychopathological symptoms in those at high-risk of developing psychosis, but no such relationship was found with impulsive non-conformity (Dembińska-Krajewska and Rybakowski, 2014). Additionally, in Chapter 3, I hypothesised an association between the Introvertive Anhedonia dimension and a reduced evoked beta oscillation power, as previously suggested (Smucny et al., 2013), however, the present work did not replicate this finding. Further, no correlation was found between the introvertive anhedonia score, as a reflection of negative schizotypy, and the beta range evoked power scores.

It is a vital point to make that not all descriptions of schizotypy or ‘psychosis proneness’ are identical. For example, in studies of the general population where subgroups are operationally defined by their range of scores on questionnaire measures, in the way the groups were defined presently, it may be uncritically

accepted that a schizotypy group is synonymous with what Meehl (1962) or Claridge and Broks (1984) defined as schizotypal. The definition given by Lenzenweger (2018a, p1) suggests schizotypy to be a "*personality organisation determined by any number of as-yet-unknown schizophrenia-related genetic influences acting against a background of polygenic assets and liabilities as well as impacts from the environment, can manifest itself variously at the phenotypic level, ranging from clinically diagnosable schizophrenia through pathological personality manifestations to subtle, sub-clinical psychotic-like phenomenology (e.g., perceptual aberrations, magical ideation, referential thinking, interpersonal aversiveness)*", which I feel is synonymous with the definition used throughout this thesis. This is not a limitation of the present research but simply provides a definition for individual differences within our population cohort and alters our interpretation of the findings.

A 6-month-old infant population was chosen for the present research due to the developmental trajectories observed in both sensory gating and facial expression perception at this age. We know from the literature that sensory gating can be observed from as young as 2- (Hutchison et al., 2017) or 3-months of age (Hunter et al., 2015), although there are inconsistencies in the developmental trajectory due to large age-gaps in the published literature. Additionally, previous research on the behavioural and physiological correlates of infant's attention consistently reveals that infants begin to allocate more attention to negative (vs. positive) stimuli between 5-7-months of age (de Haan et al., 2004; Geangu et al., 2011; Taylor-Colls et al., 2015). For this reason, it was felt that 6-month-old infants would demonstrate this capacity, as in Chapter 4.

6.3 Future Directions and Societal Implications

A question that has lingered throughout this thesis, which I will now give my interpretation of, is: how does schizotypy actually fit on the schizophrenia-spectrum?

It is important to state that a great amount of disagreement on this topic can be traced back to subtle but crucial definitions in the conceptualisation of 'schizotypy' as a liability for mental illness or a proneness for unusual experiences and beliefs that are commonly experienced in the general population. Once again, not all descriptions of schizotypy or 'psychosis proneness' are identical, but the present research has examined a subgroup of the general population that are operationally defined by their

range of scores on questionnaire measures. It may therefore be uncritically accepted that the present schizotypy groups are synonymous with what Meehl (1962) or Claridge and Broks (1984) defined as schizotypal. This is a complex debate that requires further, and on-going examination.

The conclusion of this thesis is that the schizophrenia-spectrum and by extension, schizotypy, sit on a fully dimensional continuum. By this I mean that the general population may experience 'traits' descriptively similar to those further along the spectrum, albeit to a milder degree (Ettinger et al., 2014). In support of this, it has been observed that other disorders found on this spectrum score highly on scales specifically designed to measure schizotypy (for example, Bipolar; Heron et al., 2003). Knowing this, it is difficult to escape the conclusion that there is considerable overlap between schizophrenia-spectrum disorders and sub-clinical schizotypy, as represented by the fully dimensional approach. Thus, varying combinations of genes and environmental risk factors result in a different range of phenotypic expressions lying on a continuum from typical through to clinical psychosis. Following progression along this continuum into the clinical 'realm' of mental illness, the 'traits' become 'symptoms' and different classifications may be made to account for severity of symptoms.

Longitudinal studies have observed how levels of personality traits may exhibit flexibility, especially during important developmental stages (Roberts, Walton and Viechtbauer, 2006). This has led the literature to study the factors influencing both the development of personality traits and the stability of these traits across time. Clarifying the factors that affect the development and stability of personality, and its overlap with psychopathology, are central to the understanding of how an individual's personality unfolds across the lifespan, and how psychopathology may produce trait level changes in our personality (Krueger and Tackett, 2003). As such, it is possible to suggest that pre-dispositions are present across the population, but requires an *environmental facilitator* (for example, childhood stress or trauma; Phillips, 2007; Varese et al., 2012; Xian-Bin et al., 2018) to act as a 'spring-board' for further development into mental illness. The severity of this alleged facilitator, however, remains to be explored; whether as severe as childhood trauma or more sensitive as an atypical developmental environment. In this way, schizotypy acts as a sub-clinical manifestation of this pre-disposition within the population, but requires these

facilitators in order to cross over into a diagnosable form of the schizophrenia-spectrum.

While personality traits are generally viewed as broadly consistent over time, stress and other factors may influence these traits and put pressure on them; potentially even shifting them to symptoms in the absence of a diagnosed syndrome (Mason, 2014). Further to this, we must work to understand how traits are transformed into symptoms along the illness spectrum and how the mechanisms that promote healthy functioning in some individuals can just as easily be translated into clinical diagnosis.

Prior research has consistently suggested that the deficits observed are dimensional at the population level and lie on a continuum with schizophrenia-spectrum disorders (Nelson et al., 2013). If this is the case, then future findings may help to reduce the stigma surrounding schizophrenia, and mental health in general. It is understood that schizophrenia is not a clear categorical diagnosis but rather a dimensional one, with multiple dimensional symptoms and schizotypy traits present as a continuum of these in the general population. Recent research has illustrated how the description of schizophrenia as a continuum have a positive effect on views of mental health in non-clinical individuals (Corrigan et al., 2017), and lower the desire for social distance from patients diagnosed with schizophrenia (Subramaniam et al., 2017).

It is important to take away the notion that although mothers who experience schizotypic traits show the gating and facial expression deficits associated with the schizophrenia-spectrum, they do not pass these deficits on to their 6-month-old infants. This is important to consider for families who may be concerned about passing on sensory and cognitive deficits to their children, as the present research suggests that these personality-linked deficits are not present at 6 months of age. It is worth questioning the progression of these deficits, however, and whether they may become discernable as developmental trajectories progress.

In addition to hereditary factors, chronic psychosocial stressors including childhood adversity (Varese et al., 2012) among other factors have been accepted as increasing the risk of schizophrenia-spectrum disorders. Furthermore, acute stressors play a role in triggering psychotic symptoms (Lataster et al., 2012) and impaired stress tolerance is associated with prodromal symptoms (Reininghaus et al., 2016). In addition to severe childhood adversities, it is also of principal importance to explore the affect of

atypical developmental environment as these have also been shown to correspond to the core domains where dysfunction occurs in childhood and adulthood configurations of mental illness (van Bockstaele et al., 2014). It is understood that social experiences with a depressed parent (along with temperamental or genetic predispositions) could thereby make an infant vulnerable to increased social withdrawal and internalising behaviours which are characteristic of diagnosable depression and that of the behaviours noted in preschool children of depressed mothers (Feng et al., 2008). Moreover, mothers who experience symptoms of depression are observed to be less sensitive in their mothering ability (Meins et al., 2001) and exhibit a particular pattern of resting electrical activity, which is marked by greater right frontal EEG power, and is also observed in their infants. This atypicality is observed from 1-week postnatal (Diego et al., 2004), remains stable between 3-months and 3-years (Jones et al., 1997), and is consistent with the EEG asymmetry of their mothers (Field et al., 2004; Wen et al., 2017), and other adults with depression diagnoses (Field and Diego, 2008). Despite this oscillatory similarity between offspring and mothers with a depression diagnosis, the present thesis did not find this association with the personality dimension schizotypy. Perhaps this is the result of frequent comorbidity between depression and other mental disorders, or perhaps a personality dimension is not sensitive enough to be influential by 6-months-old, but the correlations observed throughout the present thesis proposing schizotypic dimensionality does show associations with the deficits associated with the schizophrenia-spectrum. For this reason, it is an unexplored future progression to investigate whether exposure to maternal schizotypy during infancy, leads to the observation of schizotypic deficits during childhood or adolescence.

Following the implications for families with schizotypic individuals, or a history of psychotic mental health, it is worthwhile exploring the risk factors that have been associated with schizotypy, and schizophrenia, which act as environmental facilitators in conjunction with genetic predisposition. For example, a growing literature has contributed to the notion of an association between trauma and hallucination-proneness. Large population-based explorations and cross-sectional studies propose that traumatic events may increase the likelihood of experiencing psychotic symptoms (for a review, van Os et al., 2010), with specific associations between different types of adversities and specific psychotic symptoms (Bentall and Fernyhough, 2008).

Moreover, strong positive correlations between childhood maltreatment and psychotic symptoms were reported by DeRosse et al (2014), while Kelleher et al (2013) observed a dose-response relationship between the severity of childhood trauma and incidence of psychotic experiences; reporting that cessation of childhood trauma decreased the chance of experiencing psychotic episodes, as well as contributing to the morbidity and severity of bipolar disorder (Etain et al., 2013; Erten et al., 2014).

6.4 Concluding Remarks

To summarise the reported findings, throughout Chapter 2, 3, and 4; results consistently illustrated how mothers who identified as experiencing schizotypic traits displayed similar deficits to those demonstrated by individuals on the schizophrenia-spectrum. The infants' results were as consistent, with the infants presenting significant differences in their electrophysiological activity between stimuli (*S1* vs. *S2*, or Fearful vs. Happy, for example) although no significant group differences were observed as a result of their mothers' schizotypy dimensionality, as is consistent with the results of Chapter 5.

The individualities that are used to define neurodevelopmental and neuropsychiatric disorders are best conceptualised as variations of sensory, perceptual, and behavioural domains that are observable and distributed throughout the general population (Kotov et al., 2017; Hengartner and Lehmann, 2017; Evans et al., 2018). Moving forward, we should aim to reflect on psychiatric deficit as a *shift* in the continuous distribution of neurodevelopmental traits toward greater impairment, whilst maintaining commonality with the population distribution (van Os et al., 2009). The use of the sO-LIFE questionnaire aids in the fulfillment of this, resulting from its multi-dimensional approach to individual differences observed across the general population.

In sum, schizotypy is *not* akin to a normative personality dimension such as extraversion, but rather it is derivative from mental illness; supported by the consistent deficits exhibited by the current schizotypic mother population (Lenzenweger, 2018b). Schizotypy, which continues to be determined by any number of as-yet-unknown schizophrenia-related genetic influences (working against a field of polygenic assets and liabilities as well as environmental facilitators), can manifest itself with phenotypical variability; ranging from clinically diagnosable schizophrenia through pathological personality manifestations (e.g., schizotypal, paranoid, schizoid

personality disorders) to subtle, subclinical psychotic-like phenomenology (e.g., perceptual aberrations, magical ideation, referential thinking, and interpersonal aversions). Schizotypy may also manifest itself in an imperceptible manner, undetectable by the unaided eye, through deviance on endophenotypes that have established valid relations with the schizophrenia-spectrum.

Decades of research have reported the impact of the environment on personality development, and its relationship entangled with hereditary deficits. The proposition that our environmental exposure influences the maturity, and the strengthening of certain traits (Briley and Tucker-Drob, 2017; Krzeczkowski and van Lieshout, 2018) supports the bidirectional nature of psychosis-proneness. Schizotypal expression during adolescence and adulthood is critically linked to childhood risk markers and endophenotype, which confer a role of potential *developmental facilitators* on the road to psychosis proneness (Debbané, 2015, pp. 88). As such, a developmental model of schizotypy holds the necessary ingredients to bring a developmental psychopathology account for psychotic disorders, which is a void that needs to be further understood.

Bibliography

Addington, J., Penn, D., Woods, S. W., Addington, D., & Perkins, D. O. (2008). Social functioning in individuals at clinical high risk for psychosis. *Schizophrenia Research, 99(1),* 119-124.

Ainsworth, M.D.S. (1985). Patterns of infant-mother attachments: antecedents and effects on development. *Bulletin of the New York Academy of Medicine, 61*.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control, 19(6),* 716-723.

Aktar, E., & Bögels, S. (2017). Exposure to Parents' Negative Emotions as a Developmental Pathway to the Family Aggregation of Depression and Anxiety in the First Year of Life. *Clinical Child and Family Psychology Review, 20(4),* 369-390.

Aleman, A., & Kahn, R.S. (2005). Strange feelings: do amygdala abnormalities dysregulate the emotional brain in schizophrenia? *Progress in Neurobiology, 77(5),* 283–298.

Allardyce, J., Suppes, T., & van Os, J. (2007). Dimensions and the positive psychosis phenotype. *International Journal of Methods in Psychiatric Research, 16(Suppl. 1),* s34–s40.

Andrewes, D. ed., (2002). Recovery From Brain Damage. In: *Neuropsychology From Theory to Practice,* 1st ed. Taylor & Francis Ltd, p.457.

Angold, A., & Costello, E. J. (1995). Developmental epidemiology. *Epidemiology Review, 17,* 74-82.

Arteche, A., Joormann, J., Harvey, A., Craske, M., Gotlib, I. H., Lehtonen, A., Counsell, N., & Stein, A. (2011). The effects of postnatal maternal depression and anxiety on the processing of infant faces. *Journal of Affective Disorders, 133(1-2),* 197-203.

Ashman, S., Dawson, G., & Panagiotides, H. (2008). Trajectories of maternal depression over 7 years: Relations with child psychophysiology and behavior and role of contextual risks. *Development and Psychopathology, 20(1),* 55-77.

Barrantes-Vidal, N., Chun, C., Myin-Germeys, I., & Kwapil, T. R. (2013). Psychometric schizotypy predicts the experience of psychotic-like, paranoid, and negative symptom experience in daily life. *Journal of Abnormal Psychology, 122*, 1077-1087.

Barrantes-Vidal, N., Grant, P., & Kwapil, T.R. (2015). The Role of Schizotypy in the Study of the Etiology of Schizophrenia Spectrum Disorders. *Schizophrenia Bulletin, 41(Suppl 2),* 408–416. doi: 10.1093/schbul/sbu191

Basar-Eroglu, C., Struber, D., Schurmann, M., Stadler, M., & Basar, E. (1996). Gamma-band responses in the brain: a short review of psychophysiological correlates and functional significance. *International Journal of Psychophysiology, 24,* 101-112.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67(1),* 1-48.

Bazhenova, O. V., Stroganova, T. A., Doussard-Roosevelt, J. A., Posikera, I. A., & Porges, S. W. (2007). Physiological responses of 5-month-old infants to smiling and blank faces. *International Journal of Psychophysiology, 63(1),* 64–76.

Bearden, C. E., Rosso, I. M., Hollister, J. M., Sanchez, L. E., Hadley, T., & Cannon, T. D. (2000). A Prospective Cohort Study of Childhood Behavioral Deviance and Language Abnormalities as Predictors of Adult Schizophrenia. *Schizophrenia Bulletin, 26(2),* 395-410.

