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Event-Related Potential Correlates of Social and Nonsocial Cognitive Processes Related to Schizotypy

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EVENT-RELATED POTENTIAL CORRELATES OF SOCIAL AND NONSOCIAL COGNITIVE PROCESSES RELATED TO SCHIZOTYPY

by

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EVENT-RELATED POTENTIAL CORRELATES OF SOCIAL AND NONSOCIAL COGNITIVE PROCESSES RELATED TO SCHIZOTYPY

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Social cognitive, neurocognitive, and social functioning research in serious mental illness (SMI) have recently proliferated. Their synergy requires translational bridges to applied research. This project aims to develop a measurement protocol capable of measuring independent components of social cognitive and neurocognitive brain functioning. These brain processes should each vary systematically with schizotypal traits whose extremes represent core elements of psychotic disorders. The measurement technology must be affordable, efficient, and acceptable for use in clinical settings.

An ERP protocol was developed that incorporates an array of candidate measures. The stimuli consist of emotional (angry and happy), neutral, and scrambled (non-face comparison) faces. Each stimulus was displayed in a sequence of subliminal then supraliminal same-stimulus presentation. The protocol was piloted in an undergraduate sample recruited for a range of schizotypal traits.

Several specific sets of hypotheses were tested. First, feasibility in terms of implementation and attrition was shown to be acceptable with some notable limitations. Second, the ERP protocol was tested for producing reliable conditional waveforms in expected electrode regions. Reliable measurement was achieved for the target components, P1, N170, and P300. Finally, these ERP measures were tested for 1)

convergent validity with neuropsychological tests that are used to measure similar brain processes in SMI; 2) reliability as markers of traits that covary with degree of schizotypy and thus may be expected to parallel those in people with SMI; and 3) discriminative validity in measuring independent variance in brain responses to social and non-social stimuli.

Results showed complex conditional effects, including replication, non-replication, and opposite effects compared to hypotheses and previous literature. However, altogether, the results suggest the ERP protocol and assessment battery successfully measured variance in an analogue sample reflecting dimensions related to SMI.

Finally, after having interpreted the relationships of each candidate waveform and comparison independently and with external measures, a brief version of the ERP protocol is proposed that hones in on the stimuli that produce the most powerful measures according to the aforementioned hypotheses.

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DEDICATION

This dissertation is dedicated to my family and mentors. This project and thesis would not have been possible without the substantial support, consultation, and encouragement from my family and my amazing wife. I have been extremely lucky to work with devoted, intellectually provocative, and intrinsically motivated mentors across disciplines, from sports to music to religious studies to clinical psychology and neuroscience and so on. I hope that following the intended achievements represented by this dissertation, I will find myself qualified and able to carry on the tradition of love and mentorship for which I am eternally indebted.

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CHAPTER 1: INTRODUCTION

Social Cognition

The ability to perceive, interpret, and process social information, or "social cognition," is essential to successful and meaningful psychosocial functioning (Peer, 2005). Social cognitive deficits are evident across many mental illnesses, and psychological intervention components directly addressing such abilities are increasingly recognized for effectiveness in treating serious mental illness (SMI; e.g., Combs et al., 2007), such as schizophrenia-spectrum disorders (SSD) and other mental illness (e.g., depression, Fu et al., 2007; autism-spectrum disorders, Mesibov & Shea, 2011; borderline personality disorder, Linehan, 1983).

Social cognitive deficits are characterized by dynamics among multiple dimensions and biosystemic levels of functioning (Spaulding, Sullivan, & Poland, 2003). They interact with more molecular abilities (e.g., prefrontal development and face recognition abilities, Wong, 2009) and simultaneously uniquely influence social functioning (e.g., social knowledge and independent living skills; Couture, Penn, & Roberts, 2006). In spite of the explosion of psychopathology research addressing social cognition, this knowledge base is still in translation to practical clinical utility (Pinkham, Penn, Perkins, Lieberman, 2003). There exist extensive cognitive neuroscience literature and feasible techniques, but neurophysiological assessment of social cognitive processing is yet rare in clinical research (Miller, Elbert, Sutton, & Heller, 2007).

Assessment and Treatment of Social Cognition in SMI

Robust tools must be developed to integrate social cognitive neural processes into understanding of illness and treatment processes for this vital dimension of illness and recovery to be integrated with its physiological, neurocognitive, and behavioral counterparts. Preliminary evaluation of performance characteristics of these tools in a normative population is prerequisite to clinical piloting.

The purpose of this research is to test a prototype ERP assessment protocol designed for use in research on treatment outcomes and the course of recovery in SMI. The assessment protocol was designed to generate ERP data to: 1) distinguish social and non-social cognitive processes, and 2) distinguish early and later stages of social information processing. In addition, the paradigm must be portable and practical for assessing subjects with SMI in typical service settings (e.g., day rehabilitation programs).

NIMH's "Research Domain Criteria" (RDoC) initiative illustrates the psychological research community confronting the necessity to understand psychopathology along continuous dimensions that span biosystemic and developmental levels of analysis (NIMH, 2013). Improved and expanded assessment can substantially increase the discriminative power of assessments of treatment efficacy, illness etiology, or other issues of interest in mental health. Such discriminative power is essential to personalization of treatment, another of NIMH's strategic goals (NIMH, 2008).

On one end of the biosystemic spectrum, schizotypal personality characteristics are promising candidates for developing RDoC (e.g., RFA-MH-12-100; Sponheim et al., 2009). Importantly, these traits in their extremes are integral predictors of risk, deterioration, and recovery in SMI (Tsuang, Stone, Tarbox, Faraone, 2002).

Understanding the underpinnings and the effects of schizotypy across all levels of schizotypal traits is thus essential.

At approximately the other end of the biosystemic spectrum, brain imaging biomarkers are at the heart of the RDoC initiative, and event-related potential (ERP) measurement has produced viable candidate biomarkers in SMI for neurocognitive endophenotypic markers (e.g., Calkins et al., 2007; Lenzenweger, 2011) as well as response to neuroleptics (Coburn et al., 1993), cognitive remediation (Popov et al., 2012), and psychosocial treatment (Mazza et al., 2010). The relationships between endophenotypic brain processing markers of SSD symptoms and personality traits, symptoms, and social functioning are thought to be mediated by social perception and other social cognitive abilities, which are more also more conceptually proximal to social functioning (Brekke, Kay, Lee, & Green, 2005). Emotion perception measures are strong behavioral indicators of individual illness profile and prognosticators of treatment response (Brekke et al., 2005; Kee et al., 2003).

Additionally, it is clear that neurocognitive and social cognitive recovery occurs in some individuals, provided a sufficiently therapeutic milieu (Spaulding et al., 1999; Brekke, Hoe, & Green, 2009). So far, this has been tracked primarily with neuropsychological instruments; biological measures have not been systematically studied (e.g., Roder, Mueller, Mueser, & Brenner, 2006).

In summary, deficits in social cognition and social ability are significant barriers to recovery for people with SMI. Cognitive and social cognitive abilities, including facial affect perception, are linked with rehabilitation response (Kurtz, Bronfeld, & Rose, 2012; Meyer & Kurtz, 2009). Measurement of social perception abilities is essential for

treatment planning, evaluating treatment outcome, and developing treatment techniques and decision systems that will better help people recover from these disabling mental illnesses (Spaulding & Deogun, 2011; Green et al., 2008; Kopelowicz, Liberman, & Zarate, 2006). Neuroimaging markers may indicate previously indiscriminable neural changes in treatment response (Ruiz et al., 2013; Popov et al., 2011).

Analogue research, with participants who do not have SMI, is an essential component in the iterative march of science. Analogue samples allow greater statistical power and design flexibility as participants are not as likely to be at-risk or vulnerable as participants with SMI. This study aims to address the relationship between social brain processes and schizotypy in an analogue sample and to develop and isolate the most powerful and efficient ERP protocol for implementation in treatment outcome studies (Davidson, Tarasenko, & Spaulding, 2013).

Schizotypy as an SMI Analogue

Schizotypy has become a key dimensional behavioral psychopathology construct in non-clinical, pre-clinical, and clinical SMI research (e.g., Koychev et al., 2012; Phillips & Seidman, 2008). One reason for this trend is that schizotypy has meaningful variance among both people with and people without SMI (Asai, Sugimori, Bando, & Tanno, 2011). This not only allows entry to the undergraduate samples so common to many areas of human-subjects research, but also it allows assessment of one or more dimensional "phenotype(s)" related to psychopathological processes in SSD (Raine, 2006). These schizotypal phenotypes are thought to represent a continuum on which SSD represent an extreme, in terms of personality traits (Rossi & Daneluzzo, 2002), neurocognition (Dinn et al., 2002), and neurophysiology (Gruzelier, 2002).

Psychosis-like experiences in people without psychotic disorders have been noted throughout the history of psychiatry (Lenzenweger, 2006). Since the original conceptualization of dimensions including schizotypy (Rado 1953; Meehl 1962), much research has been devoted to organizing the polygenic dimensions of schizophrenia and related characteristics. Meehl (1990) clearly delineated the concept of schizotypy as a personality organization directly related to a genetically-linked brain abnormality named schizotaxia. He noted that schizotypy is defined not only by behavioral or personality characteristics, which may manifest to any degree in a person with schizotaxia given the presence of polygenic potentiators during childhood and adult development, but also is defined at other levels of analysis that may be less affected by environmental factors, such as attention deficits, eye-tracking abnormalities, somatosensory dysfunction, or other possibly endophenotypic manifestations (Lenzenweger, 2006).

Others have conceptualized schizotypy as a form of attenuated schizophrenia, representing a premorbid phase of the illness (Raine, 2006). Importantly, Meehl's conceptualization emphasized schizotypy as a much broader phenomenon than schizotypal personality disorder or attenuated schizophrenia. "Schizotypes" (people with schizotaxic brains) exist at all levels of social functioning, and only given certain developmental events ("potentiators") would this diathesis result in risk for a disabling psychiatric disorder such as schizophrenia. It is important to note that modern psychiatric neuroscience is not moving towards identifying a certain set of brain characteristics that unequivocally identify schizotaxia but instead this relatively old-fashioned term is convenient for encapsulating an array of genetic and brain characteristics that confer vulnerability for SMI.

Overall, most individuals who display schizotypal characteristics will never develop schizophrenia, but research conducted with these individuals does indicate that those with high levels of schizotypy have a higher, though still low, risk of developing SSD (Horan, Blanchard, Clark, and Green, 2008). Meehl's conceptualization is not incompatible, but is both more and less specific than the widely-used clinical tools and concepts delineated by Millon and colleagues (2009; Rasmussen, 2005; Choca et al., 1992). Meehl's schizotypy is defined more by neurological, genetic, and vulnerability factors, while Millon's system more specifically defines the relationships between adaptive personality and behavioral systems. High schizotypy as measured in the present study is likely to include participants who would likely have elevations in schizotypy, paranoid, schizoid, avoidant, or other Millon prototypes that share uncommon experiences or social problems but may have developed or interact with these problems

and experiences in different patterns, as expressed by Millon. Similar heterogeneity is noted in SMI and SSD, and this lack of specificity is one of many reasons that clinical researchers aim to more precisely measure specific dimensional traits above and beyond diagnostic criteria (NIMH, 2008).

The traits measured in psychometric assessments of schizotypy are downstream products of differing degrees of schizotypy and are by definition much more common than SSD. At the same time, these measured phenomena are expected to identify people with a schizotaxic brain who are likely to have characteristic abnormalities of neurocognitive processes, evidence of heritability, increased risk for psychiatric illness, and differences in areas of social functioning. The various phenomena, from genes to social skills, that research has shown are abnormal in SSD are not exclusive to SSD and are manifest in people who have neither SSD nor increased risk for SSD. So, the concept of schizotypy with most utility is one of a set of traits indicating a relatively common (compared to SSD) base-rate cognitive organization that confers higher risk for SSD but is not exclusive to people with SSD. Meehl's schizotypy is thus one of the most useful psychopathology dimensions in analogue biosystemic SSD and SMI research and guides the design and interpretation of the present study.

Relationship between schizotypy and SMI research.

A brief note on terminology: "serious mental illness" (SMI) includes "schizophrenia-spectrum disorders" (SSD) and other disabling psychiatric problems. SMI is the target of this research, but the bulk of psychiatric and cognitive neuroscience

research in the past decades has focused on SSD, and thus the term is used in contexts in which the literature being discussed is primarily focused on SSD rather than SMI.

Studies conducted with healthy nonclinical samples, or with those who display mild schizotypal personality characteristics, can reveal individual differences in how these profiles differ compared to a clinical sample as well as differences between individuals (Krause, Steimer-Krause, and Hufnagel, 1992). Variance between individuals can indicate how these phenomena vary in a healthy population, which, when compared to a clinical population, maps these results on a continuum, such that the likely extreme scores of participants with SMI indicate a symptom that confers substantial loss of functioning. Results collected from healthy participants are thus informative about SMI research and treatment (Compton, Goulding, Bakerman, and McClure-Tone, 2009).

Schizotypy is heritable, it is related to heritability of SSD, and specific aspects of schizotypy are related to specific allelic variants (Kaczorowski, 2012). It has long been clear not only that SSD have relatively high heritability, but also that many of the characteristics that are "symptoms" of the mental illness are also heritable in less disabling manifestations (Gunderson et al., 1983; Kendler et al., 1995; Tsuang et al., 1991). Both negative and positive symptom-like experiences appear to be more common in relatives of people with SSD, and negative symptom-like characteristics appear to be most common in relatives of people with SSD (Fanous, Gardner, Walsh, & Kendler, 2001). These characteristics, which all fall under the umbrella of schizotypy, include especially social isolation, blunted affect, and avolition. Interpersonal difficulties, communication impairment, suspiciousness, odd beliefs, and magical thinking also appear to be relatively heritable and related to family history of SSD (Docherty et al.,

1998). Social perception deficits are also related to family history of SSD (Kremen et al., 1997).

Schizotypy includes traits that are common in people before the onset of more debilitating symptoms and also parallel symptoms that are pivotal in progress of adult and chronic SMI (Faraone, Green, Seidman, and Tsuang, 2001). "Negative schizophrenia symptoms" and social isolation are some of the most robust behavioral predictors of future psychotic disorders (Kwapil, 1998). Schizotypy often includes clear manifestations of sub-clinical negative symptoms, such as anhedonia and avolition, which are central to disability in SSD and are rarely responsive and sometimes iatrogenically impaired by psychotropic medications (Siever et al., 2002). Social isolation and social difficulties that are common in schizotypy are reliable elements of high-risk for SSD (Auerbach et al., 1993; Lencz et al., 2004). Relative reductions in neuropsychological abilities from childhood into early adulthood are also associated with higher risk for developing SSD (Cornblatt, Lenzenweger, Dworkin, & Erlenmeyer-Kimling, 1992; Kremen & Hoff, 2004; Cornblatt, Lencz, Smith, & Auther, 2004, Seidman et al., 2006).

Schizotypy is associated with reduced social functioning that appears to mirror the trajectories to disability associated with SMI (Small, 1990; Dworkin et al., 1994; McCleery et al., 2012). For example, Henry, Bailey, and Rendell (2008) showed, using the Social Functioning Scale (Birchwood et al., 1990), that negative schizotypy was associated with poorer social functioning, even after controlling for overall negative affect. This relationship was mediated by affective empathy, an element of social perception and social cognition.

SBQ-BRU preliminary analyses and screening study.

The measures used in the present study to assess visual and auditory attention and working memory, immediate and delayed memory, perception and recognition, affect perception, and other aspects of social cognition were selected for their extensive normative development and history of demonstrated utility in SMI research. While the measure chosen for assessing dimensions of schizotypy fits this description, its form and interpretation are presently substantially more controversial among SMI researchers (e.g., Cohen et al., 2010; Wuthrich & Bates, 2005; Fonseca-Pedrero et al., 2011). Also, it is expected that personality questionnaires by their nature may have more complex unexplained sources of error than neuropsychological, cognitive, and social cognitive tasks. Considering these relatively ambiguous personality constructs were the primary mechanism of stratified recruitment, it was particularly important to assure their fit and reliability in this specific recruitment sample.

The SPQ was developed in the early 90's and has been used continuously in research since then, although it is receiving increased attention due to the trend of increasing schizotypy research described above. The original SPQ was originally validated on an undergraduate sample and tested for its ability to discriminate between people diagnosed with Schizotypal Personality Disorder (SPD), a personality disorder on the schizophrenia spectrum, and controls (Raine, 1991). Since then, researchers have recognized its more generalized psychopathological measurement capabilities, and the SPQ has evolved as a measure of dimensional schizotypy traits rather than a diagnostic tool for SPD. Changes in the instrument have improved its dimensionality and utility,

such as the development of short-forms (e.g., Raine & Benishay, 1995) and ordinal response options (e.g., Wuthrich & Bates, 2005).

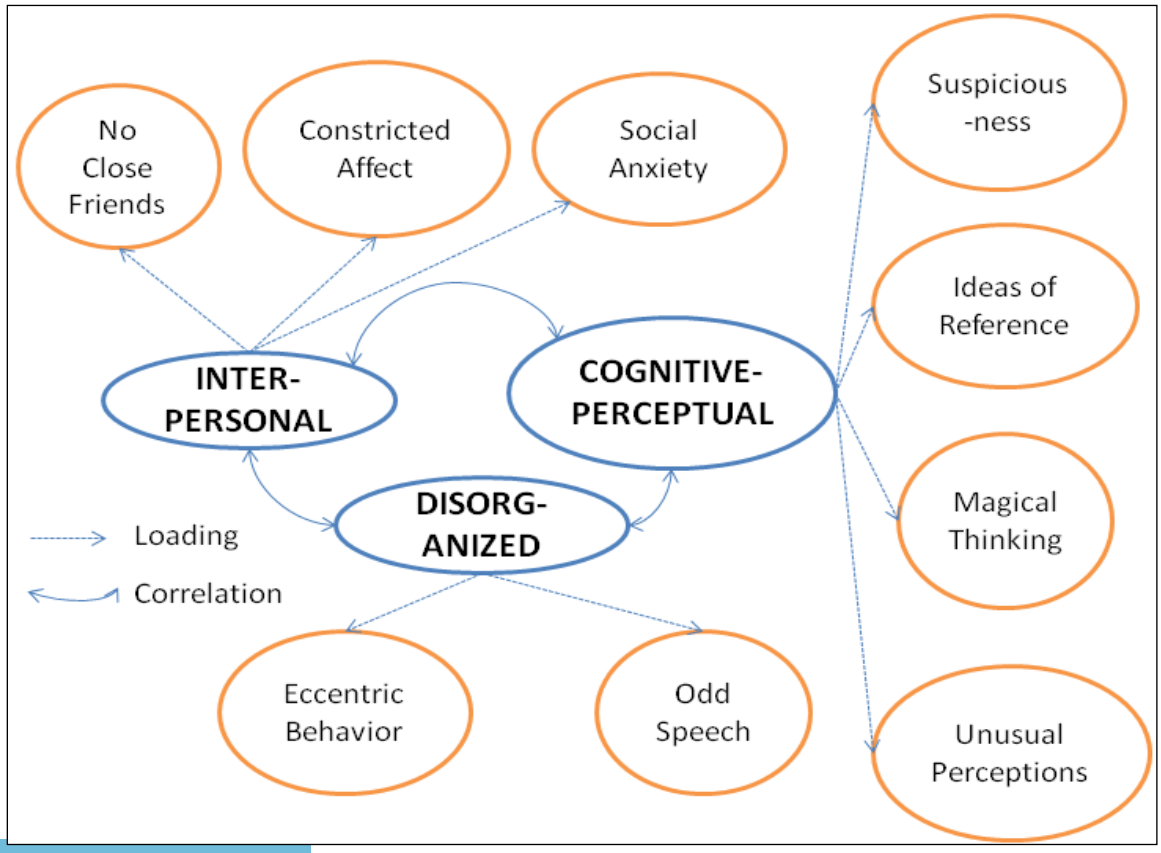
The recruitment sample for screening included responses to the SPQ-BRU (Davidson, Hoffman, & Spaulding, in preparation), a set of demographic and psychiatric historical questions, and a set of validity-check items (e.g., "Respond 'Strongly Agree' if you are still paying attention"). During each semester of recruitment for this study, students enrolled in psychology courses at a large Midwestern university were recruited for the departmental "mass screening." The mass screening is a short set of online questionnaires provided by many different researchers at the beginning of each semester. Participants who agreed to be contacted for further studies were recruited based on mass screening responses. Recruitment methods were highly standardized, due in part to close collaboration with the university Institutional Review Board (IRB), which approved all items entered into the screening. Students received course credit.

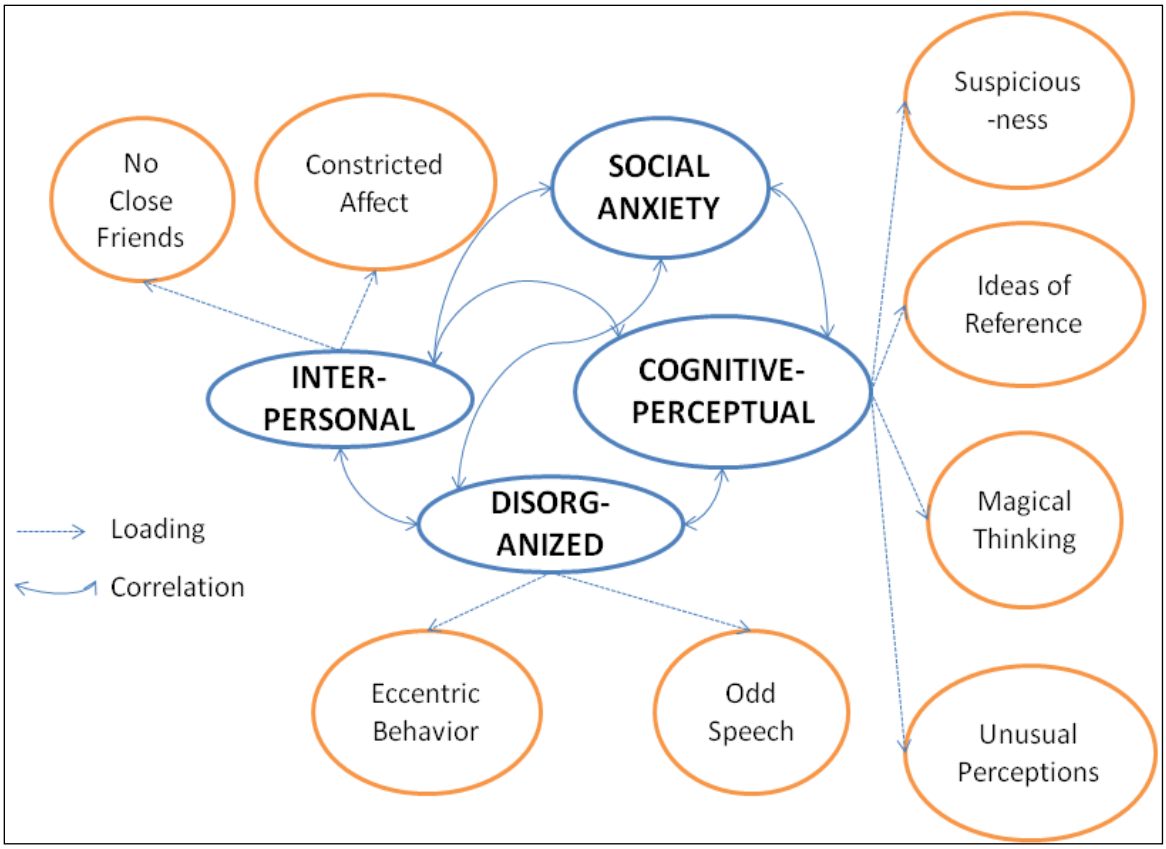
Participants for this study were recruited at the beginning of four different semesters from Fall, 2011 to Spring, 2012. Participants completed the Schizotypal Personality Questionnaire-Brief Revised (SPQ-BR; Cohen et al., 2010, Appendix 1) in the 2011 fall semester and a revised version of the same items (SPQ-BR "Updated," or SPQ-BRU, Appendix 2) for the remaining three semesters. A total of 2412 individuals' responses were used for the analysis. Of these, 736 used the original SPQ-BR wording, and the rest used the SPQ-BRU wording.

The SPQ-BR (Cohen et al., 2010) is a 32-item self-report scale with an ordinal (five-point, from "strongly disagree" to "neutral" to "strongly agree") response format that measures schizotypy on three or four super-ordinate factors and six or seven

subordinate factors. The SPQ-BR is reported to have two equivalently good-fitting hierarchical factor structures. The first includes three correlated higher-order factors, Interpersonal (IP), Cognitive-Perceptual (CP), and Disorganized (DO), and their sub-factors. The IP higher-order factor includes: No Close Friends (CF), Constricted Affect (CA), and Social Anxiety (SA). The CP higher-order factor includes: Ideas of Reference (IR), Suspiciousness (SU), Magical Thinking (MT), and Unusual Perceptions (UP). The DO higher-order factor includes: Eccentric Behavior (EB) and Odd Speech (OS). The second equivalent good-fitting higher-order structure includes SA as a fourth higher-order factor not loading on the higher-order IP factor. These higher-order structures are displayed in Figure 1.1 and 1.2.

Figure 1.1. *Higher-Order Models for SPQ Lower-order factors: Three and Four-factor Models.*

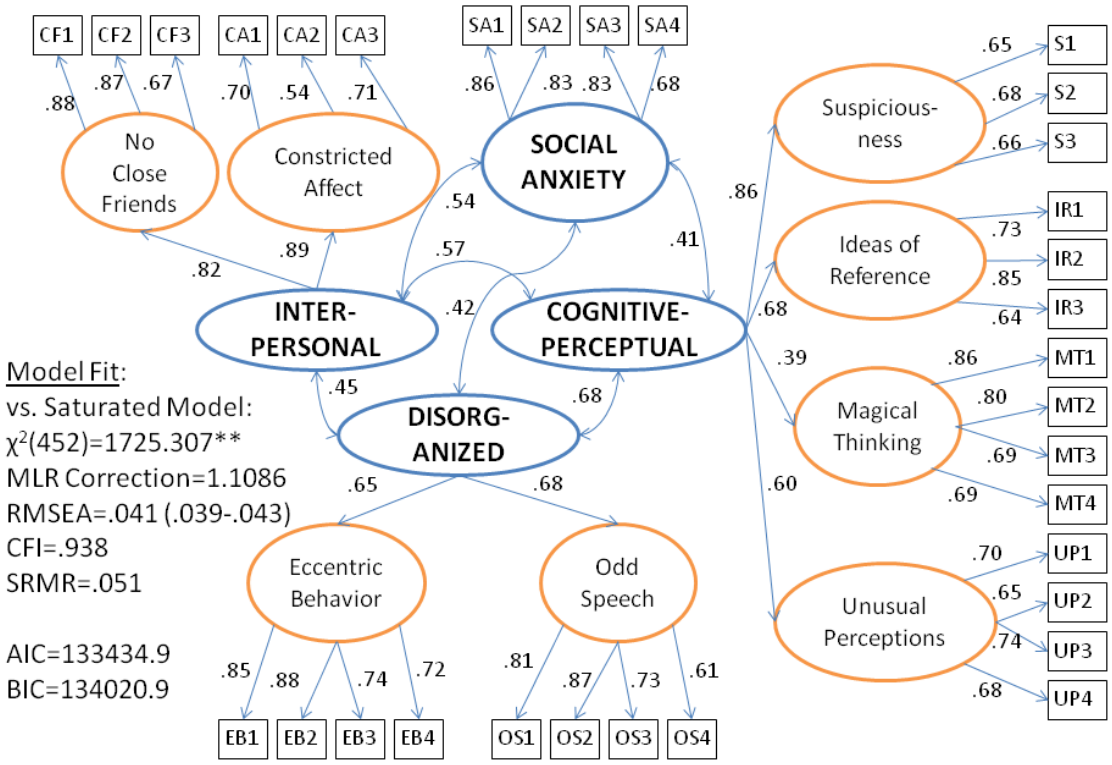




Confirmatory Factor Analytic (CFA) techniques were used to assess the fit and stability of the SPQ-BRU as well as to demonstrate the nature of the confound that was ameliorated by the updated wording from SPQ-BR to SPQ-BRU (Davidson, Hoffman, & Spaulding, in preparation). A single-order nine-factor structural model best fit the data. Specifically, this model specifies all of the most molecular categories based on the original conceptualization of the SPQ instrument (Raine , 1991). "Best fit" means that this structure best reproduced the pattern of covariance among the individual items. These nine factors had generally adequate reliability and fit, and when the data was split into cohorts by recruitment semester, the structure generally showed stable (invariant) structure. Additionally, the wording confound that was noted in the SPQ-BR and revised in the SPQ-BRU was empirically demonstrated, lending more confidence to the interpretation of model fit and of individual scores in the SPQ-BRU.

A more parsimonious, four-factor higher-order model best reproduced the covariance between the previously-mentioned nine-factor single-order model, as shown in Figure 1.2. Although the inter-factor correlations, item, and subfactor loadings are generally strong and as expected, it is important to note the relatively low loading of Magical Thinking on the Cognitive-Perceptual factor, as this measurement issue is quite evident in relationships to ERP data.

Figure 1.2. *SPQ-BRU CFA Summary. Four-Factor Structure, Model Fit, and Standardized Loadings.*



This final model allows schizotypal traits to be categorized in a way that better mirrors common clinical thinking in psychology. Traits can be divided approximately into "positive," Cognitive-Perceptual traits, Disorganization, and "negative" Interpersonal

traits, mirroring the commonly used Bleulerian terminology (Sarkin, Dionisio, Hillix, & Granholm, 1998; Dinn et al., 2002). Importantly, the latter "negative" traits are separated from Social Anxiety traits (Cohen et al., 2010). This is important because the face validity of measuring schizotypal "social anxiety" in an undergraduate population is quite poor. As the data showed, social anxiety appears to vary quite differently in the undergraduate population than other Interpersonal traits of Constricted Affect and No Close Friends, which are more likely to tap into the intended schizotypal traits in this type of population. Social anxiety certainly varies widely in undergraduates and is related to significant functioning difficulties, but this is a separate measurement issue that is not isomorphic with schizotypal social anxiety (Vollema & Bosch, 1995).

In summary, Meehl's conceptualization of schizotypy as a downstream product of schizotaxia is ideal for analogue SMI research. The SPQ-BRU measures these traits reliably and its four-factor structure fits adequately, parsimoniously, and without a confound found in the SPQ-BR.

Neurocognition and social cognition in schizotypy and SMI.

Laboratory measures of social cognition appear more proximal to behavioral functioning in SMI than neurocognitive measures (e.g., neuropsychological tests), and are partially moderated by neurocognitive variability (Brekke, Kay, Lee, Green, 2005). However, neurocognitive measures are potent predictors of outcome. Both neurocognition and social cognition should be included in studies of treatment course and outcome (Kee, Green, Mintz, & Brekke, 2003).

Neurocognition also predicts vulnerability in adolescents at high-risk for psychoses, suggesting neurocognitive measures may index a downstream effect of heritable schizotaxia (Faraone et al., 2001; Seidman et al., 2006). Schizotypy is related to neurophysiology as well as neurocognitive and social cognitive abilities. These characteristics have high heritability in families with SMI (Faraone et al., 2001). Negative symptoms are not only thought to be more closely related to risk for psychosis than positive and disorganized symptoms, but also appear to be linearly related to degree of neurological soft signs of sub-clinical schizotypy (Kaczorowski, Barrantes-Vidal, & Kwapil, 2009). Kaczorowski and colleagues demonstrated that psychomotor, memory, and eye movement abnormalities, all of which have been found to be related to family history of SSD, are closely associated with negative symptoms in subclinical schizotypy. Their findings supported a large body of research suggesting motor performance and eye movement abnormalities (particularly smooth-pursuit eye movements) are related to schizotypy in both clinical and nonclinical samples (Lenzenweger & Maher, 2002; Levy et al., 2010; Lenzenweger & O'Driscoll, 2006). They also found that positive symptoms in subclinical schizotypy were related to sensory integration dysfunction. Theleritis and colleagues (2012) replicated these findings, supporting the concept that negative symptoms of schizotypy in particular are associated with neurodevelopmental abnormalities, or in Meehl's terms, possible manifestations of schizotaxia.

Biological substrates of impairments related to symptoms of SMI have been clearly demonstrated. People with SSD on average have widespread reductions in grey matter volumes, particularly in frontal and medial temporal lobe regions (Shenton, Dickey, Frumin, & McCarley, 2001). At the time of the first-episode of schizophrenia

symptoms (and before initiating psychotropic medication), participants with SMI have smaller grey matter volumes, particularly in the superior temporal gyrus, that are related to cognitive, positive, and negative symptoms (Asami et al., 2012). Brain regions associated with specific visual sensory processing deteriorate over the course of illness and are also associated with first-episode schizophrenia (Hosokawa et al., 2013; Nakamura et al., 2007). These grey matter volumes are closely linked to ERP responses in SMI (McCarley et al., 2008), as are fMRI results related to face processing in SMI (Onitsuka et al., 2006). Additionally, diffusion-tensor imaging (DTI) research in combination with ERP techniques have demonstrated relationships between long-range connectivity and positive symptoms (Whitford et al., 2010, 2011).

Schizotypy, as well as family history or high-risk for SSD, are associated with deficits in many areas of neuropsychological functioning, and these deficits are typically at a severity between that of control samples and people with SSD. Schizotypy appears to be particularly related to tasks requiring maintaining an increased cognitive load or inhibiting interference (Seidman et al., 2012; Lenzenweger et al., 1991). Various instantiations of Continuous Performance Tests (CPT) have been used extensively in SSD research, and have shown a consistent relationship between performance, particularly focusing of attention, and schizotypy (Cornblatt & Keilp, 1994). Neurocognitive deficits in schizotypy and SSD appear to be particularly related to prefrontal functions, which has been demonstrated thoroughly in research utilizing versions of the Wisconsin Card Sorting Test (Gur et al., 2007; Mann et al., 1997; Lenzenweger & Korfine, 1994). Dividing their sample of college students' measurements into low, median, and high positive and negative schizotypy groups, Dinn and colleagues

(2002) suggested positive schizotypy is related to temperolimbic dysfunction while negative schizotypy is related to frontal executive dysfunction. Performance on Trail-Making Tests A and B (Tombaugh, 2004), classic tests of frontal executive functioning, was related to negative but not positive schizotypy. In a college sample, Matheson and Langdon (2008) found relationships between performance on both the Trail-Making Tests and the Letter-Number Sequencing task (Wechsler, 2008) with both negative and positive schizotypy, suggesting executive working memory is impaired in schizotypy across visual and auditory modalities. Importantly, both the Trail-Making and Letter-Number Sequencing Tests are included in the final MATRICS consensus cognitive battery, which was specifically designed for replicable assessment of change in cognition in SSD (Keefe et al., 2011). Neurocognitive deficits, which are so common in SMI, are also linked to specific genetic polymorphisms and are more common in relatives of people with SMI (Lopez-Garcia et al., 2013). Schizotypal traits have been consistently related to abnormalities in facial perception and emotion recognition (Platek & Gallup, 2002; Germine & Hooker, 2011) and other social cognitive abilities (Shean, Bell, & Cameron, 2007; Aguirre, Sergi, Levy, 2008). Additionally, social cognitive abilities in people with chronic SMI have been linked to social functioning using the Social Functioning Scale (Davidson et al., 2012).

Psychophysical and Electrophysiological Characteristics in Schizotypy and SMI

Face emotion perception.

Cognitive neuroscience has recently uncovered considerable evidence of neural processes and structures that appear to have evolved towards social functions. For example, "mirror" neurons are present in many animals and provide a straightforward neural mechanism by which some functions of social perception may be achieved (Spaulding, 2013; Hill et al., 2013; Charvet, Cahalane, & Finlay, 2013). Face perception, an inherently social process, clearly undergoes differentiated modular processing in humans. Like nearly all cognitive processes, the precise nature of these modules is debated, but it has become relatively clear that a dynamic processing network exists, with the fusiform face area, a gyrus of the medial occipitotemporal brain region, uniquely involved in processing of invariant configural aspects of faces, and other areas, particularly the superior temporal gyrus, involved in processing variant aspects of faces (Haxby, Hoffman, & Gobbini, 2000; McCarthy et al., 1997). These areas also process other modalities and serve different functions, but their integral involvement in face processing is clear (McCandliss, Cohen, & Dehaene, 2003; Tsao et al., 2006). Functional imaging has demonstrated the role of the fusiform gyrus in contrasting faces to other objects or scrambled images (Kanwisher, McDermott, & Chun, 1997). Fusiform activation is also modulated in various contexts, including attention (Haxby et al., 1994), and is part of a dynamic parallel processing system for perception (Eimer & Holmes, 2002). Individual differences in face processes not only arise from differences in face-specific modules, but also from non-specific differences, for example related to task demands or stimulus ambiguity (Rapcsak et al., 2000).

People with SMI in general have abnormal facial processing and facial emotion recognition. On average, people with schizophrenia have deficits in discrimination of

negative facial expressions (Borod, Martin, Brozgold, & Welkowitz, 1993). People with SMI seem to have particular difficulty in fear and anger recognition and may ascribe negative emotions to neutral facial expressions (Penn et al., 2006; Edwards et al., 2002). Further, affect perception in SMI has been linked to social functioning abilities (Brekke, Kay, Kee, & Green, 2005; Kee, Green, Mintz, & Brekke, 2003), and the negative effects of emotion processing deficits in SMI have been linked to reductions in fusiform grey matter volume (Onitsuka, 2006). Similarly, greater incorrect classifications of neutral face stimuli has been associated with increased symptoms (Lynn & Salisbury, 2008).

The nature of human emotion is a diverse and expansive area of study, but for the purposes of this study, a two-axial, dimensional model of emotion categories suffices. Russell (1980) described emotion categories lying along one axis of pleasant to unpleasant and a non-orthogonal axis of high arousal to low arousal. While incomplete, this model provides an interpretive heuristic that has parsimonious and reliably strong, if imperfect, convergence with neurobiological studies of face perception (e.g., Cottrell & Hsiao, 2011; Duval et al., 2013). In this model, surprised and angry emotion categories populate the high arousal space of the pleasant-to-unpleasant axis, and neutral and sad emotion categories populate a low arousal, unpleasant-to-neutral area of the dimensional space. Disgust, anger, and sadness populate the unpleasant, moderately-high to moderately-low arousal space, and happiness is isolated in the pleasant, medium-arousal space.

In deliberating on which types of emotion may best elicit brain responses that differ systematically with schizotypy, the social communicative function is also relevant (Scherer, 2000). For example, while fearful faces may elicit the most diametrically-

opposed responses to neutral faces due to their high arousal and unpleasantness, the social function is likely one of eliciting vigilance and arousal in others, whereas anger may more often function to communicate a direct, personalized meaning to the viewer (e.g., Marsh, Ambady, & Kleck, 2005). In the present study, angry and happy faces were chosen both for their salience and ability to reliably elicit different ERPs from neutral faces, but also due to their lack of ambiguity and likeliness to be perceived as personally directed (Adolphs, 2002). Additionally, in SMI, anger misperceptions have been associated with negative symptoms and functional impairments, while happiness perception has been linked to better social functioning and less symptoms (Cohen, Nienow, Dinzeo, & Docherty, 2009).

Integrating a large body of research, Adolphs (2002) explicated a well-received model of emotional face processing. Specifically, he described a theoretical network that starts with "fast early perceptual processing of highly salient stimuli" until 120ms after stimulus onset, then "detailed perception [and] emotional reaction" starting around 170ms, and "conceptual knowledge of the emotion signaled by the face" occurring after 300ms (Adolphs, 2002, p. 52). This model is essential to interpretation of the functional brain imaging related to emotional face stimuli.

Subliminal visual processing

Entirely subcortical perception has been termed "blindsight," although visual processing in the absence of striate cortex has been debated (Weiskrantz, 1996; Adolphs, 2002). Regardless of the exact processing stream, it is clear that perception without conscious visual experience is possible, and while this processing is relatively

impoverished, "subliminal" visual stimuli are processed sufficiently to alter behavior and represent relatively isolated early subcortical and extrastriate visual processes (Bernat, Bunce, & Shevrin, 2001). People with blindsight due to brain injury and people with normal vision presented with masked stimuli at a subliminal speed can discriminate emotional faces to some degree (de Gelder, Vroomen, Pourtois, & Weisenkrantz, 1999; Kouider, Eger, Dolan, & Henson, 2009).

It is thought that subliminal face perception represents the more rapid and automatic processing that usually occurs before and in parallel with cortical processing that occurs as the stimulus becomes consciously perceived (Adolphs, 2002). Some authors have posited that this consciousness of visual stimuli may be equivalent to ventral visual stream processing or fusiform activation (Fang & He, 2005). However, the evidence for specific indicators of conscious perception is inconsistent, in part due to difficulty defining and manipulating consciousness or visual experience (Kouider et al., 2009). Responses to highly-salient emotional subliminal stimuli appear to be modulated by the amygdala, and thus individual differences in subliminal emotion processing may represent individuals' automatic and pre-attentive emotion processing without the confounds of top-down modulation, recognition, and consciousness. Importantly, while the precise nature of subliminal visual processing is uncertain and clearly involves complex temporospatial network dynamics, masked subliminal stimuli produce defining characteristic behavioral responses and electrophysiological waveforms compared to the same supraliminal stimuli (Bernat, Bunce, & Shevrin, 2001).

People with SMI require longer presentation time to consciously access visual stimuli, but appear to process subliminal stimuli to the same degree as people without

SMI (Del Cul, Dehaene, & Leboyer, 2006). This consciousness threshold was correlated with negative, positive, and disorganized symptoms. The finding of intact early visual processing is consistent with findings using other stimulus paradigms (Minzenberg, Ober, & Vinogradov, 2002). This suggests that the difference between supraliminal and subliminal processing of the same stimulus in people with SMI may provide an index of bottom-up visual processing that can reasonably be expected not to be impaired and provide a matched baseline for assessing individual differences in conscious facial processing. Notably, early visual processing in SMI has been shown to be abnormal in people with schizophrenia, but the studies identifying these abnormalities have generally utilized stimuli requiring conscious cognitive control and attention orienting, later processes that are often impaired in people with SMI (Del Cul, Dehane, & Leboyer, 2006; Butler et al., 2001). Finally, abnormalities in subliminal image processing through backward masking has also been shown in psychometrically-defined schizotypy (Bedwell & Orem, 2008).

Differential deficit.

While it is outside of the scope of the present study to address the classic problem of differential deficit (Miller et al., 1995), this problem is central to the hypotheses of the present study and must be briefly invoked. Biological psychiatry has made enormous progress in understanding the biological underpinnings of mental illness, but in some cases, perhaps due to the interminable search for magic bullet cures for mental illness research trajectories have become decontextualized while searching for the one cause of a particular disorder (Ferguson, 2001; Miller & Rockstroh, 2013). In SMI research, this

direction has constantly run into the obstacle of generalized deficits. In other words, it is relatively difficult to identify areas of functioning for which people with SMI on average do not function abnormally compared to controls. Consequently, no single psychological test, brain measure, or chemical imbalance exists to date that uniquely identifies people with SSD or SMI. A large element of this issue is succinctly expressed by Miller and Rockstroh (2013), "Primary reliance on DSM and ICD categorical approaches must stop" (p. 15.24). The present study utilizes multiple dimensions of schizotypy to avoid this problem, but as previously mentioned, archetypal schizotaxia is yet elusive and probably represents the currently best approximation of the true variance in human behavior and brain function. The brain measures described in this study are designed to differentially measure individual differences related to schizotypy, with the intention of identifying "probe pairs" that index separate but related aspects of neural processing (McCarley et al., 1991, p. 214). As in McCarley and colleagues' (1991) apologia for the direction of his lab's and general schizophrenia neuroimaging research, the present study aims to identify ERPs that are

> "(a) cognitively meaningful as shown by links to a specific cognitive task in normals, and (b) likely to provide information on disturbed function in schizophrenia, because of the ERPs' relationship to clinical symptoms or other pathology" (p. 212).

The primary difference between this study and a biological psychiatric approach is that the present study aims to identify individual differences that vary across all

degrees of schizotypy. This continuous approach reflects the aforementioned adherence to Meehl's conceptualization of schizotypy, as well as other personality theories, and allows for the possibility that the identified measures can be honed to ideally measure individual differences between people with SMI for whom different treatment approaches may be suitable but whose relevant characteristics are not distinguishable with current technology (Lenzenweger, 2011; Millon et al., 2009). The ERP and psychological assessment protocol developed by the present study may indeed be used to identify the source of dysfunction in people with SMI. However, the present study is designed specifically to circumvent the incumbent issues of etiological research by instead working towards a better understanding of treatment effects and individualized treatment - a goal with substantially more foreseeable clinical utility than the relentless search for the cause of schizophrenia. It is clear that neurocognitive and social cognitive abilities, and change therein, play dominant roles in recovery (Penn, Addington, & Pinkham, 2006; Penn, Corrigan, Bentall, Racenstein, & Newman, 1997). If measures of brain processes with minimal overlap in variance underlying these different biosystemic levels of social processing can be identified, it is reasonable to expect that the gap between social cognitive neuroscience and social cognitive treatment may be narrowed, regardless of if these measures index processes unique to any particular symptom or disorder.