Beauchaine, T. P., Lenzenweger, N. F., & Waller, N. G. (2008). Schizotypy, taxometrics, and disconfirming theories in soft science. Comment on Rawlings, Williams, Haslam, and Claridge. *Personality and Individual Differences, 44*, 1652-1662.

Bediou, B., Franck, N., Saoud, M., Baudouin, J. Y., Tiberghien, G., Dalery, J., & d'Amato, T. (2005). Effects of emotion and identity on facial affect processing in schizophrenia. *Psychiatry Research, 133,* 149–157.

Bediou, B., Henaff, M. A., Bertrand, O., Brunelin, J., D'amato, T., Saoud, M., & Krolak-Salmon, P. (2007). Impaired fronto-temporal processing of emotion in schizophrenia. *Clinical Neurophysiology, 37*, 77–8710.

Begus, K., Gliga, T., & Southgate, V. (2016). Infants' preferences for native speakers are associated with an expectation of information. *Proceedings of the National Academy of Sciences, 113(44),* 12397-12402. doi: 10.1073/pnas.1603261113

Belsky, J., & Barends, N. (2002). Personality and parenting. In M. Bornstein (Ed.), *Handbook of parenting (2nd edn), Vol. 3: Being and becoming a parent* (pp. 415–438). Mahwah, NJ: Erlbaum.

Belsky, J., & De Haan, M. (2011). Annual Research Review: Parenting and Children's Brain Development--The End of the Beginning. *Journal of Child Psychology and Psychiatry, 52(4),* 409-428.

Bentall, R. P., Fernyhough, C. (2008). Social predictors of psychotic experiences: specificity and psychological mechanisms. *Schizophrenia Bulletin, 34*, 1012–1020.

Bernier, A., Calkins, S., & Bell, M. (2016). Longitudinal Associations Between the Quality of Mother–Infant Interactions and Brain Development Across Infancy. *Child Development, 87(4),* 1159-1174.

Bibbig, A., Faulkner, H. J., Whittington, M. A., & Traub, R. D. (2001). Self-organized synaptic plasticity contributes to the shaping of gamma and beta oscillations in vitro. *The Journal of Neuroscience, 21*, 9053-9067.

Blanchard, J. J., Collins, L. M., Aghevli, M., Leung, W. W., & Cohen, A. S. (2011). Social anhedonia and schizotypy in a community sample: The Maryland Longitudinal Study of Schizotypy. *Schizophrenia Bulletin, 37*, 587-602.

Blass, E., & Camp, C. (2003). Biological bases of face preference in 6-week-old infants. *Developmental Science, 6(5),* 524–536.

Blumenfeld, L. D., & Clementz, B. A. (2001). Response to the first stimulus determines reduced auditory evoked response suppression in schizophrenia: single trial analysis using MEG. *Clinical Neurophysiology, 112,* 1650-1659.

Bodatsch, M., Ruhrmann, S., Müller, R., Klosterkötter, J., & Brockhaus-Dumke, A. (2010). Mismatch negativity is reduced in schizophrenia patients with deficit syndrome. *Schizophrenia Research, 117(2-3),* 360-361.

Boutros, N. N., Korzyuko, O., Oliwa, G., Feingold, A., Campbell, D., Mcclain-Furmanski, D., Struve, F., Jansen, B. H. (2004). Morphological and latency abnormalities of the mid-latency auditory evoked responses in schizophrenia: A preliminary report. *Schizophrenia Research, 70*, 303-313. doi: 10.1016/j.schres.2003.12.009

Boutros, N. N., Brockhaus-Dumke, A., Gjini, K., Vedenjapin, A., Elfakhani, M., Burroughs, S., & Keshaven, M. (2009). Sensory-gating deficit of the N100 mid-latency auditory evoked potential in medicated schizophrenia patients. *Schizophrenia Research, 113*, 339-346. doi: 10.1016/j.schres.2009.05.019

Bowlby, J. (1969). *Attachment and loss: vol. 1.* (vol. 1) London: Hogarth Press.

Boyce, P., Hickie, I., & Gordon, P. (1991). Parents, partners or personality? Risk factors for post-natal depression. *Journal of Affective Disorders, 21(4),* 245-255.

Braff, D. L., Freedman, R., Schork, N. J., & Gottesman, I. I. (2007). Deconstructing schizophrenia: an overview of the use of endophenotypes in order to understand a complex disorder. *Schizophrenia Bulletin, 33*, 21-32.

Braff, D. L., & Light, G. A. (2004). Preattentional and attentional cognitive deficits as targets for treating schizophrenia. *Psychopharmacology, 174*, 75-85. doi: 10.1007/s00213-004-1848-0

Brennan, P. A., Hammen, C., Andersen, M. J., Bor, W., Najman, J. M., & Williams, G. M. (2000). Chronicity, severity, and timing of maternal depressive symptoms: relationships with child outcomes at age 5. *Developmental Psychology, 36,* 759-766.

Brenner, C. A., Kieffaber, P. D., Clementz, B. A., et al. (2009). Event-related potential abnormalities in schizophrenia: a failure to "gate in" salient information? *Schizophrenia Research, 113*, 332-338.

Briley, D., & Tucker-Drob, E. (2017). Comparing the Developmental Genetics of Cognition and Personality over the Life Span. *Journal of Personality, 85(1),* 51-64.

Brown, L. A., & Cohen, A. S. (2010). Facial emotion recognition in schizotypy: the role of accuracy and social cognitive bias. *Journal of the International Neuropsychological Society, 16(3),* 474-483.

Burch, G. S. J., Hemsley, D. R., Corr, P. J., & Gwyer, P. (2006). The relationship between incidental learning and multi-dimensional schizotypy as measured by the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE). *Personality and Individual Differences, 40(2),* 385-394.

Cadenhead, K.S., Light, G.A., Geyer, M.A., & Braff, D.L. (2000). Sensory gating deficits assessed by the P50 event-related potential in subjects with schizotypal personality disorder. *The American Journal of Psychiatry, 157(1),* 55-59. doi: 10.1176/ajp.157.1.55

Cadenhead, K.S., Light, G.A., Shafer, K.M., & Braff, D.L. (2005). P50 Suppression in Individuals at Risk for Schizophrenia: The Convergence of Clinical, Familial, and Vulnerability Marker Risk Assessment. *Biological Psychiatry, 57(12),* 1504-1509.

Camisa, K. M., Bockbrader, M. A., Lysaker, P., Rae, L. L., Brenner, C. A., & O'Donnell, B. F. (2005). Personality traits in schizophrenia and related personality disorders. *Psychiatry Research, 133(1),* 23-33.

Campanella, S., & Guerit, J. M. (2009). How clinical neurophysiology may contribute to the understanding of a psychiatric disease such as schizophrenia. *Clinical Neurophysiology, 39,* 31-39.

Campbell, S. B., Matestic, P., von Stauffenberg, C., Mohan, R., Kirchner, T. (2007). Trajectories of maternal depressive symptoms, maternal sensitivity, and children's functioning at school entry. *Developmental Psychology, 43,* 1202-1215.

Carlson, G. A., & Fish, B. (2005). Longitudinal course of schizophrenia spectrum symptoms in offspring of psychiatrically hospitalized mothers. *Journal of Child and Adolescent Psychopharmacology, 15*, 362–383.

Cedro, A., Kokoszka, A., Popiel, A., & Narkiewicz-Jodko, W. (2001). Alexithymia in schizophrenia: an exploratory study. *Psychological Reports, 89*, 95-98.

Cents, R. A., Diamantopoulou, S., Hudziak, J. J., Jaddoe, V. W., Hofman, A., Verhulst, F. C., Lambregtse-van den Berg, M. P., Tiemeier, H. (2013). Trajectories of maternal depressive symptoms predict child problem behaviour: the Generation R study. *Psychological Medicine, 43,* 13-25.

Cheng, C., Chan, P., Niddam, D., Tsai, S., Hsu, S., & Liu, C. (2016). Sensory gating, inhibition control and gamma oscillations in the human somatosensory cortex. *Scientific Reports, 6(1),* 20437.

Cicchetti, D., & Dawson, G. (2002). Editorial: Multiple levels of analysis. *Development and Psychopathology,14(3),* 417-420.

Claridge, G. (1997). *Schizotypy: Implications for illness and heath*. Oxford: Oxford University Press.

Claridge, G. (1997). Theoretical background and issues. In G. Claridge (Ed.), *Schizotypy: Implications for illness and health.* Oxford: Oxford University Press.

Claridge, G. (2009). Personality and Psychosis. In: P. Corr and G. Matthews, ed., *The Cambridge Handbook of Personality Psychology.* Leiden: Cambridge University Press, pp.631-648.

Claridge, G. (2015). Old thoughts: new ideas: future directions. In O. Mason & G. Claridge (Eds.), *Schizotypy: New dimensions* (pp.217-225). Routledge.

Claridge, G., & Beech, T. (1995). Fully and quasi-dimensional constructions of schizotypy. In: Raine, A., Lencz, T., Mednick, S.A. (Eds.), *Schizotypal Personality.* Cambridge University Press, Cambridge, pp. 192–216.

Claridge, G., & Broks, P. (1984). Schizotypy and hemisphere function: I. Theoretical considerations and the measurement of schizotypy. *Personality and Individuals Differences, 8,* 303-312.

Claridge, G., & Davis, C. (2003). *Personality and Psychological Disorders.* Arnold, London.

Claridge, G., McCreery, C., Mason, O., Bentall, R., Boyle, G., Slade, P., & Popplewell, D. (1996). The factor structure of 'schizotypal' traits: A large replication study. *British Journal of Clinical Psychology, 35*, 103-115.

Clementz, B. A., & Blumenfeld, L. D. (2001). Multichannels electroencephalographic assessment of auditory evoked response suppression in schizophrenia. *Experimental Brain Research, 139,* 377-390.

Clementz, B. A., Barber, S. K., & Dzau, J R. (2002). Knowledge of stimulus repetition affects the magnitude and spatial distribution of low-frequency event-related brain potentials. *Audiology and Neurotology, 7,* 303-314.

Clementz, B. A., Blumenfeld, L. D., & Cobb, S. (1997). The gamma band response may account for poor P50 suppression in schizophrenia. *Neuroreport, 8,* 3889–93.

Cochrane, M., Petch, I., & Pickering, A. D. (2010). Do measures of schizotypal personality provide non-clinical analogues of schizophrenic symptomatology. *Psychiatry Research, 176(2),* 150-154.

Cohen, A., Mohr, C., Ettinger, U., Chan, R. C. K., & Park, S. (2015). Schizotypy as an organising framework for social and affective sciences. *Schizophrenia Bulletin, 41,* S427-435.

Cook, D. R. (1979). Influential Observations in Linear Regression. Journal of the American Statistical Association. *American Statistical Association, 74(365),* 169–174. doi:10.2307/2286747.

Cornish, A. M., McMahon, C. A., Ungerer, J. A., Barnett, B., Kowalenko, N., & Tennant, C. (2005). Postnatal depression and infant cognitive and motor development in the second

postnatal year: the impact of depression chronicity and infant gender. *Infant Behaviour and Development, 28(4), 407–* 417.

Corr, P. (2010). The psychoticism–psychopathy continuum: A neuropsychological model of core deficits. *Personality and Individual Differences, 48(6),* 695-703.

Corr, P.J. (2000). *Psychoticism. Encyclopedia of psychology.* Washington: American Psychological Association/Oxford University Press.

Corrigan, P., Schmidt, A., Bink, A., Nieweglowski, K., Al-Khouja, M., Qin, S., & Discont, S. (2017). Changing public stigma with continuum beliefs. *Journal of Mental Health, 26,* 411–418.

Csibra, G., Davis, G., Spratling, M. W., & Johnson, M. H. (2000). Gamma oscillations and object processing in the infant brain. *Science, 290,* 1582–1585.

Dalecki, A., Croft, R., & Johnstone, S. (2011). An evaluation of P50 paired-click methodologies. *Psychophysiology, 48(12),* 1692-1700. doi: 10.1111/j.1469-8986.2011.01262.x

Davidson, C., Kiat, J., Tarasenko, M., Ritchie, A., Molfese, D., & Spaulding, W. (2018). Exploring electrophysiological correlates of social cognition in subclinical schizotypy. *Personality and Mental Health,12(3),* 179-191.

Dawson, G., Ashman, S., Pangiotides, H., Hessl, D., Self, J., Yamada, E., & Embry, L. (2003). Preschool outcomes of children of depressed mothers: Role of maternal behaviour, contextual risk, and children's brain activity. *Child Development, 74*, 1158–1175.

Dean, K., Stevens, H., Mortensen, P. B., Murray, R. M., Walsh, E., & Pedersen, C. B. (2010). Full spectrum of psychiatric outcomes among offspring with parental history of mental disorder. *Archives of General Psychiatry, 67,* 822–829.

Debbané, M. (2015). Schizotypy. A Developmental Perspective. In O. Mason & G. Claridge (Eds.), *Schizotypy: New dimensions* (pp.84-95). Routledge.

Debbané, M., & Barrantes-Vidal, N. (2015). Schizotypy from a developmental perspective. *Schizophrenia Bulletin, 41(2),* 386-95. doi: 10.1093/schbul/sbu175

de Haan, M. (2007). *Infant EEG and event-related potentials (Studies in developmental psychology).* Hove: Psychology Press.

de Haan, M., & Gunnar, M. R. (2009). *Handbook of Developmental Social Neuroscience.* New York: The Guildford Press.

de Haan, M., & Nelson, C.A. (1998). Discrimination and categorization of facial expressions of emotion during infancy. In A. Slater (Ed.), *Perceptual development: Visual, auditory, and language development in infancy.* London: University College London Press.

de Haan, M., Belsky, J., Reid, V., Volein, A., & Johnson, M.H. (2004). Maternal Personality and Infants' Neural and Visual Responsivity to Facial Expressions of Emotion. *Journal of Child Psychology and Psychiatry, 45(7),* 1209-1218.

de Haan, M., Nelson, C., & Dannemiller, J. L. (1999). Brain Activity Differentiates Face and Object Processing in 6-Month-Old Infants. *Developmental Psychology, 35(4),* 1113-1121.

Dembińska-Krajewska, D., & Rybakowski, J. (2014). The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) schizotypy scale in psychiatry. *Archives of Psychiatry and Psychotherapy, 16(2),* 15-22.

DeRosse, P., Nitzburg, G. C., Kompancaril, B., & Malhotra, A. K. (2014). The relation between childhood maltreatment and psychosis in patients with schizophrenia and non-psychiatric controls. *Schizophrenia Research, 155*, 66-71.

Diego, Field, Jones, Hernandez-Reif, Cullen, Schanberg, & Kuhn. (2004). EEG responses to mock facial expressions by infants of depressed mothers. *Infant Behavior and Development, 27(2),* 150-162.

Diego, M. A., Field, T., Jones, N. A., & Hernandez-Reif, M. (2006). Withdrawn and intrusive maternal interaction style and infant frontal EEG asymmetry shifts in infants of depressed and non-depressed mothers. *Infant Behavior and Development, 29(2),* 220-229.

Diego, M. A., Jones, N. A., & Field, T. (2010). EEG in 1-week, 1-month, and 3-month-old infants of depressed and non-depressed mothers. *Biological Psychology, 83,* 7–14. doi:10.1016/j.biopsycho.2009.09.007.