Electrophysiological measures.

Visual, facial, and facial emotion processing-specific ERPs are well-documented in cognitive neuroscience (Adolphs, 2002). Abnormalities in these ERPs and associated behavioral measures are robust effects in SMI (Turetsky et al., 2007). Additionally, ERPs

are associated with dimensions of schizotypy in SSD (Mannan, Hiramatsu, Hokama, & Ohta, 2001), first-degree relatives of people with schizophrenia (Kimble et al. 2000), and controls (Koychev, El-Deredy, Haenschel, & Deakin, 2010).

Visual perception is often impaired in SMI, and several theories for the specific etiology of this impairment exist (e.g., Silverstein & Keane, 2011). As previously mentioned, these theories are outside of the scope of the present study. This study instead takes the relatively atheoretical approach of focusing on individual differences in separable visual processes that are associated with schizotypy.

Sensory processing ERPs have been associated with schizotypal characteristics (Croft, Lee, Bertolot, Gruzelier, 2001; Evans, Gray, Snowden, 2007; Koychev, El-Deredy, Haenschel, Deakin, 2010). Relationships have been identified between both early and late sensory processing ERP components and multiple dimensions of schizotypy (Bedwell, Rassovsky, Orem, Kamath, 2011; Croft et al., 2001; Evans et al., 2007; Koychev et al., 2010). However, the large part of ERP research in schizotypy and SSD, especially in treatment outcome studies, has utilized basic auditory and visual stimuli. These paradigms are typically expected to tap into basic temporolimbic or prefrontal inhibition or gating processes that are thought to underlie positive and negative symptoms (McCarley et al., 1991; Whitford et al., 2010). To the knowledge of this author, no published research has utilized social stimuli in an ERP paradigm designed for treatment outcome studies in SMI.

Three specific ERPs have been associated most commonly with face-specific stimulus processing. The N170 is perhaps the most well-known, as it is thought to be related to conscious perception of a visual stimulus as a face and is generated in part by a

neural system including the fusiform face area (Bentin et al., 1996). The N170 is a negativity at occipito-temporal electrodes that has greater magnitude for faces compared to objects, scrambled faces, or other non-face stimuli. Notably, the N170 typically occurs earlier than the "170ms" mark set by Bentin and colleagues (1996; Joyce & Rossion, 2005).

The N170 is the negative trough following the P1, a waveform thought to indicate processing of low-level visual stimulus properties. The face-specificity of N170 or P1 is debated, but they are both clearly integral to the time course of face processing, especially configural aspects for which the viewer is expert (Rousselet et al., 2008, 2011; Dering et al., 2011; Eimer, 2011). The VPP is thought to be the dipole of the N170 component, occurring at centro-frontal sites, and their magnitude is linearly related to the location of the reference electrode (Joyce & Rossion, 2005). Later components are typically thought to represent modulation, orientation, and integration processes. However, early components such as N170 and even early components for unconscious stimuli can be modulated by emotional differences (Kiss & Eimer, 2007; Blau et al., 2007; Eimer & Holmes, 2002).

Different tasks elicit a different complex of waveform components following N170, but the P190 is sometimes measured immediately following N170, although its function is less clear, the N250 component is an inferior temporal component thought to represent response to facial affect modulation or affect decoding, and the P300 is a parietal component typically utilized to index attention orienting (Katayama & Polich, 1999; Turetsky et al., 2007).

Complementing research showing impaired performance on face recognition and emotion perception tasks in SMI, research has shown clear abnormalities in face perception neural processes in SMI. Turetsky and colleagues (2007) found reduced N170 magnitude in people with SMI for very sad, sad, neutral, happy, and very happy faces, which participants with SMI also identified less accurately. More accurate recognition of happy faces was associated with less severe negative symptoms, and reduced N170 response to sad faces was associated with the severity of positive symptoms, delusions in particular. The N250 was not different across groups. While P300 was different for all stimulus types, its variance appeared to be fully moderated by the N170. On the other hand, Wynn, Lee, Horan, and Green (2008) found that only N250 amplitude, and not N170 or P1, was different between people with SMI and controls, but subsequently Wynn and colleagues found that both N170 and P250 amplitudes and N170 latencies discriminated people with SSD and bipolar from controls (2013). Lynn and Salisbury (2008) utilized a task requiring participants to detect neutral faces from among emotional expressions, and participants with SMI performed equivalently to controls. However, while control participants' N170 had slightly larger magnitude for emotional faces, people with SMI did not show this modulation. While the group with SMI was not different from controls in performance on the task, within the SMI group, failure to button press to neutral faces was associated with greater severity of positive and negative symptoms. Campanella and colleagues (2006) replicated these findings, noting in particular a lack of N170 modulation in SMI in response to fearful faces. These authors also noted that not only P300 amplitude but also latency shifts in SMI may be moderated by earlier processing, as indexed by N170. However, some authors have reported that

both N170 and P300 represent discriminable abnormalities in SMI (Ramos-Loyo et al., 2009; Ergen et al., 2008). Obayashi and colleagues (2009) found no difference in N170 latency or amplitude for people with SMI, but N170 and not P1 amplitudes were related to global functioning in the SMI group. N170 has been associated with social cognition and neuropsychological abilities (Petroni et al., 2011), and is more responsive to emotional face tasks than gender identification or object discrimination tasks in participants with schizophrenia and controls (Wynn et al., 2008).

Although the focus in face emotion research has typically been on later processes and N170, P1 has shown differences in SMI and interpreted as indicating abnormalities in early dorsal rather than ventral visual stream processing (Foxe, Doniger, & Javitt, 2001; Caharel et al., 2007). Reduced P1 has also been associated with poorer working memory performance (Haenschel et al., 2007). It has also been suggested that P1 may be magnified by scrambled images as opposed to faces due to different spatial frequencies (Morgan et al., 2008).

Finally, P300 has been examined most commonly using auditory stimuli, and has shown reliable differences in SMI (Tamminga et al., 2014). P300 related to face perception has also shown correlations with face recognition performance above and beyond N170 or P1 (Turetsky et al., 2007). The most common paradigm for eliciting visual P300 is an oddball task, for which P300 is also reliably reduced in schizophrenia (Park, Han, & Jeon, 2010), including designs using face stimuli (Ueno et al., 2004). However, other forms of visual P300 have been examined in schizophrenia, including face recognition tasks (e.g., Vianin et al., 2002), visuospatial attention tasks (e.g., Potts et al., 2002), and face emotion (Turetsky et al., 2007). Interestingly, Potts and colleagues

(2002) found that in a visual attention task, participants with schizophrenia showed reduced amplitudes for early, "attention-sensitive" components but not P300.

Recent research has replicated these face emotion electrophysiology findings in participants at-risk for psychotic disorders, including participants whose risk was defined by clinician rating-based attenuated symptoms (Wölwer et al., 2012). Participants at risk had reduced facial affect recognition and reduced P1, N170, and N250 peak amplitudes, although P300 was not assessed. A report of face ERP in psychometrically-defined schizotypy did not show group differences in N170 amplitudes, but did show correlations between overall schizotypy and reduced N170 amplitudes (Batty, Rossell, & Francis, 2010). Further, sensory processing as indexed by neuroimaging appears to be a key element in understanding the development of prodromal symptoms (Bodatsch, Klosterkötter, Müller, & Ruhrmann, 2013).

Electrophysiology and treatment.

Central to the present study is the assumption that brain processes, as measured by electrophysiological technology, change during treatment. It is clear that treatment modalities exist that can help a person with SMI change characteristics at nearly any biosystemic level of functioning (Spaulding, Sullivan, & Poland, 2003). Contrary to Platonic mind/brain dualism, any of these changes must be reflected in some degree of biological change, but the present study still begs the question if the gross brain processes indexed by neuroimaging technology change in response to treatment.

ERP measurement has also shown promise as a tool for treatment outcome studies. Current ERP and neuroimaging paradigms appear capable of separately tracking changes in neurocognitive and social cognitive impairments in subjects with SSD.

ERP measurement has been utilized relatively extensively in psychotropic medication trials due to the technique's efficiency and waveforms' proximity to the expected medication-based changes in neural connectivity. The auditory mismatch negativity (MMN), a waveform typically recorded between 100 and 240ms after an "oddball," or infrequent, auditory stimulus which is compared to a baseline frequent auditory stimulus, has been utilized often due to its glutamatergic sources (Butler, 1968; Stephan, Baldeweg, & Friston, 2006). Several glutamatergic psychotropic medications have been reported to normalize MMN (e.g., Leung, Croft, O'Neill, & Nathan, 2008; Wienberg, Glenthoj, Jensen, & Oranje, 2010; Yuan, Zhou, & Yao, 2009). More common medications of the antipsychotic class, such as clozapine and haloperidol, have had more mixed evidence of changing MMN (Horton, Millar, Labelle, & Knott, 2011; Pekkonen et al., 2002).

There is accumulating evidence that specific psychosocial therapeutic procedures can induce changes in ERP measures associated with neurocognitive impairments and social cognitive impairments.

MMN, in addition to being related to medication effects, has also been associated with social functioning (Light & Braff, 2005; Wynn et al., 2010). Kawakubo and colleagues (2007) utilized a spoken phoneme MMN paradigm to assess electrophysiological changes during a three month social skills program, and MMN predicted skills acquisition. This provides precedent for utilizing an ERP stimulus set

more proximal to the particular skills under remediation. In other words, the authors updated the typical oddball paradigm (with tones of different pitches) to stimuli (spoken phonemes) that more directly map onto the types of skills that people aim to improve during social skills training.

Mazza and colleagues (2010) are, to this author's knowledge, the only group to report electrophysiological responses to a specifically social cognitive treatment package. Participants' treatment-related improvements in facial affect recognition and theory of mind abilities were associated with increases in N200 amplitude.

As psychotropic trials have utilized ERP techniques due to their measurement proximity to the desired treatment effects, cognitive remediation researchers have recently utilized electrophysiology to assess more directly the cognitive processes addressed in psychosocial and computerized cognitive remediation modalities.

Popov and colleagues (2011) used a paired-click paradigm to measure early sensory gating ERPs (P50), which improved in response to specific psychological training. Notably, this particular component has been associated with a specific genetic abnormality that varies systematically with schizotypal traits in healthy participants (Roussos et al., 2011). This finding is also particularly important due to the fact that biomarkers such as P50 that are thought to be endophenotypes can in fact change in response to psychosocial interventions (Braff, 2011).

Supporting this point from another biological direction, it has also been shown that working memory, a central deficit in SMI, can be improved using transcranial direct current stimulation (Jeon & Han, 2012). Inversely, Gazzaley (2013) reported older adults' gains in sustained attention were closely related to changes in Theta band

electroencephalogram (EEG) coherence, and Hooker (2013) demonstrated increases in Theta synchrony, thought to index dorsolateral prefrontal cortex connectivity, in participants with SMI's response to cognitive remediation. Further, the neurofeedback literature has shown clear effects wherein people who purposefully practice modulating their EEG response during attention tasks can also change their attention abilities in real-world situations (Gevensleben, 2009). Researchers have also demonstrated changes in BOLD fMRI signals in response to cognitive remediation (Stan, 2013; Penadés, 2013; Hooker, 2013; Subramaniam et al., 2012). Further, it has been shown in a non-psychiatric sample that visual tuning, which is thought to be an essential neurological determinant of masked image processing, be enhanced through behavioral intervention (Zhang, Meeson, Welchman, & Kourtzi, 2010; Green et al., 2011). Finally, it has become abundantly clear that synaptic plasticity in humans and animals at all stages of development allow reorganization and improvements in sensory perception abilities once thought to be fixed traits (Buonomano & Merzenich, 1998).

ERP technology and methodology have become mobile and user-friendly enough to permit highly reliable, repeated data collection under conditions quite tolerable to subjects with SSD, including portability, electrode arrays that can be applied in minutes, impedance management software that eliminates many methodological complications of EEG, time-efficient computerized stimulus control, and low task difficulty and processing demands (Molfese, Molfese, & Kelly, 2001).

Given their sensitivity to processes underlying treatment of SMI, their ability to be modulated in treatment, their proximity to treatment targets in social cognitive modalities such as Social Cognition and Interaction Training (Combs et al., 2007) and

Integrated Psychological Therapy (Roder, Brenner, Mueller, & Spaulding, 2010), and the efficiency of the EEG technique, ERP responses to emotional facial stimuli seem ideally-suited for developing a biological measurement protocol for treatment outcome research.

CHAPTER 2: THE PRESENT STUDY

Primary Hypotheses and Goals

Hypothesis #1) The ERP protocol and assessment battery are feasible in terms of implementation and attrition.

a) No participants will drop out of the study due to any aspect of the electrophysiological testing protocol (barring more common attrition, such as no-shows, cancellations, fire alarms, etc.).

b) No adverse events will occur related to the electrophysiological protocol.

c) The full testing protocol will be completed within the allotted four hours for all participants.

d) ERP data for a large portion (≥80%) of participants will be usable.

e) The protocol will be capable of portability (i.e., fully transferable to a portable system).

Hypothesis #2) The ERP protocol will produce reliable conditional waveforms in expected electrode regions. ERP components will show discriminative validity in measuring independent variance in brain responses to emotional, social, and non-social stimuli.

Utilizing both the preliminary empirical waveform derivation (temporal PCA) and subsequent peak and latency analysis:

a) The P1 component will be reliably identified in response to faces and scrambled images.

i. P1 will be identified most focally in Temporoparietal and Occipital electrode regions and diffuse positivity in anterior electrodes.

ii. P1 will be enhanced for faces vs. scrambled images in both subliminal and supraliminal presentations.

b) The N170 component will be reliably identified in response to faces and scrambled images.

i. N170 will be identified most focally in Occipital and Temporoparietal electrode regions, with a simultaneous focal positivity in electrode regions near the vertex (VPP) and nearly simultaneous diffuse positivity in anterior electrodes (dipole).

ii. N170 will be enhanced for faces vs. scrambled images in both subliminal and supraliminal presentations.

iii. Emotional faces will modulate the N170 such that responses to angry faces have the largest magnitude and neutral faces the least, with happy faces reliably in between, in both subliminal and supraliminal presentations.

iv. Across angry, neural, and happy faces, supraliminal faces will evoke a greater magnitude N170 than subliminal faces. This effect is expected to be reduced for Angry faces, which may elicit a stronger subliminal response due to increase salience.

v. Primed supraliminal images will have lower magnitude and earlier latency N170 compared to unprimed supraliminal images. If this comparison is significant, it will show a priming effect, implying that

this within-block subliminal and supraliminal design is not appropriate for efficient assessment of the supraliminal vs. subliminal comparison (having to control for priming).

c) The P300 component will be reliably identified in response to faces and scrambled images.
    i. P300 will be focused in Parietal and proximal electrode regions, with its negative dipole diffused across anterior electrodes.
    ii. P300 will be enhanced for faces vs. scrambled images in supraliminal but not subliminal presentations.
    iii. P300 will be enhanced for angry vs. happy images in supraliminal but not subliminal presentations.

d) The subliminal blank vs. other faces comparison will be significant for all waveform components. This is expected but not meaningful. Any nonsignificant differences would be notable.

Hypothesis #3) ERP components will show convergent validity with neuropsychological and social cognitive tests that are used to measure similar brain processes in SMI.

a) Trail-Making Tests (visuomotor processing speed and visuospatial working memory)
    i. Trail-Making Test A performance will be inversely correlated with P1 (faster visuomotor processing speed associated with greater magnitude P1).
    ii. Trail-Making Test A performance will be inversely correlated with N170 magnitude (faster visuomotor processing speed with greater

magnitude N170) for all stimulus types in subliminal but not supraliminal presentations.

iii. Trail-Making Test B performance will be negatively associated with both N170 and P300 magnitude (faster visuospatial working memory with greater magnitude N170 and P300) for all stimulus types in supraliminal but not subliminal presentation times.

b) BTFR and WMS-iii Faces (face memory and identification)

i. Face memory and identification will be positively correlated with the N170 difference component between neutral and scrambled face stimuli (i.e., people with better face memory and identification abilities will show a greater face-specific enhancement of N170).

ii. Face memory and identification will be positively correlated with the magnitude of P300 for face stimuli but not for scrambled images.

c) VEIT, FEIT, and ACS (emotion perception)

i. Emotional main effects (angry vs. happy, emotional vs. neutral) for N170 and P300 will be correlated positively with emotion perception, such that those with a greater magnitude peak differenceform will have better emotion perception.

Hypothesis #4) ERP components will show reliability as markers of traits that covary with degree of schizotypy and social functioning and thus may be expected to parallel differences between people with SMI.

a) Several of the above neuropsychological and social cognitive relationships with ERP will also be present in the relationship between schizotypy and social functioning.

   i. P1 and P300 will both be negatively correlated with Cognitive-Perceptual schizotypy and positively with social functioning, such that lower magnitude amplitude is associated with greater positive schizotypal traits and lower social functioning.

   ii. The difference between supraliminal neutral vs. scrambled face N170 will be negatively correlated with Interpersonal schizotypy and positively correlated with social functioning, such that a smaller difference between the conditional waveforms is associated with greater negative schizotypy traits and poorer social functioning.

   iii. The difference between subliminal angry vs. happy face N170 will be positively correlated with Cognitive-Perceptual schizotypy, such that a greater modulation of the subliminal N170 by an angry face is associated with greater positive schizotypy. Notably, this is a slightly paradoxical hypothesis, given the hypothesis above that this comparison will be associated with better emotion recognition skills, when we know that emotion recognition skills are generally poorer in people with extreme positive symptoms. However, the author is treating these as two separate hypotheses and assuming that this hypothesis may be driven by a perceptual bias toward threatening stimuli in people with suspicious characteristics - one element of positive schizotypy.

Hypothesis #5) Finally, after having analyzed each candidate waveform and comparison independently, a brief version of the ERP protocol will be proposed that hones in on the stimuli that produce the most powerful measures according to the aforementioned hypotheses. This project will produce an ERP protocol that is empirically devised for maximal utility in measuring brain processes expected to predict individual differences in treatment response in SMI.

a) It is hypothesized that the waveforms with the best criterion-related validity will be the overall magnitude of the P1, N170, and P300 across stimulus types and the emotional and face-specific comparisons in both subliminal and supraliminal presentation times, which are hypothesized to have different, but complementary external correlates. This is to say, it is hypothesized that the priming effect will not be particularly valuable compared to the stimulus type and presentation time effects. It is also hypothesized that the "happy" stimulus type may not be necessary to achieve strong predictive value.

    i. Such a result would imply that the best protocol moving forward would include three stimulus types (angry, neutral, and scrambled) with two presentation times (subliminal and supraliminal), not necessarily paired. This would reduce the study time by approximately half. However, if this is determined not to be sufficient reduction, supraliminal vs. subliminal presentations would have to compete. It is further hypothesized, should it be necessary to compare, that the supraliminal presentation will have more predictive value than the subliminal presentation.

CHAPTER 3: METHODS

Participants

Twenty-seven undergraduates were recruited through a departmental subject pool and received course credit for their participation. Data from seven subjects were excluded due to excessive noise artifact (less than 15 of 20 usable trials per condition). The final twenty participants were 60% female and on average 20 years old (range=18-23, SD=1.6). All experimental procedures were approved by the university institutional review board (IRB# 20111011874FB).

Measures

Screening Measures

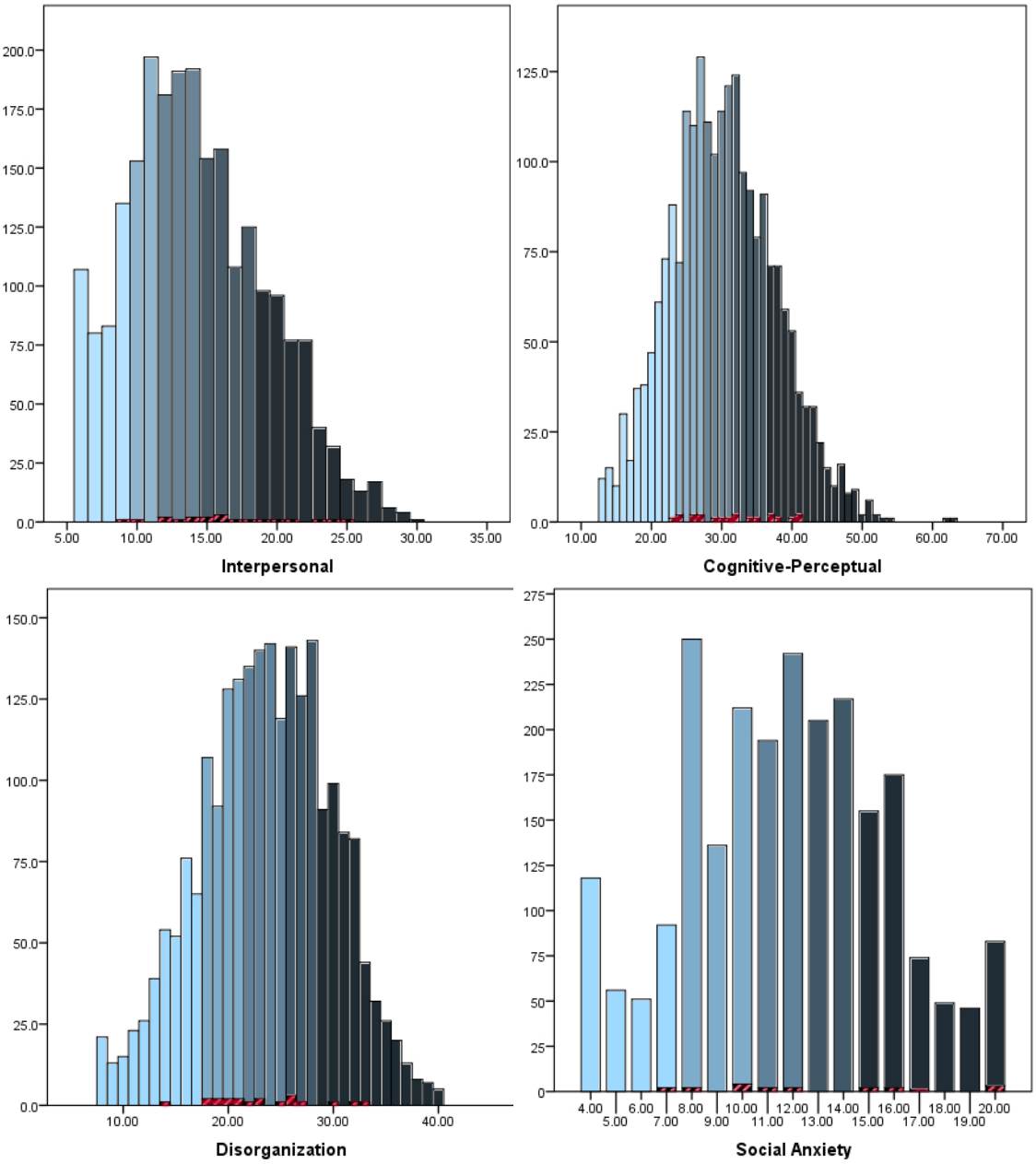
As described above, participants were recruited from a large departmental subject pool that completed a screening survey. This research group's questionnaires included the SPQ-BRU (Davidson, in preparation, Appendix 2), and a set of demographic and psychiatric history questions that were used for screening (Appendix 6).

SPQ-BRU.

The development and testing of the SPQ-BRU is described in detail above. Participants were recruited based on factor scores for the Interpersonal and Cognitive-Perceptual factors. Respondents in the top 85% on either of these two factors were recruited, and participants within a standard deviation of the median on both scales were also recruited. The distribution of the screening sample and the participants whose ERP

data was used is provided in Figure 3.1. A representative sample of the full range of all schizotypal traits was achieved.

Figure 3.1. *Distribution of Schizotypal Characteristics: Screening and ERP Samples*.



*Screening sample is shaded blue, with each shade representing a quintile. 20 participant ERP sample is represented by red striped bars.

Exclusionary Criteria.

Participants were excluded from participation if they had: cochlear implants, significant hearing loss, a fragile health status, a history of seizures or current use of anticonvulsants, currently receiving treatment for a psychiatric disorder, a history of head injury involving loss of consciousness, vomiting, headaches, prolonged confusion, or memory loss, significant uncorrected loss of visual acuity, shrapnel, neurostimulators, a history of metal fragments in the eyes or skin, or any metal or electromagnetic implants.

Assessment Battery.

Several self-report and researcher-administered tasks were chosen to assess social cognition and neurocognitive abilities. Neurocognitive indices were selected based on the MATRICS (Nuechterlein et al., 2008). Speed of processing, visuospatial working memory and face memory were assessed using Trail Making Tasks A & B, Wechsler Memory Scale – 3rd Ed - Faces subtest (Weschler, 1997), respectively. Facial processing abilities were indexed with the Benton Face Recognition Test (Benton, Hamsher, Varney, & Spreen, 1983), and facial emotion distinction with the Facial Emotion Identification Task (Kerr & Neale, 1993). Degree of schizotypal traits was assessed using the Schizotypal Personality Questionnaire-Brief Revised (Cohen et al., 2010; Kline et al., in press). Social indices were selected based on Nangle, Hansen, Erdley, and Norton (2010). Community social functioning was assessed by the Social functioning Scale (Birchwood et al., 1990). Demographics was assessed via a demographic measure assessing age, education level, ACT score, ethnicity, relationship status, and personal and family psychiatric history. Handedness was evaluated with the Edinburgh Handedness Inventory (Oldfield, 1971).

Computerized Questionnaire.

All self-report measures in the assessment battery that could be administered in survey form were administered in a set of computerized tests using Qualtrics survey software (http://www.qualtrics.com). The SPQ-BRU was administered a second time for each participant on the day of the session.

- Face Emotion Identification Test (FEIT; Kerr and Neale, 1993)
- Schizotypal Personality Questionnaire-Brief Revised Updated (SPQ-BRU; Davidson et al., in preparation)
- Social Functioning Scale (SFS; Birchwood et al., 1990; Appendix 5)
- Edinburgh Handedness Task (Oldfield, 1971; Appendix 3)
- Demographics questionnaire: Basic demographics relevant to the study including age, education level, ethnicity, relationship status, and personal and family psychiatric history (Appendix 6).

One measure was administered on the computer with researcher assistance:

- The Benton Test of Facial Recognition (BTFR: Benton et al., 1983)

Researcher-administered Measures.

The remaining measures were administered in the ERP testing room by a trained researcher.

- Voice Emotion Identification Test (VEIT; Kerr and Neale, 1993; Appendix 4)
- Advanced Clinical Solutions - Social Perception (ACS; Wechsler, 2010)

  - ACS data was only available for a subsample of participants. ACS materials were provided at a discounted rate according to the Pearson Research Assistance Program (http://www.pearsonassessments.com/pai/ca/support/rap/ResearchAssistanceProgram.htm).

- Speech Sounds Perception Test-Short Form (SSPT-DEF; Charter, 2000)
- Trail Making Test A & B (Trails; Tombaugh, 2004)
- Letter-Number Sequencing from the WAIS-IV (Wechsler, 2008)
- Wechsler Memory Scale—III; Faces subtest (WMS-III Faces; Weschler, 1997)

ERP Stimuli.

An ERP protocol was developed and piloted that incorporates an array of candidate measures - waveform amplitudes, latencies, and conditional comparisons. More specifically, the ERP stimulus protocol was designed to provide a maximal number of different candidate waveforms and conditional effects, such that the best possible candidate might be selected. The stimuli consist of emotional, neutral, and scrambled (non-face comparison) faces. Each stimulus was displayed in a sequence of subliminal followed by supraliminal presentation of the same face. Half of the trials had a blank subliminal image to control for priming.

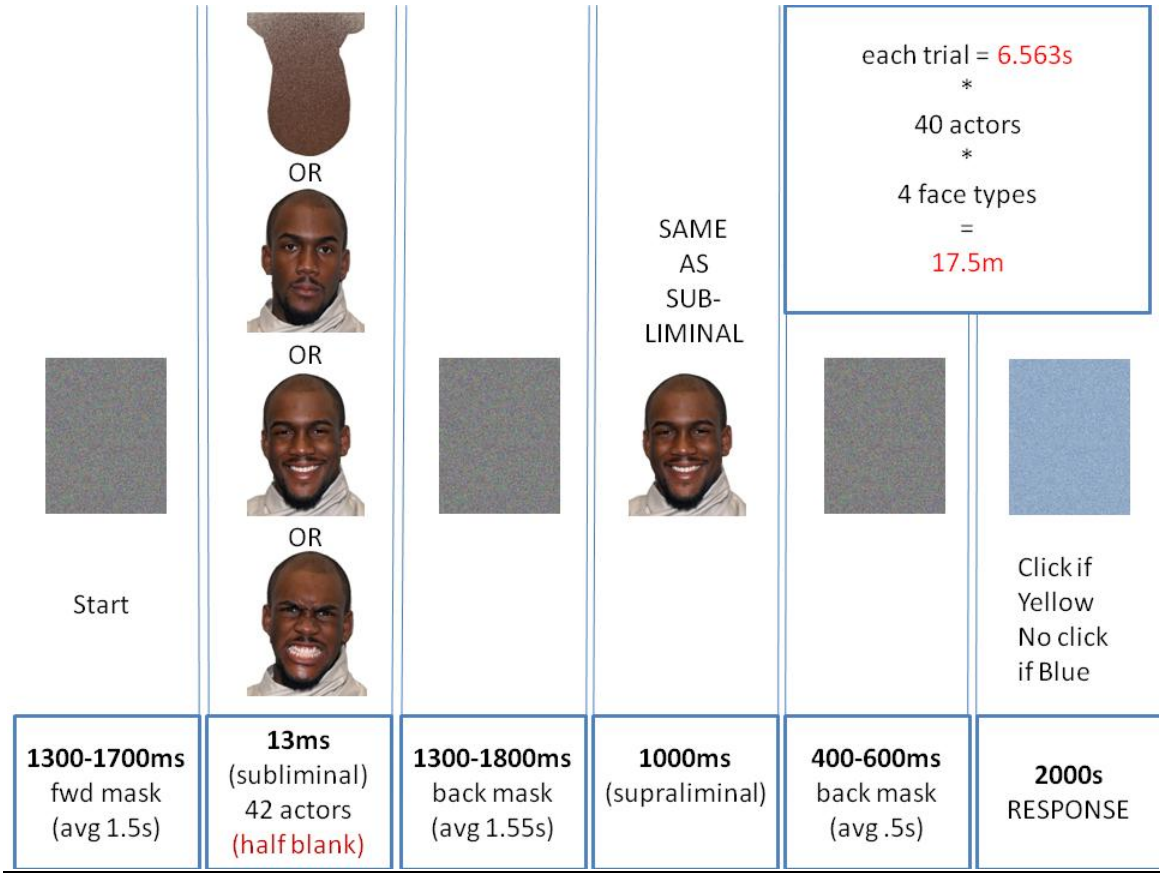
The faces used for this experiment were derived from the NIMSTIM dataset. Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at

tott0006@tc.umn.edu for more information concerning the stimulus set (Tottenham et al., 2002).

For each actor, the emotional faces with the most extreme ratings and best interrater agreement were chosen, and the neutral faces with the best agreement were chosen. Scrambled images were created using the GNU Image Manipulation Program, v.2.8.6 (http://www.gimp.org). For each selected happy, angry, or neutral face, a scrambled face was created. Notably, the images actually show the bust and head of the actor, not just the face. First, the entire actor's image was selected, excluding the background. A filter was applied that randomly redistributed every pixel within the selected area. This filter was repeated three times (applied four times total). Then, curves along the edges that were very obviously hair or ears were smoothed, retaining the same total image area with a more feathered edge. Finally, the entire image was rotated 180 degrees. As such, the image had all of the same visual properties as the neutral and emotional faces used, but lacked the definitive configural patterns of the face, and inversion further reduced the likelihood of the stimuli being perceived as social. The mask and response color images were the same shape as the face images. They were created by selecting an arbitrary face image, using the random redistribution of pixels (without having first isolated the face) repeatedly until the entire image space was acceptably covered and no apparent patterns were seen by the researcher. Then, the image was desaturated to be grayscale. The color response images were created simply by isolating the appropriate color from the grayscale image. All images were presented against a background that was scrambled in the same way, with its color balanced enhanced to be slightly darker than the target area.

The ERP face design is displayed in Figure 3.2. This figure shows one block of stimuli, which consists of two ERP epochs (more epochs could be used, but at this point, our hypotheses are only about these two). Blocks are randomized, and only one face stimulus image is used in a single block. After a forward mask, either a subliminal masked face or a blank box are shown and promptly removed from the retina with a backward mask after 13ms. If it is a face, it could be either angry, happy, neutral, or scrambled. Otherwise, it was white (blank) space, matching the background in the face images. After the subliminal stimulus and its attendant masks, the same image was presented supraliminally (note, if the subliminal stimulus was blank, the same image that 'would' have been there was then presented supraliminally). This image remained on the screen for 1000ms. It was closed by a backward mask, which was followed by a blue or yellow mask. Participants were asked to respond by a button press only to yellow masks, which occurred a third of the time, but to inhibit responding to blue masks. Participants completed four practice trials before experimental trials began. Notably, no participants made more than two mistakes in the experimental trials. The length of all the masks were jittered to prevent a rhythm and timed expectations.

Figure 3.2. *ERP Face Design.*



Participants' responses are purposefully unrelated to the stimuli of interest. This aspect of the protocol was decided upon in order to avoid the confound of attentional control and task difficulty, which might dominate individual differences between people with schizotypy in social and emotional processes, limiting differential assessment capabilities.

Forty different actors' faces were presented in this way. Each had four stimulus types (neutral, happy, angry, and scrambled), and each trial lasted 6557ms. So, the entire ERP protocol took 17.5 minutes total. At least one pause was taken about halfway through to allow participants to blink and get comfortable.

Procedures

Data Collection and ERP Assessment.

Recruitment and analyses for the schizotypy screening measures are described above. Participants in the recruitment sample also responded to a set of screening and demographic questions (Appendix 6), which allowed the researchers to recruit only participants who were eligible for ERP.

Stratified recruitment was achieved by heavily recruiting the participants in the top 85% of Cognitive-Perceptual and Interpersonal schizotypy response sets, and the remaining participants were recruited from around the median scores.

Participants were instructed not to consume caffeine, nicotine, alcohol, or processed sugar the morning prior to testing. Participants sat one meter in front of a high-resolution, high refresh-rate computer monitor. The ERP paradigm was presented using E-Prime software, and presentation was controlled by the Electrophysiological Graphical Imaging System (EGIS), v. 2.2. Participants responded with a button-box.

During completion of the task, participants' EEG and behavior was continuously monitored. Stimulus presentation was suspended during motor activity or inattention and resumed once this had subsided.

A computer running NetStation 4.1.1 (EGI, Inc.) was used to record the electrophysiological data at a sampling rate of 250 samples/s. ERP data collection was conducted under the supervision of Dr. Dennis Molfese in the Center for Brain, Biology, and Behavior (CB^3), at which all experimental procedures and waveform analysis were completed. For ERP collection, an Electrical Geodesics Incorporated (EGI) 256-channel EEG/ERP system was used. The system includes a high-impedance 200-series amplifier, an Apple Mac Pro computer with two 2.4GHz Quad-Core Intel Xeon "Westmere"

processors and 6GB memory running NetStation 4.3 software, a Dell Windows PC for stimulus presentation using E-Prime 2.0 Professional, ERP NetStation software, and high-density EEG nets fitted to three different head circumferences each containing 256 electrodes. Nets were soaked in potassium chloride for electrolyte solution, and all materials were disinfected after each use. The nets are comfortable, safe, and trained researchers were generally able to apply the net in less than a minute. The entire ERP set-up process could be completed in less than ten minutes.

Brainwaves were recorded using a high-density array of 256 HydroCel electrodes embedded in soft sponges arranged in a net (Geodesic Sensor Net, EGI Inc.). During recording, all electrodes were referenced to Cz and later transformed to an average reference. Impedances remained at or below 40 kOhms throughout testing as indicated by measures taken before and after the experiment. The FIR filter setting for high-pass was set to 0.3Hz and the low-pass set to 30Hz with rolloff at 2Hz. Components of interest occur within the first 1000ms of stimulus onset (Dehaene et al., 1998). The EEG was thus recorded for 1000ms, plus a 200ms baseline before the onset of each stimulus. Offsets were calculated for each stimulus presentation type and checked monthly, and ERP segmentation was offset by this delay. Offsets were consistently 36ms for all stimuli on multiple testing occasions.

The face ERP protocol was randomized within a set of ERP protocols, including another researcher's two four-minute ERP protocols. Altogether, the ERP acquisition lasted about 25 minutes, and the entire ERP session including set-up, experiment, pauses, impedance measurement, debriefing, and clean-up, lasted about 45 minutes.

After ERP, participants completed behavioral tasks and questionnaires in the same room as the ERP session and then in an adjacent computer room.

ERP Debriefing.

After the faces ERP protocol, participants were asked informal follow-up questions to ascertain the participants' perception of the face emotions and the subliminal stimulus. The primary researcher (CD) asked these questions, and started with the least leading questions, and asking more and more leading questions until disclosing the nature of the face emotion and the fact that there were subliminal stimulus. Then, participants were informed of the purpose of the subliminal stimuli and asked not to share this information with anyone. The question prompts were:

> "What did you see in this task? [Query for more information]. The faces (that weren't scrambled) were showing three emotions, what do you think they were? [Debrief about not sharing that task is subliminal if they noticed]."

In retrospect, the questions were not recorded with sufficient detail or designed in a way to be quantifiable. However, nearly all participants noticed a "blink" before the face was fully revealed, and about half of participants recognized that it was most often the "same face," but most were not sure if it was the "same expression."

Analytic Rationale

First, the non-ERP measures were analyzed independently. This data has been analyzed with the full set of data, including participants who did not complete this ERP task and participants whose ERP data was unusable, as reported in Keplinger, Davidson, and Spaulding (2013). Next, the characteristics of the non-ERP measures were re-examined including only the participants who had usable ERP data.

The non-ERP data were analyzed using basic descriptive and correlational analysis to better understand the characteristics and biosystemic relationships among measures in this sample and if they replicate those found in the full non-ERP sample. The primary hypotheses of interest are about relationships between biosystemic levels of functioning that are typically found in SMI. These include expected correlations between attention and working memory, face memory and recognition, face emotion recognition, and all combinations thereof. Relationships of these tests with outcome measures are expected, namely schizotypy subfactors and subcategories of social functioning. As mentioned above, the full dataset has shown relationships between neuropsychological measures and positive and negative schizotypy, as well as relationships between schizotypy and social functioning. However, other measures are not related to the degree that would be expected in an SMI sample. As such, it is not expected that the smaller subsample of these data from participants with usable ERP will evidence any more parallels with the biosystemic relationships found in SMI. Any exceptional differences between the results using the full testing dataset and the limited ERP dataset are noted.

Next, EEG recordings were processed and each set of ERP conditions were analyzed.

Before conducting analyses of amplitudes and latencies, individual ERP epochs were analyzed for artifacts that occur for reasons other than the stimulus manipulation, following procedures outlined by Molfese, Molfese, and Kelly (2001).

First, data collected in Net Station were filtered with a 0.1-30Hz filter. The data were then segmented into epochs from 200ms prior to stimulus onset to 1000ms post-stimulus. Next, the waveforms were visually inspected and matched to observations and impedance testing from the testing session to exclude any electrode channels with noisy data clearly due to artifact (e.g., missing sponges, loose wires, or a bad connection with the scalp).

Next, using a semi-automated artifact algorithm, the data were scanned for artifacts resulting from eye blinks, head movements, participant fatigue, or other sources of artifact. Electrophysiological activity generated from eye movements and blinks were detected by electrodes placed at canthal, supra-orbital, and sub-orbital positions around each eye. ERP trials in which eye channel voltage exceeded 150 μV were omitted from further analyses. The spherical interpolation algorithm described by Picton and colleagues (2000) was utilized to interpolate values for electrodes that generated distorted signals on more than 10% of trials.

Next, all trials were visually inspected for trials that were unusable (e.g., containing slope due to EEG activity that was not filtered and not detected by the automated algorithm) or individual electrode sites during individual trials whose connection was only momentarily disrupted, as evidenced by isolated electrode slope or peaks in amplitude clearly unlike all other electrodes. After removing artifacts, the average baseline EEG was calculated from the data collected 200ms prior to stimulus

onset. The remaining data was corrected to this baseline and subsequently re-referenced to the average level of activity at all other electrodes.

ERP signals for each participant were then averaged at each of nine electrode regions (inferior temporal, orbital, orbito-frontal, temporal, prefrontal, temporo-parietal, parietal, occipital, and inferior occipital) and hemisphere (left and right) for each stimulus condition.

After pre-processing of the data was complete, ERPs were entered into temporal Principal Components Analysis (PCA), according to the procedures described by Molfese et al. (2001), in order to identify which temporal regions of the ERPs account for differences between conditions, topographic regions, and participants, and to produce PCA factor scores for further analysis.

The time range for the PCA was limited to stimulus onset to 600ms poststimulus, as all expected waveforms occur in that time period. The ERPs were analyzed by 8ms intervals, the standard sampling rate for ERP studies, resulting in 100 time points. Varimax rotation was applied to the factors identified in the temporal PCA in order to facilitate interpretation of the factors. All of the average ERPs for each participant, condition, region, and hemisphere were each treated as separate cases. Cattell's Scree test (1966) was used to determine how many factors should be derived from the temporal PCA. Hypotheses are made at this point in the analysis about the nature of the waveforms suggested by the temporal distribution of the PCA factors, and this preliminary screening determines which factors will be entered into further analysis. These hypotheses are confirmed through the following steps of PCA factor score MANOVA and between-

condition tests of peaks and latencies during the temporal window suggested by these PCA factors.

Each PCA factor of interest will first be entered as the random effect in MANOVA by condition, region, and hemisphere. Each specific comparison ("contrast") will be examined individually to determine which PCA factors (i.e., empirically-derived ERP component variance) in which regions best differentiate stimulus manipulations. The primary comparisons of interest are determined by the study design.

Notably, all comparisons approximately replicate previously reported ERP reports to the knowledge of this author with the exception of the Primed vs. Unprimed comparison, although there is at least one report of behavioral responses to a similar paradigm (Gohier et al., 2013), and the subliminal face vs. blank image comparison. This latter effect is not of specific interest in the study, but the priming comparison is necessary in order to interpret the subliminal vs. supraliminal comparison and primed vs. unprimed supraliminal comparisons.

Step 2: The most promising and consistent PCA factor score MANOVA results (conditional effects) will be followed up by examining the conditional peaks and latencies and difference peaks to determine the precise nature (in amplitude or latency) of the revealed effects. These peak and latency effects will then be examined in relationship to external variables. Step 2 maps onto Primary Hypothesis 2.

Step 3: The results for different conditions and components will be compared to determine the degree to which each component of the study design contributes to criterion-related validity. Step 3 maps onto Primary Hypotheses 3, 4, and 5.

Step 4: Implications for the relationships noted for the best comparison or set of comparisons will be discussed, and a potential novel, honed paradigm based on these results will be recommended.

Protocol Development Process

The development of this protocol and technical development of the experimental materials involved substantial consultation, trial-and-error, and unexpected limitations. It is not within the scope of the present document to detail the entire process, but a two development processes are worth noting.

The development of the emotional face ERP paradigm was carried out with a team of exceptional researchers, including members of the present dissertation committee as part of an unfunded grant submission and re-submission for PA-11-111, the pre-doctoral NRSA or F31. The decision process was complex and protracted, but the final motivation can be summarized as piloting for exploratory analysis of differential assessment. Extant research designs in the literature typically involved faces vs. non-face comparisons, emotional vs. neutral comparisons, subliminal vs. supraliminal presentation times, or in a few cases the combination of two such manipulations. However, the goal was to identify independent ERPs indicating processes that are relatively non-social, face-specific, and emotion-specific without the overriding moderation by attention

abilities that is omnipresent in SMI psychopathology research. The best approach was determined to be a "shotgun" approach, wherein the most productive face emotion designs from the literature would be combined into a single experiment to increase the chance of within-person discrimination of multiple independent ERPs capable of indexing differential characteristics. The present design achieved combining these several lines of research, but created an artifactual condition of priming that had to be controlled, and thus the experiment was doubled in duration due to the need for a control condition for priming. The final design was determined to have the best chance, due to the most conditional effects that have been proved in the literature, of finding the conditional effects that discriminate differential processes and show criterion-related validity with external measures, which would link them directly to a long history of SMI treatment and psychopathology research. The downside of this approach is that the ERP protocol lacks precise replication of any previous designs in the literature, as each conditional effect is different from previous studies in its present context. Nonetheless, the present design appears optimal for simultaneously piloting and finally selecting and optimizing an efficient design for both analogue and clinical SMI social cognitive ERP research.