Dinsdale, N. L., Hurd, P. L., Wakabayashi, A., Elliot, M., & Crespi, B. J. (2013). How are autism and schizotypy related? Evidence from a non-clinical population. *PLoS One, 8(5),* e63316.

Dolan, M., & Fullam, R. (2006). Face affect recognition deficits in personality-disordered offenders: Association with psychopathy. *Psychological Medicine, 36*, 1563–1570.

Duchene, A., Graves, R.E., Brugger, P. (1998). Schizotypal thinking and associative processing: a response commonality analysis of verbal fluency. *Journal of Psychiatry and Neuroscience, 23,* 56–60.

Edwards, J., Jackson, H. J., & Pattison, P. E. (2002). Emotion recognition via facial expression and affective prosody in schizophrenia: A methodological review. *Clinical Psychology Review, 22(6),* 789-832.

Edwards, J., Pattison, P.E., Jackson, H.J., & Wales, R.J. (2001). Facial affect and affective prosody recognition in first-episode schizophrenia. *Schizophrenia Research, 48(2–3),* 235–253.

Eley, T., Mcadams, T., Rijsdijk, F., Lichtenstein, P., Narusyte, J., Reiss, D., Spotss, E. L., Ganiban, J. M., & Neiderhiser, J. M. (2015). The Intergenerational Transmission of Anxiety: A Children-of-Twins Study. *The American Journal of Psychiatry,172(7),* 630-7.

Eley, T. C., McAdams, T. A., Rijsdijk, F. V., Lichtenstein, P., Narusyte, J., Reiss, D., et al. (2015). The intergenerational transmission of anxiety: A children-of-twins study. *American Journal of Psychiatry, 172*, 630–637.

Emery, N. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience and Biobehavioral Reviews, 24(6),* 581-604.

Erten, E., Finda, U. A., Saatcioglu, O., Ozdemir, A., Fistikci, N., & Cakmak, D. (2014) Effects of childhood trauma and clinical featues on determining the quality of life in patients with bipolar I disorder. *Journal of Affective Disorders, 162*, 107-113.

Etain, B., Aas, M., Andreassen, O. A., Lorentzen, S., Dieset, I., Gard, S., Kahn, J. P., Bellivier, F., Leboyer, M., Melle, I., & Henry, C. (2013). Childhood trauma is associated with severe clinical characteristics of bipolar disorders. *Journal of Clinical Psychiatry, 74,* 991-998.

Ettinger, U., Kumari, V., Crawford, T. J., Flak, V., Sharma, T., Davis, R. E., & Corr, P.J. (2005). Saccadic eye movements, schizotypy, and the role of neuroticism. *Biological Psychology, 68,* 61-78.

Ettinger, U., Meyhöfer, I., Steffens, M., Wagner, M., & Koutsouleris, N. (2014). Genetics, cognition, and neurobiology of schizotypal personality: a review of the overlap with schizophrenia. *Frontiers in Psychiatry, 5,* 18.

Evans, D., Lusk, L., Slane, M., Michael, A., Myers, S., Uljarević, M., Mason, O., Claridge, G., & Frazier, T. (2018). Dimensional assessment of schizotypal, psychotic, and other psychiatric traits in children and their parents: Development and validation of the Childhood Oxford-Liverpool Inventory of Feelings and Experiences on a representative US sample. *Journal of Child Psychology and Psychiatry, 59(5),* 574-585.

Evans, D. W., Michael, A. M., Ularević, M., Lusk, L. G., Buirkle, J. M., & Moore, G. J. (2016). Neural substrates of a schizotypal spectrum in typically-developing children: Further evidence of a normal-pathological continuum. *Behavioural Brain Research, 315,* 141-146.

Evans, L.H., Gray, N.S., & Snowden, R.J. (2005). Prepulse inhibition of startle and its moderation by schizotypy and smoking. *Psychophysiology, 42,* 223–231.

Evans, L.H., Gray, N.S., & Snowden, R.J. (2007). A new continuous within-participants latent inhibition task: examining associations with schizotypy dimensions, smoking status and gender. *Biological Psychology, 74*, 365–373.

Evans, S., Shergill, S.S., Chouhan, V., Bristow, E., Collier, T., & Averbeck, B. (2011). Patients with schizophrenia show increased aversion to angry faces in an associative learning task. *Psychological Medicine, 41(7),* 1471–1479.

Eysenck, H. J. (1992). The definition and measurement of psychoticism. *Personality and Individual Differences, 13,* 757-785.

Eysenck, H. J., & Eysenck, S. B. G. (1992). *Manual for the Eysenck Personality Questionnaire-Revised.* San Diego, CA: Educational and Industrial Testing Service.

Eysenck, S. B. G., Eysenck, H. J., & Barrett, P. (1985). A revised version of the Psychoticism scale. *Personality and Individual Differences, 6,* 21–29.

Fai, A. H-T., & Cornelius, P. L. (1996). Approximate F-tests of multiple degree of freedom hypotheses in generalized least squares analyses of unbalanced split-plot experiments. *Journal of Statistical Computation and Simulation, 54(4),* 363-378, DOI: 10.1080/00949659608811740.

Feng, X., Shaw, D. S., Kovacs, M., Lane, T., O'Rourke, F. E., & Alarcon, J. H. (2008). Emotion regulation in pre-schoolers: The roles of behavioural inhibition, maternal affective behaviour, and maternal depression. *Journal of Child Psychology and Psychiatry, 49*, 132-141.

Fervaha, G., Zakzanis, K. K., Jeffay, E., Graff, Guerrero, A., Foussias, G., Agid, O., & Remington, G. (2014). Amotivation as central to negative schizotypy and their predictive value for happiness. *Personality and Individual Differences, 68*, 37-42.

Field, T., & Diego, M. (2008). Maternal Depression Effects on Infant Frontal EEG Asymmetry. *International Journal of Neuroscience, 118(8),* 1081-1108.

Field, T., Diego, M., & Hernandez-Reif, M. (2009). Depressed mothers' infants are less responsive to face and voices. *Infant Behavior and Development, 32*, 239–244.

Field, T., Diego, M., Dieter, J., Hernandez-Reif, M., Schanberg, S., Kuhn, C., Yando, R., & Bendell, D. (2004). Prenatal depression effects on the fetus and the newborn. *Infant Behavior and Development, 27(2),* 216-229.

Fluckiger, R. Ruhrmann, S., Debbane, M., Michel, C., Hubl, D., Schimmelmann, B. G., et al. (2016). Psychosis-predictive value of self-reported schizotypy in a clinical high-risk sample. *Journal of Abnormal Psychology, 125*, 923-932.

Fonseca-Pedrero, E., Fumero, A., Paino, M., de Miguel, A., Ortuno-Sierra, J., lemos-Giraldez, S., & Muniz, J. (2014). Schizotypal personality questionnaire: new sources of validity evidence in college students. *Psychiatry Research, 219(1),* 214-220.

Fonseca-Pedrero, E., Lemos-Giraldez, S., Paino-Pineiro, M., Villazon-Garcia, U., & Muniz, J. (2010a). Schizotypal traits, obsessive-compulsive symptoms, and social functioning in adolescents. *Comprehensive Psychiatry, 51(1),* 71-77.

Fonseca-Pedrero, E., Linscott, R.J., Lemos-Giráldez, S., Paino, M., & Muñiz, J. (2010c). Psychometric properties of two measures for the assessment of schizotypy in adolescents. *Psychiatry Research, 179*, 165-170.

Fonseca-Pedrero, E., Paino, M., Lemos-Giraldez, S., Sierra-Baigrie, S., & Muniz, J. (2010b). Factor structure and measurement invariance of the Wisconsin Schizotypy scales across gender and age. *Spanish Journal of Psychology, 13(2),* 941-950).

Forssman, L., Peltola, M. J., Yrttiaho, S., Puura, K., Mononen, N., Lehtimäki, T., & Leppänen, J. M. (2014). Regulatory variant of the TPH2 gene and early life stress are associated with heightened attention to social signals of fear in infants. *Journal of Child Psychology and Psychiatry, 55,* 793–801.

Fraley, R. C., Roisman, G. I., & Haltigan, J. D. (2013). The legacy of early experiences in development: Formalizing alternative models of how early experiences are carried forward over time. *Developmental Psychology, 49*, 109–126.

Freedman, R., Adler, L., Waldo, M., Pachtman, E., & Franks, R. (1983). Neurophysiological evidence for a defect in inhibitory pathways in schizophrenia: Comparison of medicated and drug-free patients. *Biological Psychiatry, 18*, 537-551.

Freedman, R., Adler, L. E., Gerhardt, G. A., Waldo, M., Baker, N., Rose, G. M., et al. (1987). Neurobiological studies of sensory gating in schizophrenia. *Schizophenia Bulletin, 13*, 669–678.

Freedman, R., Adler, L.E., Olincy, A., Waldo, M.C., Ross, R.G., Stevens, K.E., & Leonard, S. (2002). Input dysfunction, schizotypy, and genetic models of schizophrenia. *Schizophrenia Research, 54*, 25-32. doi: 10.1016/S0920-9964(01)00348-6

Freedman, R., Adler, L. E., Waldo, M. C., Pachtman, E., & Franks, R. D. (1983). Neurophysiological evidence for a defect in inhibitory pathways in schizophrenia: comparison of medicated and drug-free patients. *Biological Psychiatry, 18*, 537-551.

Friedman, D., & Johnson, R. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: a selective review. *Microscopy research and technique, 51(1),* 6-28.

Gałecki, A., & Burzykowski, Tomasz. (2013). *Linear mixed-effects models using R : A step-by-step approach* (Springer texts in statistics). New York, NY: Springer.

Geangu, E., Hauf, P., Bhardwaj, R., & Bentz, W. (2011). Infant pupil diameter changes in response to others' positive and negative emotions. *PLoS ONE, 6(11),* e27132.

Giesbrecht, F., & Burns, J. (1985). Two-Stage Analysis Based on a Mixed Model: Large-Sample Asymptotic Theory and Small-Sample Simulation Results. *Biometrics, 41(2),* 477-486.

Gjini, K., Burroughs, S., & Boutros, N. N. (2011). Relevance of attention in auditory sensory gating paradigms in schizophrenia: A pilot study. *Journal of Psychophysiology, 25*, 60-66. doi: 10.1027/0269-8803/a000042

Gooding, D. C., Tallent, K. A., & Matts, C. W. (2005). Clinical status of at-risk individuals 5 years later: further validation of the psychometric high-risk strategy. *Journal of Abnormal Psychology, 114,* 170-175.

Goodman, S., Gotlib, I., & Bjork, R. A. (1999). Risk for Psychopathology in the Children of Depressed Mothers: A Developmental Model for Understanding Mechanisms of Transmission. *Psychological Review,106(3),* 458-490.

Gottesman, I. I., & Gould, T. D. (2003). The endophenotype concept in psychiatry: etymology and strategic intentions. *American Journal of Psychiatry,160,* 636–45.

Gottesman, I. I., & Shields, J. (1982). *Schizophrenia,the epigenetic puzzle.* Cambridge: Cambridge University Press.

Gottesman, I. I., Laursen, T. M., Bertelsen, A., & Mortensen, P. B. (2010). Severe mental disorders in offspring with 2 psychiatrically ill parents. *Archives of General Psychiatry, 67,* 252–257.

Goulding, A. (2004). Schizotypy models in relation to subjective health and paranormal beliefs and experiences. *Personality and Individual Differences, 37(1),* 157-167.

Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Parkkonen, L.,& Hämäläinen, M. S. (2014). MNE software for processing MEG and EEG data. *NeuroImage, 86*, 446-460.

Grossmann, T., & Albarracín, D. (2015). The Development of Social Brain Functions in Infancy. *Psychological Bulletin, 141(6),* 1266-1287.

Gruzelier, J., Burgess, A., Stygall, J., Irving, G., Raine, A. (1995). Patterns of cerebral asymmetry and syndromes of schizotypal personality. *Psychiatry Research, 56,* 71–79.

Gur, R. E., Calkins, M. E., Gur, R. C., et al. (2007). The Consortium on the Genetics of Schizophrenia: neurocognitive endophenotypes. *Schizophrenia Bulletin, 33*, 49–68.

Gur, R. E., Nimgaonkar, V. L., Almasy, L., Calkins, M. E., et al. (2007b). Neurocognitive endophenotypes in a multiplex multigenerational family study of schizophrenia. *American Journal of Psychiatry, 164,* 813–819.

Gurrera, R., Nestor, P., & O'Donnell, B. (2000). Personality traits in schizophrenia: Comparison with a community sample. *The Journal of Nervous and Mental Disease, 188(1),* 31-5.

Guttentag, C. L., Landry, S. H., Williams, J. M., Baggett, K. M., Noria, C.W., Borkowski, J. G., & Ramey, S. L. (2014). “My Baby & Me”: Effects of an early, comprehensive parenting intervention on at-risk mothers and their children. *Developmental Psychology, 50*, 1482–1496. doi: 10.1037/a0035682.

Haenschel, C., Baldeweg, T., Croft, R. J., Whittington, M, & Gruzelier, J. (2000). Gamma and beta frequency oscillations in response to novel auditory stimuli: a comparison of human electroencephalogram (EEG) data with in vitro models. *Proceedings of the National Academy of Sciences of the United States of America, 97,* 7645-7650.

Hall, M. H., Taylor, G., Dalisbury, D. F., & Levy, D. L. (2011). Sensory gating event-related potentials and oscillations in schizophrenia patients and their unaffected relatives. *Schizophrenia Bulletin, 37,* 1187-1199.

Hane, A., & Fox, N. (2006). Ordinary Variations in Maternal Caregiving Influence Human Infants' Stress Reactivity. *Psychological Science, 17(6),* 550-556.

Hane, A., Henderson, H., Reeb-Sutherland, B., & Fox, N. (2010). Ordinary variations in human maternal caregiving in infancy and biobehavioral development in early childhood: A follow-up study. *Developmental Psychobiology, 52(6),* 558-567.

Hengartner, M.P., & Lehmann, S.N. (2017). Why psychiatric research must abandon traditional diagnostic classification and adopt a fully dimensional scope: Two solutions to a persistent problem. *Frontiers in Psychiatry, 8,* 101.

Heron, J., Jones, I., Williams, J., Owen, M. J., Craddock, N., & Jones, L. A. (2003). Self-reported schizotypy and bipolar disorder: demonstration of a lack of specificity of the Kings Schizotypy Questionnaire. *Schizophrenia Research, 65*, 153-158.

Himberg, J., & Hyvarinen, A. (2003). Icasso: Software for investigating the reliability of ICA estimates by clustering and visualization. Neural Networks for Signal Processing. NNSP'03. 2003 IEEE 13th Workshop on, 2003, 259-268.

Hoehl, S., & Wahl, S. (2012). Recording Infant ERP Data for Cognitive Research. *Developmental Neuropsychology, 37(3),* 187-209.