The second development process of note is an overambitious error and cautionary tale. It is apparently common knowledge in researchers who use attentional blink and backward masking designs that cathode-ray tube (CRT) computer monitors tend capable of short presentation durations for which LCD monitors fall short. Most reasonably-priced LCD monitors refresh at 60Hz. However, high quality CRT monitors have become difficult to find. There are now plenty of LCD monitors on the market with high refresh rates, and although repeated interactions with customer service for several major

computer companies failed to elucidate the computation of horizontal scan range, vertical scan range, refresh rate, and frames per second, online video-gaming resources provide the needed information. The calculation is actually quite simple once you can find a refresh rate in Hz (cycles [or frames, in this case] per second). The minimum duration of each new frame is simply 1000ms/refreshrateHz. So, a typical 60Hz monitor has a minimum frame duration of 16.67ms, 75Hz has 13.33ms, and 120Hz has 8.33ms. Del Cul, Baillet, and Dehaene (2007) found a mean subjective threshold for conscious perception at 43.9ms ±10.5 and objective threshold at 40.8ms±12.4. Although perception was not different from chance at 16 and 33ms (p=.011 and p=.059, respectively), this author thought it prudent to go past this extremely short presentation time to remove any error from an expected relatively small sample. Months of work went into timing tests for various monitors, including one rated at 120Hz, aiming for a 7ms stimulus onset asynchrony (i.e., presentation time). Bottlenecks were removed at the level of the stimulus computer's video card, the length, type, and quality of the video cable, and any possible issues with Netstation or the EEG recording computer were ruled out. However, timing tests revealed a limit at approximately 13ms. With time, it was found that the current version of the stimulus presentation software, E-Prime, was not capable of presentation at refresh rates greater than 75Hz. So, the study was limited to a 13ms subliminal presentation time, barring researching, purchasing, and learning programming for a different stimulus presentation software program. In retrospect, it seems fair to say that 17ms with a 60Hz monitor should have been acceptable, as this was the minimum presentation time for seminal literature in this field (e.g., Del Cul, Dehaene, & Leboyer, 2006).

Finally, the study began with only graduate-level experimenters with months of training in ERP methodology and analysis. This quickly became impossible as the recruited participants' schedules were not compatible with the experimenters. A protocol was developed for training ambitious undergraduate research assistants to be the second experimenter with very limited interaction with ERP equipment or the consent process, except for the process of applying saline solution via pipette to unresponsive electrodes. Research assistants were trained to administer hearing and vision tests and all measures of the assessment battery that did not require extensive training. Research assistants were able to administer the tests successfully, albeit under nearly constant supervision, and were able to gain skills and content knowledge through running participants and regular research meetings with this author. Very few errors were noted, although there is one noted instance in which a research assistant forgot to administer the second (delayed) part of the WMS-iii Faces test. One research assistant collaborated on a poster for a professional conference, and another developed a curriculum for independent study to pilot a complementary psychophysical protocol. Altogether, this experience showed that the ERP protocol is indeed possible to implement with a highly-trained researcher and relatively novice research assistant and can be done so in a manner that benefits both parties.

CHAPTER 4: RESULTS

Recruitment

A combination of chance and apparently systematic exigencies resulted in a relatively poor representation of very high schizotypy in the eventual usual sample. Of the participants who had valid responses and agreed to be contacted for further research, 18.8% were recruited by e-mail specifically for higher-than-average responses in the Cognitive-Perceptual (CP) or Interpersonal (IP) or both SPQ-BRU items. Eight participants were recruited who were in the top quintile for both CP and IP. Three of these eight agreed to participate in the study. One had a head circumference that was too great for the available nets at that time (63"). Another disclosed that (s)he had been prescribed psychiatric medications before, but declined to disclose any further detail. The ERP data from this participant was not usable. Data from the third participant in this range was usable. Thirty-five participants with CP (but not IP) scores in the top quintile and were recruited. Four responded, and two agreed to participate. Neither participant's data were usable due to a combination of amplifier malfunction and difficulty with blinking. Thirty-eight participants with IP (but not CP) scores in the top quintile were recruited. Ten responded, and nine agreed to participate. One canceled a week ahead of time. One had a head circumference that was too great. One person had very poor English communication abilities, described the facial stimulus emotions as "sad" and "disturbing," where other participants described some version of "angry" and "happy," and overall (s)he had a poor EEG signal. Six of these participants participated and had no

apparent difficulties with ERP tasks or with equipment during their sessions. Five of these six had usable ERP data.

Unfortunately, detailed data were not kept for participants recruited from the median range. So, the above descriptions cannot be interpreted as different from typical recruiting difficulties. However, these data do serve a "case study" purpose of describing the difficulties and low recruitment rate of people with high ratings for schizotypy, although it is unclear if these difficulties are different from those with median ratings. The overall impression of this extremely small and informal recruitment sample is that people with a high degree of Cognitive-Perceptual symptoms were less likely to respond to recruitment efforts than those with only a high degree of Interpersonal characteristics.

Non-ERP Results

Assessment battery data were analyzed using the full dataset of participants who completed the testing battery, only a portion of whose visual ERP task data are used in the present study. No notable differences in direction or magnitude of effects were noted when comparing these results to the same models in the ERP-only sample.

Several variables had highly non-normal distributions. In these cases, Spearman's *Rho*, a rank-order correlation, was used instead of Pearson's *r*. These included Trail-Making Tests A and B, ACS Emotional Tone Total, SPQ-BRU Magical Thinking, Social Functioning Scale Interpersonal Communication, and Social Functioning Scale Independence-Competence.

Overall, expected correlations between emotional, auditory, and visual perception and recognition with each other and with neuropsychological, personality, and social

functioning measures were not significant. However, schizotypal traits correlated with both neuropsychological performance and social functioning, as shown in Tables 4.1 and 4.1. Visual and auditory working memory were associated with positive (Cognitive-Perceptual) traits and negative (Interpersonal) traits, respectively. The relationship between visual working memory and Cognitive-Perceptual traits was driven by the Unusual Perceptions subscale, which correlated with both Trail-Making Tests A and B, but not with the residual of B on A, suggesting that this correlation was more related to visuomotor attention and processing speed than to isolated executive functioning. Negative schizotypy was highly related to multiple aspects of social functioning, and Social Engagement and Withdrawal was associated with negative, positive, and disorganization schizotypal characteristics.

Table 4.1. *Neuropsychological Tests and Schizotypal Personality Questionnaire-BRU Correlations.*

Correl-ations[a] (N=34)	**Cognitive-Perceptual (CP)**	CP subscale: Ideas of Reference (IR)	CP subscale: Suspiciousness (S)	CP subscale: Magical Thinking (MT)	CP subscale: Unusual Perceptions (UP)	**Inter-personal (IP)**	**Social Anxiety (SA)**	**Disorganization (DO)**
Trails A	.229	-.041	-.097	-.049	.492**	.320	.314	.033
Trails B	.371*	.042	.050	-.028	.494**	.234	.121	.221
Trails B on A (residual)	.251	.079	.079	.011	.204	.039	-.102	.179
Letter Number Sequencing (LNS)	-.147	-.129	.001	.101	-.055	.122	.087	.053

LNS-Longest Span	.125	-.016	.164	.087	.065	.438*	.431*	.186

**=p<.01; *=p<.05; [a]Spearman's *Rho* except for CP, IP, SA, and DO with LNS, which are Pearson's *r*.

Table 4.2. *Social Functioning and Schizotypal Personality Questionnaire-BRU Correlations.*

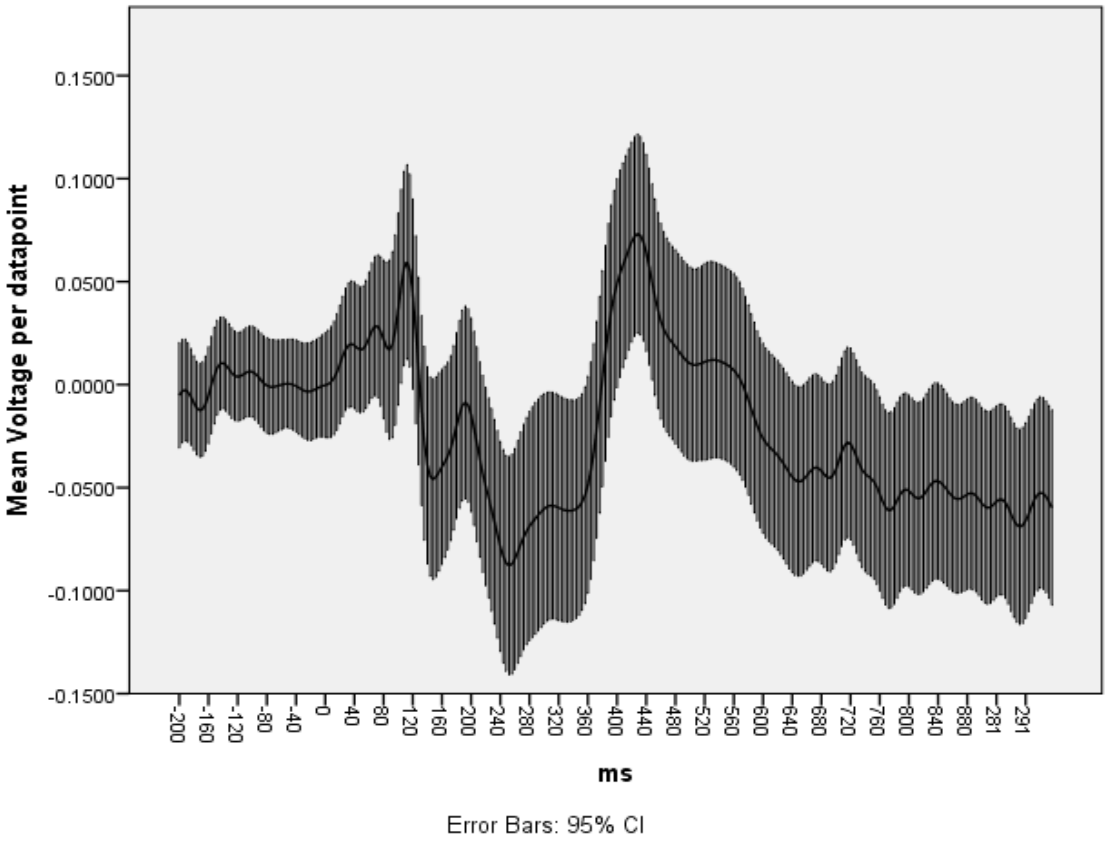
Correlations[a] (N=37)	**Cognitive-Perceptual (CP)**	**Inter-personal (IP)**	**Social Anxiety (SA)**	**Disorganiz-ation (DO)**
Social Engagement / Withdrawal	-.361*	-.714**	-.674**	-.387*
Interpersonal Communication	-.152	-.611**	-.613**	-.264
Recreation	-.022	-.372*	-.243	-.033
Pro-social	-.308	-.713**	-.620**	-.098
SFS Total	-.263	-.694**	-.575**	-.145

**=p<.01; *=p<.05; [a] Interpersonal Communication uses Spearman's *Rho*, all others are Pearson's *r*.

Grand Mean Waveform

The grand mean ERP waveform is displayed with error bars in Figure 4.1. As expected, there is relatively little variation around the mean for the 200ms preceding stimulus onset. The amount of variance (represented by 95% Confidence Interval error bars for every datapoint) increases substantially approaching 100ms, and remains very large through the duration of the waveform.

Figure 4.1*: Grand mean ERP Waveform, Across All Stimuli and Presentation Times.*



It is expected that the wide range of manipulations to stimuli (including blank stimuli, scrambled images, and faces, presented at subliminal and supraliminal presentation times) make the shape of the grand mean relatively uninterpretable, though there is a semblance of the presence of the quintessential visual P1, subsequent negative trough that may include N170 , P190, and N250, and subsequent positivity including an early peak around 300ms and a later positivity. However, the grand mean is not a quintessential face waveform.

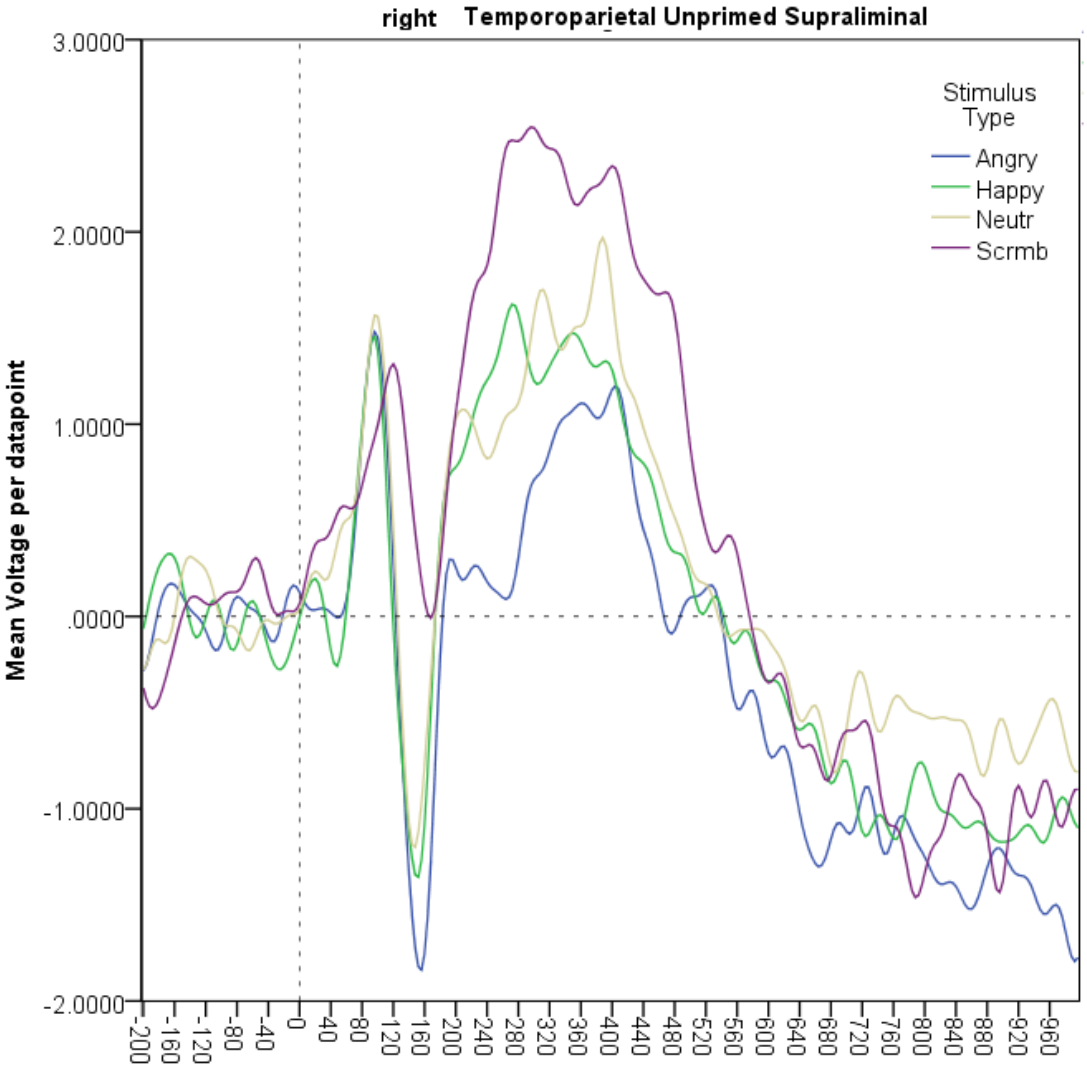
As can be seen by comparing the grand mean waveform (Figure 4.1) to the right Temporoparietal supraliminal, un-primed ERP (Figure 4.2), the waveforms composing the grand mean are quite complex. The specific differences in the average waveform for primed vs. non-primed (i.e., responses to the supraliminal presentation of faces whose antecedent subliminal presentation was either blank (subB) or the same face (subP) is

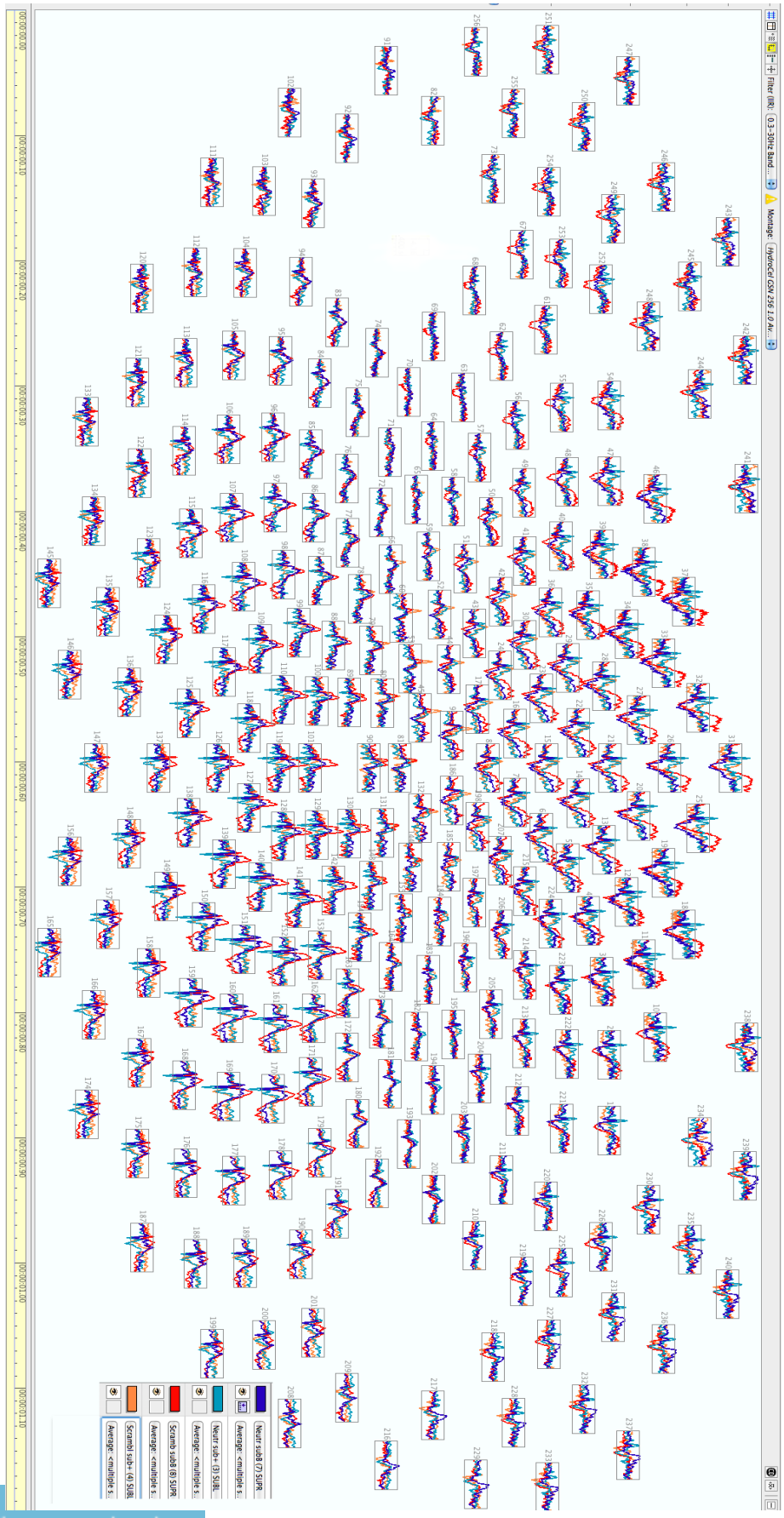
presented in Figure 4.3, and the average waveform comparing subliminal vs. supraliminal presentations of the same face is displayed in Figure 4.4. These waveforms are averaged across the blank and non-blank subliminal effects, which is most apparent in the exaggerated negativity for subliminal stimuli in Figure 4.3. These waveforms are presented to illustrate the degree to which the grand mean waveform is exaggerated by the blank subliminal stimulus condition.

The right Temporoparietal average waveform for supraliminal, un-primed stimuli is displayed in Figure 4.2 for reference, along with topographical maps (brain electrical activity mapping) at the midpoint of the N170 and P300 components.

These conditional waveforms show clear evidence of visual P1, N170, and P300-like components, although P190 and N250 are not apparent. These impressions will be confirmed using temporal PCA, peak and latency analysis, and inspection of a subsample of individual cases to establish expected stimulus effects.

Figure 4.2. *Neutral vs. Scrambled Face characteristic ERP and Topomaps at 147 and 299ms.*





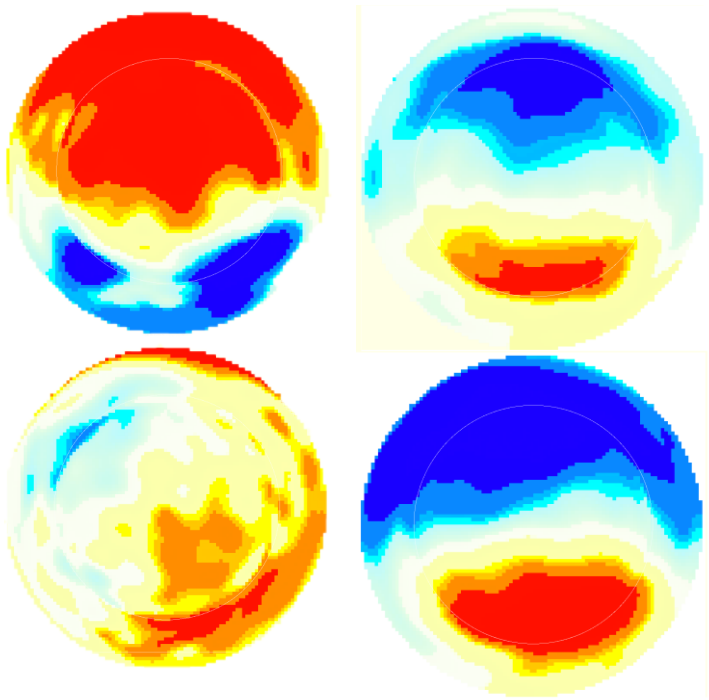


Figure 4.3*: Waveform by Priming.*

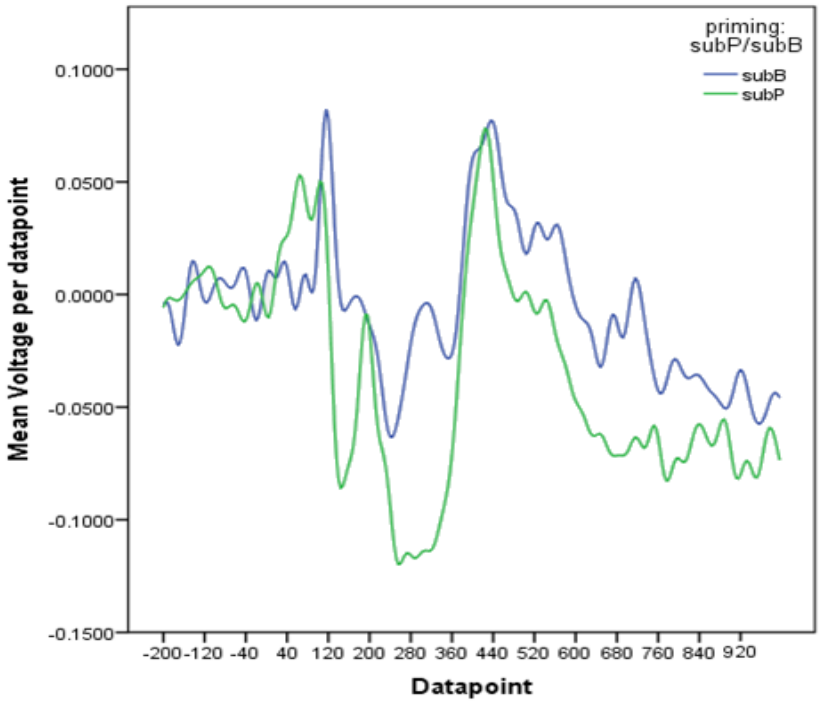
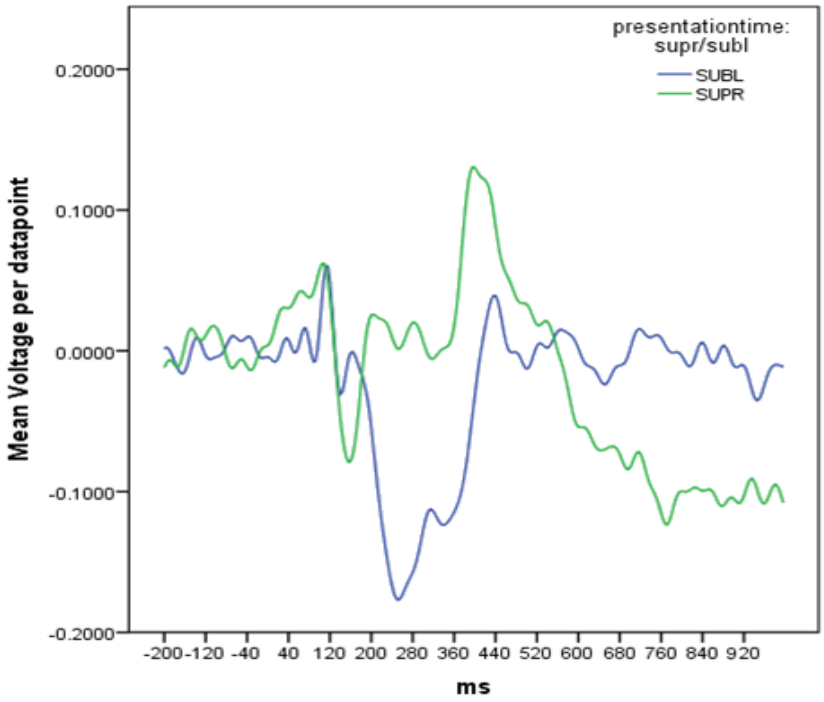


Figure 4.4: *Waveform by Presentation Duration.*



PCA Analysis Results

In the PCA analysis, eight factors were derived that appeared to identify a P300 component, a P1, and an N170, respectively, as well as other components that may that are not expected to be used for this study.

The four PCA factors of interest are presented in Figure 4.5, displayed as PCA factor loadings by condition across presentation types. The latencies and factor loading thresholds for all of the derived PCA factors are presented in Table 4.4.

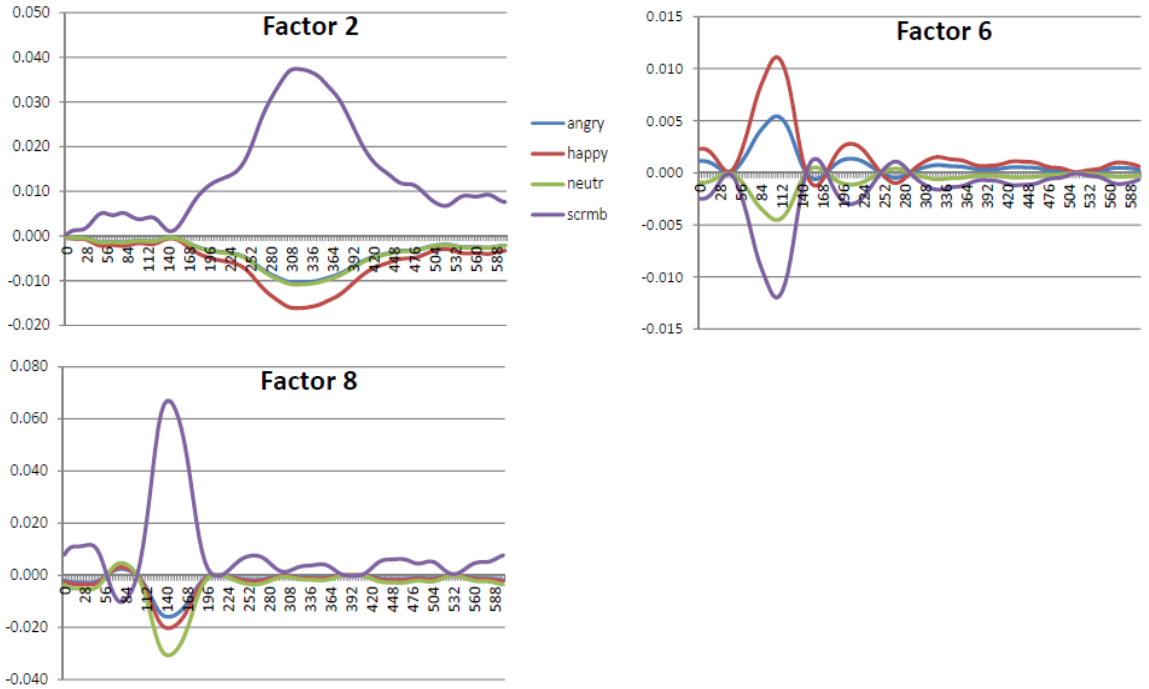
Table 4.4. *PCA Derived Factors.*

Factor	Latency Min (ms)	Peak (ms)	Latency Max (ms)	Threshold (loading)	Use in present study	% Total Variance[a]
1	512	572	600	.800		20.8%
2	300	314	344	.800	P300	20.7%
3	404	420	436	.650		10.1%
4	232	240	248	.800	*(N250)*	10.6%
5	32	48	60	.700		4.0%
6	92	104	116	.800	P1	6.2%

7	180	184	192	.800	*(P190)*	6.2%
8	132	142	156	.800	N170/VPP	6.3%

[a] Rotation sums of squared loadings. [b] Parenthetical italicized descriptions were not used in the study, but were used to discriminate proper temporal windows for the components of interest.

Figure 4.5*: PCA Factor Loadings by Stimulus Type.*



* PCA factor loadings for factors of interest over post-stimulus time, organized by stimulus type, across presentation times.

MANOVA with PCA Factor Scores

In addition to confirming the nature of the waveforms and their timeframes by comparing the autocorrelations and conditional differences of average waveforms and the foci of peaks using topographical maps, individual factor scores for the PCA are also entered into MANOVA to determine their regional foci and between which conditions they may discriminate. Each of the eight derived factors were entered into a MANOVA with region, hemisphere, and condition (stimulus type: "stimulus", subliminal or supraliminal: "presentation", and primed or not: "priming") within-subjects. For the three binary conditions, hemisphere, presentation time, and priming, Polynomial contrasts were

used, which results in a linear contrast across the two categories. Polynomial contrasts were not employed for the multi-categorical conditions, as a linear interpolation across the categories' codes is not interpretable (i.e., the difference between "angry" and "neutral" faces is neither the same as the difference between "neutral and scrambled" stimuli nor equal to one, or any other easily derivable integer). The contrasts employed are not orthogonal, as the contrasts between different electrode regions and different types of face or non-face stimuli are not orthogonal. The condition "region", which represents 9 categories that are not ordered but have a great degree of covariance (due to electrode neighborhood and dipole effects), was analyzed using a Deviation contrast, which analyzes deviations from the grand mean. This is easily interpretable, as it represents most closely the voltage referencing. The condition "stimulus type," which represents categories of scrambled image, neutral face, angry face, or happy face, was analyzed using a Simple contrast, which contrasts each level to the last coded level, which in this case is the scrambled image. This also provides simple interpretability. Notably, these contrasts do not change the overall model, main effects, or interactions.

This serves as a "protected" test, using the empirically-derived factor scores rather than raw amplitudes to confirm that the temporal ranges identified in those empirically-derived factor scores represent waveforms that are likely to reliably differentiate between conditions and to specify which regions and hemispheres (or comparisons thereof) are most likely to identify between and within-person differences.

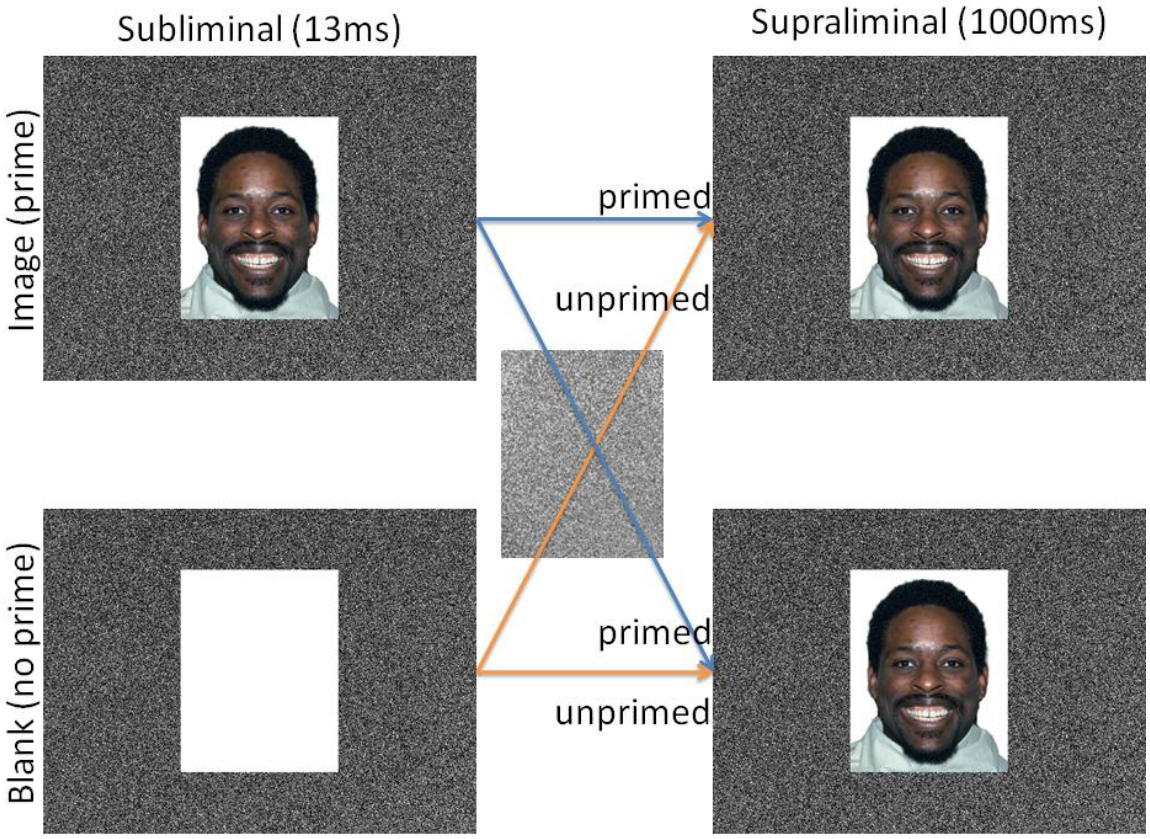
Notably, although there are patterns in the magnitude and direction of PCA factor scores that parallel those expected of the waveforms they are thought to represent, the magnitude and direction of PCA factor scores are interpreted with caution due to the

many possible sources of variance in the scores derived from this particular PCA. These differences are essential to protecting the objectivity of ERP analysis, but instead of interpreting these results, they will be used here as an indication of the timeframes and waveforms that should be followed up with peak and latency analysis. However, it will be shown that the within-person effects identified with factor scores are very similar to those with derived peaks and latencies.

Finally, the effects of priming and presentation time are confounded in this analysis. For example, one would assume the main effect of "presentation time" represents the comparison of supraliminal vs. subliminal stimuli for the marginal mean across electrode regions, face stimulus types, and primed or non-primed stimuli. While this is technically true, it is confounded with the presence of blank images in the subliminal set that precede the "unprimed" supraliminal stimuli. So, one is not only comparing subliminal to supraliminal stimuli, but also images that are half blank and half scrambled stimuli to images that are all face or scrambled stimuli. The main effects of priming and presentation time are thus non-independent and are not independently meaningful. The interaction of priming and presentation time is also not particularly meaningful, a significant F-test only confirming that responses to blank images are different than responses to non-blank images. While difficult to interpret, interactions with presentation*priming have some interpretive value. For example, if stimulus*presentation*priming is significant, either the priming effect for supraliminal responses, the difference between blank and non-blank subliminal responses, the comparison of supraliminal to subliminal responses, or all of the above are different for different stimulus types. Unfortunately, this broad MANOVA will not provide

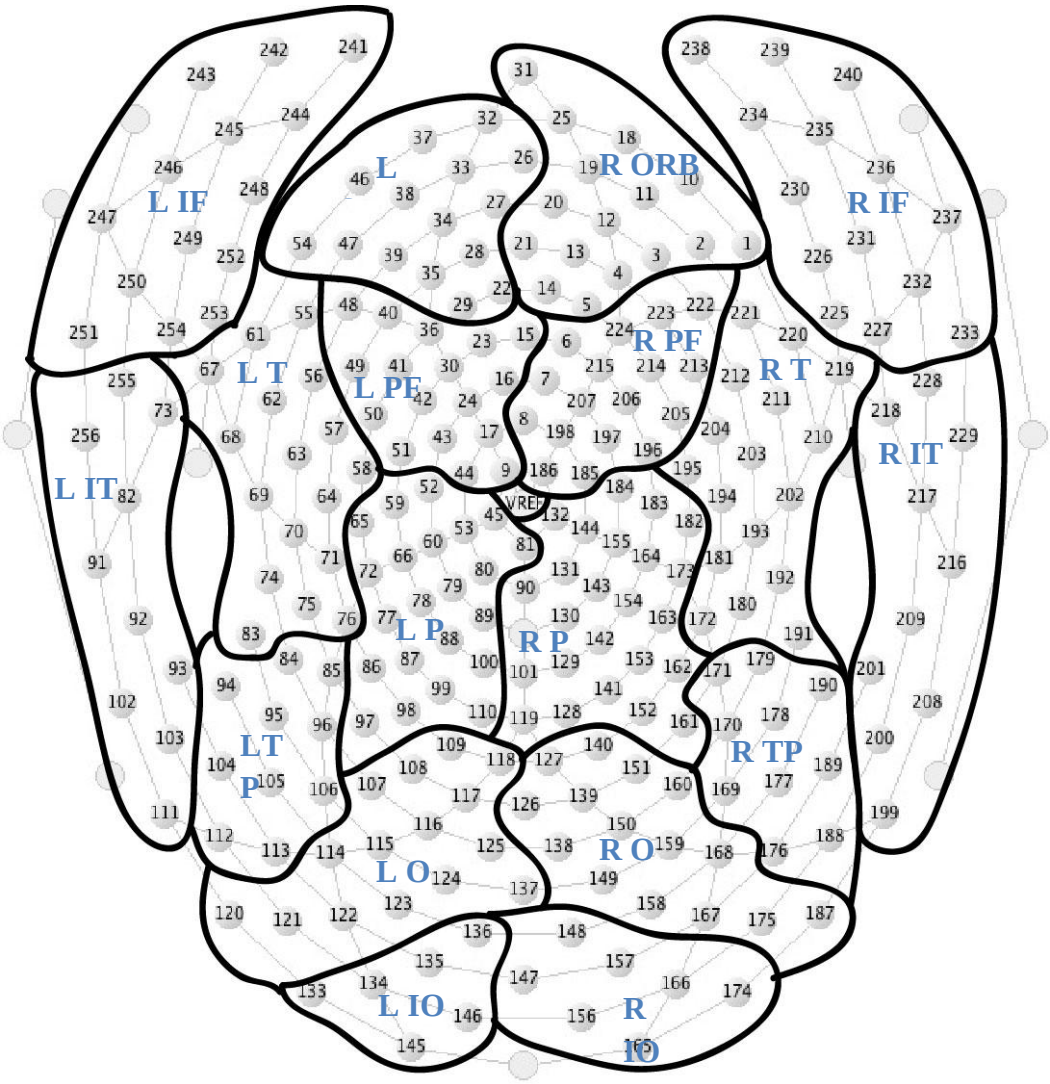
specification, but the interactions can provide leads for which marginal means can be inspected and followed-up with more specific peak and latency analyses.

Figure 4.6. *Illustration of the Prime*Presentation Confound.*



For ease of interpretation of region and hemisphere effects, see Figure 4.7 for a visual representation of the topographical electrode regions.

Figure 4.7. *Electrode Regions: 9 Regions X 2 Hemispheres.*



PCA Factor 2 MANOVA.

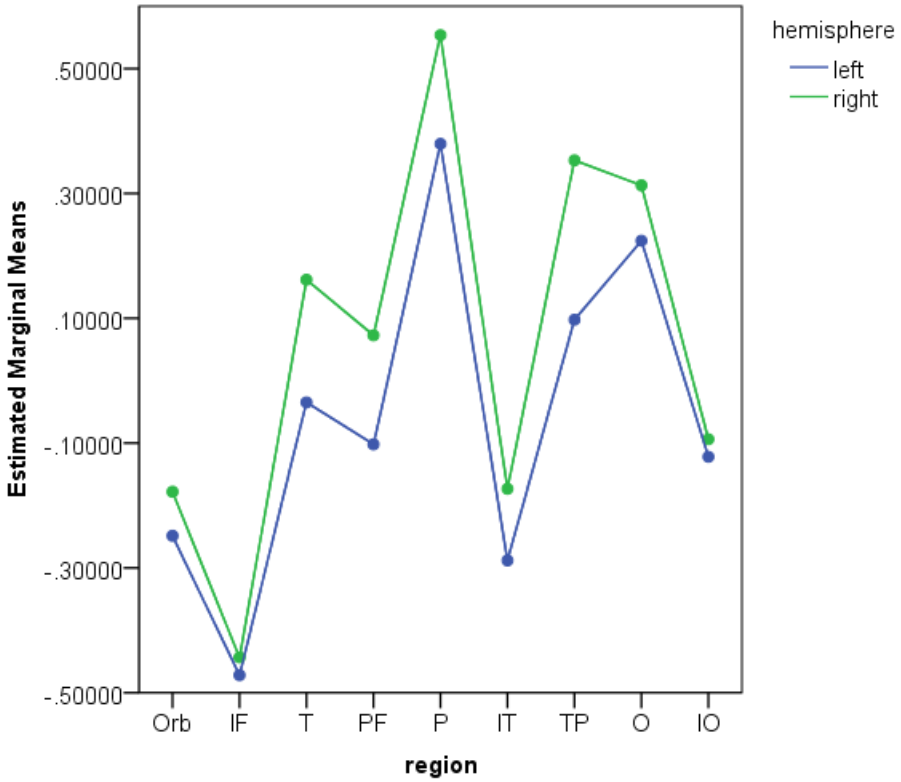
PCA factor 2 was focalized (PCA rotated component loadings > .800) between 300- 344ms post-stimulus, with its peak loading at 314ms. Based on its timeframe and main effect distinguishing scrambled images from faces, it was hypothesized that PCA factor 2 represents the visual single-stimulus P300.

Region and Hemisphere.

The main effect of region was significant ($F(8,152)=5.308$, $p<.0005$). The effects of hemisphere and region*hemisphere were not significant ($F(1,19)=1.716$, $p=.206$ and $F(8,152)=1.603$, $p=.128$, respectively).

As shown in Figure 4.8, PCA factor 2 factor score marginal means were focalized positively in central and posterior regions, Parietal (P), Temporoparietal (TP), and Occipital (O) regions, and negatively in inferior and frontal regions, Inferior Frontal (IF) and Inferior Temporal (IT). Other regions' marginal means were not significantly different from the grand mean of regions (zero; ps>.05).

Figure 4.8. *PCA Factor 2 Marginal Means by Region and Hemisphere.*

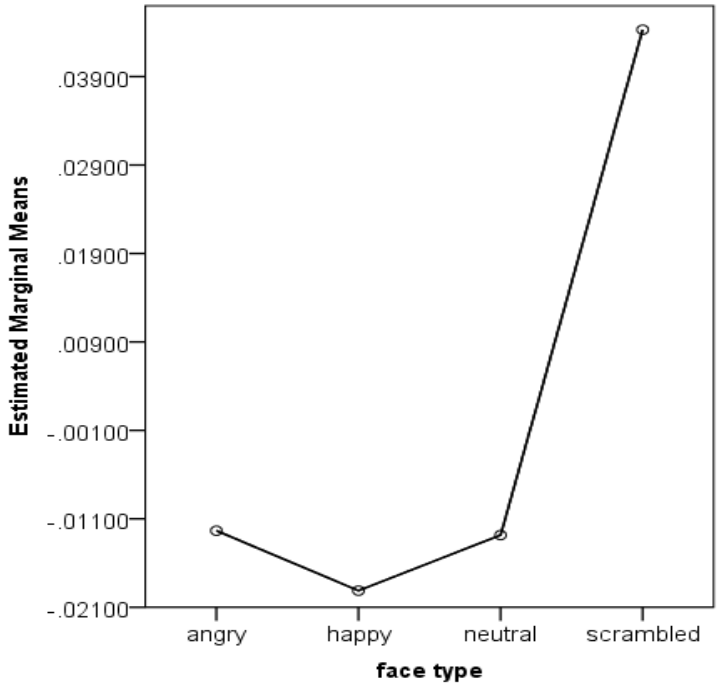


Stimulus Type.