Hoehl, S., Wiese, L., & Striano, T. (2008). Young infants' neural processing of objects is affected by eye gaze direction and emotional expression. *PLoS ONE, 3*, e2389. doi:10.1371/journal.pone.0002389

Hong, L., Buchanan, R., Thaker, G., Shepard, P., & Summerfelt, A. (2008). Beta (~16 Hz) frequency neural oscillations mediate auditory sensory gating in humans. *Psychophysiology, 45(2),* 197-204.

Hong, L. E., Summerfelt, A., McMahon, R., et al. (2004b). Evoked gamma band synchronization and the liability for schizophrenia. *Schizophrenia Research, 70,* 293–302.

Hong, L. E., Summerfelt, A., McMahon, R. P., Thaker, G. K., & Buchanan, R. W. (2004a). Gamma/beta oscillation and sensory gating deficit in schizophrenia. *Neuroreport, 15,* 155–9.

Horan, W. P., Reise, S. P., Subotnik, K. L., Ventura, J., & Nuechterlain, K. H. (2008). The validity of psychosis proneness scales as vulnerability indicators in recent-onset schizophrenia patients. *Schizophrenia Research, 100(1-3),* 224-236.

Hunter, S.K., Gillow, S.J., & Ross, R.G. (2015). Stability of P50 auditory sensory gating during sleep from infancy to 4 years of age. *Brain and Cognition, 94,* 4-9. doi: 10.1016/j.bandc.2014.12.004

Hutchison, A., Hunter, S., Wagner, B., Calvin, E., Zerbe, G., & Ross, R. (2017). Diminished Infant P50 Sensory Gating Predicts Increased 40-Month-Old Attention, Anxiety/Depression, and Externalizing Symptoms. *Journal of Attention Disorders, 21(3),* 209-218.

Huttenlocher, P. R. (2002). *Neural plasticity: The effects of environment on the development of the cerebral cortex.* Harvard University Press; Cambridge, MA.

Itier, R.J., & Taylor, M.J. (2002). Inversion and contrast reversal affect both encoding and recognition of faces: a repetition study using ERPs. *Neuroimage, 15*, 353–372.

Jeong, J. W., Wendimagegn, T. W., Chang, E., Chun, Y., Park, J. H., Kim, H. J., & Kim, H. T. (2017). Classifying Schizotypy Using an Audiovisual Emotion Perception Test and Scalp Electroencephalography. *Frontiers in human neuroscience*, *11*, 450. doi:10.3389/fnhum.2017.00450

Jeste, S., Frohlich, J., & Loo, S. (2015). Electrophysiological biomarkers of diagnosis and outcome in neurodevelopmental disorders. *Current Opinion in Neurology, 28(2),* 110-116.

Johannesen, J. K., Kieffaber, P. D., O'Donnell, B. F., Shekhar, A., Evans, J. D., & Hetrick, W. P. (2005). Contributions of subtype and spectral frequency analyses to the study of P50 ERP amplitude and suppression in schizophrenia. *Schizophrenia Research, 78,* 269-284.

Jones, E., Venema, K., Lowy, R., Earl, R., & Webb, S. (2015). Developmental changes in infant brain activity during naturalistic social experiences. *Developmental Psychobiology, 57(7),* 842-853.

Jones, L. A., Hills, P. J., Dick, K. M., Jones, S. P., & Bright, P. (2016). Cognitive mechanisms associated with auditory sensory gating. *Brain and Cognition, 102*, 33-45.

Jones, N., Field, A., Davalos, T., & Pickens, M. (1997). EEG Stability in Infants/Children of Depressed Mothers. *Child Psychiatry and Human Development, 28(2),* 59-70.

Jones, R., Slade, P., Pascalis, O., & Herbert, J. S. (2013). Infant interest in their mother's face is associated with maternal psychological health. *Infant Behavior and Development, 36(4),* 686–693.

Juth, P., Lundgvist, D., Karlsson, A., & Ohman, A. (2005). Lookinf for foes and friends: perceptual and emotional factors when finding a face in the crowd. *Emotion, 5(4),* 379-395.

Kaduk, K., Elsner, B., & Reid, V. M. (2013). Discrimination of animate and inanimate motion in 9-month-old infants: An ERP study. *Developmental Cognitive Neuroscience, 6,* 14-22.

Kaitz, M., Maytal, H. R., Devor, N., Bergman, L., & Mankuta, D. (2010). Maternal anxiety, mother–infant interactions, and infants' response to challenge. *Infant Behavior and Development, 33(2),* 136-148.

Kappenman, E. S., & Luck, S. J. (2010). The effects of electrode impedance on data quality and statistical significance in ERP recordings. *Psychophysiology, 47(5),* 888-904.

Kelleher, I., Keeley, H., Corcoran, P., Ramsay, H., Wasserman, C., Carli, V., Sarchiapone, M., Hoven, C., Wasserman, D., & Cannon, M. (2013). Childhood trauma and psychosis in a prospective cohort study: cause, effect, and directionality. *American Journal of Psychiatry, 170*, 734-741.

Kendler, K.S., & Diehl, S.R. (1993). The genetics of schizophrenia: a current, genetic-epidemiologic perspective. *Schizophrenia Bulletin, 19*, 261–285.

Kerns, J., & Watson, D. (2006). Schizotypy Facets, Cognitive Control, and Emotion. *Journal of Abnormal Psychology, 115(3),* 418-427.

Keshavan, M., Montrose, D.M., Rajarethinam, R., Diwadkar, V., Prasad, K., & Sweeney, J.A. (2008). Psychopathology among offspring of parents with schizophrenia: Relationship to premorbid impairments. *Schizophrenia Research, 103(1-3),* 114-120. doi: 10.1016/j.schres.2008.03.006

Kirkbride, J., Coid, J., Morgan, C., Fearon, P., Dazzan, P., Yang, M., Lloyd, T., Harrison, G., Murray, R., & Jones, P. (2010). Translating the epidemiology of psychosis into public mental health: Evidence, challenges and future prospects. *Journal of Public Mental Health, 9(2),* 4-14.

Kisley, M. A., & Cornwell, Z. M. (2006). Gamma and beta neural activity evoked during a sensory gating paradigm: Effects of auditory, somatosensory and cross-modal stimulation. *Clinical Neurophysiology, 117(11),* 2549-2563.

Kisley, M. A., Noecker, T. L., & Guinther, P. M. (2004). Comparison of sensory gating to mismatch negativity and self-reported perceptual phenomena in healthy adults. *Psychophysiology, 41(4),* 604-12.

Kisley, M. A., Polk, S. D., Ross, R. G., Levisohn, P. M., & Freedman, R. (2003). Early postnatal development of sensory gating. *Neuroreport, 14,* 693-697.

Kjaer, T. W., Sorensen, H., Groenborg, S., Pedersen, C. R., & Duun-Henriksen, J. (2017). Detection of Paroxysms in Long-Term, Single-Channel EEG-Monitoring of Patients with Typical Absence Seizures. *IEEE journal of translational engineering in health and medicine, 5,* 2000108. doi:10.1109/JTEHM.2017.2649491

Klimesche, W. (1999). EEG alpha and theta oscillation reflect cognitive and memory performance: a review and analysis. *Brain Research Reviews, 29,* 169-195.

Knight, R. T., Scabini, D., & Woods, D. L. (1989). Prefrontal cortex gating of auditory transmission in humans. *Brain Research, 504*, 338-342. doi: 10.1016/0006-8993(89)91381-4

Kobiella, A., Grossmann, T., Reid, V., & Striano, T. (2008). The discrimination of angry and fearful facial expressions in 7-month-old infants: An event-related potential study. *Cognition & Emotion, 22(1),* 134-146.

Kochanska, G. (2001). Emotional development in children with different attachment histories: the first three years. *Child Development, 72(2),* 474-490.

Kochanska, G., Kim, S., Boldt, L., & Nordling, J. (2013). Promoting Toddlers' Positive Social-Emotional Outcomes in Low-Income Families: A Play-Based Experimental Study. *Journal of Clinical Child & Adolescent Psychology, 42(5)*, 700-712.

Kohler, C., Walker, J., Martin, E., Healey, K., & Moberg, P. (2010). Facial Emotion Perception in Schizophrenia: A Meta-analytic Review. *Schizophrenia Bulletin, 36(5),* 1009-1019.

Kohler, C.G., Turner, T.H., Bilker, W.B., Brensinger, C.M., Siegel, S.J., Kanes, S.J., Gur, R.E., & Gur, R.C. (2003). Facial emotion recognition in schizophrenia: intensity effects and error pattern. *American Journal of Psychiatry, 160(10),* 1768–1774.

Kolb, B., Mychasiuk, R., Muhammad, A., Li, Y., Frost, D., & Gibb, R. (2012). Experience and the developing prefrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America, 109(Suppl 2),* 17186-93.

Kopell, N., Ermentrout, G. B., Whittington, M. A., & Traub, R. D. (2000). Gamma rhythms and beta rhythms have different synchronization properties. *Proceedings of the National Academy of Sciences, USA, 97*, 1867–1872.

Korfine, L., & Lenzenweger, M.F. (1995). The taxonicity of schizotypy: a replication. *Journal of Abnormal Psychology, 104(1*), 26–31.

Korzyukov, O., Pflieger, M. E., Wagner, M., Bowyer, S. M., Rosburg, T., Sundaresan, K., Elger, C. E., Boutros, N. N. (2007). Generators of the intracranial P50 response in auditory sensory gating. *NeuroImage, 35(2),* 814-826.

Kosmidis, M. H., Bozikas, V. P., Giannakou, M., Anezoulaki, D., Fantie, B. D., & Karavatos, A. (2007). Impaired emotion perception in schizophrenia: a differential deficit. *Psychiatry Research, 149*, 279–284.

Kotov, R., Krueger, R.F., Watson, D., Achenbach, T.M., Althoff, R.R., Bagby, M., … & Zimmerman, M. (2017). The Hierarchical Taxonomy of Psychopathology (HiTOP): A dimensional alternative to traditional nosologies. *Journal of Abnormal Psychology, 126,* 454–477.

Kotsoni, E., de Haan, M., & Johnson, M.H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30*, 1115–1125.

Krueger, R. F., & Tackett, J. L. (2003). Personality and Psychopathology: Working Toward the Bigger Picture. *Journal of Personality Disorders, 17(2),* 109-128.

Krzeczkowski, J. E., & Van Lieshout, R. J. (2018). Prenatal influences on the development and stability of personality. *New Ideas in Psychology*.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). LmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software,82(1),* 1-26.

Kwapil, T. R., & Barrantes-Vidal, N. (2012). Schizotypal personality disorder: an integrative review, in T.A. Widiger (Ed.), *The Oxford Handbook of Personality Disorders*, Oxford University Press, New York, NY (2012), pp. 437-477.

Kwapil, T. R., & Barrantes-Vidal, N. (2014). Schizotypy: looking back and moving forward. *Schizophrenia Bulletin, 41(Suppl 2),* S366-373. Doi: 10.1093/schbul/sbu186.

Kwapil, T. R., Barrantes-Vidal, N., & Silvia, P. J. (2008). The dimensional structure of the Wisconsin Schizotypy Scales: factor identification and construct validity. *Schizophrenia Bulletin, 34,* 444-457.

Kwapil, T. R., Gross, G. M., Silvia, P. J., & Barrantes-Vidal, N. (2013). Prediction of psychopathology and functional impairment by positive and negative schizotypy in the Chapmans' ten-year longitudinal study. *Journal of Abnormal Psychology, 122(3),* 807-815.

Kıymık, M. K., Güler, I., Dizibüyük, A., & Akın, M. (2005). Comparison of STFT and wavelet transform methods in determining epileptic seizure activity in EEG signals for real-time application. *Computers in Biology and Medicine, 35(7),* 603-616.

Lachat, F., Hugueville, L., Lemaréchal, J., Conty, L., & George, N. (2012). Oscillatory Brain Correlates of Live Joint Attention: A Dual-EEG Study. *Frontiers in Human Neuroscience, 6,* 156.

Lataster, J., Myin-Germeys, I., Lieb, R., Wittichen, H. U., van Os, J. (2012). Adversity and psychosis: A 10-year prospective study investigating synergism between early and recent adversity in psychosis. *Acta Psychiatrica Scandinavia, 125*, 388-399.

Lee, K.H., Williams, L.M., Haig, A., & Gordon, E. (2003). "Gamma (40 Hz) phase synchronicity" and symptom dimensions in schizophrenia. *Cognitive Neuropsychiatry, 8,* 57–71.

Lei, X., & Liao, K. (2017). Understanding the Influences of EEG Reference: A Large-Scale Brain Network Perspective. *Frontiers in Neuroscience, 11*, 205.

Leicht, G., Kirsch, V., Giegling, I., Karch, S., Hantschk, I., Möller, H-J., Pogarell, O., Hegerl, U., Rujescu, D., & Mulert, C. (2010). Reduced Early Auditory Evoked Gamma-Band Response in Patients with Schizophrenia. *Biological Psychiatry, 67(3),* 224-231.

Lenzenweger, M. (2018a). Schizotypy, schizotypic psychopathology and schizophrenia. *World Psychiatry,17(1),* 25-26.

Lenzenweger, M.F. (1994). Psychometric high-risk paradigm, perceptual aberrations, and schizotypy: an update. *Schizophrenia Bulletin, 20(1),* 121–135.

Lenzenweger, M.F. (2006). Schizotypy: an organizing framework for schizophrenia research. *Current Directions in Psychological Science, 15(4),* 162–166.

Lenzenweger, M. F. (2011). *Schizotypy and Schizophrenia: The View from Experimental Psychopathology*. New York: Guildford Press.

Lenzenweger, M. F. (2018b). Schizotypy, Schizotypic Psychopathology, and Schizophrenia: Hearing Echoes, Leveraging Prior Advances, and Probing New Angles. *Schizophrenia Bulletin, 44(2)*, S564–S569.

Lenzenweger, M. F., & Dworkin, R. H. (1996). The dimensions of schizophrenia phenomenology: not one or two, at least three, perhaps four. *British Journal of Psychiatry, 168,* 432-440.

Leong, V., Byrne, E., Clackson, K., Georgieva, S., Lam, S., & Wass, S. (2017). Speaker gaze increases information coupling between infant and adult brains. *Proceedings of the National Academy of Sciences of the United States of America, 114(50),* 13290-13295.

Leppänen, J. (2011). Neural and Developmental Bases of the Ability to Recognize Social Signals of Emotions. *Emotion Review, 3(2),* 179-188.

Leppänen, J., & Hietanen, J. (2003). Affect and Face Perception: Odors Modulate the Recognition Advantage of Happy Faces. *Emotion, 3(4),* 315-326.

Leppänen, J. M. (2011). Neural and developmental bases of the ability to recognize social signals of emotions. *Emotion Review, 3,* 179–188.

Leppänen, J. M., & Nelson, C. A. (2008). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience, 10(1),* 37-47.

Leppänen, J. M., Moulson, M. C., Vogel-Farley, V. K., & Nelson, C. A. (2007). An ERP study of emotional face processing in the adult and infant brain. *Child Development, 78,* 232–245.

Li, H., Chan, R., McAlonan, G., & Gong, Q. (2010). Facial Emotion Processing in Schizophrenia: A Meta-analysis of Functional Neuroimaging Data. *Schizophrenia Bulletin, 36(5)*, 1029-1039.