The main effect of stimulus type was significant ($F(3,57)=10.792$, $p<.0005$). Specifically, as shown in Figure 4.9, all three faces had small negative marginal means, while scrambled images had a high significantly more positive marginal mean

(Fs(1,19)>13.8, *p*s<.001). Emotional faces were not different from neutral faces, and angry faces were not different from happy faces (*p*s>.05).

Figure 4.9. *PCA Factor 2 Marginal Means by Stimulus Type.*

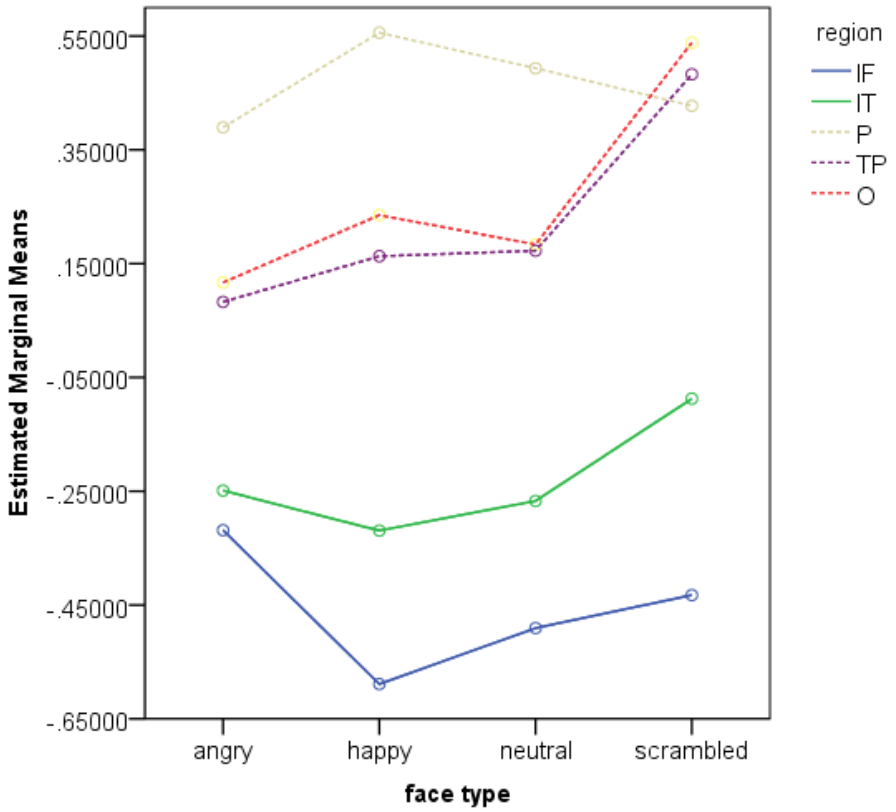


The main effect of stimulus type differed by region ($F(24,456)=4.746$, $p<.0005$). For ease of interpretation, Figure 4.10 shows this effect only in regions whose marginal mean factor scores were significantly different from zero. The inferior regions with significant positive marginal means are dashed, whereas the central and posterior regions with significant negative marginal means are contiguous lines. As shown, the main effect of scrambled greater than faces appears to hold in TP and O regions. This was true (*p*s<.05) for all comparisons in these two regions, except that Occipital happy faces were not different from scrambled images ($F(1,19)=3.069$, $p=.096$). Angry, Happy, and Neutral faces remained not significantly different from each other (*p*s>.05) in these two regions. However, the marginal means in the Parietal region, which is closer to the vertex

than TP or O, show a different pattern. Happy faces were significantly higher than scrambled images ($F(1,19)=5.959$, $p=.025$) and angry faces ($F(1,19)=10.862$, $p=.004$) but not neutral faces ($F(1,19)=1.155$, $p=.296$). Neutral faces were significantly higher than Angry faces ($F(1,19)=5.753$, $p=.027$). However, marginal means for scrambled images were not different from angry or neutral faces (ps>.05). Interestingly, this pattern appeared to be approximately mirrored in the Inferior Frontal region. Specifically, angry faces were significantly less negative than happy faces ($F(1,19)=9.298$, $p=.007$), but no other stimulus type comparisons were significant (ps>.05). Although the overall mean of the Inferior Temporal region was negative, its shape approximated more closely that of the main effect that was echoed in TP and O regions, but its absolute shape (magnitude) more closely resembled the shape of the P and IF regions. Specifically, scrambled image marginal means were less negative than happy faces ($F(1,19)=6.736$, $p=.018$) but not significantly less negative than angry or neutral faces ($F(1,19)=3.054$, $p=.097$ and $F(1,19)=3.269$, $p=.086$, respectively). Angry, Happy, and Neutral faces were not different from each other (ps>.05).

Overall, it appears there were two patterns of effects, one that particularly discriminates scrambled faces as more positive in O and TP regions, and one that is of higher magnitude (in opposite directions) for happy compared to angry faces for P and IF regions.

Figure 4.10. *PCA Factor 2 Stimulus by Region.*



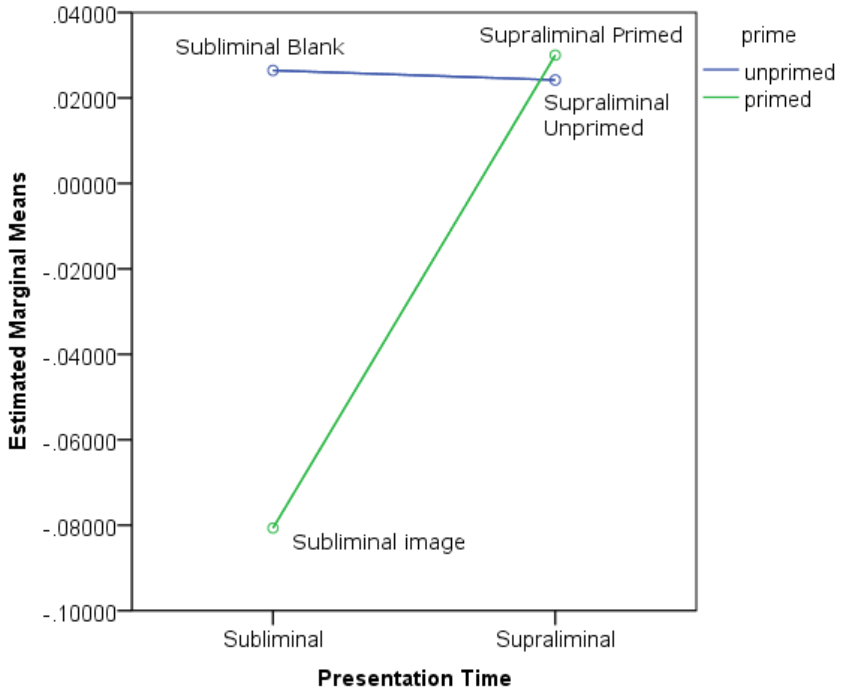
The main effects of hemisphere and the interaction of hemisphere with region were not significant ($F(1,19)=1.716$, $p=.206$ and ($F(8,152)=1.603$, $p=.128$, respectively).

Presentation Time and Priming.

The main effects of presentation and prime were significant ($F(1,19)=14.479$, $p=.001$ and $F(1,19)=14.271$, $p=.001$, respectively), such that supraliminal marginal means are greater than subliminal marginal means and unprimed/blank were higher than primed/image marginal means. Their interaction was also significant ($F(1,19)=15.206$, $p=.001$). As shown in Figure 4.11, there is a substantial presentation time effect for images (primed), but none apparent for the comparison of blank subliminal to unprimed

supraliminal responses. There is a great difference between subliminal blank and non-blank images, but there is no apparent effect of priming on supraliminal images.

Figure 4.11. *PCA Factor 2 Presentation Time and Priming*.



This effect differed significantly by region ($F(8,152)=5.583$, $p<.0005$). Of the regions with main effects significantly different from zero (negative: IF, IT; positive: P, TP, O), there were substantial differences. The main effect is that supraliminal marginal means are strongly positive and subliminal are strongly negative. This remained for TP and O regions ($F(1,19)=0.611$, $p=.444$ and $F(1,19)=0.084$, $p=.775$, respectively), but the interaction was different for IF, IT, and P ($F(1,19)=5.028$, $p=.037$, $F(1,19)=11.449$, $p=.003$, and $F(1,19)=11.317$, $p=.003$, respectively). Specifically, the marginal means did not appear to be different by presentation time for IF and P, and not as different for IT. In other words, the presentation time effect appears to be most reliable for TP and O, rather

than the more anterior electrode regions. Figure 4.13 shows that there is no apparent effect of priming on supraliminal marginal means, even after accounting for region.

Figure 4.12. *PCA Factor 2 Presentation Time by Region for Primed/non-Blank Stimuli*.

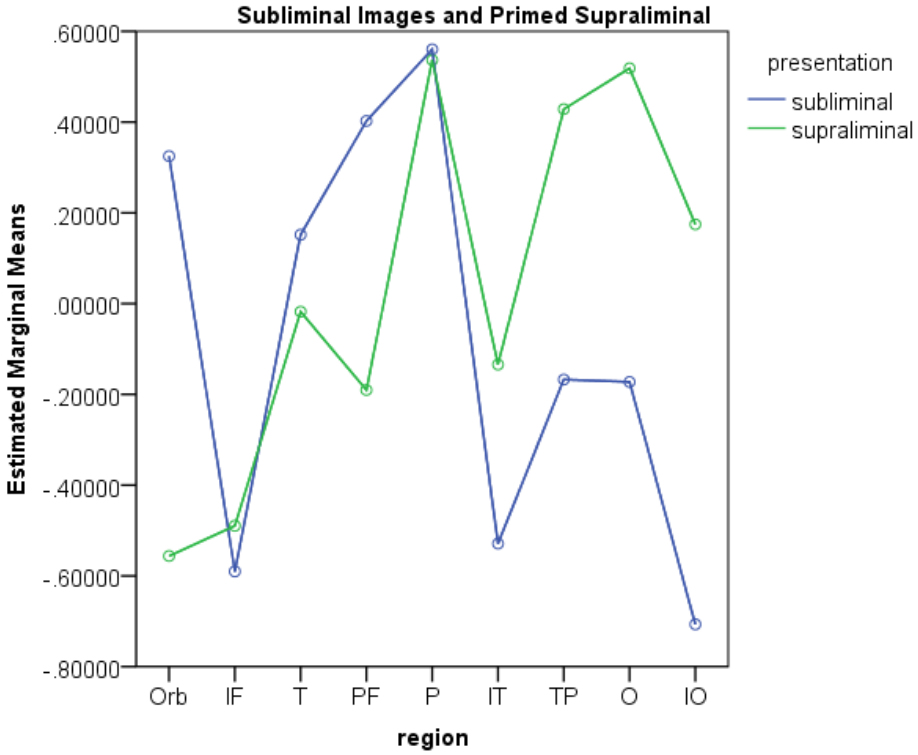
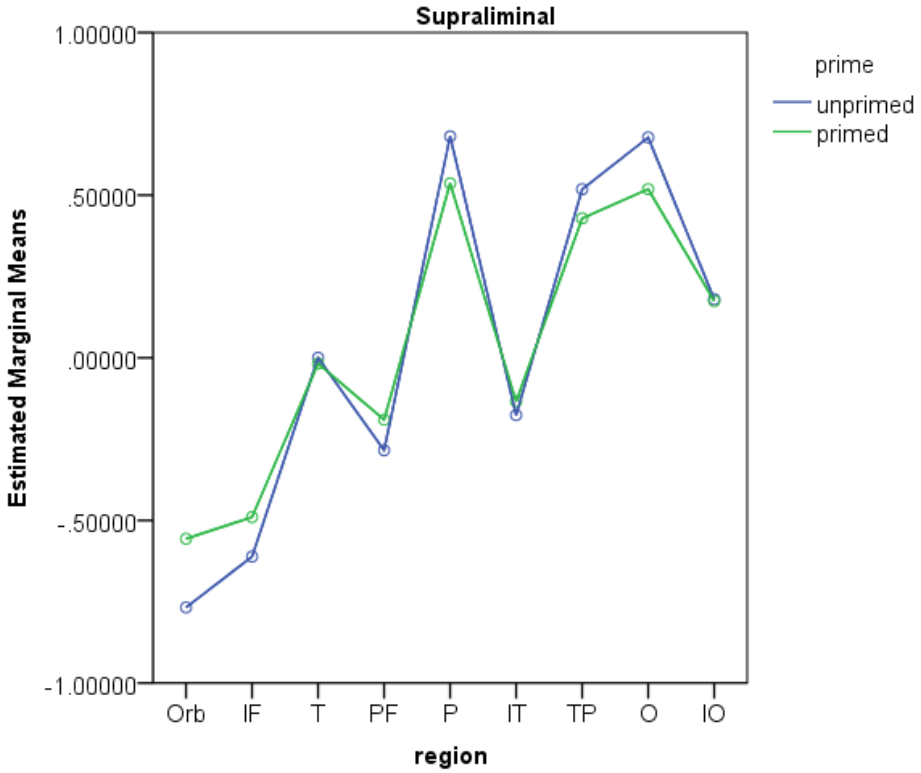


Figure 4.13. *PCA Factor 2 Priming by Region for Supraliminal Stimuli*.



The interaction of presentation*prime with hemisphere was not significant ($F(1,19)=2.646$, $p=.120$), nor was the interaction of presentation*prime*region with hemisphere ($F(8,152)=1.833$, $p=.075$). Although this is not significant, it appears there is a trend for this effect to be greater in the right hemisphere.

Stimulus Type, Presentation Time, and Priming.

The interaction of presentation*prime with stimulus type was not significant ($F(3,57)=0.390$, $p=.760$).

Presentation*prime*stimulus did not interact with hemisphere ($F(3,57)=1.118$, $p=.350$). However, it did interact with region ($F(24,456)=2.180$, $p=.001$). Individual contrasts by region showed no differences between different stimulus types, but significant differences in the face vs. scrambled image comparisons for the IF, TP, and O

regions (*ps*<.05). This effect is represented in TP and O regions in Figures 4.14 and 4.15. As shown, the main effect of supraliminal greater than subliminal remained, but the effect of scrambled images having a greater marginal mean than faces appeared to be diminished, particularly for unprimed supraliminal stimuli. The difference between angry faces and scrambled images remained, but the other face comparisons were less reliable. Priming may have moderated this effect, such that neutral and happy faces were only different from scrambled images for primed supraliminal images.

Figure 4.14. *PCA Factor 2 Presentation and Priming by Stimulus Type in Temporoparietal.*

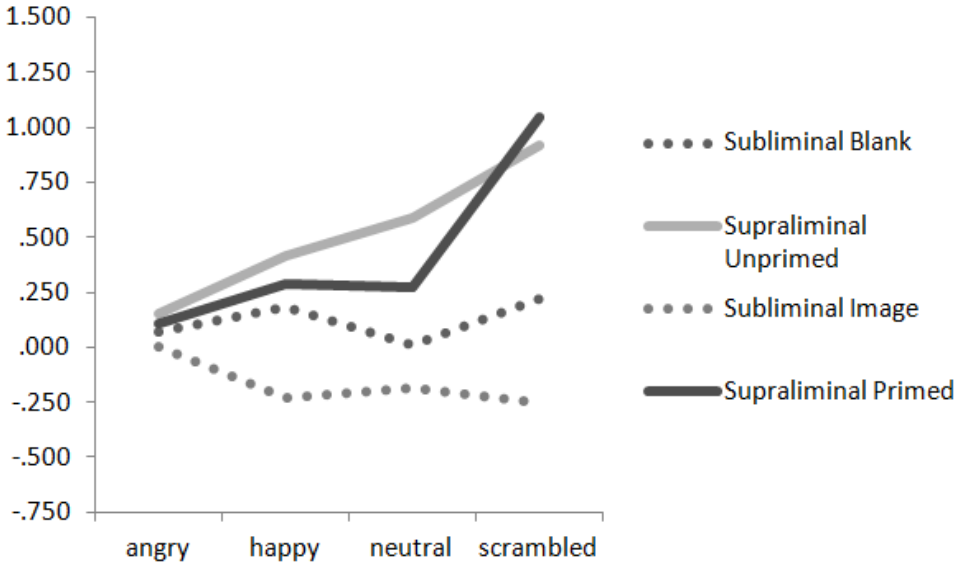
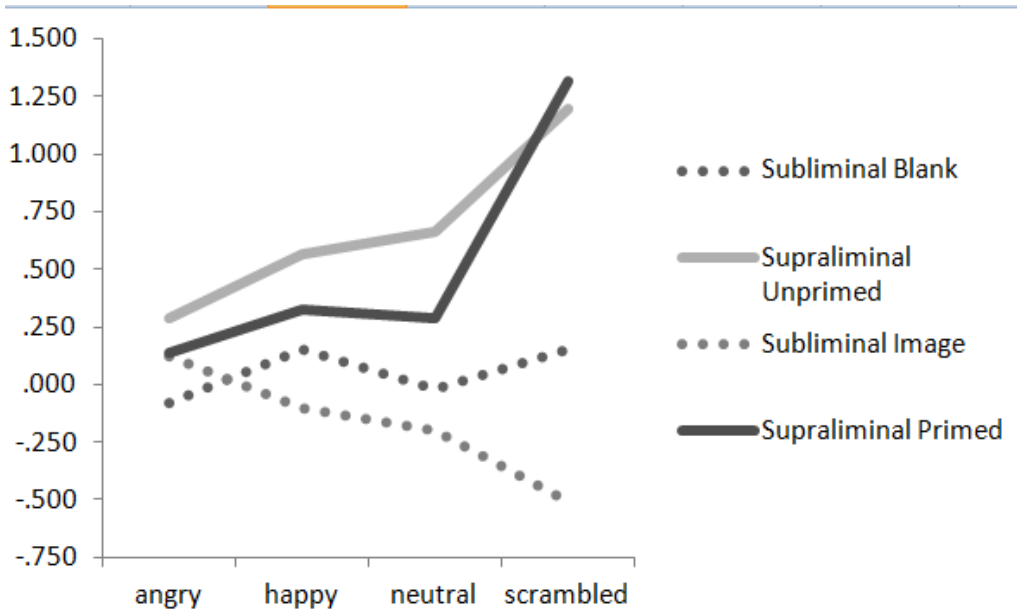


Figure 4.15. *PCA Factor 2 Presentation and Priming by Stimulus Type in Occipital.*



As shown in Figures 4.16 and 4.17, the major qualitative differences noted across regions in the main effect of region are in fact also dependent on presentation time. The angry vs. happy difference only applies to supraliminal presentations. The face vs. non-face difference is present for all three non-blank stimulus types, but the direction is reversed for subliminal images.

Figure 4.16. *PCA Factor 2 Presentation and Priming by Stimulus Type in Inferior Frontal.*

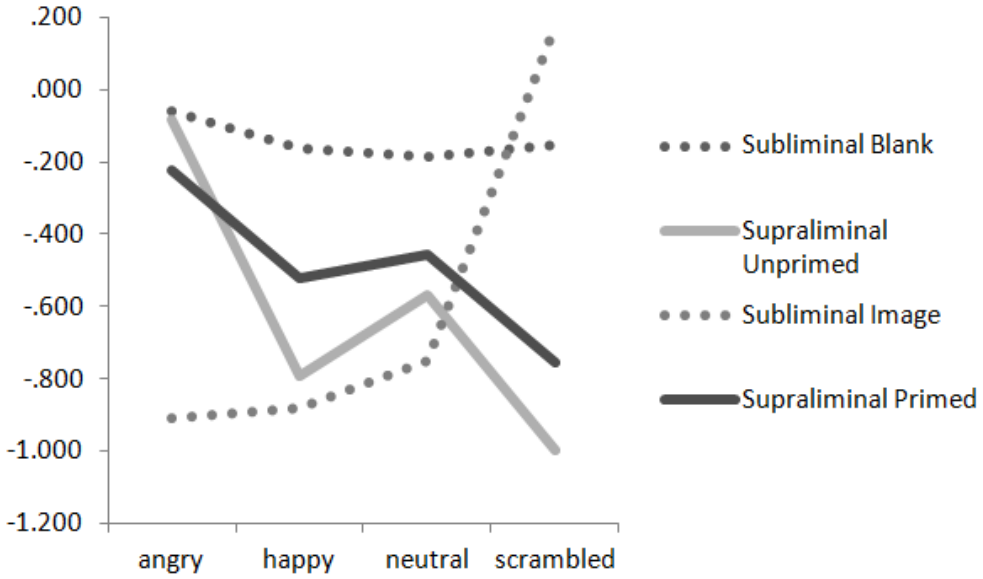
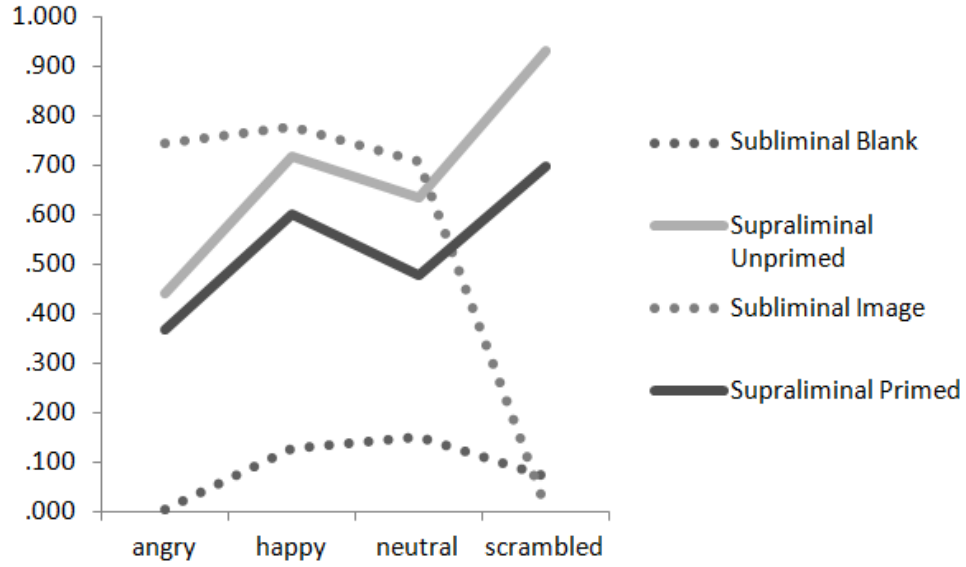


Figure 4.17. *PCA Factor 2 Presentation and Priming by Stimulus Type in Parietal.*



Presentation*prime*stimulus*region also did not interact with hemisphere ($F(24,456)=.828$, $p=.701$).

PCA Factor 2 Summary.

PCA Factor 2 is hypothesized to represent the visual single-stimulus P300 component. It was most prominent positively in TP, O, P, and negatively in IF, and IT

regions. The main effect of face differed across regions - there was an emotional main effect for IF and P regions (inverted but similar in magnitude), and there was a scrambled vs. face effect for TP and O regions. There was also an overall effect of presentation time, wherein posterior electrode regions had greater marginal means for supraliminal presentation compared to subliminal presentation. In these regions, the scrambled vs. face effect interacted with the supraliminal greater than subliminal effect by priming, such that the stimulus type effect was diminished for unprimed stimuli. So, priming appeared to result in a greater discrimination between scrambled images and faces in these regions. However, these priming effects were not significant. In inferior and parietal regions, the same face vs. non-face comparison was present in subliminal images in the opposite direction from supraliminal images, and the angry vs. happy difference was only present for supraliminal presentation time.

PCA Factor 6 MANOVA.

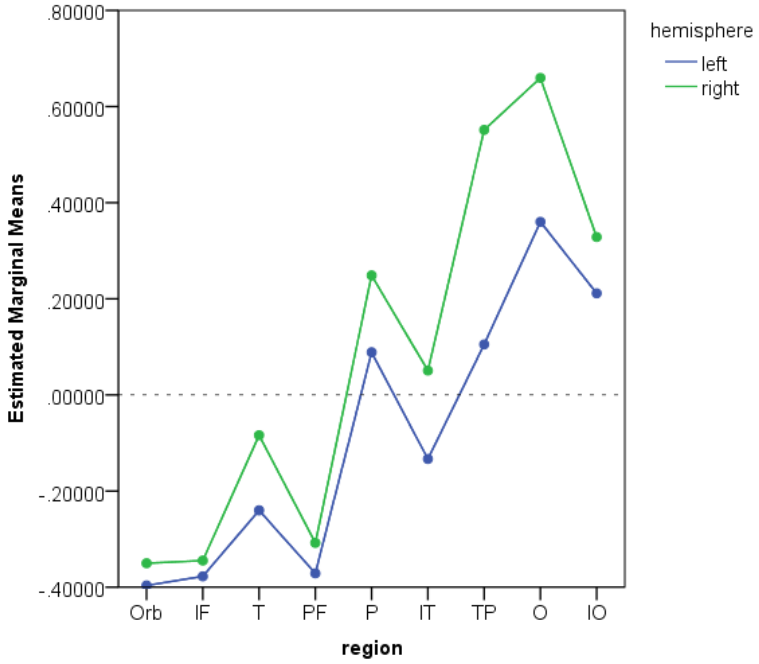
PCA factor 6 was focalized (PCA rotated component loadings > .800) between 92-116ms post-stimulus, with its peak loading at 104ms. Based on its timeframe and main effects for different types of visual stimuli, it was hypothesized that PCA factor 6 represents the P1.

***Region and Hemisphere*.**

The main effects of both region ($F(8,152)=4.951$, $p<.0005$) and hemisphere ($F(1,19)=7.172$, $p=.015$) were significant, as was their interaction ($F(8,152)=6.286$, $p<.0005$).

Specifically, PCA factor 6 factor scores' marginal means for region were focalized positively in posterior regions, Temporoparietal (TP) and Occipital (O), and negatively in anterior regions, Inferior Frontal (IF), Temporal (T), and Prefrontal (PF). Orbital (Orb) and Inferior Occipital (IO) regions appeared to be focal, but their marginal mean factor scores were not significantly different from the mean across regions (*p*s>.05).

Figure 4.18. *PCA Factor 6 Electrode Regions by Hemisphere.*



PCA factor 6 factor scores' marginal means were significantly more positive in the right hemisphere than the left hemisphere overall (mean difference 0.167, SE=.062, *p*=.015).

This difference between hemispheres differed by region, an effect which in this case is somewhat complex. As previously mentioned, the contrasts by region are compared individually against the marginal mean. The hemisphere contrast is a simple binary comparison. The significance tests for contrasts within the interaction of region

and hemisphere thus can be interpreted as if the marginal mean difference between hemispheres holds for each region. In some regions, the marginal effect was not different from the main effect. For example, in the Temporal region, the marginal mean difference was $0.156^{n.s.}$ (left SE=.068, right SE = .066; $F(1)=.060$, $p=.810$), which is not different from the difference between hemispheres overall (0.167, SE=.062). However, in the IF and PF regions, the hemispheric difference was very small (0.032 and 0.063, respectively), and was thus different from the main effect of hemisphere ($F(1,19)=10.873$, $p=.004$ and $F(1,19)=8.053$, $p=.011$, respectively). On the other hand, in the TP and O regions, the marginal mean differences across hemispheres (0.446 and 0.300, respectively) were larger than the main effect of hemisphere ($F(1,19)=10.375$, $p=.004$ and $F(1,19)=7.858$, $p=.011$, respectively). Figure 4.18 visually presents the case that the difference between hemispheres overall increases progressively from anterior to posterior.

Stimulus Type.

The main effect of face was not significant ($F(3,57)=0.719$, $p=.545$), as were the interactions with region ($F(24,456)=1.132$, $p=.303$), hemisphere ($F(3,57)=0.809$, $p=.494$), and region*hemisphere ($F(24,456)=0.992$, $p=.476$). PCA factor 6 factor scores do not appear to differ by stimulus type.

Presentation Time and Priming.

The main effects of presentation time and priming were not significant ($F(1,19)=0.111$, $p=.743$ and ($F(1,19)=0.077$, $p=.785$), as was their interaction ($F(1,19)=2.361$, $p=.141$).

The interaction of presentation*prime with region was significant ($F(8,152)=2.433$, $p=.017$) but the interaction with hemisphere was not ($F(1,19)=0.017$, $p=.898$). As shown in Figures 4.19-4.21, PCA factor 6 marginal means appeared to be of greater magnitude for non-blank images than blank images in subliminal presentation, an effect that is approximately inverted anterior-posterior across the vertex. There were no apparent effects of priming on supraliminal marginal means or of presentation time (subliminal vs. supraliminal).

Figure 4.19. *PCA Factor 6 Priming Effect by Region for Subliminal Presentation Time.*

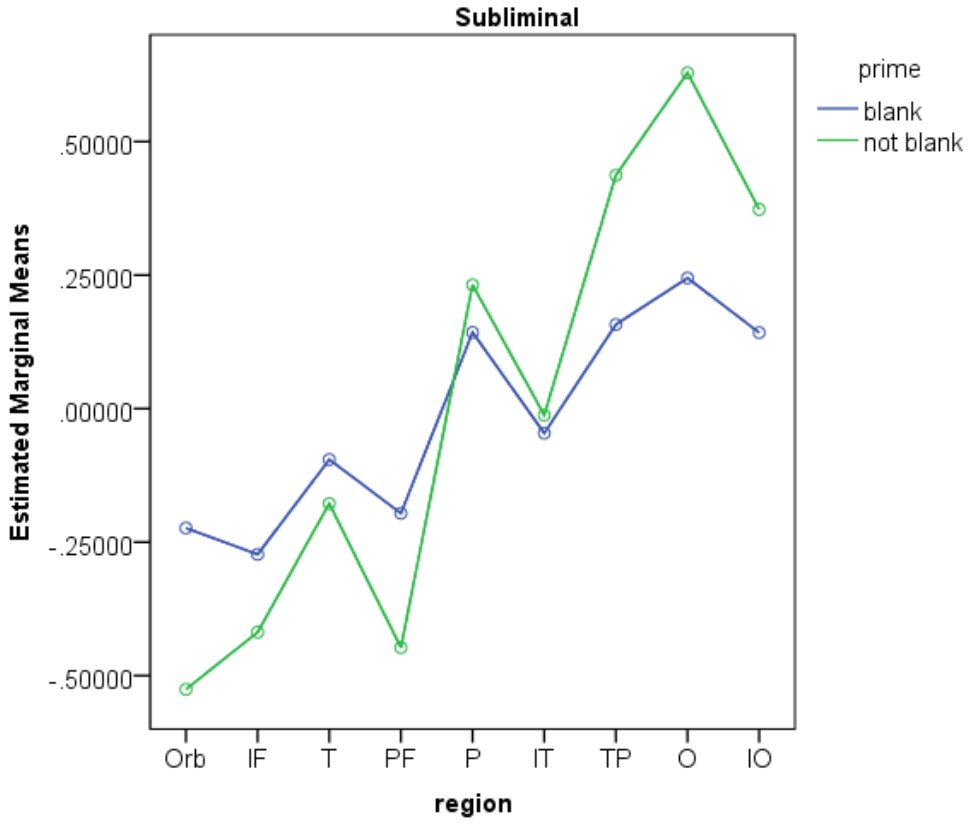


Figure 4.20. *PCA Factor 6 Priming Effect by Region for Supraliminal Presentation Time.*

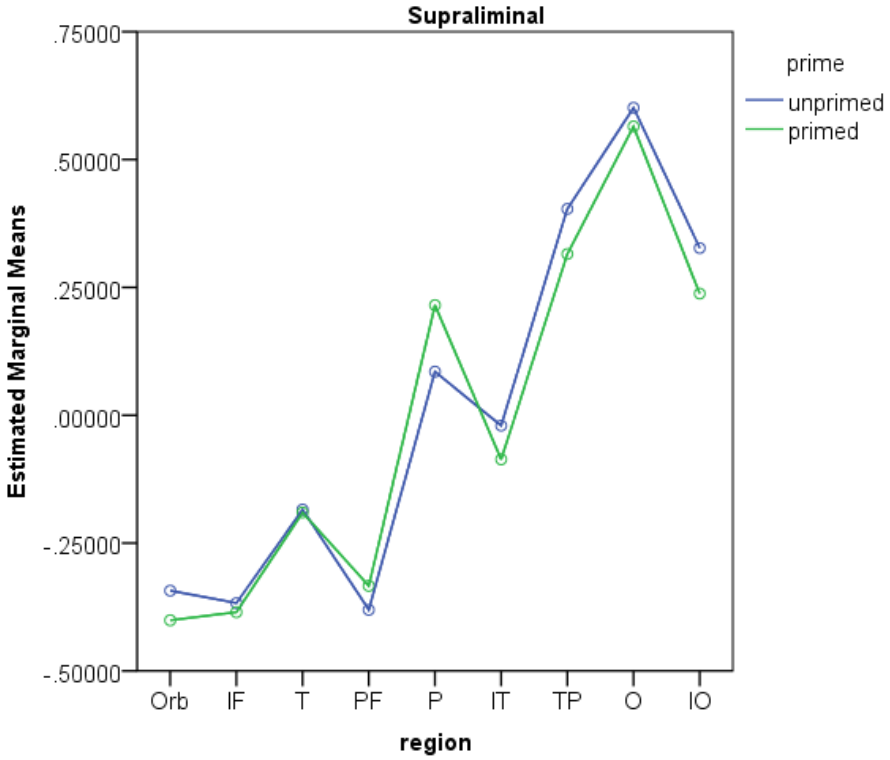
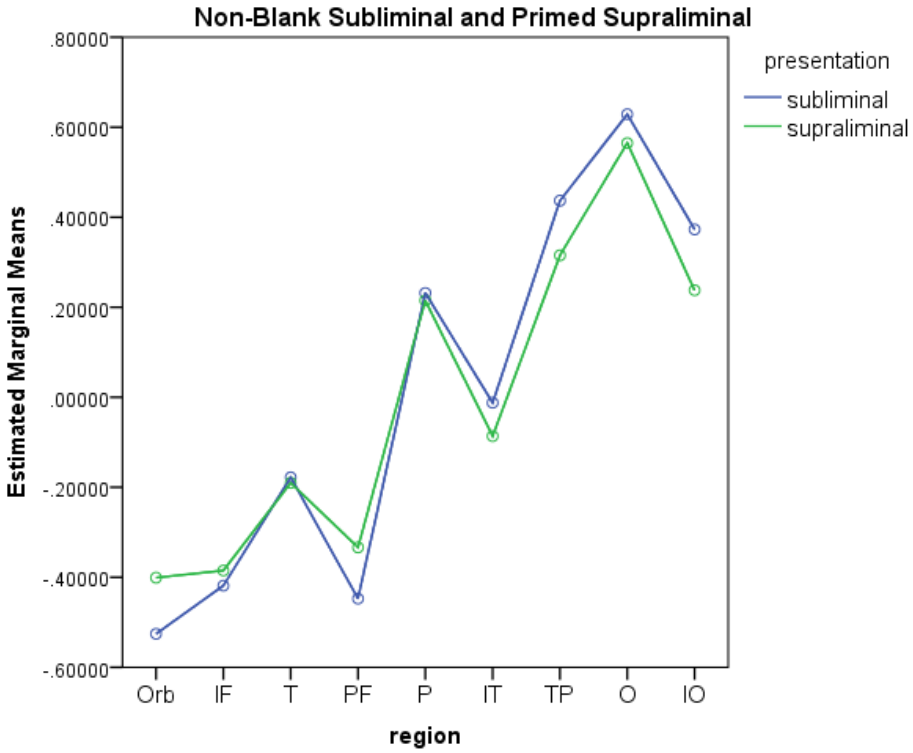


Figure 4.21. *PCA Factor 6 Presentation Time Effect by Region for Non-Blank and Primed Stimuli.*



Stimulus Type, Presentation Time, and Priming.

The interaction of the above-mentioned effect of presentation*prime*region did not interact significantly with stimulus type ($F(24,456)=1.194$, $p=.241$), nor did presentation*prime*hemisphere ($F(3,57)=0.882$, $p=.456$). However, there was a significant interaction between all of the conditions in the analysis, presentation*prime*region*hemisphere and stimulus type ($F(24,456)=1.195$, $p=.006$). In order to clarify this interaction, graphs for two regions of interest for PCA factor 6 marginal means are presented in Figure 4.22-4.25. Note that subliminal blank and supraliminal unprimed marginal means are represented with dotted lines, subliminal non-blank and supraliminal primed marginal means are represented with contiguous lines, and hemispheres are differentiated by shading (as indicated in the legends).

Figure 4.22. *PCA factor 6 Temporoparietal Subliminal Marginal Means*.

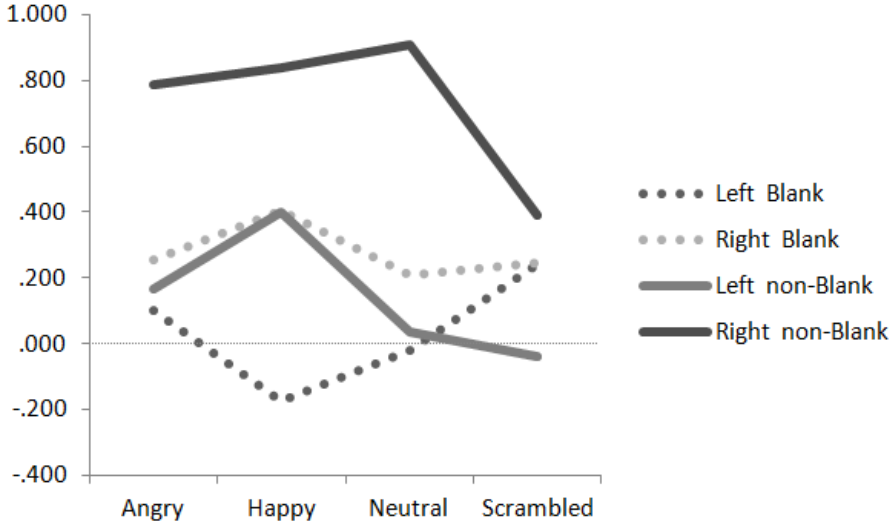


Figure 4.23 *PCA factor 6 Temporoparietal Supraliminal Marginal Means*.

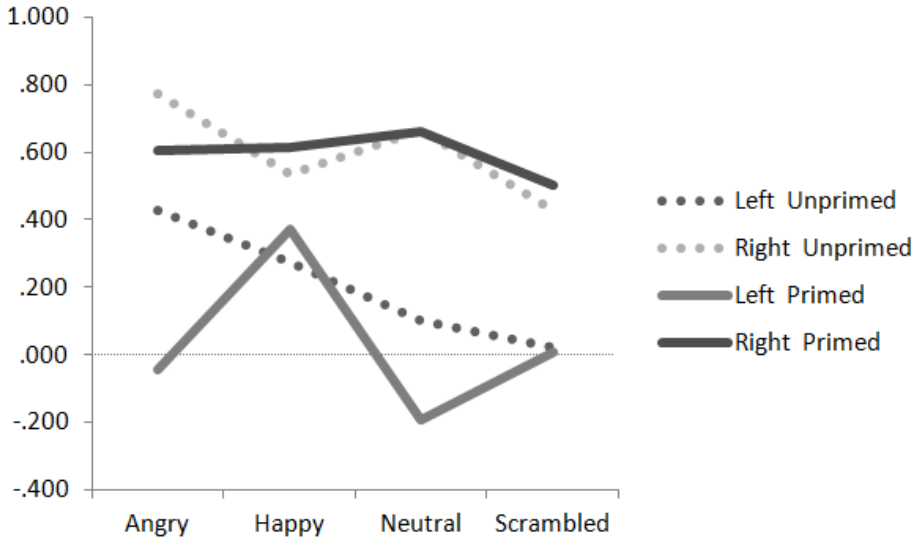


Figure 4.24. *PCA factor 6 Occipital Subliminal Marginal Means*.

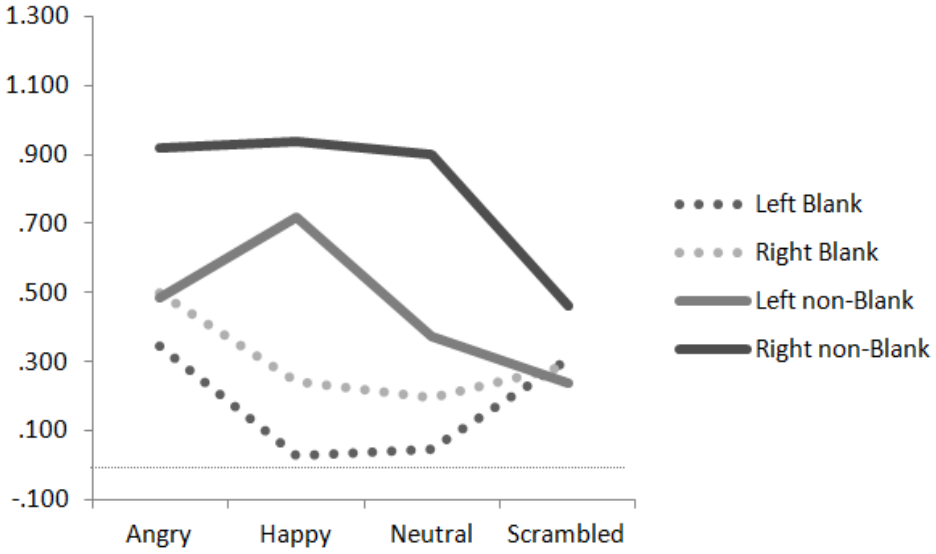
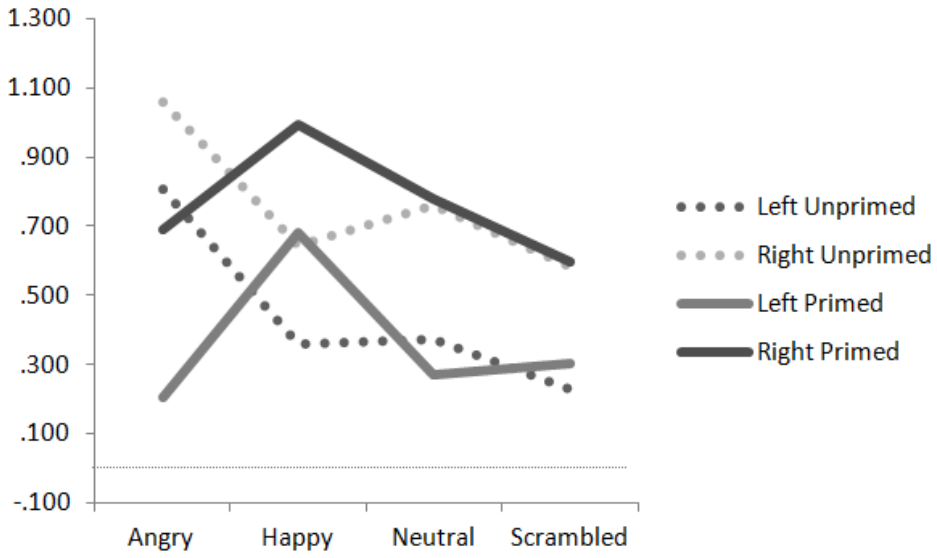


Figure 4.25 *PCA factor 6 Occipital Supraliminal Marginal Means*.



As shown in the two supraliminal graphs, there are no apparent differences between primed and unprimed supraliminal marginal means for any stimulus type except perhaps a greater marginal mean for the right compared to the left hemisphere. However, it appears that right non-blank subliminal marginal means for PCA factor 6 are substantially higher than the left hemisphere and higher than the blank images' marginal means for both hemispheres. This effect appears to be diminished for scrambled images compared to faces. Overall, this five-way interaction appears to be indicative of a general right greater than left laterality effect that did not reach significance as a main effect and an interaction where non-blank images only have greater marginal means for faces compared to blank images and primarily in the right hemisphere. In other words, the previously-mentioned interaction between presentation*prime and region (Figure 4.19) appears to be stronger for the right compared to the left hemisphere.

Figures 4.26 and 4.27 show the non-blank subliminal and primed supraliminal marginal means for comparison. It is clear here that there is no consistent effect of

subliminal compared to supraliminal presentation time for PCA factor 6 marginal means in these regions. The only notable difference is the trend toward greater magnitude in the right hemisphere.

Figure 4.26 *PCA Factor 6 Temporoparietal Subliminal Non-Blank and Supraliminal Primed Marginal Means.*

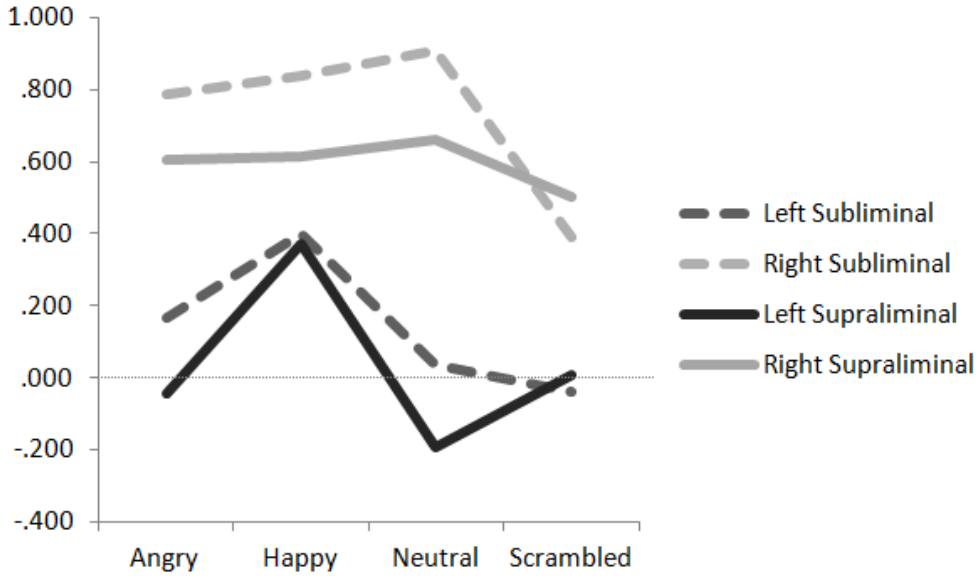
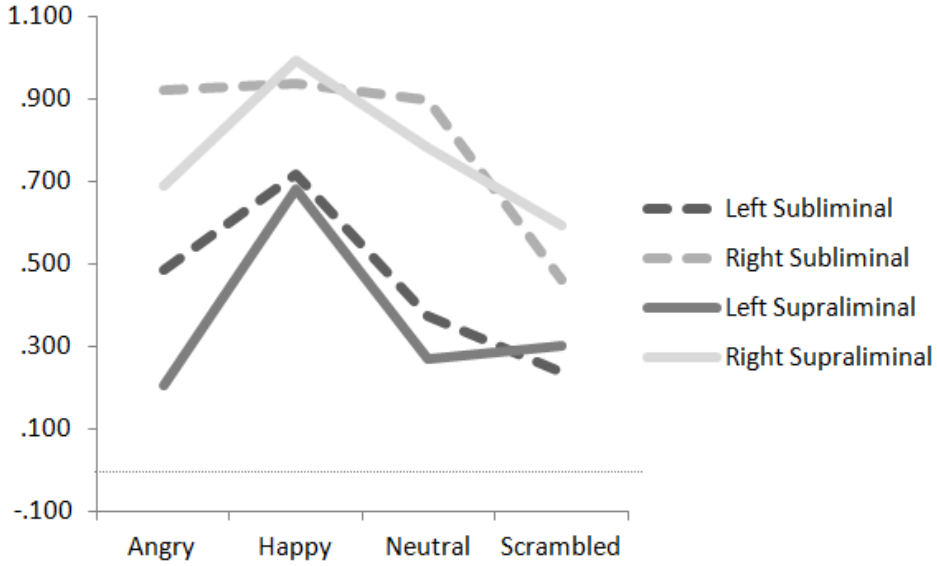


Figure 4.27 *PCA Factor 6 Occipital Subliminal Non-Blank and Supraliminal Primed Marginal Means.*



PCA Factor 6 Summary

Overall, the regional distribution and timing of PCA factor 6 are consistent with representing P1, but consistent stimulus type (face vs. scrambled, emotional vs. neutral), presentation time (subliminal vs. supraliminal), and priming (supraliminal primed vs. unprimed) differences were not indicated. The difference between responses to blank and non-blank subliminal images was not a primary hypothesis, but a lack thereof might have called into question the validity of this particular component. The five-way interaction of all conditions in this MANOVA revealed the difference between blank and non-blank stimuli is conditional on both electrode region and hemisphere.

PCA Factor 8 MANOVA.

PCA factor 8 was focalized (PCA rotated component loadings >.800) between 132-156ms post-stimulus, with its peak loading at 142ms. Based on its timeframe and clear discrimination between scrambled and face stimuli, it was hypothesized that PCA factor 8 represents the N170, the negative trough subsequent to P1 in response to visual and particularly face stimuli.

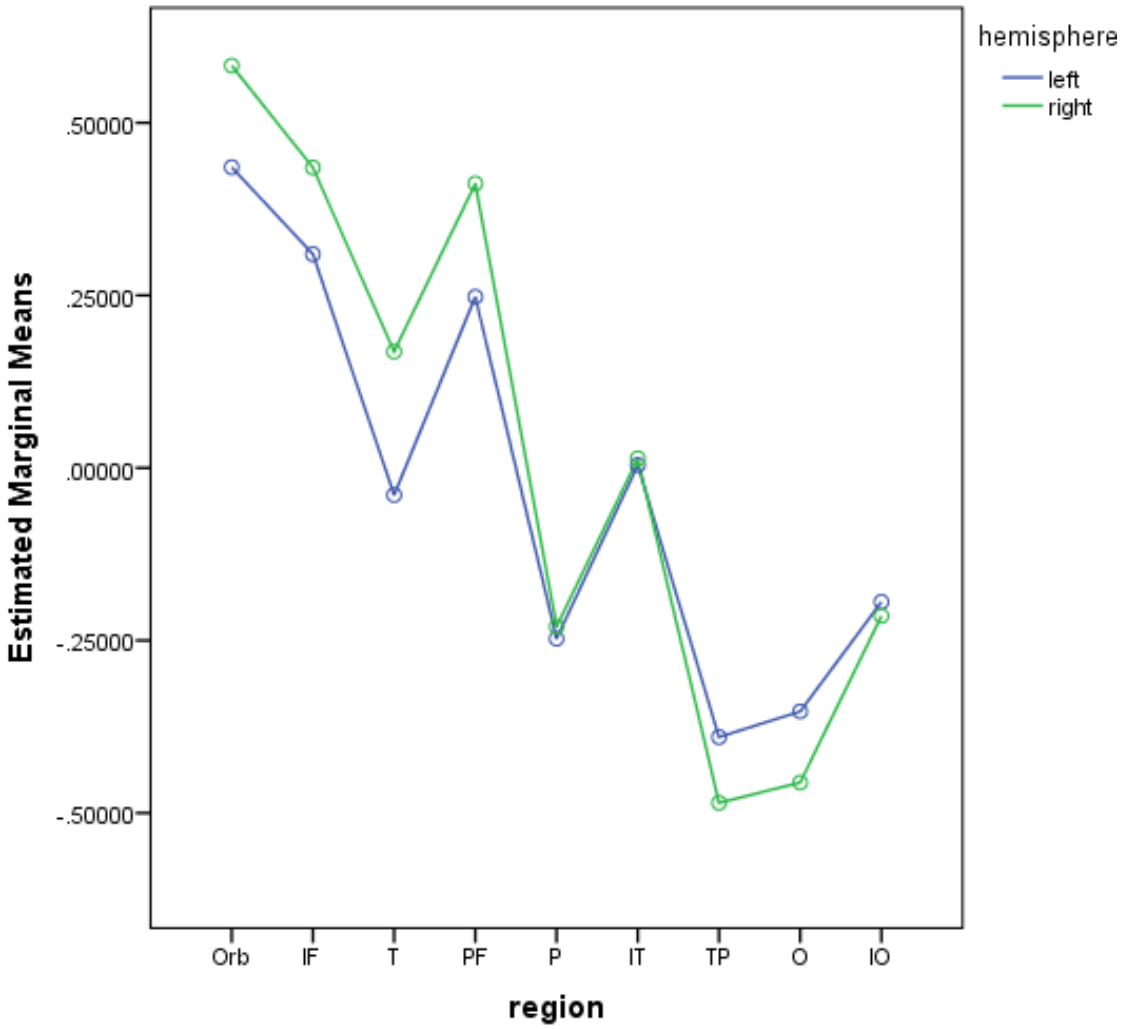
Region and Hemisphere.

The effect of hemisphere was not significant ($F(1,19)=.712$, $p=.409$). However, laterality may be hidden in the main effect by the inversion of these effects anterior-posterior across the vertex, as is examined in the region*hemisphere interaction. The effect of region was significant ($F(8,152)=8.764$, $p<.0005$). The strongest marginal means were distributed negatively among Occipital (O), Tempoparietal (TP), and Parietal (P) electrode regions, and positively among Orbital (Orb), Prefrontal (PF), and Inferior

Frontal (IF) regions. These regions, and not the others (IO, IT, and T), were significantly different from the grand mean of regions (zero). This is consistent with the typical distribution of the N170 and its dipoles. The marginal means are represented visually in Figure 4.28.

The effect of region*hemisphere was significant ($F(8,152)=4.671$, $p<.0005$), suggesting that the laterality effect differed for different regions. The differences from the grand mean for O, Orb, PF, and T were significantly stronger in the right compared to the left hemisphere ($p<.05$). Thus, in general, PCA factor 8 scores were of greater magnitude in the right hemisphere, although the effect is inverted across anterior-posterior across the vertex.

Figure 4.28. *PCA factor 8 marginal means for region*hemisphere.*

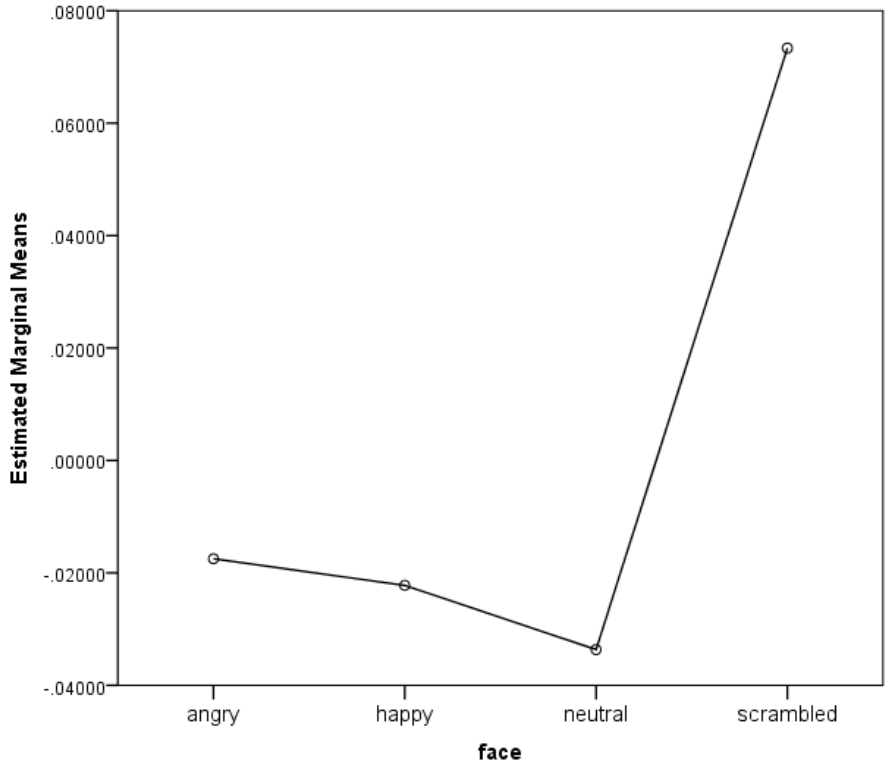


Stimulus Type.

The effect of stimulus type was significant ($F(3,57)=14.878$, $p<.0005$), suggesting PCA factor 8 showed significant differences across the four stimulus types for the marginal means of all other conditions. Specifically, as shown in Figure 4.29, scrambled faces had very strong marginal means for PCA factor 8 factor scores, and the neutral and emotional faces had moderate inverse marginal means. The difference between scrambled and other face images' marginal means were significant (mean squared differences range 1.3 - 1.8, $F(1,19)$s range 19 - 26, ps<.0005). The emotional faces'

marginal means were not different from the neutral face ("angry" $F(1,19)=.997$, $p=.335$; "happy" $F(1,19)=.477$, $p=.498$), and angry faces' marginal means were not different from happy faces ($F(1,19)=.129$, $p=.724$).

Figure 4.29. *PCA Factor 8 Marginal Means for Different Stimulus Types.*



The effect of hemisphere*stimulus was not significant ($F(3,57)=.558$, p=.645).

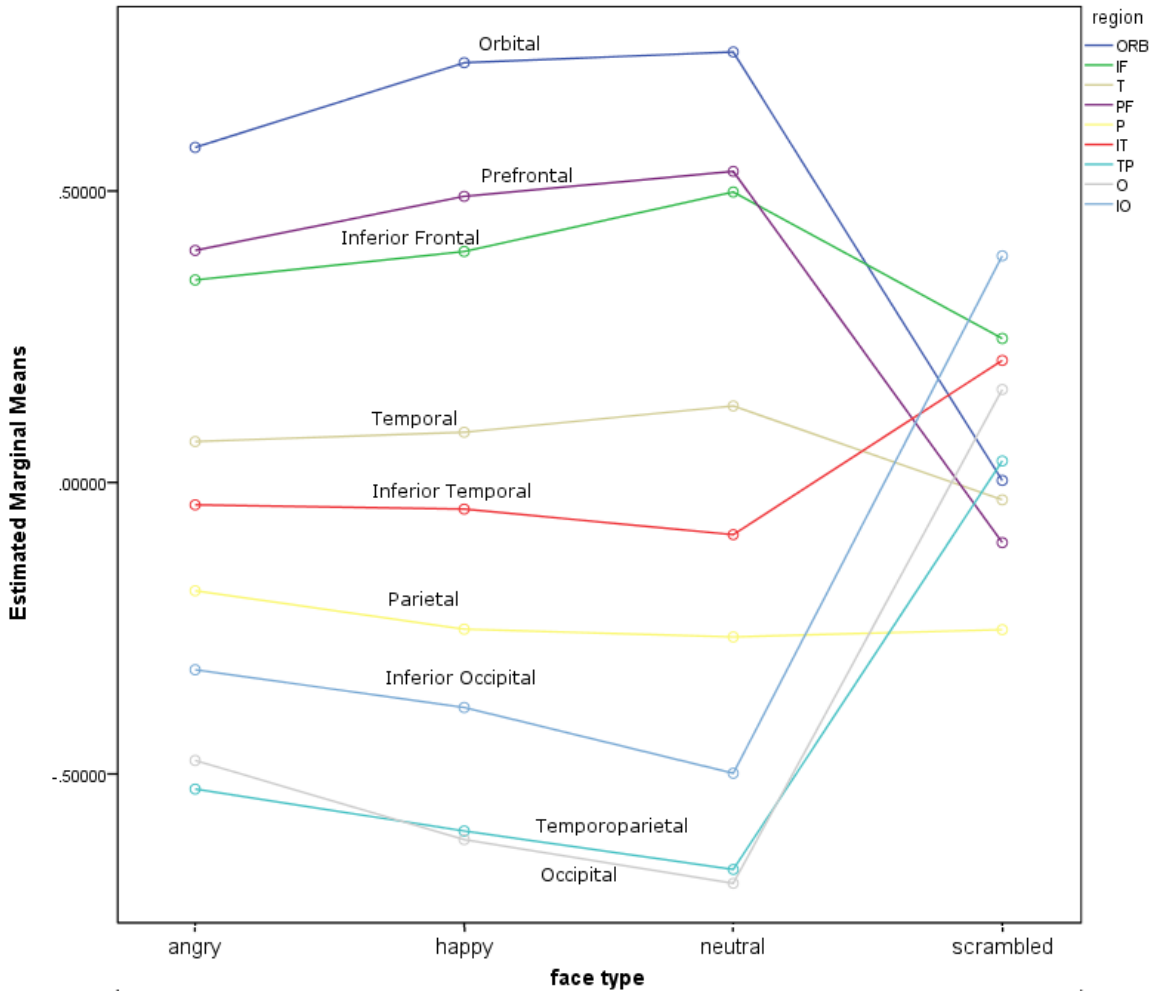
The effect of region*stimulus was significant, suggesting the differences between stimulus types' marginal means differed for different regions ($F(24,456)=11.6042$, $p<.0005$). As is clear from Figure 4.30, the true effect of stimulus type was suppressed by the interaction with region. In particular, anterior electrode regions tended to have greater magnitude marginal means for faces compared to small magnitude marginal means for scrambled images, whereas the inverse was generally true for posterior electrode regions.

So, the expected greater magnitude for faces vs. scrambled images in a factor thought to represent N170 was mirrored across the anterior-posterior midline. In addition, this conditional effect was different for different regions.

The difference between scrambled and face images was not significant for the midline Parietal electrode region (F(1,19)s range 1 - 4, ps range .185 - .425). However, the midline Prefrontal region showed a significant difference between faces and scrambled images (F(1,19s)s range 20 - 30, ps<.0005), which might indicate that the VPP is represented best by this region (Joyce & Rossion, 2005). The face vs. scrambled effects were significant for all of the other regions and face comparisons except for Inferior Frontal angry vs. scrambled (F(1,19)=2.2025, p=.154) and happy vs. scrambled (F(1,19)=3.467, p=3.467, p=.078).

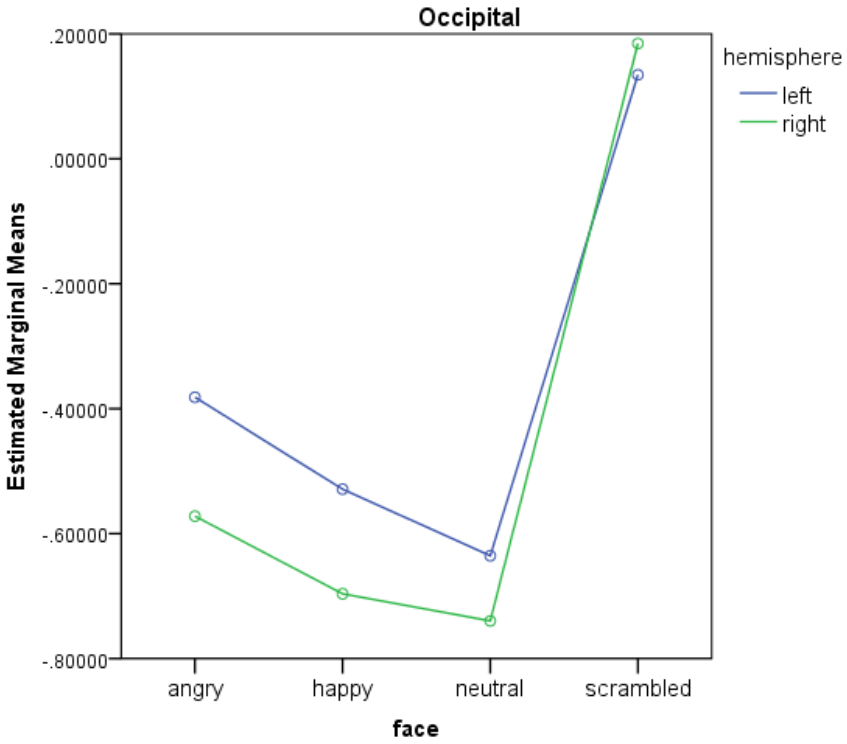
The only region for which the difference between neutral and emotional faces approached significance was Temporoparietal, for which the marginal mean for neutral faces were more negative than for angry faces (F(1,19)=3.629, p=.073). No angry vs. happy face marginal mean differences were significant (ps >.05). In all regions, the scrambled vs. face effect was of the smallest magnitude for angry faces, a middle magnitude for happy faces, and the greatest magnitude for neutral faces, consistent with the apparent shape of the main effect for face. However, these differences were not significant. So, with regard to reliable marginal differences, Figure 4.30 may be better represented by a horizontal line between angry, happy, and neutral faces, with a slope of varying steepness to scrambled images. The curve for the Parietal marginal means would be straight and horizontal.

Figure 4.30. *Factor 8 Marginal Means for Stimulus*Region.*



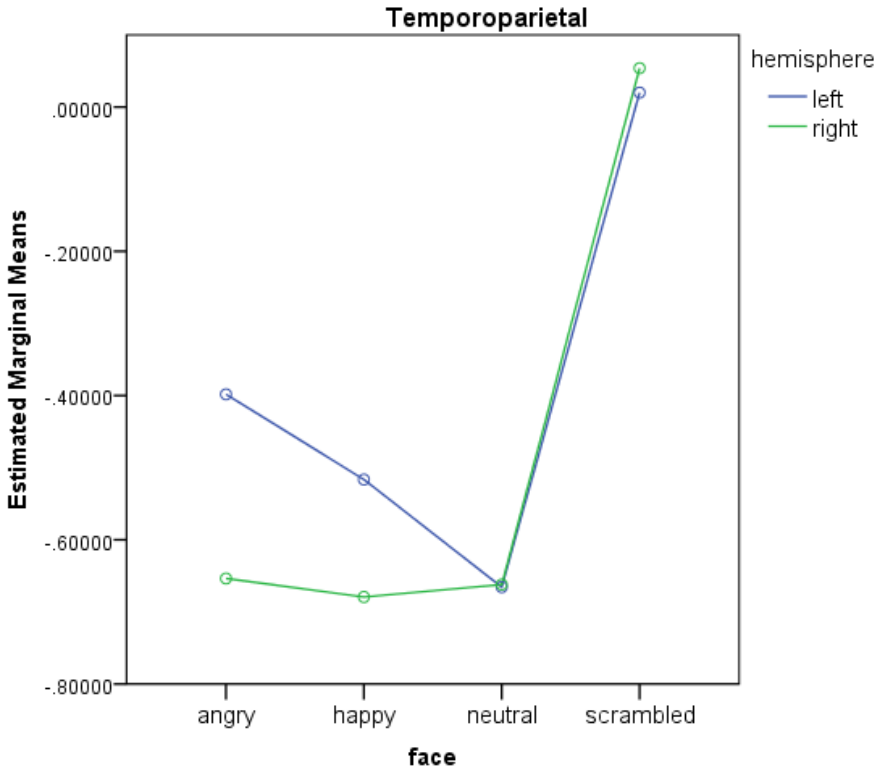
The effect for region*hemisphere*stimulus was significant, suggesting that the marginal means for face effects by region (discussed above) differed by hemisphere ($F(24,456)=1.802$, $p=.012$). Specifically, the marginal mean comparisons between faces vs. scrambled images were different across hemispheres for the Occipital region. Specifically, the Occipital marginal mean differences for scrambled vs. face stimuli were greater in the right hemisphere ($F(1,19)$s range 9 - 16, ps<.01), as shown in Figure 4.31.

Figure 4.31. *PCA Factor 8Marginal Means of Stimulus Type by Hemisphere for the Occipital Region.*



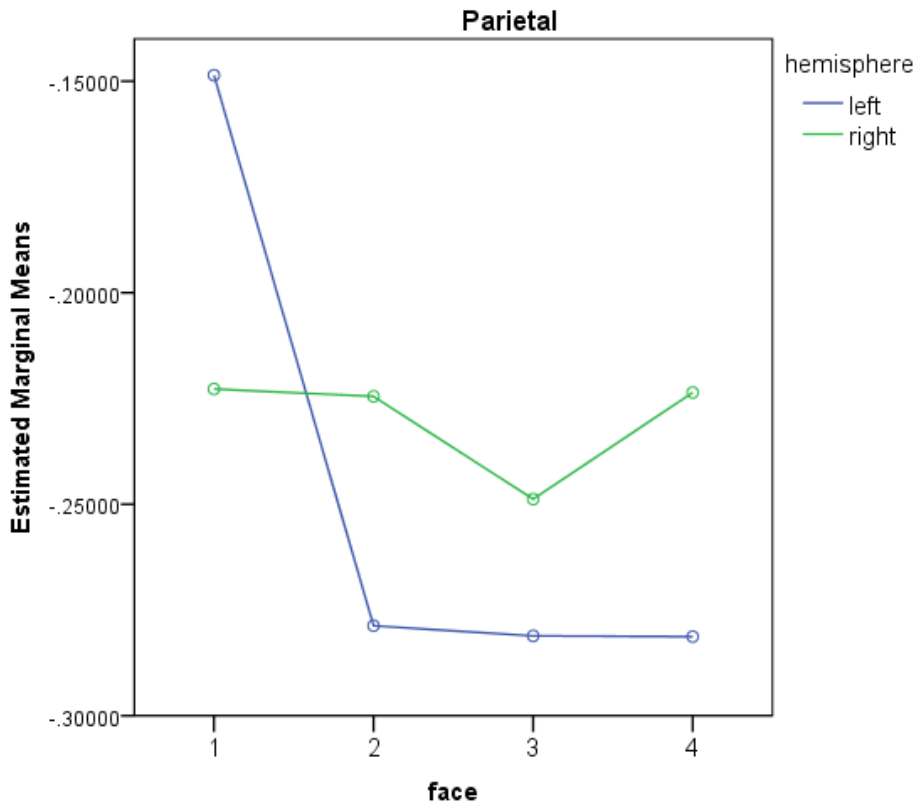
The marginal mean differences for emotional faces vs. neutral faces were all not different across hemispheres except angry faces vs. neutral faces in the Temporoparietal electrode region ($F(1,19)=5.704$, $p=.027$), where the effect is only apparent in the left hemisphere, as shown in Figure 4.32. No angry vs. happy face marginal mean differences were significant ($ps > .05$).

Figure 4.32. *PCA Factor 8 Marginal Means of Stimulus Type by Hemisphere for the Temporoparietal Region.*



As shown in Figure 4.33, the face effect appears strikingly different after considering hemisphere in the Parietal region, but this difference was not significant (*p*s > .05). This pattern showed trend-level probability values (angry vs. happy $F(1,19)=4.108$, $p=.057$; happy vs. neutral ($F(1,19)=4.238$, $p=.054$); all other comparisons were clearly not significant).

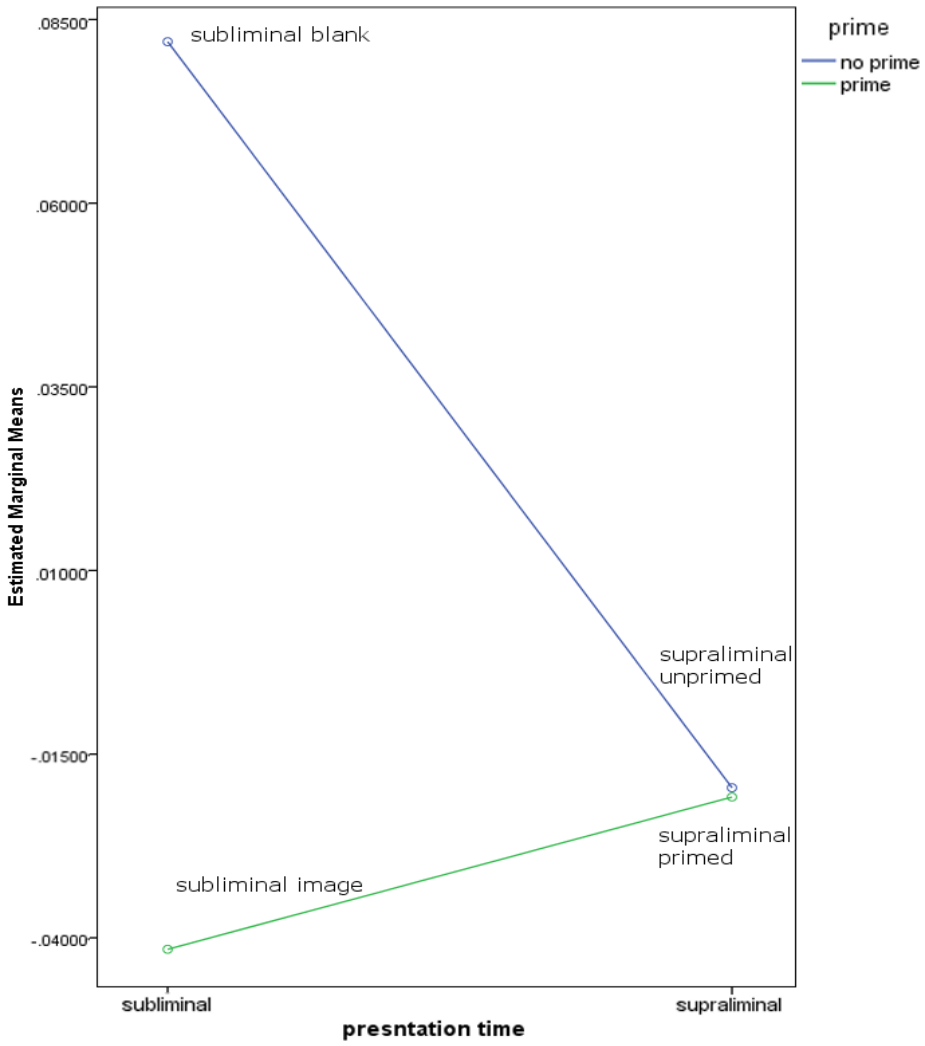
Figure 4.33. *PCA Factor 8 Marginal Means of Stimulus Type by Hemisphere for the Parietal Region.*



Presentation Time and Priming.

As expected, the interaction between presentation and prime was significant ($F(1,19)=23.252$, $p<.0005$). As such, interactions with stimulus type and electrode region are pursued. As shown in Figure 4.34, primed supraliminal responses do not appear different for PCA factor 8 marginal means, but subliminal blank images appear to have a greater marginal mean than subliminal images, and subliminal faces appear to have a slightly lower marginal mean than supraliminal faces. Notably, the marginal mean for the blank subliminal marginal mean is much greater than the marginal mean for supraliminal unprimed images, but this comparison is not meaningful as two conditions are manipulated in the comparison (image vs. blank, subliminal vs. supraliminal).

Figure 4.34. *PCA Factor 8 Presentation time and priming.*



The presentation*priming interaction differed significantly by region ($F(8,152)=25.335$, $p<.0005$). Specifically, presentation*priming was significant for all regions (ps<.0005) except Inferior Temporal ($F(1,19)=2.653$, $p=.120$), and Parietal ($F(1,19)=.015$, $p=.904$). Viewing Figure 4.35, it appears that these effects are driven by a lack of difference between marginal means for the blank subliminal image and actual subliminal image in these regions (see "P" and "IT" distance between light and dark lines).

Figure 4.35. *PCA Factor 8 Prime Type by Region for Different Presentation Times: Subliminal.*

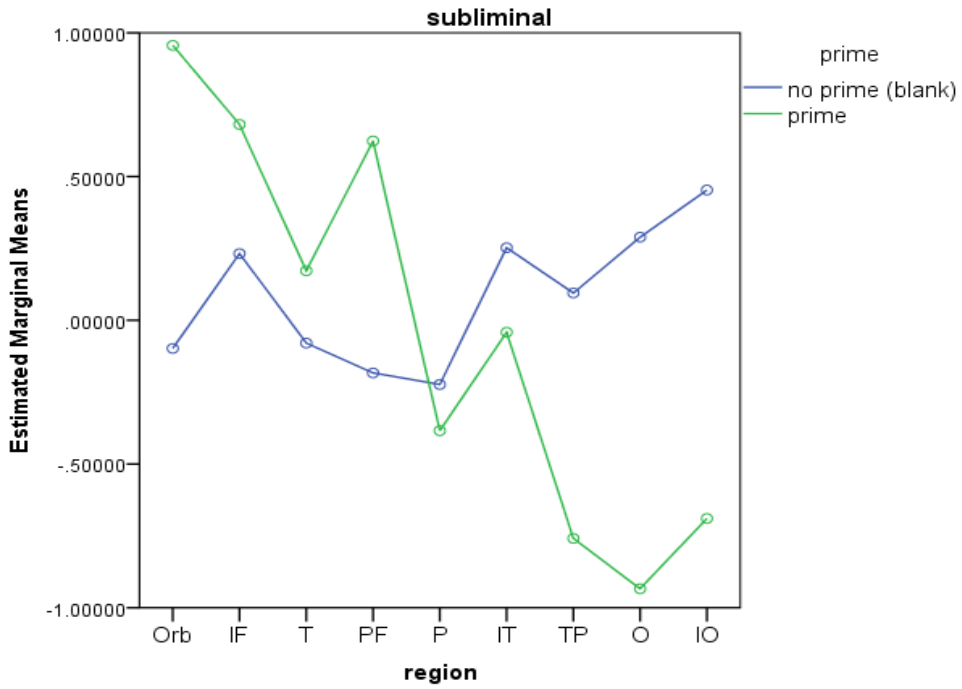


Figure 4.36. shows there does not appear to be a substantial effect of priming on supraliminal marginal means, after accounting of regional differences.

Figure 4.36. *PCA Factor 8 Prime Type by Region for Different Presentation Times: Supraliminal.*

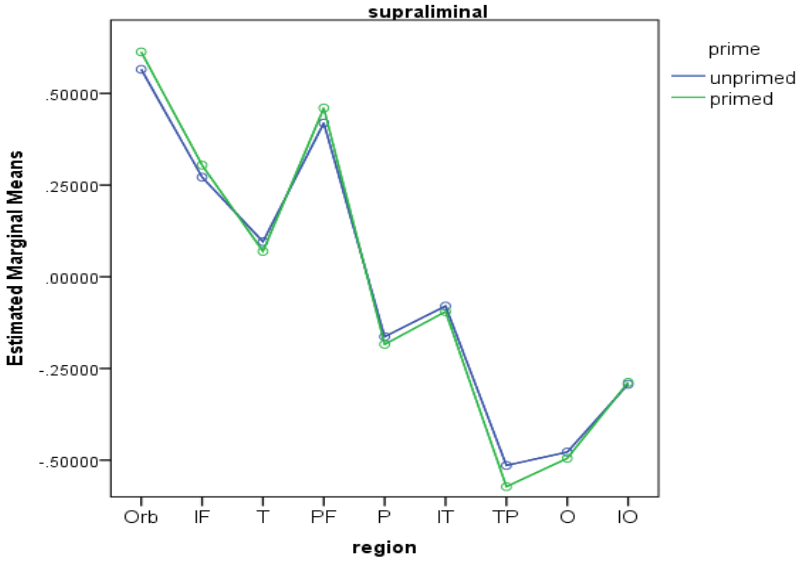
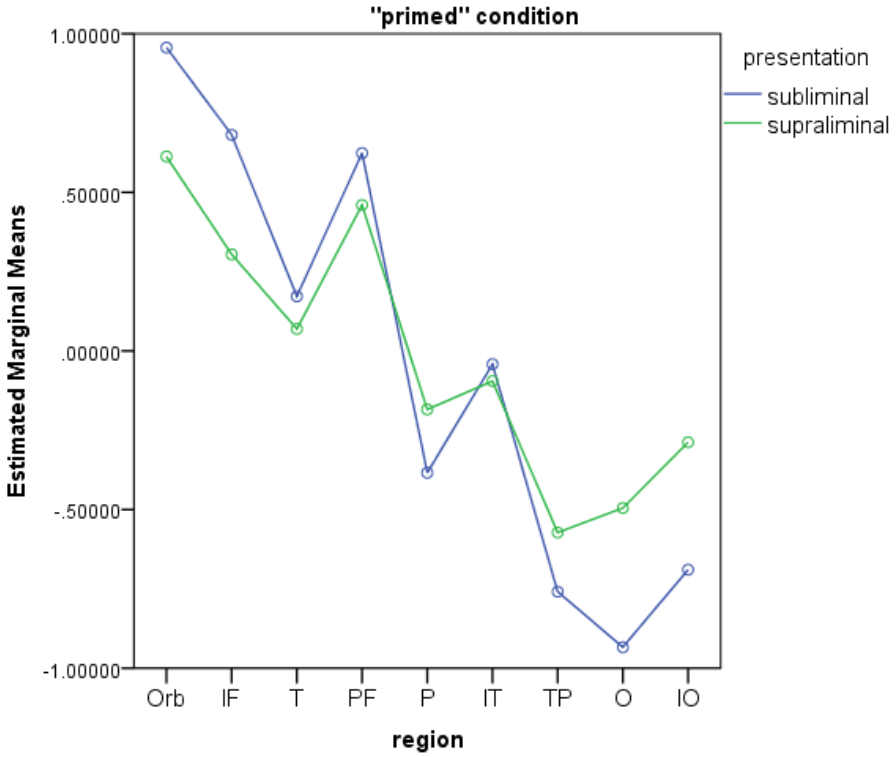


Figure 4.37 shows only "primed" stimuli, meaning that the blank subliminal stimulus set are excluded (as are the accompanying "unprimed" supraliminal stimuli), with electrode regions arranged approximately anterior to posterior. Visual inspection shows there may also be a significant effect for presentation time that is mirrored anterior-posterior, such that subliminal marginal means are of greater magnitude than supraliminal marginal means for PCA factor 8 scores.

Figure 4.37. *PCA Factor 8 Prime Type by Region for Different Presentation Times: Primed.*



Stimulus type, Presentation Time, and Priming.

The interaction of presentation*prime*stimulus was significant ($F(3,57)=6.159$, $p=.001$). Specifically, the comparisons of scrambled images to the three stimulus types were all different for different priming or presentation times ($F(1,19)$ range 6 - 15, *p*s

range .001-.028). As shown in Figure 4.38, this effect appears to be driven by the blank subliminal image responses, for which the marginal mean does not appear lower for faces compared to scrambled images. Instead, the blank subliminal marginal means for all stimulus types appear similar, with high factor scores (i.e., the darker line in the lower graph of Figure 4.39 is relatively horizontally flat compared to the curves for all other priming and presentation times across faces). Viewing Figure 4.38 and Figure 4.39 vertically across both graphs, PCA factor 8 marginal means for scrambled faces appear high and similar across all presentation types and priming, although the marginal mean for the subliminal blank image appears the highest.

Stimulus type comparisons between angry vs. happy and neutral vs. emotional faces were not different (*p*s>.05) with respect to this interaction.

Figure 4.38. *PCA Factor 8 Stimulus type by presentation time for prime and no-prime: Subliminal*

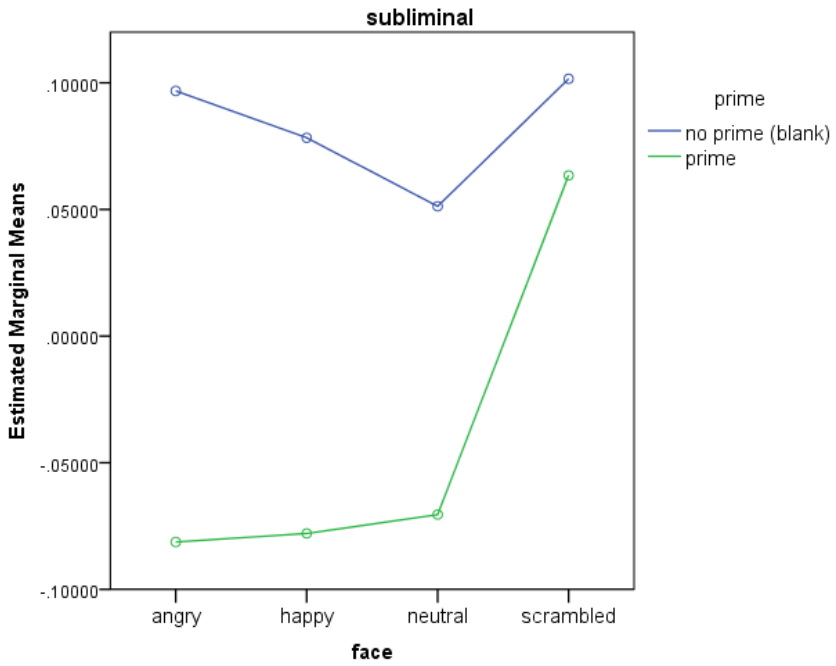
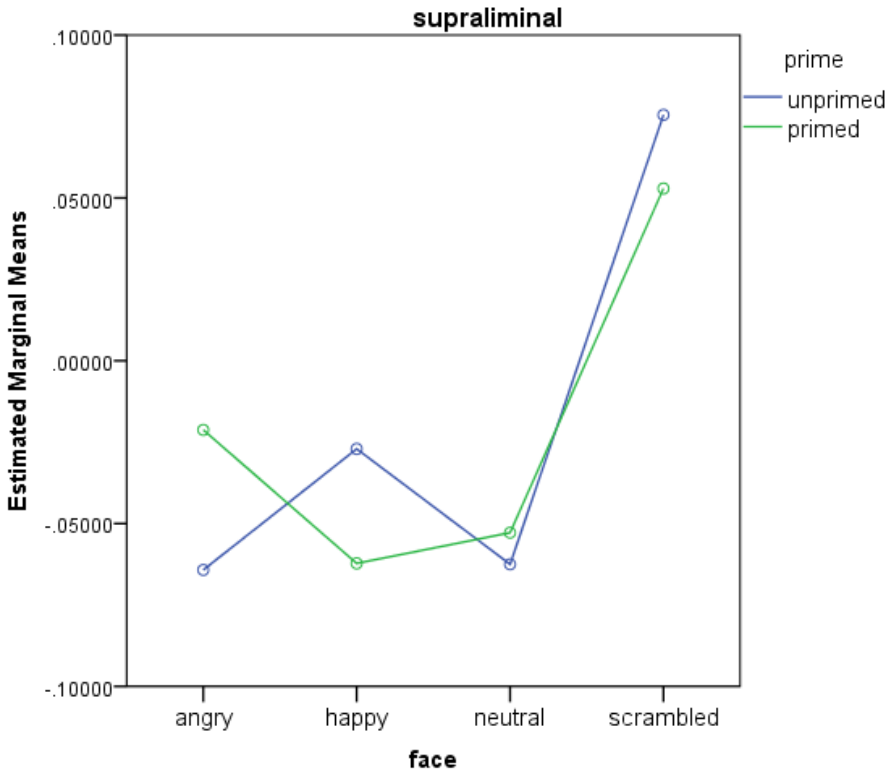


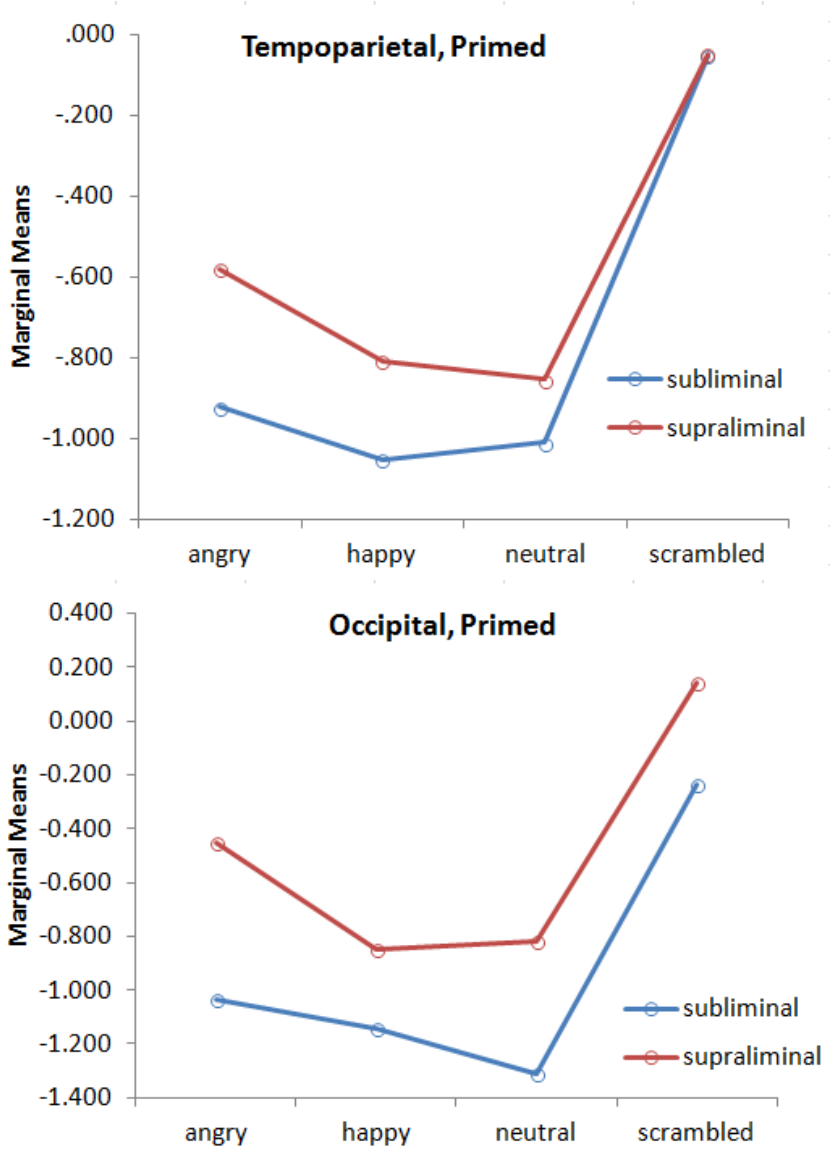
Figure 4.39. *PCA Factor 8 Stimulus type by presentation time for prime and no-prime: Supraliminal*



These effects did not differ by hemisphere ($F(3,57)=1.508$, $p=.222$), but they did differ by region ($F(24,456)=4.057$, $p<.0005$). Specifically, the interactions of priming and presentation time with scrambled vs. other stimulus type comparisons were not consistent across regions. Given that the blank vs. non-blank subliminal comparison is not a primary focus of this study, this result is followed up in regions that, based on the results of the region*presentation*prime as well as the region*stimulus marginal means, are most likely to show differences between subliminal and supraliminal presentations and showed reliable marginal mean differences for face effects. Also, the regions followed-up should have some expected relationship to N170. O and TP regions are displayed to demonstrate this effect. As shown in Figure 4.40, the general face effects, with the greatest magnitude

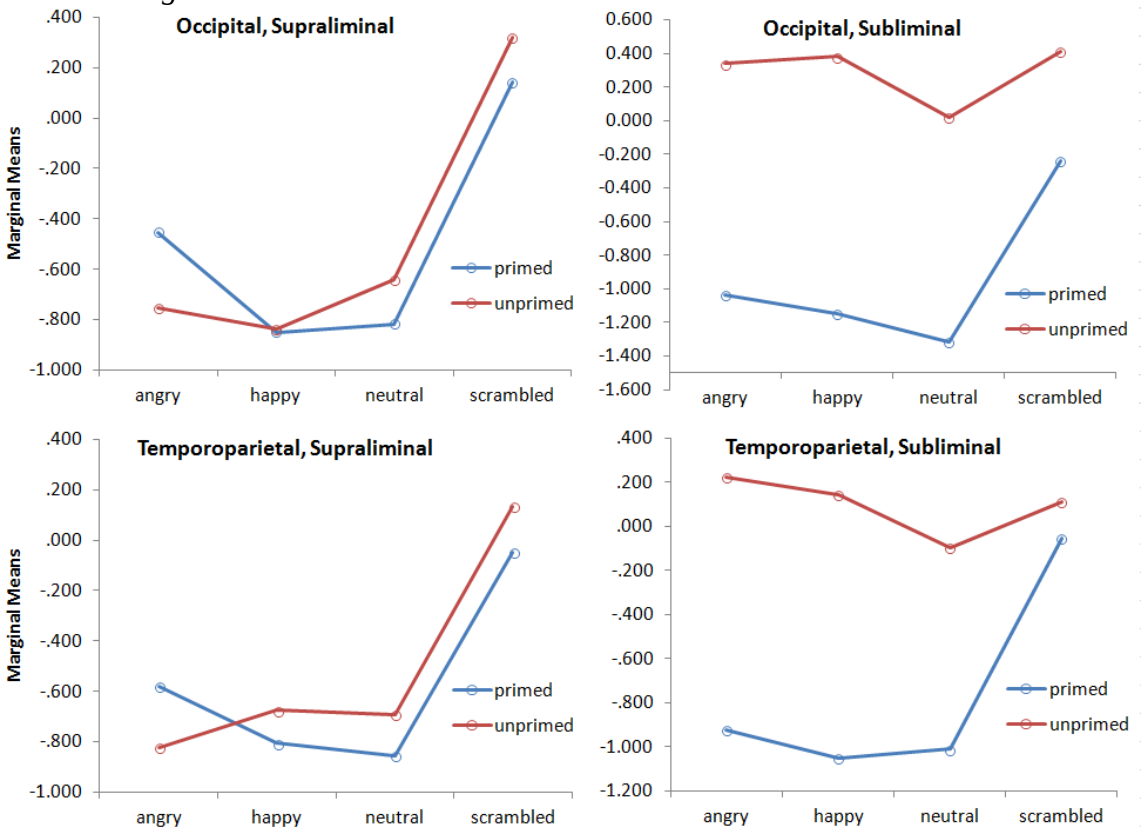
(most negative) marginal means for happy and neutral faces, slightly less negative for angry, and much less negative for scrambled images, are consistent in both subliminal and supraliminal presentations. However, as previously mentioned, PCA factor 8 marginal means appear more negative overall for subliminal face presentation. This general difference appears to be diminished for scrambled stimuli, particularly in the TP region.