Liddle, P. F. (1987). The symptoms of chronic schizophrenia. A re-examination of the positive-negative dichotomy. *The British Journal of Psychiatry, 151,* 145-151. doi: 10.1192/bjp.151.2.145.

Light, G. A., & Braff, D. L. (2000). Do self-reports of perceptual anomalies reflect gating deficits in schizophrenia patients? *Biological Psychiatry, 47(5),* 463-467.

Lijffijt, M., Lane, S.D., Meier, S.L., Boutros, N.N., Burroughs, S., Steinberg, J.L., & Swann, A.C. (2009). P50, N100, and P200 sensory gating: Relationships with behavioral inhibition,

attention, and working memory. *Psychophysiology, 46,* 1059-1068. doi: 10.1111/j.1469-8986.2009.00845.x

Lin, A., Wigman, J. T. W., Nelson, B., Wood, S. J., Vollebergh, W. A. M., Van Os, J., & Yung, A. R. (2013). Follow-up factor structure of schizotypy and its clinical associations in a help-seeking sample meeting ultra-high risk for psychosis criteria at baseline. *Comprehensive Psychiatry, 54(2),* 173-180.

Lin, C-H., Huang, C-L., Chang, Y-C., Chen, P-W., Lin, C-Y., Tsai, G. E., & Lane, H-Y. (2013). Clinical symptoms, mainly negative symptoms, mediate the influence of neurocognition and social cognition on functional outcome of schizophrenia. *Schizophrenia Research,146(1-3),* 231-237.

Linscott, R.J., & van Os, J. (2010). Categorical versus continuum models in psychosis: evidence for discontinuous subpopulations underlying a psychometric continuum. Implications for DSM-V, DSM-VI, and DSM-VII. *Annual Review of Clinical Psychology, 6,* 391–419.

Liu, T., Xiao, T., Shi, J., & Zhao, L. (2011). Sensory gating, inhibition control and child intelligence. AN event-related potentials study. *Neuroscience, 189*, 250-257. doi: 10.1016/j.neuroscience.2011.05.009

Luby, J., Nishino, T., Babb, C., Harms, M. P., Marrus, N., Botteron, K., Belden, A., & Barch, D. (2014). The effects of poverty on childhood brain development: The mediating effect of caregiving and stressful life events. (Report). *JAMA Pediatrics,167(12),* 1135-11342.

Luck, S. J., Mathalon, D. H., O'Donnell, B. F., Hämäläinen, M. S., Spencer, K. M., Javitt, D. C., & Uhlhaas, P. J. (2011). A roadmap for the development and validation of event-related potential biomarkers in schizophrenia research. *Biological Psychiatry, 70*, 28-34.

Lupien, S. J., Parent, S., Evans, A. C., Tremblay, R. E., Zelazo, P. D., Corbo, V., & Séguin, J. R. (2011). Larger amygdala but no change in hippocampal volume in 10-year-old children exposed to maternal depressive symptomatology since birth. *Proceedings of the National Academy of Sciences, 108(34)*, 14324–14329. doi: 10.1073/pnas.1105371108.

Lusby, C., Goodman, S., Bell, M., & Newport, D. (2014). Electroencephalogram patterns in infants of depressed mothers. *Developmental Psychobiology, 56(3),* 459-473.

Marshall, P., Reeb, B., Fox, N., Nelson, C., & Zeanah, C. (2008). Effects of early intervention on EEG power and coherence in previously institutionalized children in Romania. *Development and Psychopathology, 20(3),* 861-880.

Mason, O., & Claridge, G. (2006). The Oxford-Liverpool inventory of feelings and experiences: further description and extended norms. *Schizophrenia Research, 82(2),* 203-211.

Mason, O., Claridge, G., & Clark, K. (1997). Electrodermal relationships with personality measures of psychosis-proneness in psychotic and normal subjects. *International Journal of Psychophysiology, 27(2)*, 137-146.

Mason, O., Claridge, G., & Jackson, M. (1995). New scales for the assessment of schizotypy. *Personality and Individual Differences, 18(1),* 7-13.

Mason, O., Claridge, G., & Jackson, M. (1996). New scales for the assessment of schizotypy. *Personality and Individual Differences, 18(1),* 7-13.

Mason, O., Linney, Y., & Claridge, G. (2005). Short scales for measuring schizotypy. Schizophrenia Research, 78(2), 293-296. doi: 10.1016/j.schres.2005.06.020.

Mason, O. J. (2014). The Duality of Schizotypy: Is it both dimensional and categorical? *Frontiers in Psychiatry, 5,* 134.

Matijasevich, A., Murray, J., Cooper, P. J., Anselmi, L., Barros, A. J. D., Barros, F. C., & Santos, I. S. (2015). Trajectories of maternal depression and offspring psychopathology at 6 years: 2004 Pelotas cohort study. *Journal of Affective Disorders, 174*, 424-431.

McCleery, A., Divilbiss, M., St-Hilaire, A., Aakre, J. M., Seghers, J. P., Bell, E. K., & Docherty, N. M. (2012). Predicting social functioning in schizotypy: an investigation of the relative contributions of theory of mind and mood. *Journal of Nervous and Mental Disease, 200(2*), 147-152.

McElwain, N., Booth-LaForce, C., & Kazak, A. E. (2006). Maternal Sensitivity to Infant Distress and Nondistress as Predictors of Infant-Mother Attachment Security. *Journal of Family Psychology, 20(2)*, 247-255.

McLaughlin, K. A., Gadermann, A. M., Hwang, I., Sampson, N. A., Al-Hamzawi, A., Andrade, L. H., Angermeyer, M .C., Benjet, C., Bromet, E. J., Burffaerts, R., Caldas-de-Almeida, J. M., de Girolamo, G., Graaf, R., Florescu, S., Gureje, O., Haro, J. M., Hinkov, H. R., Horiguchi, I., Hu, C., Karam, A. N., Kovess-Masfety, V., Lee, S., Murohy, S. D., Nizamie, S. H., Posada-Villa, J., Williams, D. R., & Kessler, R. C. (2012). Parent psychopathology an doffspring mental disorders:results from the WHO World Mental Health Surveys. *The British Journal of Psychiatry, 200*, 290-299.

Mears, R. P., Klein, A. C., & Cromwell, H. C. (2006). Auditory inhibitory gating in medical prefontal cortex: Single unit and local field potential analysis. *Neuroscience, 141*, 47-65. doi: 10.1016/j.neuroscience.2006.03.040

Meehl, P. (1962). Schizotaxia, schizotypia, schizophrenia. *American Psychologist, 17*, 827–838.

Meehl, P.E. (1990). Toward an integrated theory of schizotaxia, schizotypy, and schizophrenia. *Journal of Personality Disorders, 4(1),* 1–99.

Meins, E. (1997), Security of attachment and maternal tutoring strategies: Interaction within the zone of proximal development. *British Journal of Developmental Psychology, 15*, 129-144.

Meins, E., Fernyhough, C., Fradley, E., & Tuckey, M. (2001). Rethinking Maternal Sensitivity: Mothers' Comments on Infants' Mental Processes Predict Security of Attachment at 12 Months. *Journal of Child Psychology and Psychiatry, 42(5),* 637-648.

Meins, E., Fernyhough, C., Russell, J., & Clark-Carter, D. (1998). Security of Attachment as a Predictor of Symbolic and Mentalising Abilities: A Longitudinal Study. *Social Development, 7(1),* 1-24.

Meins, E. , Fernyhough, C. , Wainwright, R. , Clark-Carter, D. , Das Gupta, M. , Fradley, E. and Tuckey, M. (2003), Pathways to Understanding Mind: Construct Validity and Predictive Validity of Maternal Mind-Mindedness. *Child Development, 74*, 1194-1211. doi:10.1111/1467-8624.00601

Mendoza, R., Cabral-Calderin, Y., Domínguez, M., Garcia, A., Borrego, M., Caballero, A., Guerra, S., & Reyes, M. M. (2011). Impairment of emotional expression recognition in schizophrenia: A Cuban familial association study. *Psychiatry Research, 185(1)*, 44-48.

Miller, M. B., Chapman, J. P., Chapman, L. J., & Collins, J. (1995). Task difficulty and cognitive deficits in schizophrenia. *Journal of Abnormal Psychology, 104(2),* 251–258.

Modinos, G., Mechelli, A., Ormel, J., Groenewold, N., Aleman, A., & McGuire, P. (2010). Schizotypy and brain structure: a voxel-based morphometry study. *Psychological Medicine, 4,* 1423-1431.

Mohanty, A., Herrington, J. D., Koven, N. S., Fisher, J. E., Wenzel, E. A., Webb, A, G., & Heller, W. (2005). Neural Mechanisms of Affective Interference in Schizotypy. *Journal of Abnormal Psychology, 114(1),* 16–27.

Montague, D. P. F., & Walker-Andrews, A. S. (2002). Mothers, Fathers, and Infants: The Role of Person Familiarity and Parental Involvement in Infants' Perception of Emotion Expressions. *Child Development,73(5),* 1339-52.

Morris, R.W., Weickert, C.S., & Loughland, C. (2009). Emotional face processing in schizophrenia. *Current Opinions in Psychiatry, 22*, 140–146.

Morrison, S. C., Brown, L. A., & Cohen, A. S. (2013). A multidimensional assessment of social cognition in psychometrically defined schizotypy. *Psychiatry Research, 210,* 1014-1019.

Mortensen, P. B, Pedersen, M. G, & Pedersen, C. B. (2010). Psychiatric family history and schizophrenia risk in Denmark: Which mental disorders are relevant? *Psychological Medicine, 40(2),* 201-210.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: A two-process theory of infant face recognition. *Psychological Review, 98(2),* 164.

Muller, M. M., Keil, A., Kissler, J., & Gruber, T. (2001). Suppression of the auditory middle-latency response and evoked gamma-band response in a paired-click paradigm. *Experimental Brain Research, 136*, 474-479.

Murray, L., Creswell, C., & Cooper, P. (2009). The development of anxiety disorders in childhood: An integrative review. *Psychological Medicine, 39(9),* 1413-1423.

Nelson, C.A. (1994). Neural correlates of recognition memory in the first postnatal year of life. In: Dawson, G., Fischer, K. (Eds.), *Human Behavior and the Developing Brain*. Guilford Press, New York, pp. 269–313.

Nelson, C. A. (2000). The effects of early adversity on neurobehavioral development. The Minnesota Symposia on Child Psychology, 31. *Journal of Developmental and Behavioural Pediatrics, 23(2).*

Nelson, C. A. (2001). The development and neural bases of face recognition. *Infant and Child Development, 10(1–2),* 3–18.

Nelson, C.A., & de Haan, M. (1996). Neural correlates of visual responsiveness to facial expressions of emotion. *Developmental Psychobiology, 29,* 1–18.

Nelson, M. T., Seal, M. L., Pantelis, C., & Phillips, L. J. (2013). Evidence of a dimensional relationship between schizotypy and schizophrenia: a systematic review. *Neuroscience and Biobehavioual Reviews, 37(3),* 317-327.

Nestor, P. G., Faux, S. F., McCarley, R. W., Shenton, M. E., & Sands, S. F. (1990). Measurement of visual sustained attention in schizophrenia using signal detection analysis and a newly developed computerized CPT task. *Schizophrenia Research, 3,* 329-332, doi: 10.1016/0920-9964(90)90018-3

Nivard, M. G., Dolan, C. V., Kendler, K. S., Kan, K. J., Willemsen, G., van Beijsterveldt, C. E. M., et al. (2015). Stability in symptoms of anxiety and depression as a function of genotype and environment: A longitudinal twin study from ages 3 to 63 years. *Psychological Medicine, 45*, 1039–1049.

Novic, J., Luchins, D. J., & Perline, R. (1984). Facial affect recognition in schizophrenia. Is there a differential deficit? *British Journal of Psychiatry, 144(5),* 533-537.

Onitsuka, T., Oribe, N., Nakamura, I., & Kanba, S. (2013). Review of neurophysiological findings in patients with schizophrenia. *Psychiatry and Clinical Neurosciences, 67(7),* 461-470.

Orekhova, E. V., Stroganova, T. A., Posikera, I. N., & Elam, M. (2006). EEG theta rhythm in infants and preschool children. *Clinical Neurophysiology, 117(5),* 1047-1062.

Owens, E. M., Bachman, P., Glahn, D. C., & Bearden, C. E. (2016). Electrophysiological endophenotypes for schizophrenia. *Harvard Review of Psychiatry, 24(2),* 129-147.

Pallini, S., Baiocco, R., Schneider, B., Madigan, S., Atkinson, L., & Kaslow, N. J. (2014). Early Child–Parent Attachment and Peer Relations: A Meta-Analysis of Recent Research. *Journal of Family Psychology, 28(1),* 118-123.

Papousek, I., Weiss, E. M., Mosbacher, J. A., Reiser, E. M., Schulter, G., & Fink, A. (2014). Affective processing in positive schizotypy: Loose control of social-emotional information. *Brain and Cognition, 92*, 84-91. doi: 10.1016/j.bandc.2014.10.008

Parise, E., Csibra, G., & Becchio, C. (2013). Neural Responses to Multimodal Ostensive Signals in 5-Month-Old Infants. *PLoS ONE, 8(8),* E72360.

Park, H.R., Lim, V.K., Kirk, I.J., & Waldie, K.E. (2015). P50 sensory gating deficits in schizotypy. *Personality and Individual Differences, 82*, 142-147. doi: 10.1016/j.paid.2015.03.025.

Pascalis, O., de Haan, M., Nelson, C.A., de Schonen, S. (1998). Long-term recognition memory for faces assessed by visual paired comparison in 3- and 6-month-old infants. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 249–260.

Patterson, J. V., Hetrick, W. P., Boutross, N. N., et al. (2008). P50 sesnory gating ratios in schizophrenics and controls: a review and data analysis. *Psychiatry Research, 158*, 226-247.

Peltola M. J., Leppänen J. M., Mäki S., Hietanen J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive and Affective Neuroscience, 4,* 134–142.

Perez, V. B., Roach, B. J., Woods, S. W., Srihari, V. H., McGlashan, T. H., Ford, J. M., & Mathalon, D. H. (2013). Early auditory gamma-band responses in patients at clinical high-risk for schizophrenia. *Supplements to Clinical Neurophysiology, 62*, 147-162.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*, 73–89. Doi: 10.1146/annurev-neuro-062111-150525.

Phillips, D. I. W. (2007). Programming of the stress response: a fundamental mechanism underlying the long-term effects of the fetal environment? *Journal of Internal Medicine, 261(5),* 453–460.

Phillips, L. J., Francey, S. M., Edwards, J., McMurray, N. (2007). Stress and psychosis: towards the development of new models of investigation. *Clinical Psychology Review, 27*, 307–317.

Pinheiro, A. P., Del Re, E., Mezin, J., Nestor, P. G., Rauber, A., McCarley, R. W., et al. (2013). Sensory-based and higher-order operations contribute to abnormal emotional prosody processing in schizophrenia: an electrophysiological investigation. *Psychological Medicine, 43*, 603–618.