Figure 4.40. *PCA Factor 8 Face by Presentation Time for Primed Marginal Means from TP and O Regions.*



As shown in Figure 4.41, there is no clear priming effect in supraliminal stimuli, and the effect of blank subliminal stimuli compared to non-blank stimuli appears the same as the main effect.

Figure 4.41. *PCA Factor 8 Face by Priming by Presentation Time Marginal Means from TP and O Regions*



Finally, the region*hemisphere*presentation*stimulus*priming interaction was significant ($F(24,456)=1.695$, $p=.022$). This means that the aforementioned interactions between presentation*priming with stimulus type and region differed across hemispheres. On inspecting contrasts, this difference only applied to stimulus type effects in the IO, IF, and TP regions ($F(1,19)$ range 4-12, ps range .003-.045). Most of these individual

contrasts were not strong (relatively low F values and high p-values near .05). The nature of these results suggest a re-wording of the interaction: the aforementioned presentation*prime*stimulus interactions are generally consistent with the main effects of hemisphere, but these effects differ from the main effect of hemisphere for IO, IF, and TP. Essentially, this interaction advises against collapsing across hemispheres, which is common sense in electrophysiological research.

PCA Factor 8 Summary

PCA Factor 8 primarily differentiates scrambled from face stimuli. It is focalized in regions and a timeframe consistent with representing N170 and its positive distribution across the reference, including especially Temporoparietal and Occipital regions. There may be some interesting effects closer to vertex, including Prefronal and Parietal regions, and the anterior dipoles in Orbital and Inferior Frontal electrode regions may also show some interesting effects, although they are not typically included in analyses of N170 and VPP. The factor generally appeared stronger in the right hemisphere, but some effects were stronger in the left hemisphere. This PCA factor showed some possibility of discriminating neutral and emotional faces, particularly angry vs. neutral. There was little evidence for a priming effect in supraliminal presentations. The most reliable effects were face greater than scrambled stimuli and subliminal greater than supraliminal presentation times in right posterior regions. The was an extreme effect of blank vs. non-blank subliminal images, blank images having much less negative marginal means than images. In fact, the blank subliminal images appear to have artifactually elevated the marginal means for all of the marginal means that did not differentiate prime and

presentation (blank mean = .082, all other means range -.020 to -.042). There was little evidence for supraliminal priming effects.

Peak and Latency Analysis with P1, N170, and P300

Peak and Latency Derivation.

This more traditional analysis section began with confirmation of the newer temporal PCA component derivation results. As discussed before, the conditional waveforms across participants demonstrated clear evidence (timing and topography) of the P1, N170 and P300 as expected in supraliminal face responses.

PCA can be driven by peak amplitude and latency. As such, each of these three aspects of the three components of interest were examined in peak and latency analysis. First, latencies were derived within a wide timeframe accounting for the window given by the PCA as well as the typical window analyzed in previous research. The results were visually compared against conditional average and a random sample of individual participants' waveforms to determine the best window for analysis.

In order to ensure precise extraction of peak amplitudes, "peak" variables were defined as the "adaptive mean" of a ten-second window surrounding the peak derived within each component's temporal window.

N170 Temporal Window.

Latency analysis for the N170 demonstrated the presence of components that are lost in averaging across participants, but are easily parsed by ERP post-processing

software and the temporal PCA process. For example, Figure 4.42 shows a clear P1-N170 complex that appears to be delayed for scrambled images. However, inspection of individuals' ERPs and latency analysis revealed that this grand mean was skewed by the presence of two components: the P190 (or P2), a positive inflection in the negative slope leading to the next major component, N250, a negative trough that precedes the P300 (Katayama & Polich, 1999; Turetsky et al., 2007; Balconi & Lucchiari, 2007). As such, the grand mean shows an exaggerated N170 component around 200ms that leads directly to P300, when in fact N170 occurs earlier. On the other hand, in several cases, there was no apparent discrimination between N170 and N250, leading directly into a large P190 or P300 positivity. In these cases, N170 is easily observable, typically in the earlier latency range. These components were well-discriminated in Factors 4, 7, and 8 of the temporal PCA, which is statistically designed to capture orthogonal sources of variance and thus captures relatively tight temporal frames that avoid the extant correlation between neighboring components. However, individual differences in the latency of the N170 component require a wider window that captures N170 without undue influence from the N250.

Latency analysis including the commonly-used range, 130-200ms, demonstrated the nature of the P1-N170-P190-N250 complex, as shown in Figure 4.43 (Eimer, 2011). This figure shows an individual participant, individual temporoparietal electrode's average across supraliminal unprimed scrambled and neutral responses. This particular sample was chosen to demonstrate the complexity and substantial noise in individual data. However, this pattern was noted in a subsample of ten randomly chosen participants' ERPs for this electrode in this condition. The dark vertical line is centered at

the negative peak latency derived in the 130-200ms window. The subsequent positive peak is likely representative of P190, and the large negative subsequent peak is likely N250. The latency of the N250 is not extracted by the ERP post-processing software in this window because its peak is clearly later than the 130-200ms window.

This particular result provides excellent confirmation of the utility of the temporal PCA process, as a more traditional derivation of waveform components through use of grand means would not discriminate N170 and N250.

Blank subliminal responses were not used in this analysis. The N170 latency within the 130-200ms window for temporoparietal and occipital regions was substantially later than that implied by the temporal PCA results, though within the window (mean=155.1ms, SD=17.0). This is likely due to the PCA's discrimination between N170, P190, and N250. This remained regardless of the region, hemisphere, or presentation. time. Individual N170 appeared to occur often within the PCA timeframe (132-156ms), but a substantial number appeared later, around 170ms. Based on this result and visual inspection of individual waveforms in regions of interest, the window for N170 was expanded to **130ms to 180ms**, which includes the timeframe given by the temporal PCA as well as 1.5 standard deviations above the mean derived latency. This change resulted in a mean of 152ms (SD=13). The mean did not change substantially, but the standard deviation was reduced, suggesting outliers that may represent N250 or other unintended components were excluded. Although it was not used in analysis, the latencies for the 132-156ms window were also examined. The resulting distribution was skewed such that the modal value, 156ms, accounted for more than 10% of the resulted extracted variables, thus confirming the utility of the alternative, expanded window.

Figure 4.42. *Average ERP by Stimulus Type in TP Region for Unprimed Supraliminal Stimuli.*

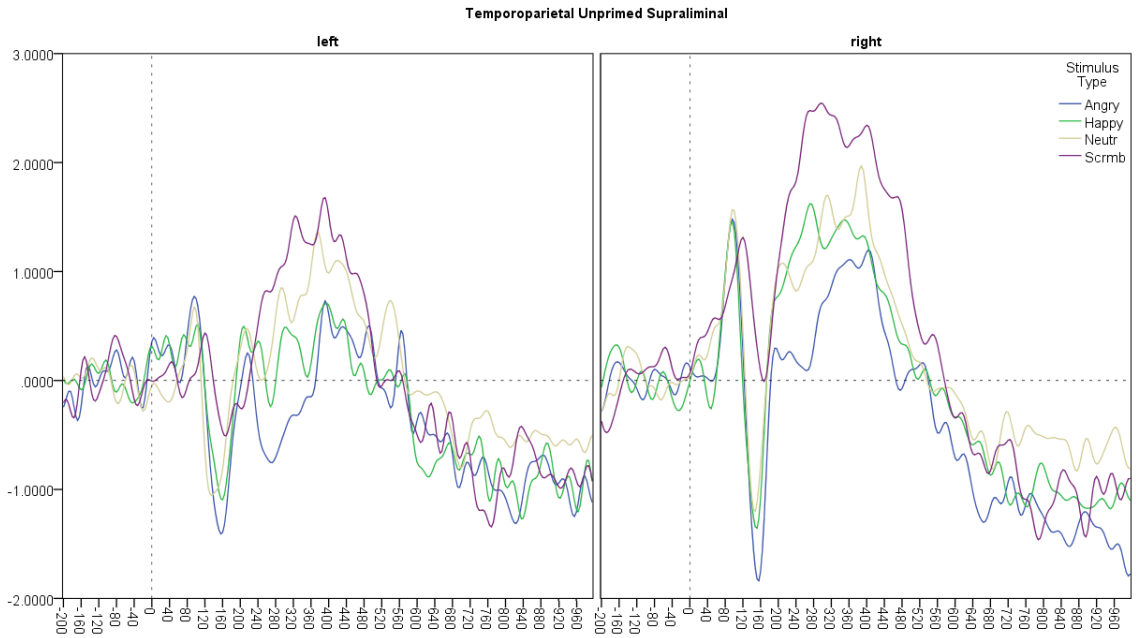
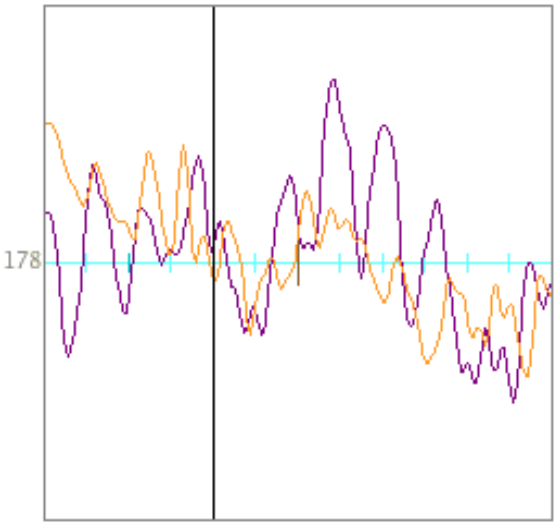


Figure 4.43. *Single Participant Single Electrode (#178) Average Waveform Right Temporoparietal Supraliminal Unprimed Condition.*



* Neutral (orange) and Scrambled (purple), and extracted Latency of N170 Marked with Black Vertical Line.

P1 Temporal Window.

There was also substantial individual variability apparent in the P1 component. Although there was less apparent variability in the waveform shape, the latency varied substantially, to the point that no reasonable time window could capture all of the observed peaks preceding the N170-P190-N250 complex. Latency was first analyzed in a liberal window of 70-120ms. A low, but reasonable mean latency was extracted (mean=95.8ms, SD=13.3), which appeared to be decreased by a relatively large proportion of extracted 72ms values (5%). Based on inspection of individual cases, alternative windows of 92-116ms (as recommended by the temporal PCA), 80-130ms, and 84-116ms were analyzed as well. For the wider and most narrow windows, the extracted values were difficult to reconcile with visual inspection of individual cases and included too many extreme (at the limit of the window) values. The medium **84-116ms** appeared to best capture the P1 component (latency mean=99.0ms, SD=9.6) with the best distribution (values within 2SD of the mean) and least values at the limit.

P300 Temporal Window.

Unlike N170 and P1, the window suggested by the temporal PCA for P300 was highly positively skewed, with the minimum 14 below the mean but the maximum 30 above the mean. The P300 for a passive, non-novelty task is expected to be late with a wide latency range, and visual inspection revealed that in fact the component ranged widely in individual cases (Ji, Porjesz, Begleiter, & Chorlian, 1999; Bennington & Polich, 1999). Combining past findings and the literature on passive, visual, non-novelty P300, a wide window of 250-460ms was first extracted. This resulted in latencies consistent with a P3b-like late positivity (mean=348.2ms, SD=48.9, mode=336ms).

Latency analysis within the temporal PCA window 300-344ms resulted in a distribution centered around 324.1ms (SD=12.7) with a modal value of 344ms, although this limit value only accounted for 5% of the total values. Although this is more consistent with a "novelty" P3a, rather than the attention orienting-related P3b, these classical P3 subcomponents are elicited in a design involving improbable or novel stimuli, which does not apply to this design (Picton, 1992; Demiralp et al., 2002). This design is more likely to invoke an earlier P3, and this smaller, earlier frame has been also been used for subliminal and supraliminal emotional face ERP studies (Strüber & Polich, 2002; Balconi & Lucchiari, 2007). Plus, later P3b-like components are more likely represented by the 1st or 3rd temporal PCA factors. As such, and to ensure consistency with the P300 derived in temporal PCA and the literature on subliminal emotion face ERP, an extended (approximately ±2SDs) version of the temporal PCA P300 was used: **290-350ms**. This resulted in a wave centered around 319.2ms (SD=17.9), which appeared to precisely identify a positivity in the early P300 range for all sampled cases.

Conditional Effects.

Analysis of conditional effects (i.e., within-person ERPs elicited by stimulus manipulations) was guided by the study design, hypotheses, and PCA MANOVA results.

P1 was remarkably unresponsive to condition in the PCA MANOVA, which allows for relatively simplistic follow-up analysis. Effects appeared strongest, though not qualitatively different, in right occipital electrodes for supraliminal presentation times with no priming. Presentation times and priming conditions could be averaged across without changing the main effects, according to the PCA MANOVA, but the present

analytic approach confers the most precise replication of predominant methods in the literature. Similarly, stimulus type could be aggregated, but for the sake of replication and interpretability, scrambled images and neutral faces will be analyzed.

N170 appeared to have the strongest, most consistent face vs. non-face effects in the right Occipital (O) region, as well as some potential emotion effects. There were no effects of supraliminal priming. So, primed supraliminal and blank subliminal conditions are unnecessary, but there was a main effect of presentation time. Peak and latency analysis will include both non-blank subliminal and unprimed supraliminal presentation times, as well as angry face, neutral face, and scrambled images.

P300 results were quite complex. The main effects appeared to be strongest in the Inferior Frontal (IF) region, and the right hemisphere generally had stronger marginal means. Presentation time effects were driven by differences in the nature of stimulus type contrasts. Although the IF showed the strongest effects, the P300 is typically derived from the parietal region, which showed similar though weaker effects, with the opposite valence. Additionally, the IF electrodes are placed across the face, which can result in excess noise. As such, the P300 results will be analyzed first in the parietal region, which mirrored those in the IF region, and followed up in the inferior frontal region.

The following analyses confirm the relationship of the peaks and/or latencies extracted to the PCA factor scores analyzed above by replicating and extending the results.

P1 Peak and Latency Conditional Effects.

Reflecting the PCA MANOVA results, occipital supraliminal unprimed P1 peak was greater for right (2.300uV) than left (1.697uV) electrode regions ($t(19)=2.854$, $p=.010$). However, latency was not different for right (98ms) vs. left (97ms) regions ($t(19)=.747$, $p=.464$).

Reflecting a trend in the PCA MANOVA results, right occipital supraliminal unprimed P1 latency was later for scrambled (106ms) vs. neutral (98ms) responses ($t(19)=-3.757$, $p=.001$). However, P1 peaks were not different for scrambled (2.350uV) vs. neutral (2.300uV) responses ($t(19)=-.120$, $p=.906$).

In summary, patterns noted in the PCA MANOVA results were replicated, but stimulus type effects were noted in latency not peak, and laterality differences were noted for peak not latency.

N170 Peak and Latency Conditional Effects.

The complex effects for N170 were first modeled in two 2X3 MANOVA models using right occipital electrodes, one each for peak and latency, each including presentation time (subliminal non-blank vs. supraliminal unprimed) and stimulus type (angry, neutral, and scrambled), with non-orthogonal contrasts for stimulus types as in the PCA MANOVA models.

The model for N170 peaks showed significant effects for presentation time ($F(1,19)=21.779$, $p<.0005$) and stimulus type ($F(2,38)=12.563$, $p<.0005$), but not their interaction ($F(2,38)=1.130$, $p=.334$).

Specifically, subliminal presentations (-2.753uV) were significantly more negative than supraliminal presentations (-1.396uV). Scrambled images were

significantly less negative than both angry ($F(1,19)=15.552$, $p=.001$) and neutral ($F(1,19)=14.943$, $p=.001$) face images, and angry faces were not different from neutral faces ($F(1,19)=0.184$, $p=.673$).

The model for N170 latencies did not reveal significant differences by condition: neither presentation time ($F(1,19)=0.139$, $p=.714$), stimulus type ($F(2,38)=1.065$, $p=.355$), nor their interaction ($F(2,38)=0.072$, $p=.930$).

In summary, face-specific and presentation time differences noted in the PCA MANOVA were replicated for N170 peaks but not latencies.

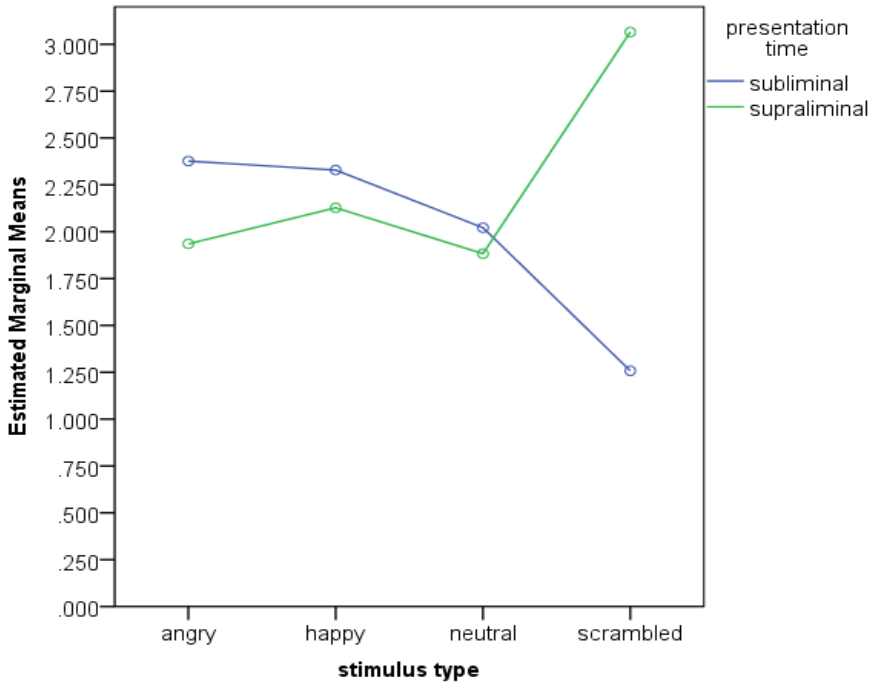
P300 Peak and Latency Conditional Effects.

The complex effects for P300 were first modeled in two 2X4 MANOVA models using right parietal electrodes, one each for peak and latency, each including presentation time (subliminal non-blank vs. supraliminal unprimed) and stimulus type (angry, happy, neutral, and scrambled), with non-orthogonal contrasts for stimulus types as in the PCA MANOVA models.

The model for P300 peaks showed no significant main effects: presentation time ($F(1,19)=1.223$, $p=.283$) and stimulus type ($F(3,57)=0.509$, $p=.678$). However, their interaction was significant ($F(3,57)=13.533$, $p<.0005$). Contrasts showed the effect of stimulus type was different for supraliminal vs. subliminal presentation times for all comparisons with scrambled images ($F(1,19)$s>20, ps$<.0005$), but not between different stimulus types (ps$>.05$). As shown in Figure 4.44, the difference in responses for scrambled vs. face images was reversed for subliminal vs. supraliminal presentations, such that scrambled image responses were more positive than neutral for supraliminal

presentations (t(19)=3.066, *p*=.006), but scrambled images responses were less positive than neutral for subliminal presentations (t(19)=-3.439, *p*=.003).

Figure 4.44. *P300 Peaks by Presentation Time and Stimulus Type for Right Parietal Electrodes.*



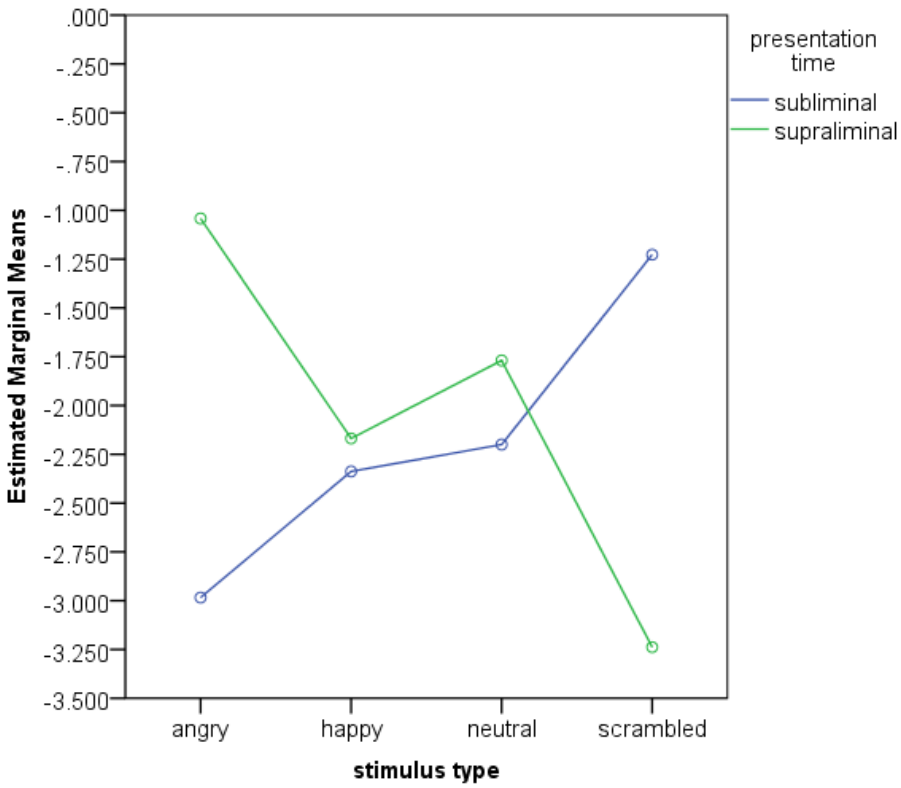
The model for P300 latencies showed no significant main effects or interactions: neither presentation time (F(1,19)=0.468, *p*=.502), stimulus type (F(3,57)=1.547, *p*=.212), nor their interaction (F(3,57)=0.658, *p*=.581).

Parietal P300 peaks replicated expected differences between neutral and scrambled images in subliminal compared to supraliminal presentation, but did not replicate expected supraliminal differences between emotional faces. Inferior Frontal (IF) peaks and latencies were analyzed using the same model to investigate this effect.

The main effects for IF peaks were the same as those for Parietal electrodes, although the simple effects were in the opposite direction, as the voltage is reversed for

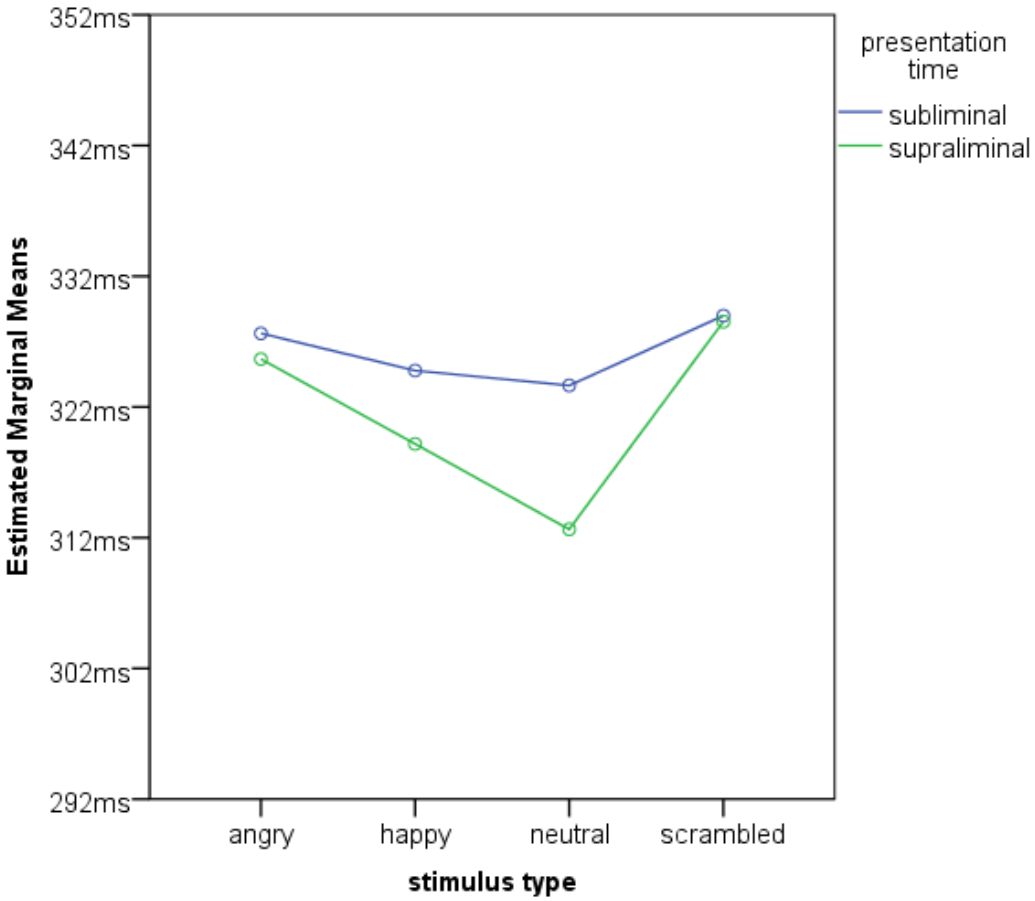
this frontal region. However, the marginal mean contrasts were significantly different. As shown in Figure 4.45, the interaction between presentation and priming was similar for scrambled image responses (i.e., the direction of the effect was reversed for supraliminal vs. subliminal presentation times; interaction $F(3,57)=13.313$, $p<.0005$). However, in IF electrodes, individual contrasts between angry and neutral stimuli showed a trend towards an interaction ($F(1,19)=4.188$, $p=.055$), and angry and happy ($F(1,19)=12.963$, $p=.002$) showed a significant interaction. Specifically, angry face responses showed a trend towards being more negative than happy faces in subliminal presentation ($t(19)=-1.981$, $p=.062$) and significantly less negative than happy faces in supraliminal presentation ($t(19)=2.542$, $p=.020$). Angry face responses were not significantly different from neutral faces in supraliminal ($t(19)=1.263$, $p=.222$) or subliminal ($t(19)=-1.780$, $p=.091$) presentations.

Figure 4.45. *P300 Peaks by Presentation Time and Stimulus Type for Right Inferior Frontal Electrodes*.



The main effect for presentation time for IF P300 latencies was not significant ($F(1,19)=1.912$, $p=.183$), but the effect of stimulus type was significant ($F(3,57)=3.788$, $p=.015$). Their interaction was not significant ($F(3,57)=0.799$, $p=.499$). The stimulus type main effect was driven by the earlier latency for neutral stimuli, which were significantly earlier than angry (mean difference=-8.51ms, $p=.003$) and scrambled (mean difference=-10.614, $p=.019$) image responses, but not different from happy face responses (mean difference -3.836, $p=.303$). Although the effect of stimulus type did not interact significantly with presentation time, this effect shows a trend for being stronger for supraliminal presentation times. Specifically, the supraliminal neutral response was 11ms earlier than the subliminal neutral response ($t(19)=-1.946$, $p=.067$).

Figure 4.46. *P300 Latencies by Presentation Time and Stimulus Type for Right Inferior Frontal Electrodes.*



In summary, face vs. non-face effects that interacted with presentation time were replicated in parietal P300 peaks, but emotional face effects were not. These effects and differences between angry and neutral faces were replicated in inferior frontal electrode P300 peaks, and a nonsignificant difference between subliminal angry and neutral faces in the opposite direction was noted at a trend level that was not apparent in the PCA MANOVA. Additionally, inferior frontal P300 latencies were earlier for neutral stimuli. This latter neutral stimulus effect was not observed in the PCA MANOVA.

ERP Peaks and Latencies with External Measures

In this exploratory pilot study, peak and latency analysis was completed for all external measures with all waveform components of interest. All correlations with external measures with very skewed distributions were examined using Spearman's Rho rather than Pearson's r. First, raw peak amplitude in the regions and conditions of interest were examined for correlations with external measures. Next, latencies were similarly analyzed. Finally, peak comparisons of interest (i.e., conditional effects revealed in PCA MANOVA and confirmed in peak and latency conditional analysis) were analyzed for correlations using simple peak differences (i.e., the peak of one conditional component minus the peak for another condition for the same component). Results are organized by roughly-categorized external measure category (neuropsychological, social cognitive, personality, and social functioning).

Concerning peak differences, it is useful to note at this point the interpretations of directions of effects for future reference:

Occipital N170 is negative, so
- for Neutral (- -) minus Scrambled (-),
  - more negative difference = more face-specific
  - 0 = not different
- for Angry (-) minus Happy (-),
  - more negative difference = greater magnitude for angry emotion valence
  - 0 = not different
  - more positive difference = greater magnitude for happy emotion valence
- for Supraliminal (-) minus Subliminal (- -),
  - more positive difference = greater magnitude for subliminal
  - 0 = not different

Parietal P300 is positive, so
- for *Subliminal* Neutral (+ +) minus Scrambled (+),
  - more positive difference = more face-specific
  - 0 = not different
- for *Supraliminal* Neutral (+) minus Scrambled (+),
  - more positive difference = greater magnitude for faces
  - 0 = not different

more negative difference = greater magnitude for scrambled
for Angry (-) minus Happy (-),
more positive difference = greater magnitude for angry emotion valence
0 = not different
more negative difference = greater magnitude for happy emotion valence
for *Parietal Scrambled* Supraliminal (+ +) minus Subliminal (+),
more positive difference = greater magnitude for supraliminal
0 = not different

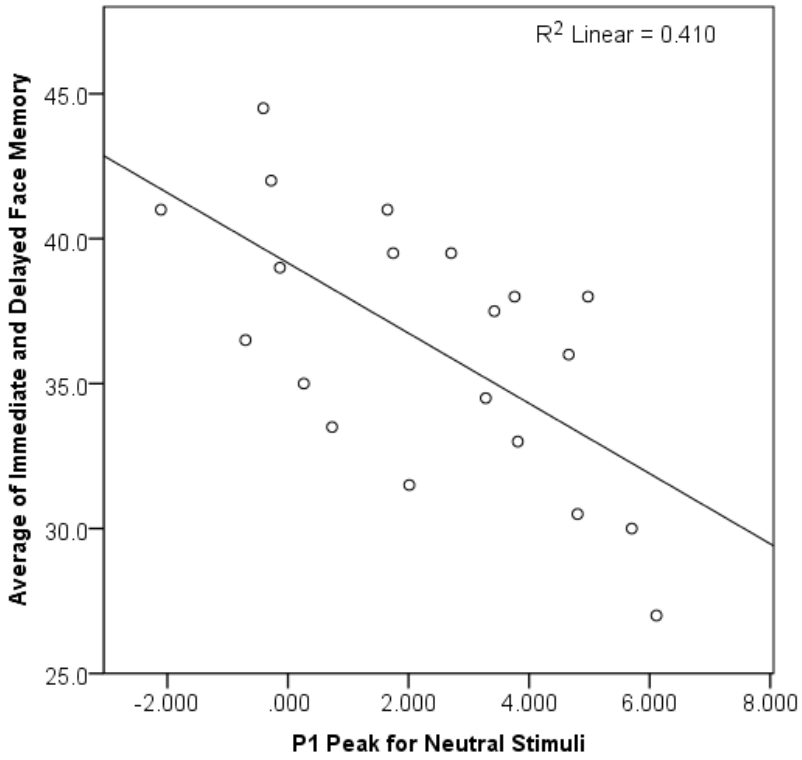
Inferior Frontal P300 is negative, so
for *Subliminal* Neutral (- -) minus Scrambled (-),
more negative difference = more face-specific
0 = not different
for *Supraliminal* Neutral (-) minus Scrambled (-),
more negative difference = greater magnitude for faces
0 = not different
more positive difference = greater magnitude for scrambled
for *Angry* Supraliminal (-) minus Subliminal (- -),
more positive difference = greater magnitude for subliminal
0 = not different
for *Scrambled* Supraliminal (- -) minus Subliminal (-),
more negative difference = greater magnitude for supraliminal
0 = not different

P1 Peaks and Latencies with External Measures.

P1 with Neuropsychological Measures.

P1 right occipital supraliminal neutral and scrambled peaks did not correlate with Trail-Making Tests (Trails) or Letter-Number Sequencing (LNS) performance, and Speech perception (SSPT) and face identification (BTFR) were also not correlated with P1. However, P1 peak for both neutral and scrambled stimulus types were correlated negatively with both immediate (r=-.584, *p*=.009 and r=-.407, *p*=.084, respectively) and delayed (r=-.640, *p*=.003 and r=-.500, *p*=.029) face memory (WMS Faces 1 and 2). This correlation is shown in Figure 4.47. P1 latencies and the peak differences between neutral and scrambled images were not correlated with neuropsychological test performance.

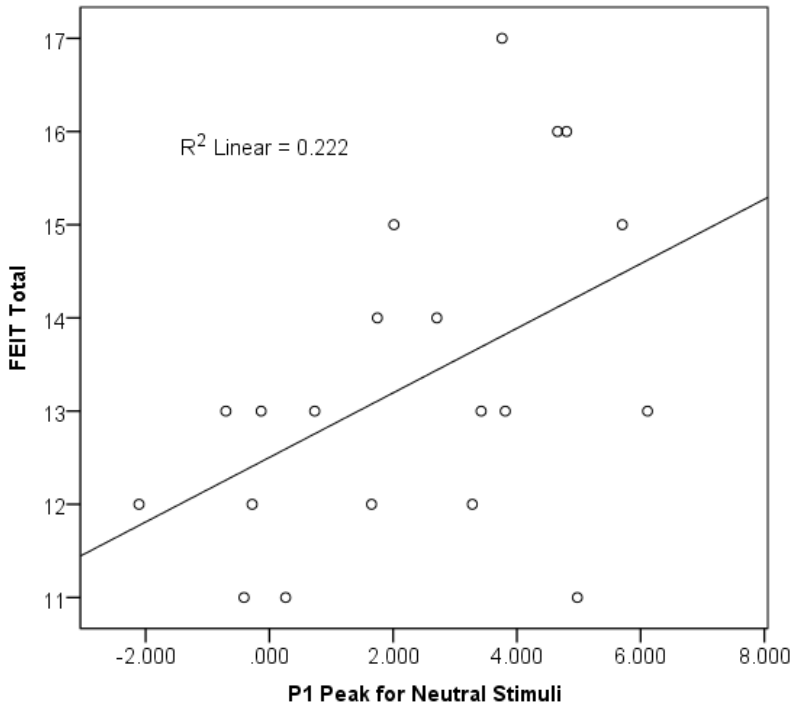
Figure 4.47. *Correlation of P1 Peaks for Neutral Stimuli and the Average of Immediate and Delayed Face Memory*.



P1 with Social Cognitive Measures.

P1 peaks were not correlated with most social cognitive measures. However, facial emotion identification (FEIT) performance was positively correlated with P1 peaks for neutral stimuli (r=.471, *p*=.036), and showed a trend towards correlation with P1 peaks for scrambled stimuli (r=.420, *p*=.065), as shown in Figure 4.48. P1 latencies were not correlated with social cognitive test performance.

Figure 4.48. *Correlation between P1 Peaks for Neutral Stimuli with FEIT*.

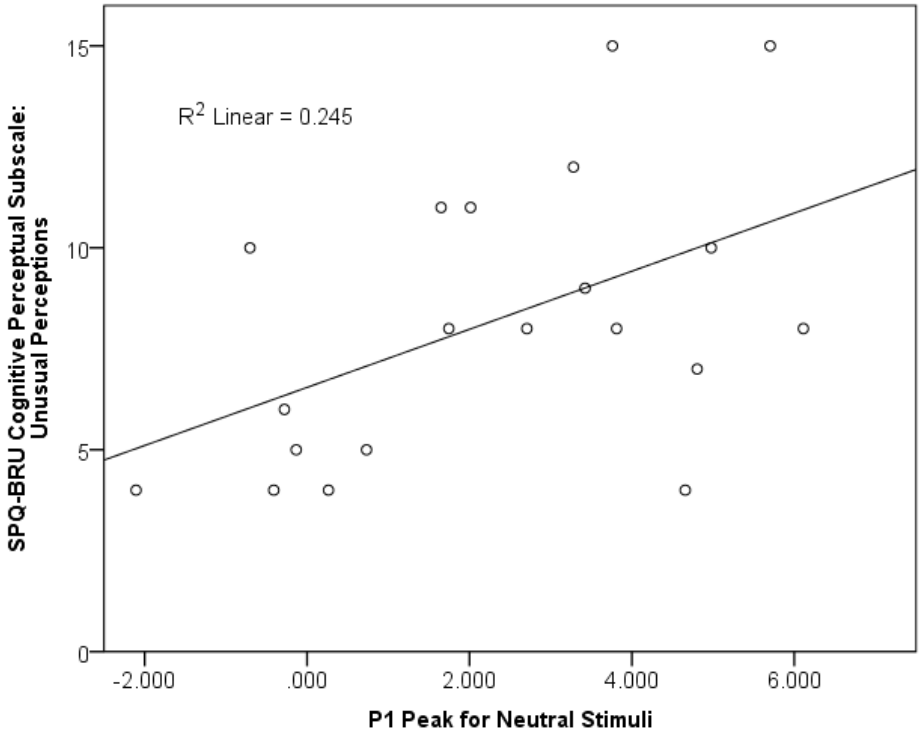


The difference of neutral - scrambled image P1 responses was negatively correlated with speech perception (SSPT; r=-.621, *p*=.005), but not face identification (BTFR; r=-.346, *r*=.135). This peak difference was not correlated with other social cognitive measures.

P1 with Personality Measures.

P1 right occipital supraliminal neutral and scrambled peaks and latencies and the peaks' peak difference did not correlate with the primary scales of the SPQ-BR: Cognitive Perceptual (CP), Interpersonal (IP), Disorganization (DO), and Social Anxiety (SA). However, one isolated correlation was noted between the Cognitive Perceptual scale, Unusual Perceptions with neutral face P1 peak (r=.495, *p*=.026), and a similar trend with scrambled face responses (r=.420, *p*=.065), but not the difference between neutral and scrambled peaks (r=.119, *p*=.616). This correlation is shown in Figure 4.49.

Figure 4.49. *Correlation of P1 Peaks for Neutral Stimuli and SPQ Unusual Perceptions*.



P1 with Social Functioning Measures.

Overall social functioning (SFS Total) was negatively correlated with P1 peaks for neutral (r=-.564, *p*=.010) but not scrambled (r=-.222, *p*=.348) stimuli. The peak difference of neutral - scrambled was also negatively correlated with SFS Total (r=-.450, *p*=.046). This effect appeared to be driven primarily by the Prosocial subscale, which was negatively correlated with P1 neutral peak (r=-.523, *p*=.018), P1 neutral-scrambled peak difference (r=-.490, *p*=.028), and not scrambled peak (r=-.146, *p*=.539). These three correlations are illustrated in Figure 4.50, and the simple correlation between the peak difference and SFS Prosocial is illustrated in Figure 4.51.