Pinkham, A., Penn, D., Perkins, D., Graham, K., & Siegel, M. (2007). Emotion perception and social skill over the course of psychosis: A comparison of individuals “at-risk” for psychosis and individuals with early and chronic schizophrenia spectrum illness. *Cognitive Neuropsychiatry, 12(3)*, 198-212.

Pinkham, A. E., Penn, D. L., Perkins, D. O., & Lieberman, J. (2003). Implications for the neural basis of social cognition for the study of schizophrenia. *American Journal of Pschiatry, 160(5),* 815-24.

Pollak, S. D., Messner, M., Kistler, D. J., & Cohn, J. F. (2009). Development of perceptual expertise in emotion recognition. *Cognition, 110,* 242–247.

Ponizovsky, A.M., Nechamkin, Y., & Rosca, P. (2007). Attachment patterns are associated with symptomatology and course of schizophrenia in male inpatients. *American Journal of Orthopsychiatry, 77,* 324–331.

Pontifex, M. B., Gwizdala, K. L., Parks, A. C., Billinger, M., & Brunner, C. (2017). Variability of ICA decomposition may impact EEG signals when used to remove eyeblink artifacts. *Psychophysiology, 54(3),* 386-398.

Poobalan, A., Aucott, L., Ross, L., Smith, W., Helms, P., & Williams, J. (2007). Effects of treating postnatal depression on mother-infant interaction and child development. *British Journal of Psychiatry, 191*, 378–386.

Popov, T., Jordanov, T., Rockstroh, B., Elbert, T., Merzenich, M. M., & Miller, G. A. (2011). Specific Cognitive Training Normalizes Auditory Sensory Gating in Schizophrenia: A Randomized Trial. *Biological Psychiatry, 69(5),* 465-471.

Posner, M. I. (2004). *Cognitive Neuroscience of Attention.* Guildford Press, New York: NY.

Premkumar, P., Onwumere, J., Albert, J., Kessel, D., Kumari, V., Kuipers, E., et al. (2015). The relation between schizotypy and early attention to rejecting interactions: the influence of neuroticism. *World Journal of Biological Psychiatry, 16(8)*, 587-601.

Premkumar, P., Onwumere, J., Wilson, D., Sumich, A., Castro, A., Kumari, V., et al. (2014). Greater positive schizotypy relates yo reduced N100 activity during rejection scenes. *Neuropsychologia, 61,* 280-290.

Prinzie, P., Stams, G. J., Dekovic, M., Reigntjes, A. H., & Belsky, J. (2009). The relations between parents' Big Five personality factors and parenting: A meta-analytic review. *Journal of Personality and Social Psychology, 97,* 351–362.

Quitadamo, L. R., Foley, E., Mai, R., De Palma, L., Specchio, N., & Seri, S. (2018). EPINETLAB: a software for seizure-onset zone identification from intracranial EEG signal in epilepsy. *Frontiers in Neuroinformatics, 12.*

Rado, S. (1953). Dynamics and classification of disordered behaviour. *American Journal of Psychiatry, 110,* 406-16.

Raine, A. (1991). The SPQ: a scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophrenia Bulletin, 17,* 555–564.

Raine, A. (2006). Schizotypal personality: Neurodevelopmental and psychosocial trajectories. *Annual Review of Clinical Psychology, 2,* 291-326.

Raine, A., & Benishay, D. (1995). The SPQ-B: a brief screening instrument for schizotypal personality disorder. *Journal of Personality Disorders, 9(4),* 346–355.

Raine A. (2006). Schizotypal personality: neurodevelopmental and psychosocial trajectories. *Annual Reviews of Clinical Psychology, 2*, 291–326.

Ramos-Loyo, J., Gonzalez-Garrido, A.A., Sanchez-Loyo, L.M., Medina, V., Basar-Eroglu, C. (2009). Event-related potentials and event-related oscillations during identity and facial emotional processing in schizophrenia. *International Journal of Psychophysiology, 71,* 84–90.

Rawlings, D., & Locarnini, A. (2008a). Dimensional schizotypy, autism, and unusual word associations in artists and scientists. *Journal of Research in Personality, 42(2),* 465–471.

Rawlings, D., Williams, B., Haslam, N., & Claridge, G. (2008b). Is schizotypy taxonic? Response to Beauchaine, Lenzenweger, and Waller. *Personality and Individual Differences, 44(8),* 1663–1672.

R Core Team (2014). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Redcay, E., Kleiner, M., & Saxe, R. (2012). Look at this: the neural correlates of initiating and responding to bids for joint attention. *Frontiers in Human Neuroscience, 6,* 169. doi:10.3389/fnhum.2012.00169.

Reininghaus, U., Kempton, M. J., Valmaggia, L., Craig, T. K. J., Garety, P., Onyejiaka, A., et al. (2016). Stress sensitivity, aberrant salience, and threat anticipation in early psychosis: An experience sampling study. *Schizophrenia Bulletin, 42*, 702, 722.

Reynolds, G. D., Bahrick, L. E., Lickliter, R., & Guy, M. W. (2014). Neural correlates of intersensory processing in 5-month-old infants. *Developmental Psychobiology, 56*, 355-372.

Richards, J. (2003). Attention affects the recognition of briefly presented visual stimuli in infants: An ERP study. *Developmental Science, 6(3),* 312-328.

Roach, B. J. & Mathalon, D. H. (2008). Event-related EEG time-frequency analysis: an overview of measures and an analysis of early gamma band phase locking in schizophrenia. *Schizophenia Bulletin, 34,* 907–926.

Roberts, B. W., Walton, K. E., Viechtbauer, W. (2006). Patetrns of mean-level change in personality traits across the life course. *A Meta-Analysis of Longitudinal Studies, 132(1)*, 1-25.

Roisko, R., Wahlberg, K-E., Hakko, H., & Tienari, P. (2015). Association of adoptive child's thought disorders and schizophrenia spectrum disorders with their genetic liability for schizophrenia spectrum disorders, season of birth and parental Communication Deviance. *Psychiatry Research, 226(2-3),* 434-440.

Rosburg, T., Trautner, P., Elger C. E., & Kurthenm M. (2009). Attention effects on sensory gating – Intracranial and scalp recordings. *Neuroimage, 48*, 554-563. doi: 10.1016/j.neuroimage.2009.06.063

Rosenkranz, J. A., & Grace, A. A. (2001). Dopamine attenuates prefrontal cortex suppression of sensory inputs to the basolateral amygdala of rats. *The Journal of Neuroscience, 21*, 4090-4103.

Ross, A., Spencer, H., Sharon, K., Groth, M.A., & Ross, R.G. (2013). P50 Sensory Gating in Infants. Journal of Visualized Experiments, *JoVE (82).* doi: 10.3791/50065.

Ross, R., & Freedman, R. (2015). Endophenotypes in Schizophrenia for the Perinatal Period: Criteria for Validation. *Schizophrenia Bulletin, 41(4),* 824-834. doi:10.1093/schbul/sbv054.

Rossi, A., & Daneluzzo, E. (2002). Schizotypal dimensions in normals and schizophrenic patients: a comparison with other clinical samples. *Schizophrenia Bulletin, 54(1–2),* 67–75.

Ross R, & Freedman R (2015): Endophenotypes in Schizophrenia for the Perinatal Period: Criteria for Validation. *Schizophrenia Bulletin, 41(4),* 824-834.

Sakkalis, V., Cassar, T., Zervakis, M., Camilleri, K. P., Fabri, S. G., Bigan, C., Karakonstantaki, E., … Micheloyannis, S. (2008). Parametric and nonparametric EEG analysis for the evaluation of EEG activity in young children with controlled epilepsy. *Computational intelligence and neuroscience, 462593.*

Sakkalis, V., Zervakis, M., & Micheloyannis, S. (2006). Significant EEG features involved in mathematical reasoning: evidence from wavelet analysis. *Brain Topography, 19(1-2),* 53–60.

Salokangas, R. K. R., Dingemans, P., Heinimaa, M., Svirskis, T., Luutonen, S., Hietala, J., et al. (2013). Prediction of psychosis in clinical high-reisk patients by the schizotypal personality questionnaire. Results of the EPS project. *European Psychiatry, 28(8),* 469-475.

Sato, T. (2005). The Eysenck Personality Questionnaire Brief Version: Factor Structure and Reliability. *The Journal of Psychology, 139(6),* 545-552.

Schmid, B., Blomeyer, D., Buchmann, A. F., Trautmann-Villalba, P., Zimmermann, U. S., Schmidt, M. H., Esser, G., Banaschewski, T., & Laucht, M. (2011). Quality of early mother–

child interaction associated with depressive psychopathology in the offspring: A prospective study from infancy to adulthood. *Journal of Psychiatric Research, 45(10),* 1387-1394.

Schwarz, G. E. (1978), "Estimating the dimension of a model". *Annals of Statistics, 6(2),* 461–464. doi:10.1214/aos/1176344136

Seidman, L. J., Giuliano, A. J., Smith, C. W., et al. (2006). Neuropsychological functioning in adolescents and young adults at genetic risk for schizophrenia and affective psychoses: results from the Harvard and Hillside Adolescent High Risk Studies. *Schizophrenia Bulletin, 32*, 507–24.

Sheinbaum, T., Bedoya, E., Ros-Morente, A., Kwapil, T. R., & Barrantes-Vidal, N. (2013). Association between attachment prototypes and schizotypy dimensions in two independent non-clinical samples of Spanish and American young adults. *Psychiatry Research, 210(2),* 408-413.

Silver, H., Bilker, W., & Goodman, C. (2009). Impaired recognition of happy, sad and neutral expressions in schizophrenia is emotion, but not valence, specific and context dependent. *Psychiatry Research, 169(2),* 101-106.

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity, and associated factors in a population-derived sample. *Journal of the American Academy of Child and Adolescent Psychiatry, 47,* 921–929.

Singer, W. (1995). Development and plasticity of cortical processing architectures. *Science, 270(5237),* 758–764. doi: 10.1126/science.270.5237.758.

Sinzig, J., Morsch, D., & Lehmkuhl, G. (2008). Do hyperactivity, impulsivity and inattention have an impact on the ability of facial affect recognition in children with autism and ADHD? *European Child & Adolescent Psychiatry, 17,* 63–72.

Smith, A. K., Edgar, J. C., Huang, M., Lu, B. Y., Thoma, R. J., Hanlon, F. M., . . . & Canive, J. M. (2010). Cognitive abilities and 50-and 100-msec paired-click processes in schizophrenia. *American Journal of Psychiatry, 167(10*), 1264-1275.

Smith, D. A, Boutros, N. N, & Schwarzkopf, S. B. (1994). Reliability of P50 auditory event-related potential indexes of sensory gating. *Psychophysiology, 31*, 495–502.

Smucny, J., Wylie, K., Rojas, D., Stevens, K., Olincy, A., Kronberg, E., Zheng, L., & Tregellas, J. (2013). Evidence for gamma and beta sensory gating deficits as translational endophenotypes for schizophrenia. *Psychiatry Research: Neuroimaging, 214(2),* 169-174.

St. John, A. M., Kao, K., Choksi, M., Liederman, J., Grieve, P. G., & Tarullo, A. R. (2016). Variation in infant EEG power across social and nonsocial contexts. *Journal of Experimental Child Psychology, 152*, 106-122.

Stewart, M. E., Ebmeier, K. P., & Deary, I. J. (2005). Personality correlates of happiness and sadness: EPQ-R and TPQ compared. *Personality and Individual Differences, 38*, 1085–1096.

Strauss, G.P., Llerena, K., & Gold, J. M. (2011). Attentional disengagement from emotional stimuli in schizophrenia. *Schizophrenia Research, 131*, 219-223.

Striano, T., Reid, V., & Hoehl, S. (2006). Neural mechanisms of joint attention in infancy. *European Journal of Neuroscience, 23(10),* 2819-2823.

Subasi, A. (2007). Signal Classification using wavelet feature extraction and a mixture of expert model. *Expert Systems with Applications, 32(4),* 10840-1093.

Subramaniam, K., Ranasinghe, K. G., Mathalon, D., Nagarajan, S., & Vinogradov, S. (2017). Neural mechanisms of mood-induced modulation of reality monitoring in schizophrenia. *Cortex, 91,* 271-286.

Sun, Y., Farzan, F., Barr, M. S., Kirihara, K., Fitzgerald, P. B., Light, G. A., & Daskalakis, Z. J. (2011). Gamma oscillations in schizophrenia: Mechanisms and clinical significance. *Brain Research, 1413(C),* 98-114.

Tallent, K. A., & Gooding, D. C. (1999). Working memory and Wisconsin Card Sorting Test performance in schizotypic individuals: a replication and extension. *Psychiatry Research, 89,* 161-170.

Tanner, D., Morgan-Short, K., & Luck, S. J. (2015). How inappropriate high-pass filters can produce artifactual effects and incorrect conclusions in ERP studies of language and cognition. *Psychophysiology, 52(8),* 997-1009.

Tarbox, S. I., & Pogue-Geile, M. F. (2008). Development of Social Functioning in Preschizophrenia Children and Adolescents: A Systematic Review. *Psychological Bulletin, 134(4),* 561-583.

Tarullo, A. R., Garvin, M. C., & Gunnar, M. R. (2011). Atypical EEG power correlates with indiscriminately friendly behavior in internationally adopted children. *Developmental Psychology, 47(2),* 417-31.

Taylor-Colls, S., & Pasco Fearon, R. (2015). The Effects of Parental Behavior on Infants' Neural Processing of Emotion Expressions. *Child Development, 86(3),* 877-888.

Teplan, M. (2002). Fundamentals of EEG Measurement. *Measurement Science Review, 2(2).*

Toyomaki, A., Hashimoto, N., Kako, Y., Tomimatsu, Y., Koyama, T., & Kusumi, I. (2015). Different P50 sensory gating measures reflect different cognitive dysfunctions in schizophrenia. *Schizophrenia Research: Cognition, 2(3),* 166-169.

Traub, R. D., Jefferys, J. G., & Whittington, M. A. (1999). *Fast oscillations in cortical circuits*. Cambridge, MA: MIT Press.

Tronick, E., & Beeghly, M. (2011). Infants' meaning-making and the development of mental health problems. *American Psychologist, 66(2),* 107–119.

Tsuji, T., Kline, E., Sorensen, H. J., Mortensen, E. L., Michelsen, N. M., Ekstrom, M., . . . Schiffman, J. (2013). Premorbid teacher-rated social functioning predicts adult schizophrenia-spectrum disorder: A high-risk prospective investigation. *Schizophrenia Research, 151(1-3),* 270-273.

Tukey, J. W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley.

Turetsky, B. I., Calkins, M. E., Light, G. A., Olincy, A., Radant, A. D., Swerdlow, N. R. (2007). Neurophysiological Endophenotypes of Schizophrenia: The Viability of Selected Candidate Measures, *Schizophrenia Bulletin, 33(1),* 69–94, https://doi.org/10.1093/schbul/sbl060.

Turney, K. (2011). Maternal depression and childhood health inequalities. *Journal of Health and Social Behaviour, 52(3),* 314–332.

Tyrka, A.R., Cannon, T.D., Haslam, N., Mednick, S.A., Schulsinger, F., Schulsinger, H., & Parnas, J. (1995). The latent structure of schizotypy: I. Premorbid indicators of a taxon of individuals at risk for schizophrenia- spectrum disorders. *Journal of Abnormal Psychology, 104,* 173–183.