Figure 4.50. *Correlation of P1 Peaks for Neutral and Scrambled Stimuli with SFS Prosocial Scores.*

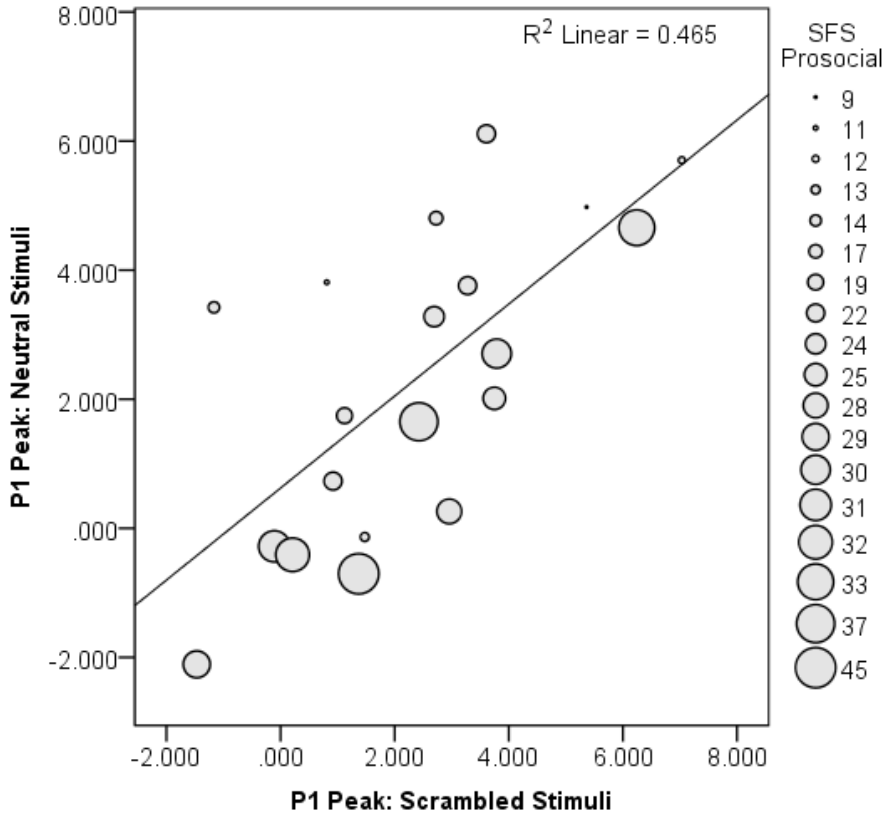
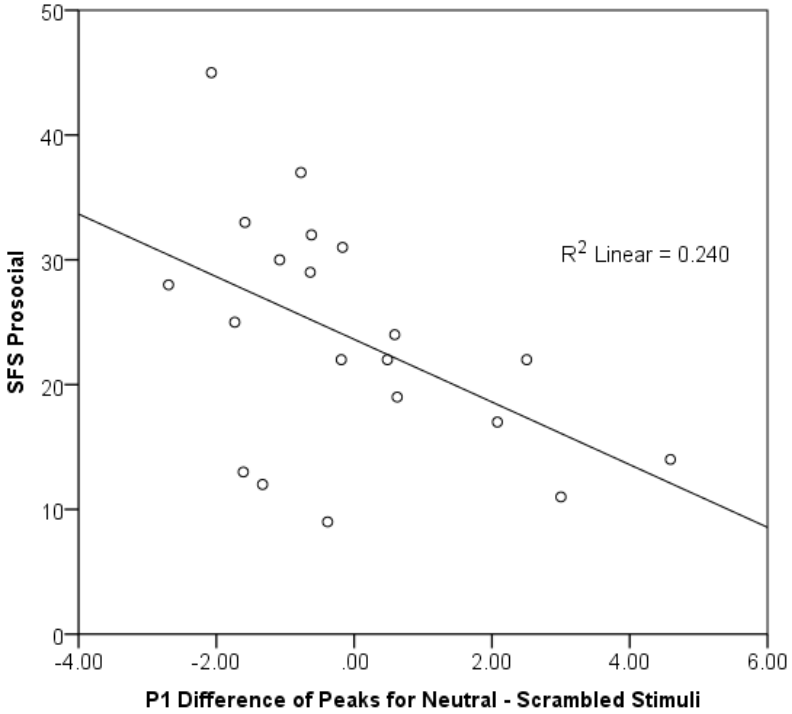


Figure 4.51. *Correlation of P1 Difference between Neutral and Scrambled Peaks with SFS Prosocial Scores.*



There was also a trend for SFS Independence-Performance to be correlated with P1 peaks for neutral (r=-.421, *p*=.065) and scrambled (*r*=-.441, *p*=.052) stimuli, but not their difference.

Although P1 latency was not correlated with SFS Total, latencies were negatively correlated with the Independence-Competence scale for neutral (rho=-.652, *p*=.002) and scrambled (rho=-.519, *p*=.019) stimuli. Note that Spearman's Rho is used for these correlations as Independence-Competence is severely non-normal. The results were not different using Pearson's r.

N170 Peaks and Latencies with External Measures.

Given the conditional effects of N170 peaks, angry, neutral, and scrambled images were used in both supraliminal and subliminal presentations, and three peak differenceforms were calculated for peaks: neutral minus scrambled (subliminal and supraliminal) and subliminal minus supraliminal (neutral only). Latencies did not differ by condition, so supraliminal and subliminal scrambled and neutral stimulus responses are used.

N170 with Neuropsychological Measures.

N170 peaks for supraliminal stimuli did not correlate with neuropsychological measures. Isolated correlations with N170 peaks for subliminal stimuli were noted. N170 peaks for subliminal neutral stimuli were correlated with immediate face memory (WMS Faces 1; r=.464, *p*=.045) but not delayed face memory (r=.288, *p*=.231) or their average (r=.393, *p*=.086). This correlation was also not significant for other stimulus types. Trail-

Making Test A was correlated with N170 peaks for subliminal scrambled stimuli (rho=.470, *p*=.036) but not Test B (rho=-.036, *p*=.915). This correlation was also not significant for other stimulus types.

The peak difference of neutral minus scrambled peaks was not correlated with neuropsychological measures for supraliminal stimuli. For subliminal stimuli, the peak difference was positively correlated with immediate face memory (r=.515, *p*=.024), showed a trend towards being correlated with delayed face memory (r=.421, *p*=.073), and was correlated with their average (r=.530, *p*=.016). This correlation was in the direction such that less negative peaks for neutral compared to scrambled subliminal stimuli were associated with better face memory. The three-variable interaction is illustrated in Figure 4.52, and the simple correlation between the peak difference and average face memory is illustrated in Figure 4.53. Figure 4.52 illustrates the trend for less negative neutral peaks to be associated with greater face memory and that neutral peaks were generally more negative than or equal to scrambled peaks. Thus, face memory was associated with less difference between neutral and scrambled peak magnitudes.

Figure 4.52. *Correlation of N170 for Subliminal Scrambled and Neutral Stimuli by Face Memory*.

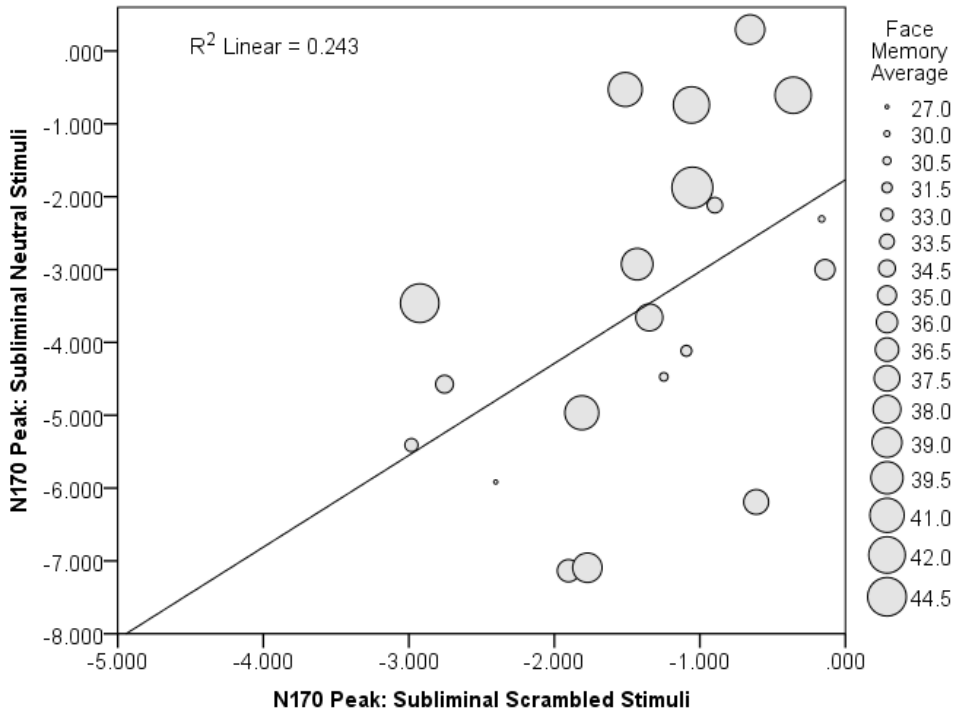
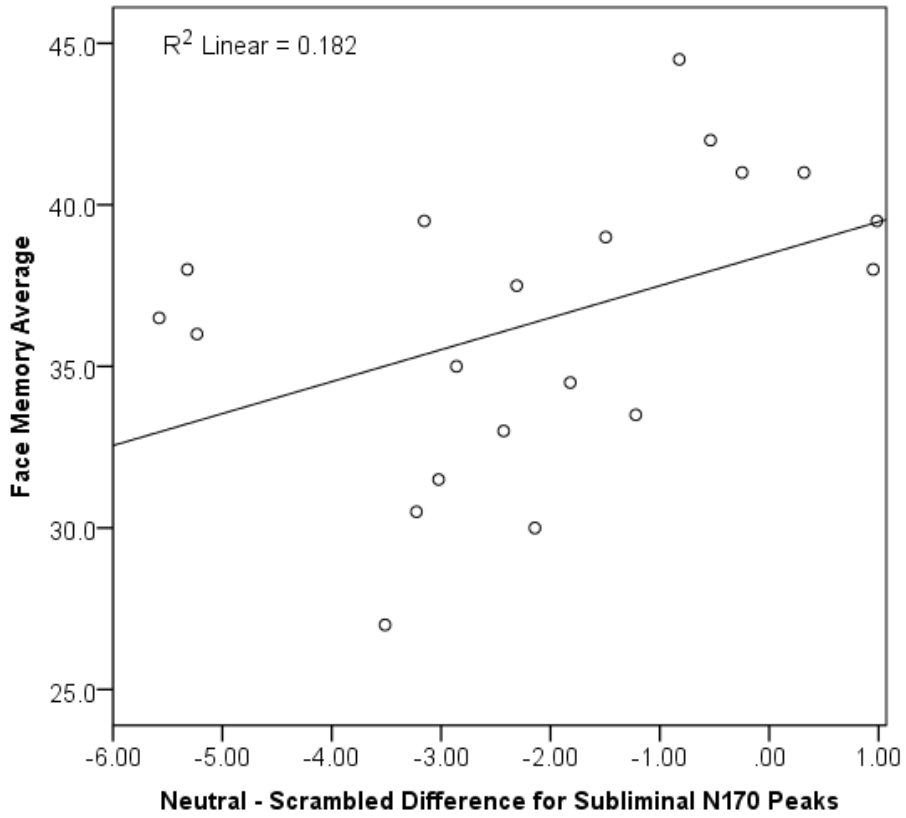


Figure 4.53. *Correlation of Subliminal N170 Neutral-Scrambled Peak Difference with Face Memory.*



The peak difference between subliminal and supraliminal N170 peaks was not correlated with neuropsychological tests.

Trail-Making Test B was positively correlated with N170 latency for neutral (rho=.592, *p*=.006) but not scrambled (rho=.197, *p*=.405) stimuli. N170 latency was not correlated with Trail-Making Test A or other neuropsychological measures.

N170 with Social Cognitive Measures.

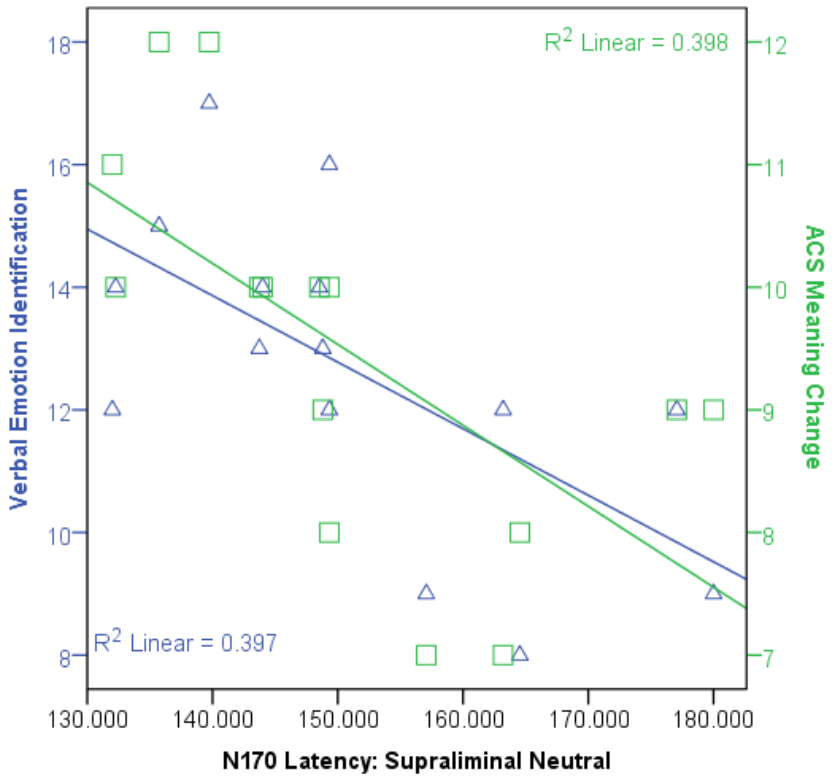
Supraliminal N170 peaks were not correlated with social cognitive measures. Moderate correlations were observed between verbal emotion identification and subliminal N170, particularly for angry but also a trend towards neutral stimuli. Specifically, angry subliminal N170 peaks were correlated negatively with verbal emotion identification (VEIT) performance (r=-.520, *p*=.019), and a similar nonsignificant correlation was noted for neutral stimuli (r=-.400, *p*=.081), but not for scrambled stimuli (r=-.318, *p*=.172). Angry responses were also correlated with ACS Meaning Change and Speaker Meaning subscores (r=-.549, *p*=.034 and r=-.519, *p*=.047 respectively). These subscales are part of the ACS Pair Matching Total scale, which was not significantly correlated with angry N170 (r=-.450, *p*=.107). The Meaning Change and Speaker Meaning subscores represent participants' ability to correctly identify changes in a speaker's meaning based on prosody and to identify what the speaker actually meant, respectively.

Difference scores for supraliminal and subliminal neutral minus scrambled images as well as supraliminal minus subliminal neutral images were not correlated with social cognitive measures generally. The ACS Speaker Meaning subscore was negatively

correlated with neutral minus scrambled difference for subliminal N170 peaks (r=-.553. *p*=-.032), but not for the Meaning Change subscore (r=-.225, *p*=.420) or the Pair Match scale (r=-.223, *p*=.444). These measures were also not correlated for the supraliminal peak difference.

N170 latencies showed a similar but more reliable pattern. Neutral supraliminal N170 latency was negatively correlated with verbal emotion identification (VEIT; r=-.624, *p*=.003), as well as the ACS Pair-Matching scale (r=-.570, *p*=.033) and its subscores, Meaning Change (r=-.631, *p*=.012) and Prosody Pair-Match (r=-.547, *p*=.035), but not the subscores Speaker Meaning (r=-.372, *p*=.172) or Emotion/Tone (r=-.161, *p*=.565). The correlations with verbal emotion identification and Meaning Change are overlaid in Figure 4.54.

Figure 4.54. *Correlation of N170 Latency with VEIT (triangles) and ACS Meaning Change (squares).*



Given the relationship between N170 angry peaks and N170 neutral latencies with verbal emotion identification and social inference, angry latencies were followed up as well. A very similar, but stronger pattern was observed for angry latencies. Subliminal, but not supraliminal, angry N170 latencies were negatively correlated with verbal emotion identification (VEIT; r=-.443, p=.050). The ACS Prosody Total score was strongly negatively correlated with supraliminal (r=-.812, p<.0005) angry latencies, though not with subliminal latencies (r=-.378, p=.165). On the other hand, the Pair Matching Total score was correlated with subliminal angry N170 latencies (r=-.682, p=.007), but not supraliminal (r=-.484, p=.079). More specifically, the Prosody Pair-Matching subscore, which represents performance in matching spoken phrases to pictures of actors in paired social postures, was correlated with both supraliminal (r=-.768, p=.001) and subliminal (r=-.606, p=.017) angry latencies. The Prosody Face-Matching

subscore, which represents matching face emotions to prosodic spoken emotions, was only correlated with supraliminal angry latency (r=-.709, *p*=.002) but not subliminal latency (r=-.287, *p*=.281).

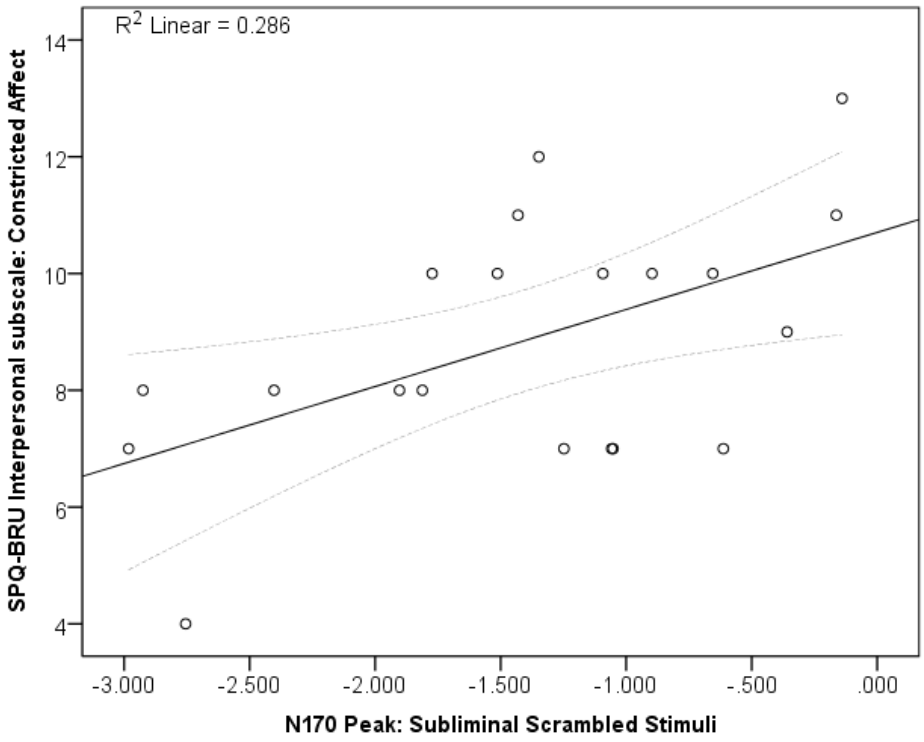
N170 with Personality Measures.

N170 supraliminal peaks were not correlated significantly with SPQ-BRU scales, but there were some notable trends with neutral responses only. Specifically, the Disorganization scale was positively correlated with supraliminal neutral N170 (r=.434, *p*=.028). Of its two subscales, only Eccentric Behavior seemed to be driving this correlation (r=.420, *p*=.065). The Social Anxiety scale was also nonsignificantly related to neutral N170 peaks (r=.412, *p*=.071). All other SPQ-BRU scales and subscales had positive correlation values, but none were significant.

N170 subliminal peaks were not correlated significantly with SPQ-BRU scales, but two subscales were correlated with subliminal N170 peaks for scrambled images only. The Cognitive Perceptual (CP) subscale Suspiciousness was correlated positively with scrambled peaks (r=.476, *p*=.034) as was the Interpersonal (IP) subscale Constricted Affect (r=.535, *p*=.015), as shown in Figure 4.55. These subscales were not correlated with subliminal peaks for other stimulus types, and their parent scales were not significantly correlated with scrambled subliminal N170 peaks (CP r=.168, *p*=.480 and IP r=.326, *p*=.161). Interestingly, the CP subscale Ideas of Reference showed a trend towards positive correlation with scrambled subliminal N170 (r=.385, *p*=.094), whereas the final CP subscale Magical Thinking showed a trend towards negative correlation with

scrambled subliminal N170 (rho=-.363, *p*=.116). All other correlation values were positive except for those with Magical Thinking.

Figure 4.55. *Correlation between N170 Subliminal Scrambled Peaks and SPQ Interpersonal Subscale, Constricted Affect; with 95% CI.*



SPQ-BRU scales and subscales were not correlated with N170 peak differences.

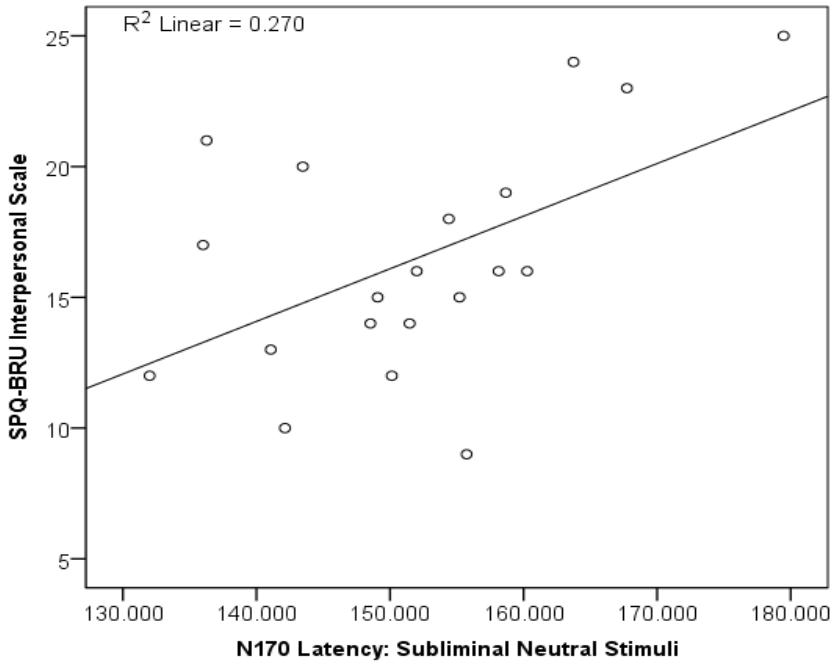
SPQ-BRU scales did show interesting relationships with N170 latencies. The correlations between neutral and scrambled N170 latencies are shown in Table 4.4. As shown, all of the Interpersonal scales, the Social Anxiety scale, and Cognitive-Perceptual Suspiciousness correlated with subliminal neutral stimuli N170 latencies. Scrambled latencies only correlated with Cognitive Perceptual Unusual Perceptions. The correlation with Interpersonal schizotypy is illustrated in Figure 4.56.

Table 4.4. *Correlations between N170 Latencies and SPQ-BRU.*

SPQ-BRU Scale	Subliminal Neutral Stimuli	Subliminal Scrambled Stimuli
Interpersonal	.519 (.019)*	.180 (.447)
No Close Friends	.451 (.046)*	.133 (.578)
Constricted Affect	.486 (.030)*	.201 (.397)
Social Anxiety	.460 (.041)*	.190 (.424)
Cognitive Perceptual	.264 (.255)	.210 (.374)
Ideas of Reference	.229 (.331)	.067 (.778)
Suspiciousness	.560 (.010)**	.070 (.768)
Magical Thinking	-.325[a] (.162)	-.021[a] (.931)
Unusual Perceptions	.297 (.203)	.530 (.016)*
Disorganization	.083 (.728)	.032 (.893)
Eccentric Behavior	.163 (.492)	.127 (.595)
Odd Speech	.115 (.628)	-.024 (.922)

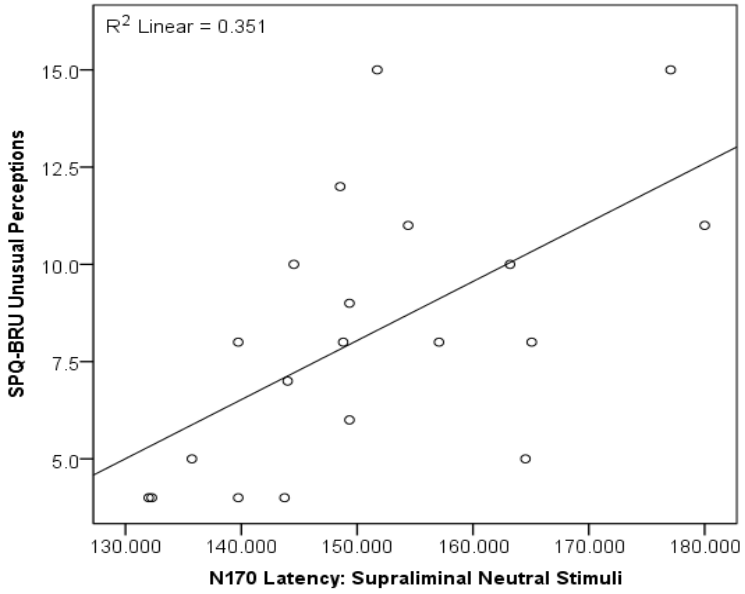
* $p<.05$. ** $p<.01$. [a] Spearman's rho. Otherwise, Pearson's r.

Figure 4.56. *Correlation between N170 Subliminal Neutral Latency and Interpersonal Schizotypy.*



Finally, supraliminal neutral, but not scrambled N170 latencies were positively correlated with SPQ-BRU Cognitive Perceptual scores (r=.503, p=.024), and specifically, the subscale Unusual Perceptions (r=.592, p=.006). This correlation is illustrated in Figure 4.57.

Figure 4.57. *Correlation of Supraliminal Neutral N170 Latency with SPQ-BRU Unusual Perceptions.*



N170 with Social Functioning Measures.

SFS scores were generally not correlated with N170 peaks, although Subliminal Neutral N170 peaks were correlated positively with SFS Independence-Performance (r=.564, *p*=.010).

Neutral minus scrambled and subliminal minus supraliminal peak differences were similarly not correlated with social functioning, but the peak difference for neutral vs. scrambled peaks for subliminal stimuli was correlated with SFS Independence-Performance (r=.522, *p*=.018), and the supraliminal peak difference showed a trend towards positive correlation (r=.387, *p*=.092). These correlations are illustrated in Figures 4.58 and 4.59.

Figure 4.58. *Correlation of Scrambled and Neutral Subliminal Stimuli by SFS Independence-Performance.*

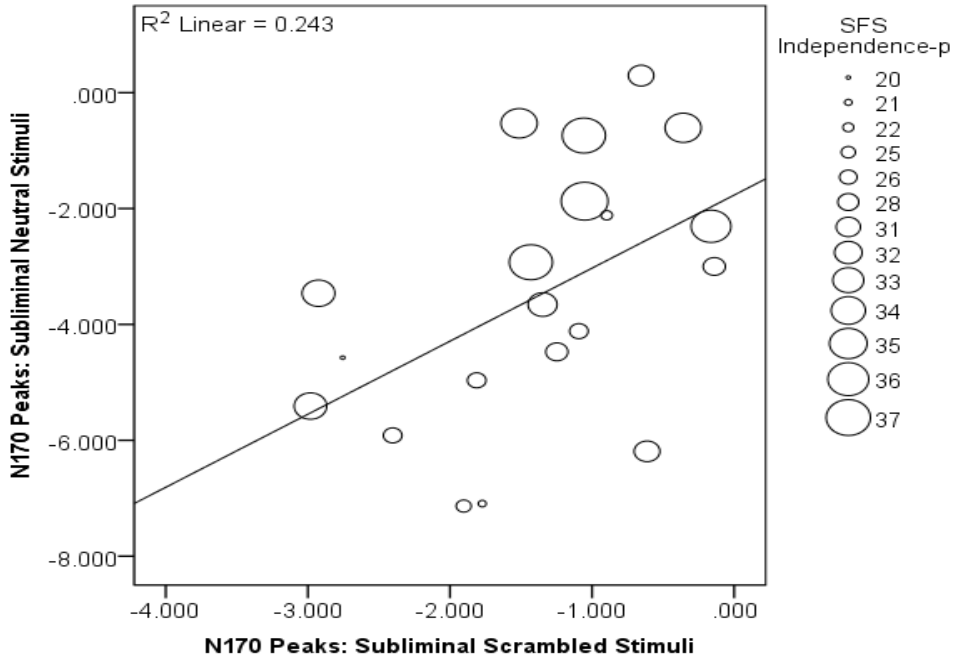
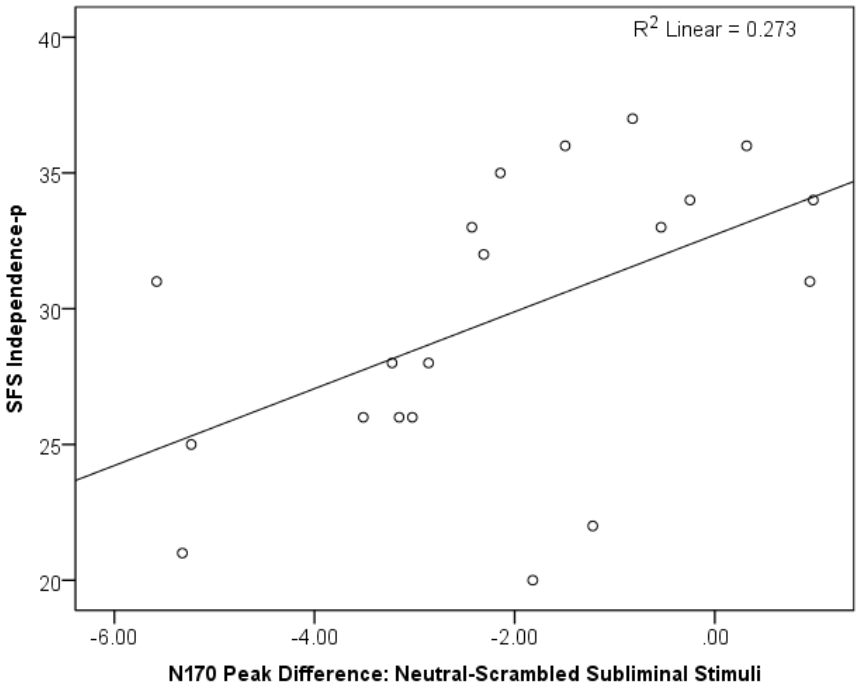


Figure 4.59. *Correlation of Scrambled minus Neutral Subliminal Stimuli Difference with SFS Independence-Performance.*



N170 latencies for supraliminal and subliminal neutral and scrambled stimuli were not significantly correlated with social functioning.

P300 Peaks and Latencies with External Measures.

P300 peaks were analyzed for all stimulus types, including both Parietal and Inferior Frontal electrode regions. Difference scores will be computed across angry and scrambled supraliminal vs. subliminal presentation times, as well as between angry vs. happy and neutral vs. scrambled peaks in both presentation times. P300 latencies did not show as complex conditional effects, and thus fewer conditions will be analyzed.

P300 with Neuropsychological Measures.

Trail-Making Test A (Trails A), but not Test B, was correlated with several P300 conditional peak amplitudes. Neutral minus scrambled and angry minus happy peak differences were not correlated with neuropsychological measures, but supraliminal minus subliminal peak differences were correlated with Trails A. Angry and happy stimulus correlations with Trails A were primarily significant in inferior frontal electrodes, but neutral stimulus correlations were only with parietal subliminal stimuli. Scrambled stimulus correlations with Trails A were only significant for supraliminal presentations in both regions, and the difference between supraliminal and subliminal peaks was correlated with Trails A in both regions. These effects are summarized in Table 4.5, and the relationship between inferior frontal P300 peaks and scrambled supraliminal and subliminal stimuli is illustrated in Figures 4.60 and 4.61.

Table 4.5. *Correlations between Trail-Making Test A and P300 Peaks*.

Correlations [rho (*p*)]		Angry		Happy		Neutral		Scrambled	
		Supra.	Subl.	Supra.	Subl.	Supra.	Subl.	Supra.	Subl.
Region	Parietal	-.407 (.075)	-.372 (.107)	-.449* (.047)	-.188 (.426)	-.391 (.088)	-.608** (.004)	-.468* (.037)	-.254 (.280)
	Inferior Frontal	.444* (.050)	.512* (.021)	.525* (.017)	.528* (.017)	.354 (.125)	.151 (.526)	.659** (.002)	-.030 (.900)

	Supra. - Subl.	Supra. - Subl.
Parietal	-.142 (.551)	-.445* (.050)
Inferior Frontal	.114 (.663)	.646** (.002)

Figure 4.60. *Correlation between Inferior Frontal P300 Peaks for Supraliminal and Subliminal Scrambled Stimuli with Trails A Performance*.

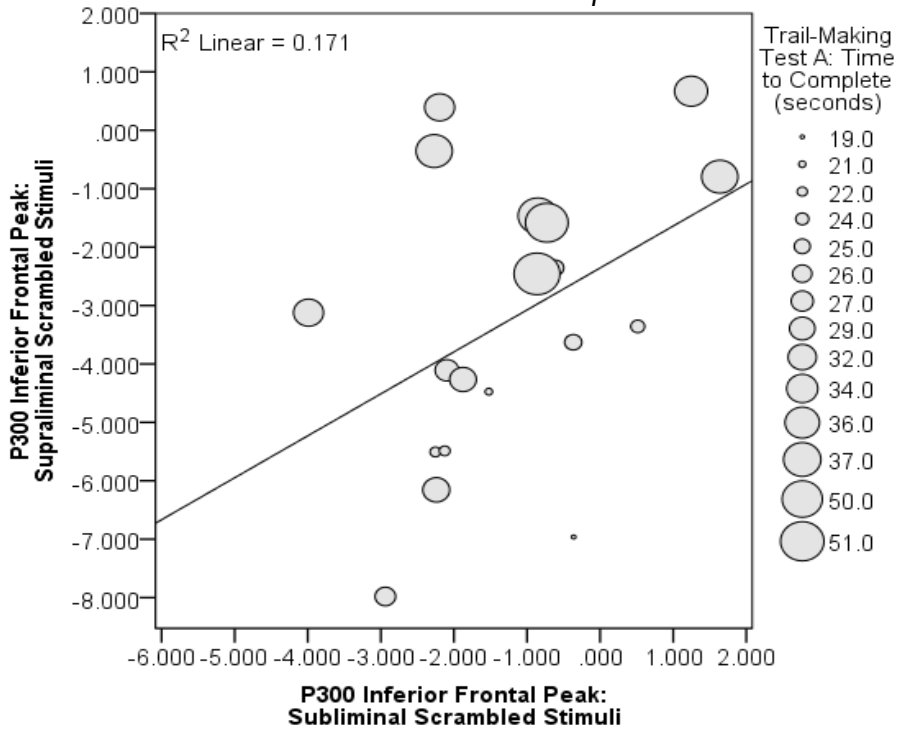
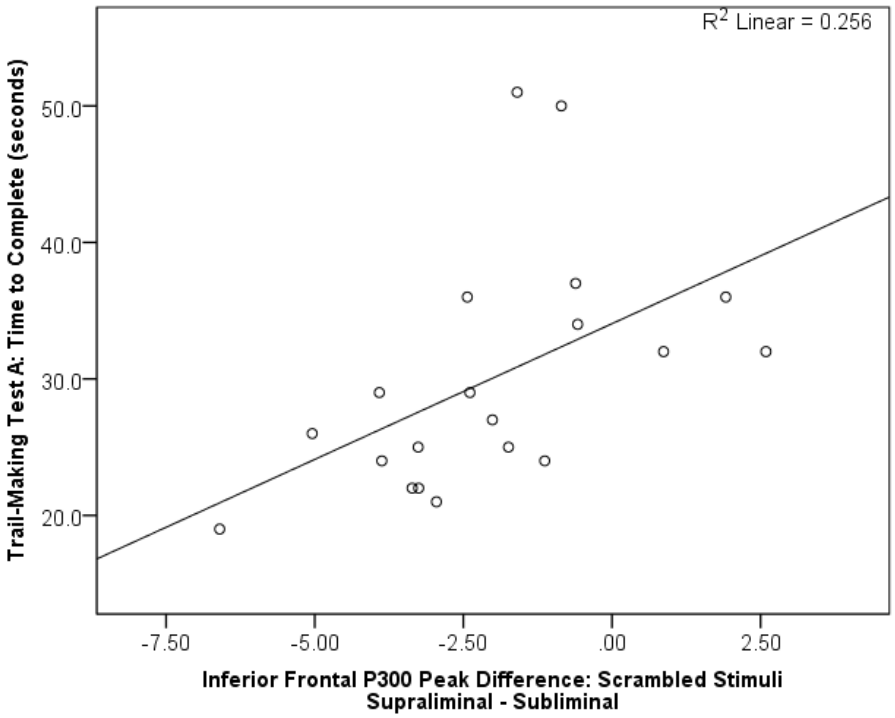


Figure 4.61. *Correlation between Inferior Frontal P300 Peak Difference for Supraliminal minus Subliminal Scrambled Stimuli with Trails A Performance*.



P300 latencies for neutral and scrambled supraliminal presentations in parietal and inferior frontal electrodes were generally not correlated with neuropsychological performance, although one isolated correlation was noted between inferior frontal P300 latency for neutral, but not scrambled stimuli and immediate face memory (r=.553, *p*=.014) but not delayed face memory (r=.392, *p*=.097).

P300 with Social Cognitive Measures.

Generally, social cognitive measures were not correlated with P300 peaks. However, an isolated subscore of the ACS Prosody-Pair Matching subtest was correlated negatively (r=-.559, *p*=.030) for parietal and positively for inferior frontal (r=.541, *p*=.037) with angry supraliminal P300 peaks.

Differences between inferior frontal and parietal supraliminal and subliminal P300 peaks were not significantly correlated with social cognitive measures.

Parietal, but not inferior frontal, differences between neutral and scrambled peaks for supraliminal, but not subliminal, P300 were significantly correlated with face emotion recognition. Specifically, the supraliminal parietal P300 difference between neutral and scrambled faces was positively correlated with ACS Affect Naming (r=.598, *p*=.007), a simple facial emotion recognition task, the ACS Social Perception Total score (r=.584, *p*=.022), and at a trend level, facial emotion identification (FEIT; r=.431, *p*=.058). This correlation with ACS Affect Naming is illustrated in Figures 4.62 and 4.63. Inferior frontal peak differences were not significant for the ACS scales, but it was significantly correlated with FEIT (r=-.486, *p*=.030).

Figure 4.62. *Correlation between Parietal P300 Peaks for Neutral and Scrambled Supraliminal Stimuli with ACS Affect Naming.*

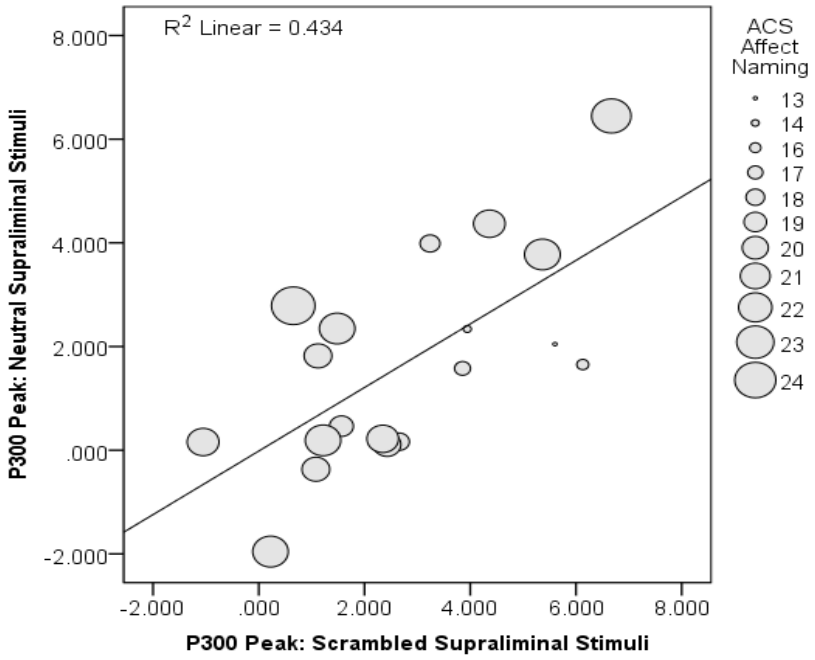
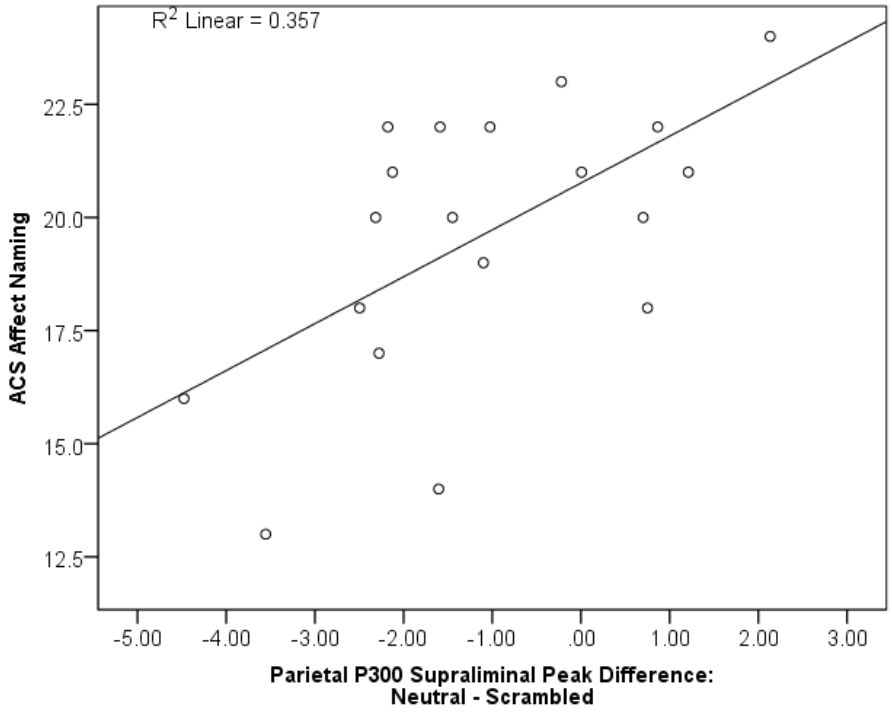


Figure 4.63. *Correlation between Parietal P300 Peak Difference of Neutral minus Scrambled Supraliminal Stimuli with ACS Affect Naming.*



In general, the angry vs. happy P300 peak difference was not significantly correlated with social cognitive measures. However, this peak difference for supraliminal, but not subliminal stimuli was negatively correlated with verbal emotion identification (VEIT; r=.678, *p*=.001) and the ACS Meaning Change subscale (r=.635, *p*=.011) but not its parent scale (r=.390, *p*=.168) for inferior frontal, but not parietal electrodes.

P300 latencies were not correlated with social cognitive measures.

P300 with Personality Measures.

P300 peak amplitudes did not correlate with SPQ scales or subscales in subliminal, supraliminal, parietal, inferior, or any stimulus type condition.

P300 peak amplitude differences between supraliminal and subliminal stimuli for angry faces correlated with SPQ in the inferior frontal (IF) region, not the parietal (P) region, and the difference between supraliminal and subliminal stimuli for scrambled images correlated with SPQ in the P region, not the IF region. Specifically, the supraliminal minus subliminal amplitude difference for IF angry faces had negative r values for all SPQ scales and subscales, and a significant negative correlation with the Interpersonal scale (r=-.460, *p*=.041 and its subscale No Close Friends (r=-.484, *p*=.031). This peak difference was also correlated with Suspiciousness (r=-.494, *p*=.027), but not its parent scale, Cognitive Perceptual (r=-.284, *p*=.224). The supraliminal minus subliminal amplitude difference for P scrambled faces was negatively correlated with the Interpersonal scale (r=-449, *p*=.047) and its subscale Constricted Affect (r=-.468, *p*=.037), and there was a trend for correlation with the Social Anxiety scale (r=-.413, *p*=.070). The No Close Friends and Constricted Affect examples are illustrated in Figures 4.64-4.67.

Figure 4.64. *Correlation of Inferior Frontal P300 Supraliminal and Subliminal Angry Stimuli with SPQ No Close Friends*.