Uhlhaas, P. J., & Singer, W. (2010). Abnormal neural oscillations and synchrony in schizophrenia. *Nature Reviews Neuroscience, 11(2),* 100-13.

Van 't Wout, M., Aleman, A., Kessels, R. P., Cahn, W., de Haan, E. H., & Kahn, R. S. (2007). Exploring the nature of facial affect processing deficits in schizophrenia. *Psychiatry Research, 150,* 227–235.

van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. (2014). A review of the current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*, 682–721.

van Os, J., Kenis, G., & Rutten, B. P. F. (2010). The environment and schizophrenia. *Nature, 468*, 203–212.

Van Os, J., Linscott, R., Myin-Germeys, I., Delespaul, P., & Krabbendam, L. (2009). A systematic review and meta-analysis of the psychosis continuum: Evidence for a psychosis proneness–persistence–impairment model of psychotic disorder. *Psychological Medicine, 39(2),* 179-195.

Varese, F., Smeets, F., Drukker, M., Lieverse, R., Lataster, T., Viechtbauer, W., et al. (2012). Childhood adversities increase the risk of psychosis: A meta-analysis of patient-control, prospective- and cross-sectional cohort studies. *Schizophrenia Bulletin, 38*, 661-671.

Venables, P. H. (1964). Input dysfunction in schizophrenia. In B. A. Maher (Ed.), *Progress in experimental personality research*, pp. 1-41. New York: Academic Press.

Versmissen, D., Janssen, I., Myin-Germeys, I., Mengelers, R., Campo, J. A., van Os, J., & Krabbendaum, L. (2008). Evidence for a relationship between mentalising deficits and paranoia over the psychosis continuum. *Schizophrenia Research, 99,* 103-110.

Wahlberg, K., Wynne, L., Hakko, H., Lksy, K., Moring, J., Miettunen, J., & Tienari, P. (2004). Interaction of genetic risk and adoptive parent communication deviance: Longitudinal prediction of adoptee psychiatric disorders. *Psychological Medicine, 34(8),* 1531-1541.

Waldo, M.C., Adler, L.E., Leonard, S., Olincy, A., Ross, R.G., Harris, J.G., & Freedman, R. (2000). Familial transmission of risk factors in the first-degree relatives of schizophrenic people. *Biological Psychiatry, 47(3),* 231-239.

Wan, L., Crawford, H.J., & Boutros, N. (2006). P50 sensory gating: Impact of high vs. low schizotypal personality and smoking status. *International Journal of Psychophysiology, 60(1),* 1-9. doi:10.1016/j.ijpsycho.2005.03.024.

Wan, L., Friedman, B.H., Boutros, N.N., & Crawford, H.J. (2008). P50 sensory gating and attentional performance. *International Journal of Psychophysiology, 67(2),* 91-100. doi:10.1016/j.ijpsycho.2007.10.008.

Wan, L., Thomas, Z., Pisipati, S., Jarvis, S. P., & Boutros, N. N. (2017). Inhibitory deficits in prepulse inhibition, sensory gating, and antisaccade eye movement in schizotypy. *International Journal of Psychophysiology, 114,* 47-54.

Webb, S., Snyder, K., Nelson, C.A. (April, 2001). Repeated presentations of a familiar stimulus during an infant ERP 126 paradigm. Poster presented at the Biennial meeting of the Society for Research in Child Development, Minneapolis, MN.

Wen, D. J., Soe, N. N., Sim, L. W., Sanmugam, S., Kwek, K., Chong, Y-S., Gluckman, P. D., Meaney, M. J., Rifkin-Graboi, A., & Qiu, A. (2017). Infant frontal EEG asymmetry in relation with postnatal maternal depression and parenting behavior. *Translational Psychiatry, 7(3),* E1057.

Widiger, T. A. (2011). Personality and psychopathology. *World Psychiaty, 10(2),* 103-106.

Wilding, E. L. (2000). In what way does the parietal ERP old/new effect index recollection? *International Journal of Psychophysiology, 35(1),* 81-87.

Williams, L. M., Simms, E., Clark, C. R., Paul, R. H., Rowe, D., & Gordon, E. (2005). The test-retest reliability of a standardized neurocognitive and neurophysiological test battery: "neuromarker." *International Journal of Neuroscience, 115,* 1605–1630.

Winter, B. (2013). Linear models and linear mixed effects models in R with linguistic applications. arXiv:1308.5499. [http://arxiv.org/pdf/1308.5499.pdf]

Wuthrich, V.M., & Bates, T.C. (2006). Confirmatory factor analysis of the three-factor structure of the schizotypal personality questionnaire and chapman schizotypy scales. *Journal of Personality Assessment, 87(3),* 292–304.

Wynn, J. K., Lee, J., Horan, W. P., & Green, M. F. (2008). Using event related potentials to explore stages of facial affect recognition deficits in schizophrenia. *Schizophrenia Bulletin, 34,* 679–687.

Xian-Bin, L., Qi-Jing, B., Qing, T., Ning-Bo, Y., Zhen, M., Wei, Z., Yu-Jie, W., & Chuan-Yue, W. (2018). Impact of childhood trauma on sensory gating in patients with first-episode schizophrenia. *BMC Psychiatry, 18(1),* 1-6.

Yeap, S., Kelly, S., Sehatpour, P., Magno, E., Javitt, D., Garavan, H., Thakore, J. H., & Foxe, J. (2006). Early Visual Sensory Deficits as Endophenotypes for Schizophrenia: High-Density Electrical Mapping in Clinically Unaffected First-Degree Relatives. *Archives of General Psychiatry, 63(11),* 1180-1188.

Yee, C. M., Williams, T. J., White, P. M., Nuechterlein, K. H., Ames, D., & Subotnik, K. L. (2010). Attentional modulation of the P50 suppression deficit in recent-onset and chronic schizophrenia. *Journal of Abnormal Psychology, 119*, 31-39. doi: 10.1037/a0018265.

Supplementary Materials

Table S 5.1. Significant three-way interactions of the linear mixed model analysis fit with the restricted maximum likelihood (REML) approach. The variables in the final model are alongside their estimates and t-tests using Satterthwaite's method.

		Estimate	t value	Pr(>|t|)
(Intercept)		0.0182	0.7960	0.4261
Frequency		-0.0009	1.1170	0.2640
Location (Ref. Left Frontal)	Right Frontal	-0.0212	-0.6550	0.5124
	Left Central	0.0007	0.0210	0.9832
	Right Central	-0.0274	-0.8530	0.3937
	Left Temporal	0.0139	0.3890	0.6974
	Right Temporal	0.0068	0.1900	0.8495
	Left Parietal	**-0.0966**	**-2.9100**	**0.0036**
	Right Parietal	**-0.0955**	**-2.8600**	**0.0042**
Event (ref. Baseline)	SPOK	-0.0120	-0.5250	0.5999
	PLAY	-0.0245	-1.0630	0.2878
	SPOK/MM	-0.0311	-1.1050	0.2691
	DYADIC	0.0240	0.7220	0.4705
	NONE	-0.0329	-1.4340	0.1516
Frequency* Location	Frequency* Right Frontal	0.0008	0.6810	0.4962

	Frequency* Left Central	0.0003	0.2550	0.7988
	Frequency* Right Central	0.0011	0.9160	0.3598
	Frequency* Left Temporal	-0.0001	-0.0780	0.9380
	Frequency* Right Temporal	0.0002	0.1760	0.8603
	Frequency* Left Parietal	**0.0028**	**2.2960**	**0.0217**
	Frequency* Right Parietal	**0.0029**	**2.3730**	**0.0177**
Frequency*Event	Frequency* SPOK	0.0008	0.9790	0.3278
	Frequency* PLAY	0.0011	1.3240	0.1856
	Frequency* SPOK/MM	0.0012	1.1980	0.2311
	Frequency* DYADIC	-0.0002	-0.1810	0.8565
	Frequency* NONE	0.0015	1.7390	0.0820
Location*Event	Right Frontal*SPOK	0.0183	0.5610	0.5751
	Left Central*SPOK	-0.0096	-0.2900	0.7720
	Right Central*SPOK	0.0215	0.6620	0.5080

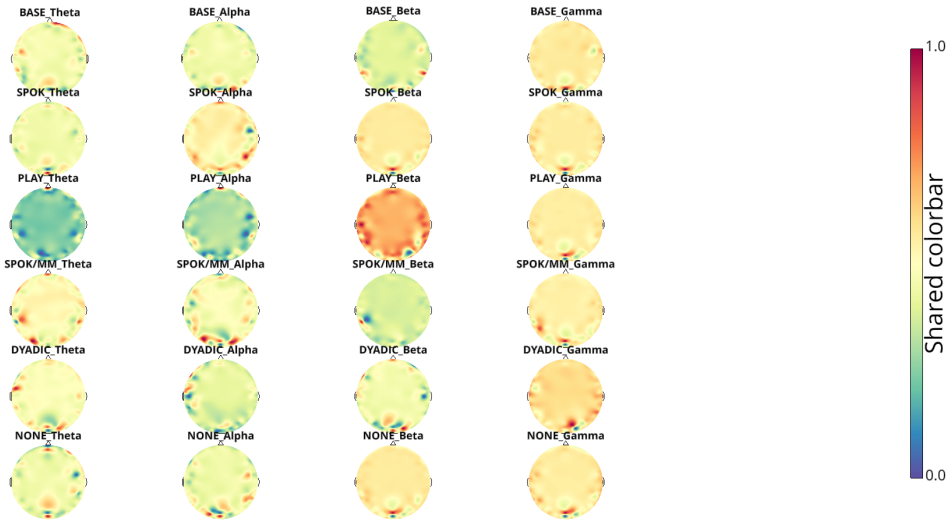
Left Temporal*SPOK	-0.0227	-0.6260	0.5311
Right Temporal* SPOK	**-0.0229**	**-0.6320**	**0.5273**
Left Parietal*SPOK	**0.0825**	**2.4550**	**0.0141**
Right Parietal*SPOK	0.0858	2.5390	0.0111
Right Frontal*PLAY	0.0259	0.7850	0.4323
Left Central*PLAY	0.0020	0.0600	0.9519
Right Central*PLAY	0.0341	1.0400	0.2982
Left Temporal*PLAY	-0.0121	-0.3310	0.7404
Right Temporal*PLAY	0.0006	0.0160	0.9876
Left Parietal* PLAY	**0.0909**	**2.6820**	**0.0073**
Right Parietal* PLAY	**0.0970**	**2.8470**	**0.0044**
Right Frontal* SPOK/MM	0.0246	0.6120	0.5404
Left Central* SPOK/MM	0.0191	0.4740	0.6357
Right Central* SPOK/MM	0.0329	0.8240	0.4102
Left Temporal* SPOK/MM	0.0101	0.2280	0.8194
Right Temporal* SPOK/MM	-0.0050	-0.1120	0.9108

	Left Parietal* SPOK/MM	0.0547	1.3240	0.1854
	Right Parietal* SPOK/MM	-0.0021	-0.0520	0.9588
	Right Frontal* DYADIC	0.0324	0.6820	0.4953
	Left Central* DYADIC	-0.0069	-0.1450	0.8849
	Right Central* DYADIC	-0.0317	-0.6690	0.5034
	Left Temporal* DYADIC	-0.0270	-0.5130	0.6079
	Right Temporal* DYADIC	-0.0933	-1.7590	0.0785
	Left Parietal* DYADIC	0.0441	0.9000	0.3683
	Right Parietal* DYADIC	-0.0645	-1.3150	0.1886
	Right Frontal*NONE	0.0256	0.7830	0.4338
	Left Central*NONE	-0.0036	-0.1080	0.9143
	Right Central*NONE	0.0325	0.9970	0.3189
	Left Temporal*NONE	-0.0213	-0.5860	0.5578
	Right Temporal* NONE	0.0131	0.3610	0.7179
	Left Parietal* NONE	**0.0840**	**2.4930**	**0.0127**
	Right Parietal*	**0.0979**	**2.8890**	**0.0039**

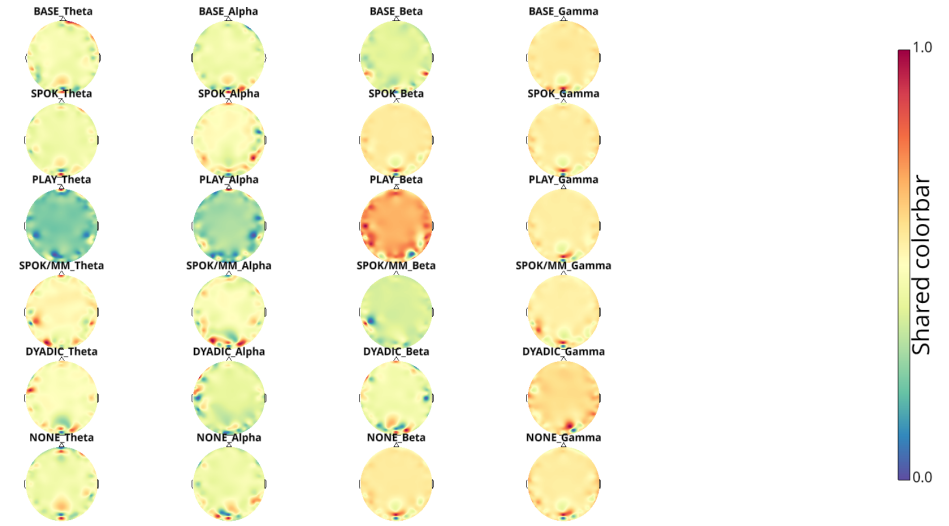
	NONE			
Frequency*Location*Event	Frequency* Right Frontal* SPOK	-0.0007	-0.5910	0.5545
	Frequency* Left Central* SPOK	-0.0001	-0.0820	0.9347
	Frequency* Right Central* SPOK	-0.0010	-0.8200	0.4125
	Frequency* Left Temporal* SPOK	0.0006	0.4130	0.6797
	Frequency* Right Temporal* SPOK	0.0005	0.3580	0.7204
	Frequency* Left Parietal* SPOK	-0.0024	-1.9400	0.0523
	Frequency* Right Parietal* SPOK	**-0.0027**	**-2.1570**	**0.0310**
	Frequency* Right Frontal* PLAY	-0.0009	-0.7480	0.4542

	Frequency* Left Central* PLAY	-0.0004	-0.3440	0.7310
	Frequency* Right Central* PLAY	-0.0013	-1.0710	0.2841
	Frequency*Left Temporal*PLAY	0.0002	0.1560	0.8757
	Frequency*Right Temporal*PLAY	-0.0001	-0.0880	0.9299
	Frequency*Left Parietal*PLAY	**-0.0026**	**-2.0850**	**0.0371**
	Frequency*Right Parietal*PLAY	**-0.0030**	**-2.3510**	**0.0187**
	Frequency*Right Frontal*SPOK/MM	-0.0010	-0.6410	0.5217
	Frequency*Left Central*SPOK/MM	-0.0009	-0.6120	0.5404
	Frequency*Right Central*SPOK/MM	-0.0013	-0.8630	0.3882
	Frequency*Left Temporal*SPOK/MM	-0.0005	-0.3110	0.7555
	Frequency*Right Temporal*SPOK/MM	0.0001	0.0440	0.9650
	Frequency*Left Parietal*SPOK/MM	-0.0016	-1.0700	0.2848
	Frequency*Right Parietal*SPOK/MM	-0.0003	-0.1970	0.8437
	Frequency*Right	-0.0010	-0.5940	0.5525

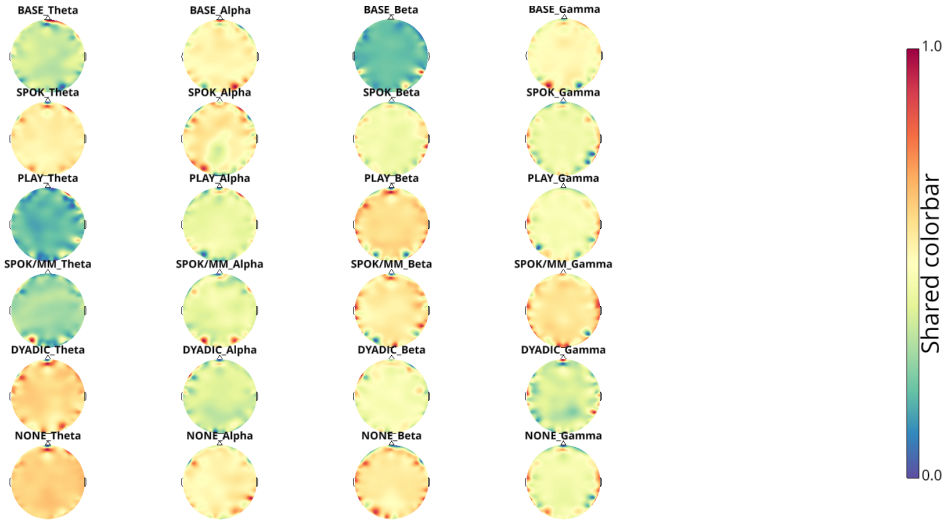
Frontal*DYADIC			
Frequency*Left Central*DYADIC	-0.0002	-0.0920	0.9270
Frequency*Right Central*DYADIC	0.0003	0.1960	0.8444
Frequency*Left Temporal*DYADIC	0.0004	0.2000	0.8416
Frequency*Right Temporal*DYADIC	0.0022	1.1180	0.2636
Frequency*Left Parietal*DYADIC	-0.0016	-0.8720	0.3832
Frequency*Right Parietal*DYADIC	0.0012	0.6540	0.5131
Frequency*Right Frontal*NONE	-0.0010	-0.8120	0.4167
Frequency*Left Central*NONE	-0.0003	-0.2810	0.7790
Frequency*Right Central*NONE	-0.0013	-1.0970	0.2728
Frequency*Left Temporal*NONE	0.0004	0.3170	0.7516
Frequency*Right Temporal*NONE	-0.0005	-0.3950	0.6928
Frequency*Left Parietal* NONE	**-0.0025**	**-2.0300**	**0.0423**
Frequency*Right Parietal*NONE	**-0.0030**	**-2.4280**	**0.0152**



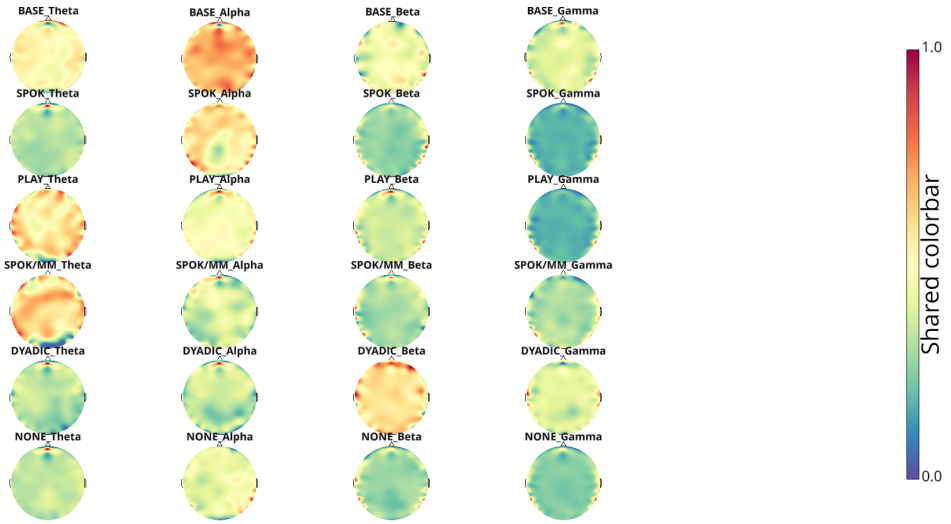
Supplementary Figure S 5.1. Topographical plots showing the oscillatory power exhibited for each behavioural classification when all electrode channels were included.



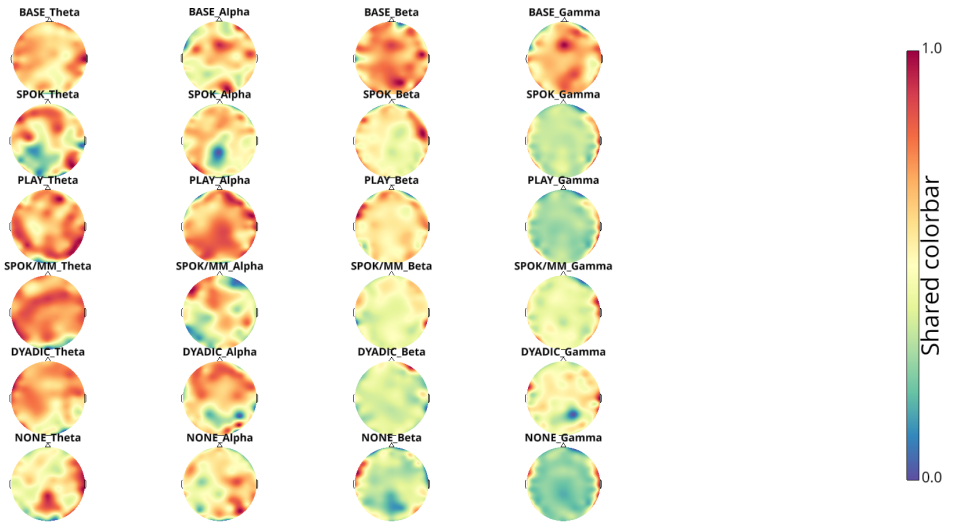
Supplementary Figure S 5.2. Topographical plots showing the oscillatory power exhibited for each behavioural classification when electrodes E48, E119, E126, E127, and were removed due to noise. The outer channels were systematically removed in 'rings'.



Supplementary Figure S 5.3. Topographical plots showing the oscillatory power exhibited for each behavioural classification when electrodes E17, E43, E48, E49, E56, E63, E68, E73, E81, E88, E94, E99, E107, E113, E119, E120, E125, E126, E127, E128, were removed due to noise. The outer channels were systematically removed in 'rings'.



Supplementary Figure S 5.4. Topographical plots showing the oscillatory power exhibited for each behavioural classification when electrodes E1, E8, E14, E17, E21, E25, E32, E38, E43, E44, E48, E49, E56, E57, E63, E64, E68, E69, E73, E74, E81, E82, E88, E89, E94, E95, E99, E100, E107, E113, E114, E119, E120, E121, E125, E126, E127, E128, were removed due to noise. The outer channels were systematically removed in 'rings'.



Supplementary Figure S 5.5. Topographical plots showing the oscillatory power exhibited for each behavioural classification when electrodes E1, E2, E8, E9, E14, E15, E17, E21, E22, E25, E26, E32, E33, E38, E39, E43, E44, E45, E48, E49, E50, E56, E57, E58, E63, E64, E65, E68, E69, E70, E73, E74, E75, E81, E82, E83, E88, E89, E90, E94, E95, E96, E99, E100, E101, E107, E108, E113, E114, E119, E115, E120, E121, E122, E125, E126, E127, E128, were removed due to noise. The outer channels were systematically removed in 'rings'.

Appendices

Appendix 1.

Oxford*-Liverpool inventory of feelings and experiences (O-LIFE) (Short Form)

Please read the instructions before continuing:
This questionnaire contains questions that may relate to your thoughts, feelings, experiences and preferences. There are no right or wrong answers or trick questions so please be as honest as possible. For each question place a circle around either the "YES" or the "NO". Do not spend too much time deliberating any question but put the answer closest to your own. Please do not discuss the questionnaire with anyone who may also complete it as this may affect their answers. It is best completed in private, without the need to hurry.

1	When in the dark do you often see shapes and forms even though there is nothing there?	YES	NO
2	Are you easily confused if too much happens at the same time?	YES	NO
3	Are you much too independent to get involved with other people?	YES	NO
4	Do you at times have an urge to do something harmful or shocking?	YES	NO
5	Is trying new foods something you have always enjoyed?	YES	NO
6	Do you think that you could learn to read other's minds if you wanted to?	YES	NO
7	Have you ever felt the urge to injure yourself?	YES	NO
8	Has dancing or the idea of it always seemed dull to you?	YES	NO
9	Do you dread going into a room by yourself where other people have already gathered and are talking?	YES	NO
10	Do you feel that your accidents are caused by mysterious forces?	YES	NO
11	Do you often feel the impulse to spend money which you know you can't afford?	YES	NO
12	Do you ever feel that your speech is difficult to understand because the words are all mixed up and don't make sense?	YES	NO
13	Do you often overindulge in alcohol or food?	YES	NO
14	Have you often felt uncomfortable when your friends touch you?	YES	NO
15	Do you ever have a sense of vague danger or sudden dread for reasons that you do not understand?	YES	NO
16	Are you a person whose mood goes up and down easily?	YES	NO
17	Do you often have difficulties in controlling your thoughts?	YES	NO

18	Do ideas and insights sometimes come to you so fast that you cannot express them all?	YES	NO
19	Do you feel very close to your friends?	YES	NO
20	Would you like other people to be afraid of you?	YES	NO
21	Do you prefer watching television to going out with people?	YES	NO
22	Do you find it difficult to keep interested in the same thing for a long time?	YES	NO
23	Can some people make you aware of them just by thinking about you?	YES	NO
24	Do you stop to think things over before doing anything?	YES	NO
25	Are there very few things that you have ever enjoyed doing?	YES	NO
26	When in a crowded room, do you often have difficulty in following a conversation?	YES	NO
27	Does a passing thought ever seem so real it frightens you?	YES	NO
28	Do you love having your back massaged?	YES	NO
29	When you look in the mirror does your face sometimes seem quite different from usual?	YES	NO
30	Are you usually in an average kind of mood, not too high and not too low?	YES	NO
31	Do you find the bright lights of a city exciting to look at?	YES	NO
32	Does your sense of smell sometimes become unusually strong?	YES	NO
33	Are your thoughts sometimes so strong that you can almost hear them?	YES	NO

34	Do you like mixing with people?	YES	NO
35	Do you often feel like doing the opposite of what other people suggest even though you know they are right?	YES	NO
36	Are you easily distracted when you read or talk to someone?	YES	NO
37	Do you ever have the urge to break or smash things?	YES	NO
38	Have you ever thought that you had special, almost magical powers?	YES	NO
39	Do you frequently have difficulty in starting to do things?	YES	NO
40	Have you sometimes sensed an evil presence around you, even though you could not see it?	YES	NO
41	Are you easily distracted from work by daydreams?	YES	NO
42	Do you consider yourself to be pretty much an average sort of person?	YES	NO
43	Is it hard for you to make decisions?	YES	NO

Appendix 2.

These are items based on the EPQ-R Neuroticism Scale (Eysenck et al., 1985)[1]

Eysenck SBG, Eysenck HJ, Barrett P (1985) A revised version of the psychoticism scale. Personal Individ Differ 6(1): 21–29

Please read the instructions before continuing:

The statements below are designed to highlight a specific element of your personality. We are interested in how you generally perceive these highlighted elements. There are no right or wrong answers or trick questions, so please be as honest as possible.

Do not spend too much time deliberating any question and please respond to each statement by circling the answer you believe to be true. Please do not discuss this questionnaire with anyone who may also complete it as this may affect his/her answers. It is best completed in private, without the need to hurry.

1) Does your mood often go up and down?	YES/NO
2) Do you ever feel 'just miserable' for no reason?	YES/NO
3) Are you an irritable person?	YES/NO
4) Are your feelings easily hurt?	YES/NO
5) Do you often feel 'fed-up"?	YES/NO
6) Would you call yourself a nervous person?	YES/NO
7) Are you a worrier?	YES/NO
8) Would you call yourself tense or 'highly strung"?	YES/NO
9) Do you worry too long after an embarrassing experience?	YES/NO
10) Do you suffer from 'nerves'?	YES/NO
11) Do you often feel lonely?	YES/NO
12) Are you often troubled by feelings of guilt?	YES/NO

[1] This questionnaire is taken from Eysenck SBG, Eysenck HJ, Barrett P (1985) A revised version of the psychoticism scale. Personal Individ Differ 6(1): 21–29

Appendix 3.

General Information Questionnaire.

Thank you for displaying an interest in participating in this research. This is a short questionnaire to provide us with general health and lifestyle information. If you have any questions please do not hesitate to contact the Principle Investigator, Ellie Smith.

Information about your Infant.

Participant Number (will be filled in by the Researcher): _____

Name: _____

Gender: _____

Age: _____

DoB: _____

Was the birth: Term (37-42 weeks) Post-Term (<42 weeks)

Did you experience any birth complications? Yes No

If yes, please give details:

_____
_____
_____

During your child's health visitation checks were any abnormalities highlighted in your child's hearing or sight? Yes No

If yes, please give details:

_____
_____
_____

During your child's health visitation checks were any developmental difficulties (e.g. movement, learning etc.) highlighted? Yes No

If yes, please give details:

_____
_____
_____

Mother.

Participant Number (will be filled in by the Researcher): _____

Name: _____

Age: _____

DoB: _____

Lifestyle.

Do you smoke? Yes No

Did you smoke during pregnancy? Yes No

Did you consume alcohol during your pregnancy? Yes No

If yes, please indicate how often:

_____
_____

Do you have a visual impairment? Yes No

If yes, please give details:

_____
_____

Do you have any hearing impairments?

Yes No

If yes, please give details:

_____
_____

Family Medical History.

Have you ever suffered from any form of mental illness? Yes No

If yes, please give details:

_____
_____
_____

Has any family member ever suffered from any form of mental illness? Yes No

If yes, please give details including family relationship:

_____
_____

Father.

Participant Number (will be filled in by the Researcher): _____

Name:_____

Age: _____

DoB: _____

Lifestyle.

Do you smoke? Yes No

Do you have a visual impairment?

Yes No

If yes, please give details:

_____
_____
_____

Do you have any hearing impairments?

Yes No

If yes, please give details:

_____
_____
_____

Family Medical History.

Have you ever suffered from any form of mental illness? Yes No

If yes, please give details:

_____
_____
_____

Has any family member ever suffered from any form of mental illness? Yes No

If yes, please give details including family relationship:

_____
_____
_____