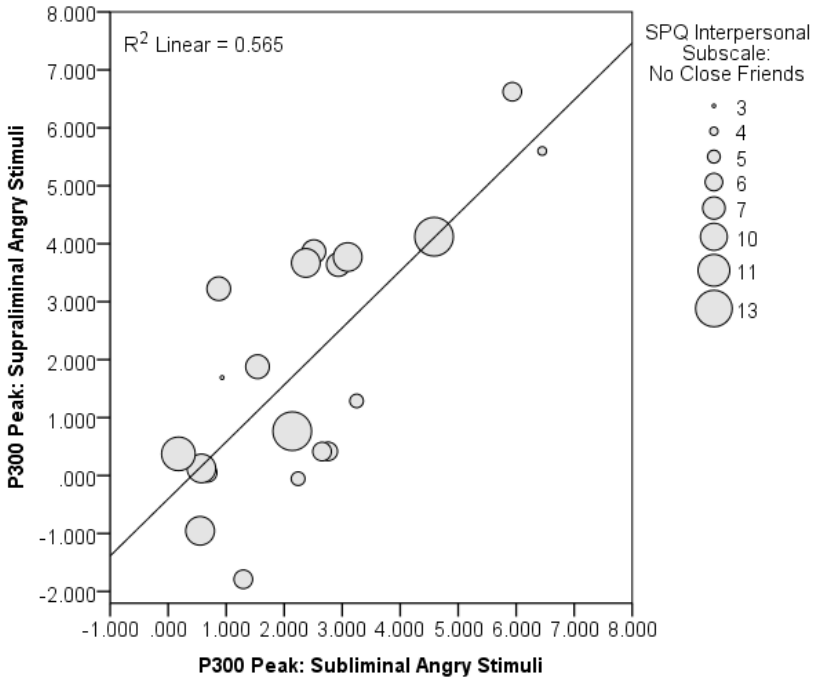


Figure 4.65. *Correlation of Inferior Frontal P300 Supraliminal minus Subliminal Difference for Angry Stimuli with SPQ No Close Friends.*

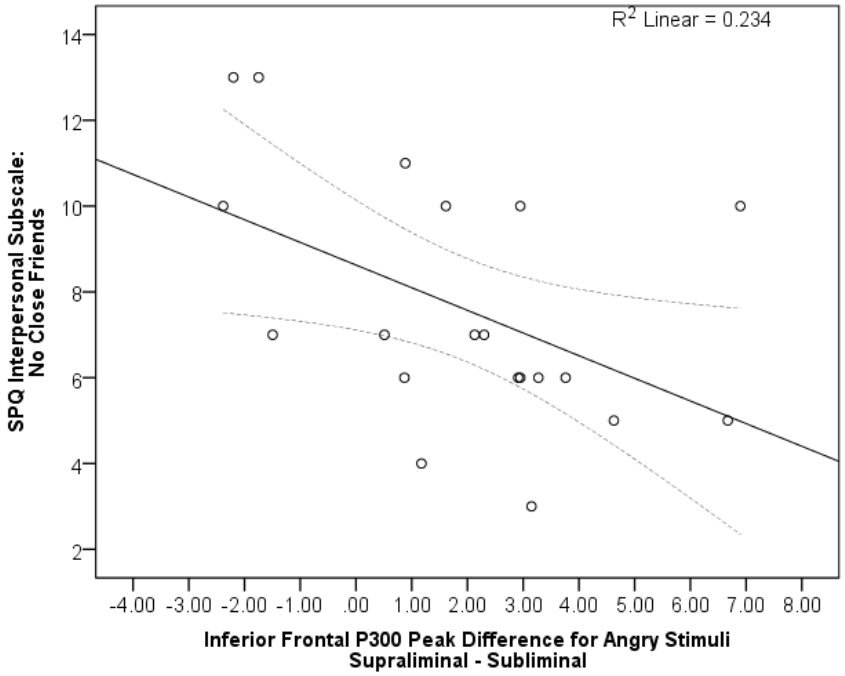


Figure 4.66. *Correlation of Parietal P300 Supraliminal and Subliminal Scrambled Stimuli with SPQ Constricted Affect.*

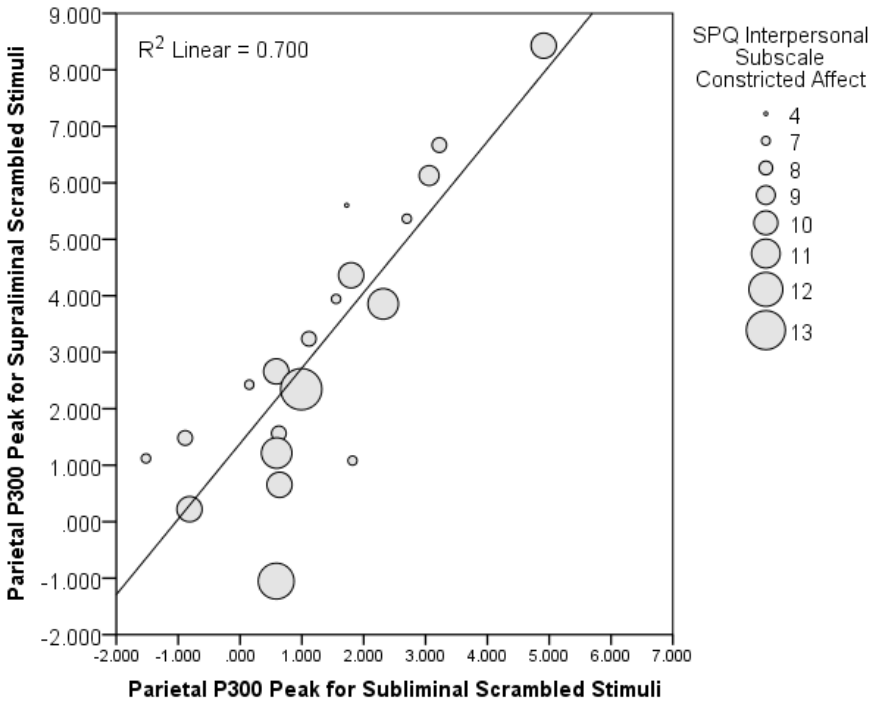
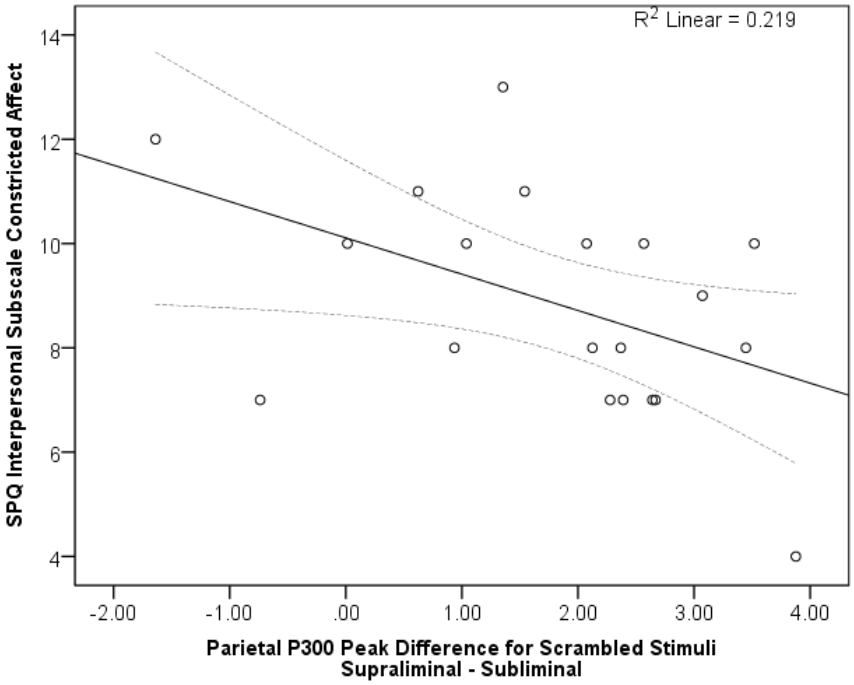


Figure 4.67. *Correlation of Parietal P300 Supraliminal minus Subliminal Difference for Scrambled Stimuli with SPQ Constricted Affect.*



The SPQ Cognitive Perceptual scale was negatively correlated with the difference between subliminal neutral minus scrambled responses for parietal P300 peaks (r=-.458,

p=.042). This was driven by negative correlations with the Ideas of Reference (r=-.447, *p*=.048) and Suspiciousness (r=-.467, *p*=.038) subscales, as well as a trend towards a negative correlation in the Unusual Perceptions subscale (r=-.424, *p*=.062), but not the Magical Thinking subscale (rho=.127, *p*=.595). This effect is illustrated in Figures 4.68 and 4.69.

Figure 4.68. *Correlation between Parietal Subliminal P300 for Neutral and Scrambled Stimuli with SPQ Cognitive Perceptual.*

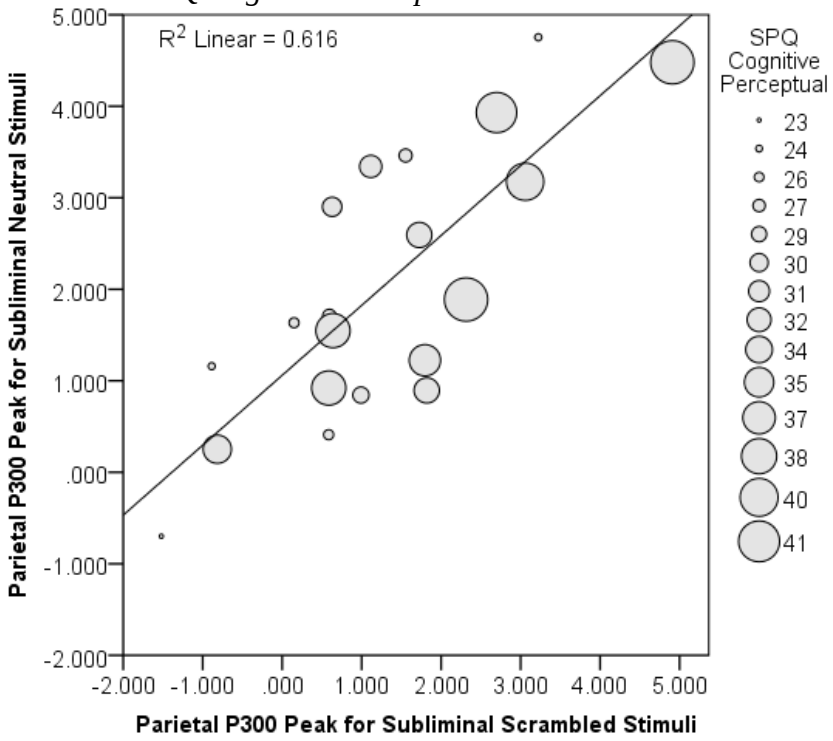
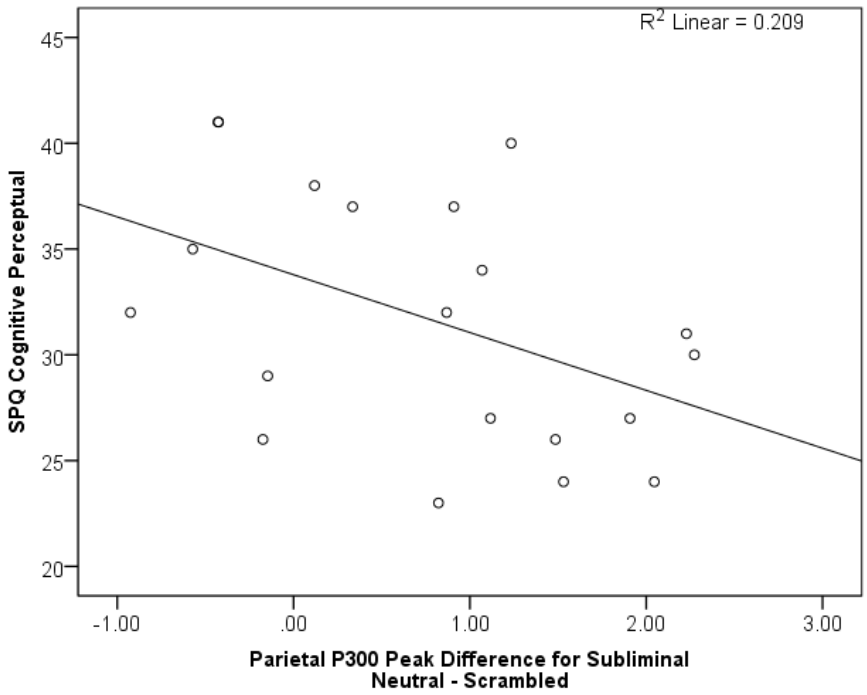


Figure 4.69. *Correlation between SPQ Cognitive Perceptual and Parietal Subliminal P300 Peak Differences for Neutral minus Scrambled Stimuli*.



The difference between angry and happy response amplitudes was correlated with SPQ Interpersonal scales only for supraliminal presentations in inferior frontal (IF) electrodes. Specifically, the peak differences between IF P300 for supraliminal angry minus happy peaks was negatively correlated with the Interpersonal scale (r=-.531, *p*=.016) and its subscale No Close Friends (r=-.567, *p*=.009). The difference was also correlated with Suspiciousness (r=-.468, *p*=.037) but not its parent scale, Cognitive Perceptual (r=-.192, *p*=.417). The correlation with No Close Friends is illustrated in Figure 4.70 and 4.71.

Figure 4.70. *Correlation of Inferior Frontal Supraliminal P300 Peaks for Angry and Happy Stimuli with SPQ No Close Friends.*

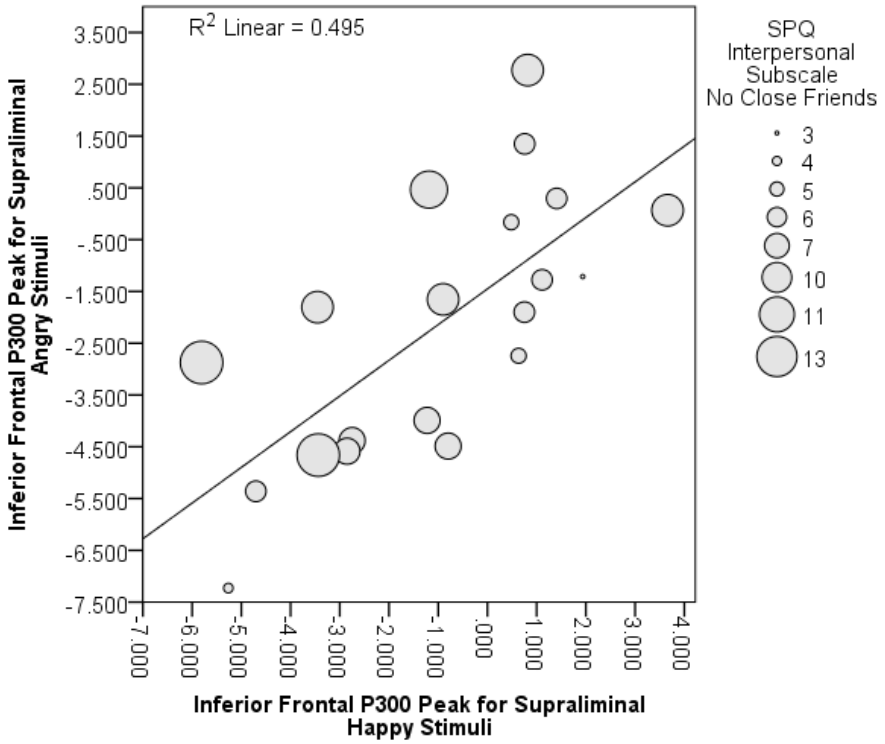
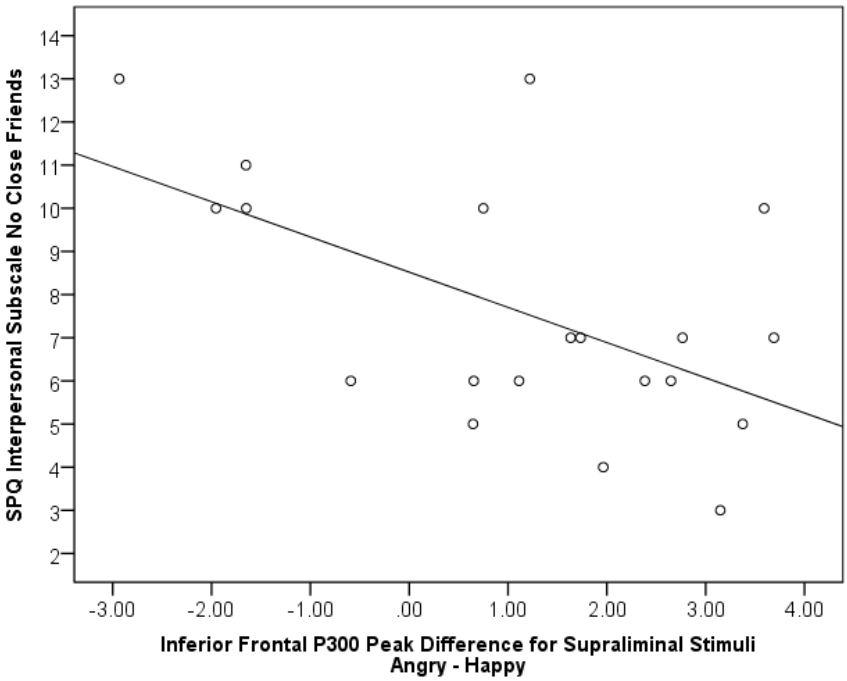


Figure 4.71. *Correlation of Inferior Frontal Supraliminal P300 Angry minus Happy Peak Difference with SPQ No Close Friends.*



P300 latencies were not correlated with personality measures.

P300 with Social Functioning Measures.

P300 peaks were not correlated with SFS scales.

P300 peak differences between supraliminal and subliminal stimuli were not correlated with SFS scales.

P300 peak differences between neutral and scrambled stimuli were generally not correlated with SFS scales, though there was one isolated correlation between SFS Independence-Competence and subliminal inferior frontal P300 neutral minus scrambled peaks (r=-.577, *p*=.008).

P300 peak differences between angry and happy stimuli correlated with SFS only for subliminal stimuli and the parietal region. The Total SFS score (r=-.532, *p*=.016) and SFS Recreation (r=-.760, *p*<.0005) negatively correlated with angry minus happy peaks, and SFS Prosocial showed a trend toward correlation (r=-.396, *p*=.084). The correlation with Total SFS is illustrated in Figures 4.72 and 4.73.

Figure 4.72. *Correlation of Parietal P300 Peaks for Subliminal Angry and Happy Stimuli with SFS Total.*

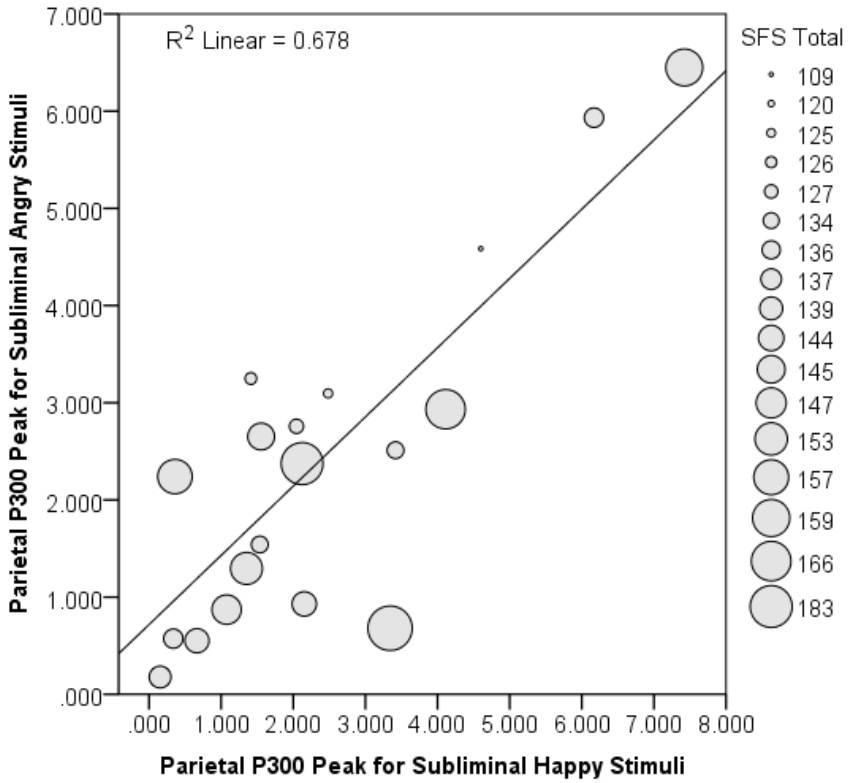
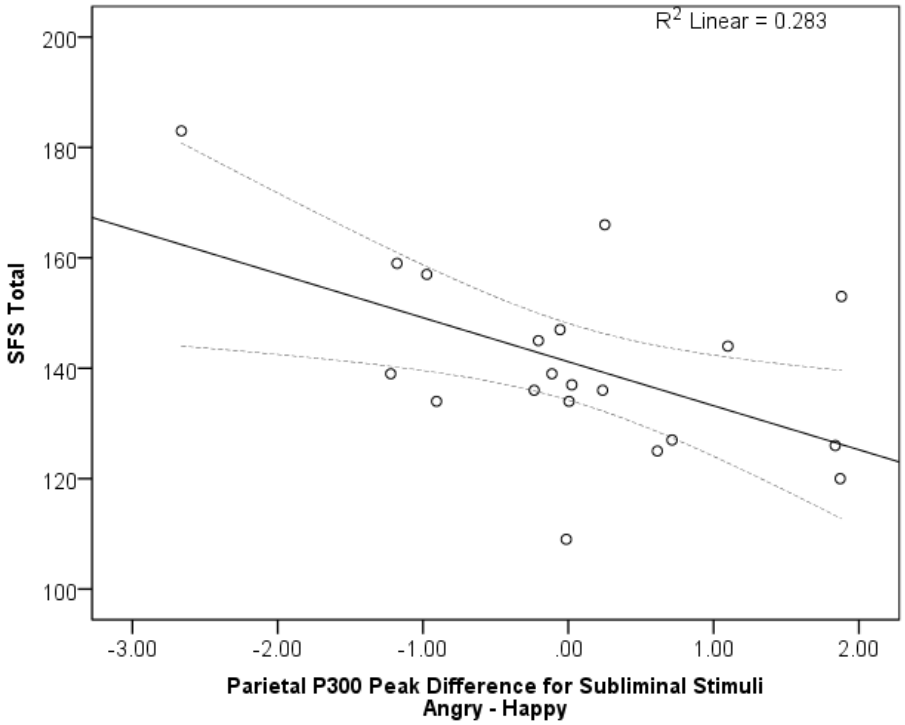
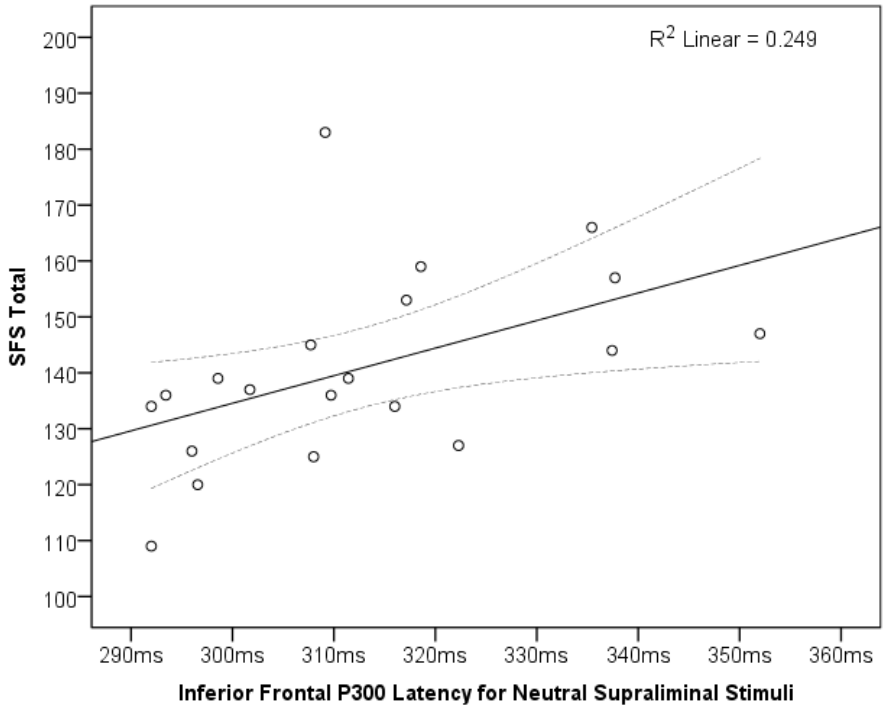


Figure 4.73. *Correlation of Parietal P300 Difference for Subliminal Angry minus Happy Peaks with SFS Total*.



P300 latencies were correlated with social functioning only for neutral, not scrambled stimuli, and only in inferior frontal electrodes. Specifically, P300 latencies were positively correlated with SFS Total (r=.499, *p*=.025), Interpersonal Communication (rho=.593, *p*=.006), Prosocial (r=.458, *p*=.042), and a trend for Social Engagement / Withdrawal (r=.389, *p*=.090). The correlation with SFS Total is illustrated below.

Figure 4.74. *Correlation of Inferior Frontal P300 Latency for Neutral Stimuli with SFS Total.*



CHAPTER 5: DISCUSSION

This study strove to explore the discriminant and criterion-related validity of ERP responses to stimulus manipulations in a complex pilot ERP protocol and relationships with an assessment battery modeled to mirror batteries used in SMI research. Undergraduate participants were recruited for Cognitive Perceptual and Interpersonal schizotypy, and the resultant sample of twenty participants represented a wide range along dimensions of schizotypal characteristics but did not represent the common extreme vs. normal schizotypy samples used for dichotomous categorization.

Reflecting several promising trends in schizotypy, SMI, and cognitive neuroscience research, the present study design included stimulus blocks including subliminal followed by supraliminal stimuli. The stimuli were angry, happy, or neutral faces or matched scrambled images. Half of the subliminal images were blank in order to provide a test of priming effects.

P1, N170, and P300 components were targeted as likely ERP components to reflect information processing processes within and between supraliminal and subliminal stimulus durations related to neuropsychological, social cognitive, personality, and social functioning measures. Given the exploratory nature of this study, external correlates were only followed up for raw peak amplitudes and latencies and reliable conditional effects.

The ultimate purposes of this study were, first, to establish the feasibility of ERP techniques in measuring social information processing related to individual differences. The targeted individual differences were those dimensions that vary among healthy individuals, as defined by schizotypy, and also represent characteristics that in their extremes represent the maladaptive personal and social dynamics that perpetuate

disability in serious mental illness and are targets of treatment (e.g., Rasmussen, 2005). Finally, given reliable measurement of ERPs that correlate with these characteristics, recommendations will be made to optimize an assessment battery including ERP for future analogue schizotypy and clinical SMI research.

Summary by of Results by Hypothesis.

Hypothesis 1: Feasibility.

Hypothesis #1) The ERP protocol and assessment battery are feasible in terms of implementation and attrition.

a) No participants will drop out of the study due to any aspect of the electrophysiological testing protocol (barring more common attrition, such as no-shows, cancellations, fire alarms, etc.).
b) No adverse events will occur related to the electrophysiological protocol.
c) The full testing protocol will be completed within the allotted four hours for all participants.
d) ERP data for a large portion (≥80%) of participants will be usable.

The protocol will be capable of portability (i.e., fully transferable to a portable system).

This hypothesis, regarding feasibility, was partially supported. There were no adverse effects or notable attrition, but there were problems with recruitment and usable data. First, recruitment of people with high levels of schizotypy proved even more

difficult than expected. Contacting and recruiting participants with high Cognitive Perceptual scores in particular had a very low success rate. Further, approximately 30% of all participants' ERP data were not usable, albeit with relatively conservative inclusion criteria. Simple issues such as blinking led to excessive noise for some participants, but the source of noise was unknown for many. However, there was no reason to expect that the EEG system and testing protocol cannot be fully portable, and many issues with EEG usability may be resolved with a briefer protocol, newer equipment, and experimenters with more experience. Nonetheless, some degree of attrition due to EEG noise may be unavoidable.

Hypothesis 2: Conditional Effects.

Hypothesis #2) The ERP protocol will produce reliable conditional waveforms in expected electrode regions. ERP components will show discriminative validity in measuring independent variance in brain responses to emotional, social, and non-social stimuli.

Utilizing both the preliminary empirical waveform derivation (temporal PCA) and subsequent peak and latency analysis:

e) The P1 component will be reliably identified in response to faces and scrambled images.
    i. P1 will be identified most focally in Temporoparietal and Occipital electrode regions and diffuse positivity in anterior electrodes.
    ii. P1 will be enhanced for faces vs. scrambled images in both subliminal and supraliminal presentations.

f) The N170 component will be reliably identified in response to faces and scrambled images.

   i. N170 will be identified most focally in Occipital and Temporoparietal electrode regions, with a simultaneous focal positivity in electrode regions near the vertex (VPP) and nearly simultaneous diffuse positivity in anterior electrodes (dipole).

   ii. N170 will be enhanced for faces vs. scrambled images in both subliminal and supraliminal presentations.

   iii. Emotional faces will modulate the N170 such that responses to angry faces have the largest magnitude and neutral faces the least, with happy faces reliably in between, in both subliminal and supraliminal presentations.

   iv. Across angry, neural, and happy faces, supraliminal faces will evoke a greater magnitude N170 than subliminal faces. This effect is expected to be reduced for Angry faces, which may elicit a stronger subliminal response due to increase salience.

   v. Primed supraliminal images will have lower magnitude and earlier latency N170 compared to unprimed supraliminal images. If this comparison is significant, it will show a priming effect, implying that this within-block subliminal and supraliminal design is not appropriate for efficient assessment of the supraliminal vs. subliminal comparison (having to control for priming).

g) The P300 component will be reliably identified in response to faces and scrambled images.
    i. P300 will be focused in Parietal and proximal electrode regions, with its negative dipole diffused across anterior electrodes.
    ii. P300 will be enhanced for faces vs. scrambled images in supraliminal but not subliminal presentations.
    iii. P300 will be enhanced for angry vs. happy images in supraliminal but not subliminal presentations.

h) The subliminal blank vs. other faces comparison will be significant for all waveform components. This is expected but not meaningful. Any nonsignificant differences would be notable.

This hypothesis regarding reliable conditional waveforms was partially supported. The expected P1, N170, and P300 components were reliably derived and PCA and peak and latency perspectives generally converged. However, several expected conditional effects were not observed, particularly for emotion-specific comparisons.

Hypothesis 2a. P1 was reliably identified in the timeframe and regions expected, but it was not different by stimulus type or presentation time. P1 has been associated with emotion and face-specificity (e.g., Batty & Taylor, 2003) but not in all studies (e.g., Bentin et al., 1996). The specificity of P1 appears to be contingent on experimental conditions (Eimer & Holmes, 2007).

Hypothesis 2b. N170 and related components were reliably identified in the expected timeframe and regions and showed the expected face-specificity, with less

negative peaks for scrambled stimuli (Eimer, 2011), supporting Hypotheses 2b-i and 2b-ii.

Hypothesis 2b-iii was not supported. Although there were trends toward a less negative N170 peak for angry stimuli (the opposite direction of the hypothesized effect), the only reliable effects were between faces and scrambled stimuli. Angry faces have shown increased N170 compared to happy faces in previous research, but not in a design similar to the present study (Krombholz, Schaefer, & Boucsein, 2007).

The opposite direction of Hypothesis 2b-iv was observed, such that subliminal N170 had greater magnitude than supraliminal N170, and the face vs. scrambled image comparison was stronger for subliminal stimuli. There was a trend such that angry faces elicited less extreme N170 for supraliminal presentations, and this effect was reduced for subliminal presentations. In other words, there was a trend towards a different effect of stimulus duration (presentation time) for angry vs. other stimulus types, but this was not significant. Recent research has generally shown greater N170 for consciously-perceived faces than subliminal faces, although such research is limited (Navajas, Ahmadi, & Quiroga, 2013). It is possible that the subliminal masking manipulation failed, and thus the intended subliminal presentation was consciously-perceived. The timing of the onset of the image to the mask was tested and consistently within ±1ms of the intended 13ms. However, the particular backward masking design or some unknown technical problem may have resulted in conscious perception of masked stimuli. It is also possible that the present design, involving paired subliminal and supraliminal priming, may change the modulation of N170 by increased stimulus presentation time.

Hypothesis 2b-v was not supported. There was no reliable effect of priming on supraliminal images or stimulus type comparisons. This was true for all three target components. Previous studies have not utilized this design. Although an effect was hypothesized, this null finding was ideal as priming effects were not the purpose of the study design. This result provides minor evidence that the combined stimulus design did not dramatically affect the individual conditional effects, although several other results suggest otherwise.

Hypothesis 2c. This hypothesis was partially supported. P300 was reliably identified in a timeframe and regional distribution consistent with previous studies of face emotion perception. In fact, the PCA factor 2 represented a timeframe consistent with emotional face studies using a "single-stimulus" task rather than the typical oddball or other infrequent vs. frequent P300 design (Strüber & Polich, 2002; Balconi & Lucchiari, 2007).

Hypothesis 2c-ii was partially supported.

The face vs. scrambled image main effect was observed in both parietal and inferior frontal regions for subliminal stimuli, but was different for supraliminal stimuli. For subliminal scrambled stimuli, P300 was nearly non-existent, whereas it was strong and relatively flat across face stimuli, similar to the P300 for scrambled images in previous studies (e.g., Bentin et al., 1996).

For supraliminal stimuli, a more complex stimulus type effect was noted, with a greater magnitude peak for angry vs. happy faces and overall greater magnitude peaks for scrambled stimuli - the opposite direction of effect than that for subliminal scrambled stimuli. Opposite effects across subliminal and supraliminal presentation times is not

uncommon (e.g., Suzuki & Noguchi, 2013). This emotion-specific finding supports hypothesis 3c-iii, but is the opposite of the effect anticipated by hypothesis 3c-ii. Greater P300 for supraliminal scrambled than face images is not typical, but similar trends have been noted in ageing research (e.g., Friedman, 2003; Anderer et al., 2003), which has been interpreted as a lack of typical inhibition of frontal mechanisms and related to the many factors that affect this component. The latency of P300 has been associated with stimulus evaluation time, but amplitude is modulated by probability of stimulus category, resource allocation, and processing allocation (e.g., Kok, 2001; Ashley, Vuilleumier, & Swick, 2004). The supraliminal condition involved a full 1000ms viewing the stimulus, which was not varied. Although the components of interest occur early in the process, participants would have expected this duration after the four practice blocks. Without imposing a particular intention or motivation on the participants, it may be conjectured that participants' processing of supraliminal stimuli was substantially more affected by these factors in the supraliminal condition - one of the advantages of the subliminal condition. Additionally, scrambled images only occurred a quarter of the time and thus functioned to an extent as an "infrequent" condition. If this is the case, then greater P300 would be expected for scrambled faces. Typical oddball tasks can elicit a typical late P300 infrequent-frequent effect in both subliminal and supraliminal presentations, but the design in the present study bears little resemblance to oddball tasks besides the reduced frequency of scrambled images (Bernat, Shevrin, & Snodgrass, 2001).

***Hypothesis 3: Neuropsychological and Social Cognitive Measures*.**

Hypothesis #3) ERP components will show convergent validity with neuropsychological and social cognitive tests that are used to measure similar brain processes in SMI.

a) Trail-Making Tests (visuomotor processing speed and visuospatial working memory)
    i. Trail-Making Test A performance will be inversely correlated with P1 (faster visuomotor processing speed associated with greater magnitude P1).
    ii. Trail-Making Test A performance will be inversely correlated with N170 magnitude (faster visuomotor processing speed with greater magnitude N170) for all stimulus types in subliminal but not supraliminal presentations.
    iii. Trail-Making Test B performance will be negatively associated with both N170 and P300 magnitude (faster visuospatial working memory with greater magnitude N170 and P300) for all stimulus types in supraliminal but not subliminal presentation times.
b) BTFR and WMS-iii Faces (face memory and identification)
    i. Face memory and identification will be positively correlated with the N170 difference component between neutral and scrambled face stimuli (i.e., people with better face memory and identification abilities will show a greater face-specific enhancement of N170).
    ii. Face memory and identification will be positively correlated with the magnitude of P300 for face stimuli but not for scrambled images.

c) VEIT, FEIT, and ACS (emotion perception)

i. Emotional main effects (angry vs. happy, emotional vs. neutral) for N170 and P300 will be correlated positively with emotion perception, such that those with a greater magnitude peak differenceform will have better emotion perception.

These hypotheses (hypotheses 3 and 4) regarding the relationship between ERP components and external measures, are to a degree contingent on the validity and reliability of these measures in this population. Several of the measures were designed for broad use and several were designed for use in an SMI population. For the latter, the meaningful variance in scores may have been reduced due to ceiling effects and measurement error. Within the neuropsychological and social cognitive measures, performance was not related across modalities to the degree that would be expected in an SMI population. This is expected, to a degree, given the generalized deficits in SMI and not control samples (Chapman & Chapman, 1978; Silverstein, 2008). However, several very similar scales were not correlated, such as FEIT and ACS Affect Naming, Trail Making Tests and LNS, and VEIT and ACS Prosody Face-Matching, which suggests these measurement constructs may function quite differently in undergraduates and/or one or both of each pair of measures is not reliable in this population. Importantly, dimensions of schizotypy were related to neuropsychological functioning and schizotypy was related to social functioning. So, although elements of the assessment battery had questionable validity and reliability in this population, the biosystemic relationships for which the battery was designed were aptly measured.

Hypothesis 3. Derived components showed promising convergent validity with neuropsychological and social cognitive measures, but these patterns were not exactly as hypothesized.

Hypothesis 3a-i through 3a-iii. These hypotheses were not supported, though some promising unhypothesized relationships were noted.

Trail-Making Tests did not correlate with P1.

Trails A was correlated in the hypothesized direction with subliminal scrambled N170, although this correlation was isolated and had a relatively high probability value (p=.036). Trails B was not correlated with N170 peaks as hypothesized, but later N170 latency for supraliminal neutral stimuli was correlated with slower Trails B performance. This correlation had a low probability value (p=.006) but was isolated. Unfortunately, other than research manipulating perceptual expertise (e.g., Busey & Vanderkolk, 2005) where later N170 has been interpreted as representing early configural processing of non-face stimuli that are specific objects of expertise, individual differences in N170 latencies have rarely been analyzed or interpreted (Eimer, 2011). The present correlation cannot be compared to the increased configural processing interpretation due to the design.

P300 amplitude across stimulus types was particularly related to Trail-Making Test A (Trails A) performance, but not Trails B or other neuropsychological tests. In the positively-oriented parietal region, this relationship was negative and strongest for neutral subliminal faces. In the negatively-oriented inferior frontal region, this relationship was positive and strongest for supraliminal scrambled images, with moderate positive correlations for supraliminal and subliminal emotional faces but not neutral faces. So,

greater magnitude P300 peaks were related to faster performance on Trails A. Correlations were noted for every stimulus type, but differentially across regions.

For scrambled, but not angry images in the negatively-oriented inferior frontal region, the P300 stimulus duration difference (supraliminal-subliminal) was also significantly positively correlated with Trails A. This suggests that participants whose supraliminal scrambled P300 was more negative (of greater magnitude) than subliminal scrambled P300 performed faster on Trails A. These comparisons are unprecedented to the knowledge of this author.

Taken in context, supraliminal scrambled P300 raw peak amplitudes showed the greatest correlation with Trails A, particularly in the inferior frontal region, and subliminal scrambled P300 peaks were not correlated with Trails A. Some researchers have questioned the validity of the relationship of P300 to selective attention processes in visuospatial attention tasks (e.g., Potts et al., 2002). However, Trail-Making Test performance is a very different measurement construct than the typical behavioral measures utilized during neuroimaging experiments. The peak amplitude correlation finding may be consistent with the finding that P300 amplitude for face stimuli is suppressed as working memory load increases (Morgan et al., 2008). For participants for whom Trails A requires greater cognitive effort, suppressed P300 may thus be expected. However, one would then expect an even greater correlation for Trails B. Additionally, one would expect the opposite effect for the supraliminal-subliminal difference, as subliminal stimuli would be expected to evoke substantially reduced working memory processes than supraliminal presentations, although this interpretation does assume a certain participant "strategy," which is not consistent with the passive experimental

design. The research on subliminal visual P300 is inconsistent. Some studies suggest subliminal P300 is typically similar in amplitude and latency to supraliminal P300, and conscious perception of the stimulus is not related to P300 (Bernat, Bunce, and Shevrin, 2001), while other studies suggest P300 in fact marks conscious perception (Ress & Heeger, 2003; Pins & Ffytche, 2003). P300 has also been interpreted as indexing conscious processing and integration of emotional content (Kiss & Eimer, 2007). So, if P300 may in fact index conscious processing of images, a greater P300 magnitude for supraliminal (fully conscious) compared to subliminal (not conscious, or minimally conscious) presentations may represent a greater degree of stimulus processing and integration. The complexity and ambiguity of the scrambled stimuli may elicit a different degree or quality of conscious processing compared to the angry or other emotional face stimuli, which comparison is apparently related in this sample to sustained attention and visuomotor speed. This effect clearly requires replication, as its precedent is sparse and previous studies typically have not explored external correlations related specifically to scrambled image response. However, this result does call into question the initial intention for scrambled images to elicit a differential "pure" visual processing ERP compared to faces. This effect appears to hold for the face-sensitive N170, as expected, but P300 results suggest the complexity of scrambled images modulates visual ERPs in itself.

Hypothesis 3b. This hypothesis was partially supported. N170 subliminal peaks were correlated with immediate face memory, and the subliminal face-specific difference (neutral-scrambled) was positively correlated with immediate face memory and the average of immediate and delayed face memory. So, as hypothesized, greater face-

specificity for N170 was associated with greater face memory, although this was only for subliminal stimuli. N170 was not related with face identification (BTFR).

P300 peaks were not correlated with face memory, but inferior frontal supraliminal P300 latency for neutral but not scrambled stimuli was correlated with immediate face memory, suggesting later inferior frontal P300s for neutral stimuli were associated with better face memory.

Hypothesis 3c. This hypothesis was partially supported. N170 was not correlated with strictly face emotion recognition. However, for a verbal and two cross-modal emotion identification subscales (VEIT, ACS Speaker Meaning, and ACS Meaning Change) moderate negative correlations were observed with subliminal N170 peaks, particularly for angry but also a trend towards neutral stimuli and no correlation for scrambled stimuli. These cross-modal (visual ERP, verbal emotion perception tests) correlations were also noted for the face-specific difference for subliminal N170 peaks. However, the probability values were relatively high for these correlations (ps>.025), excepting that of angry subliminal N170 peaks with VEIT (p=.019).

N170 latencies showed a similar pattern. Neutral supraliminal N170 latency was negatively correlated with VEIT (p=.003), as well as ACS Pair-Matching, Meaning Change, and Prosody-Pair Match. These results suggest later N170 for supraliminal neutral stimuli is related to poorer verbal emotion perception abilities. These correlations with verbal and cross-modal but not facial emotion tasks are counter-intuitive, given that the stimuli were visual and N170 is thought of as a face-specific component. However, social perception neither typically develops nor occurs in uni-modal contexts (e.g., Giard & Peronnet, 1999), and the ACS Pair-Matching and Prosody-Pair Match tasks involve

matching a verbal emotional stimulus with a visual face (or faces) target. It is alternatively possible that the purely face emotion identification tasks (ACS Affect Naming and FEIT) did not capture meaningful variance in emotion identification abilities, but it could also be that N170, particularly for neutral and high-salience emotional faces, in this case is tapping into a process that is integral to the development and maintenance of a broader multi-modal social perception information processing system.

In support of hypothesis 3c, The face-specific (neutral-scrambled) P300 effect was correlated with face emotion recognition. In the positively-oriented parietal region, the difference between supraliminal neutral and scrambled peaks was positively correlated with two face emotion recognition tasks and the overall score for ACS Social Perception. So, participants whose P300 response to subliminal neutral faces was greater than that for scrambled faces performed better on face emotion recognition tasks. This emotional modulation effect is relatively consistent with recent literature and may reflect early emotional processing or categorization of subliminal emotional stimuli (Shevrin, 2001), although some studies have not shown an effect of facial emotion on subliminal P300 (Balconi & Lucchiari, 2007), and this particular design is unprecedented.

The emotion-specific (angry-happy) effect for supraliminal P300 was positively correlated with verbal emotion identification (VEIT) and social inference (ACS Meaning Change) in the negatively-oriented inferior frontal region. These correlations had relatively low probability values (VEIT p=.001, ACS Meaning Change p=.011), although no other ACS subscales were correlated. These correlations are in the direction such that greater magnitude supraliminal angry vs. happy P300 peaks were associated with greater

verbal emotion identification and social inference. This correlation is discussed in context in the following section.

Hypothesis 4: Schizotypy and Social Functioning.

Hypothesis #4) ERP components will show reliability as markers of traits that covary with degree of schizotypy and social functioning and thus may be expected to parallel differences between people with SMI.

a) Several of the above neuropsychological and social cognitive relationships with ERP will also be present in the relationship between schizotypy and social functioning.
    i. P1 and P300 will both be negatively correlated with Cognitive-Perceptual schizotypy and positively with social functioning, such that lower magnitude amplitude is associated with greater positive schizotypal traits and lower social functioning.
    ii. The difference between supraliminal neutral vs. scrambled face N170 will be negatively correlated with Interpersonal schizotypy and positively correlated with social functioning, such that a smaller difference between the conditional waveforms is associated with greater negative schizotypy traits and poorer social functioning.
    iii. The difference between subliminal angry vs. happy face N170 will be positively correlated with Cognitive-Perceptual schizotypy, such that a greater modulation of the subliminal N170 by an angry face is associated with greater positive schizotypy. Notably, this is a slightly paradoxical

> hypothesis, given the hypothesis above that this comparison will be associated with better emotion recognition skills, when we know that emotion recognition skills are generally poorer in people with extreme positive symptoms. However, the author is treating these as two separate hypotheses and assuming that this hypothesis may be driven by a perceptual bias toward threatening stimuli in people with suspicious characteristics - one element of positive schizotypy.

This hypothesis was partially supported. All three components showed promising correlations with schizotypy, social functioning, or both, but the specific nature and direction of correlations were typically not as hypothesized.

Hypothesis 4a-i. This hypothesis was partially supported. Supraliminal neutral and scrambled N170 peaks showed isolated correlations with schizotypy, but N170 latencies showed a more reliable pattern of effects. Specifically, N170 latencies for subliminal neutral but not scrambled stimuli were positively associated with Interpersonal, Social Anxiety, and Suspiciousness schizotypy scales. Scrambled subliminal latencies showed an isolated positive correlation with Unusual Perceptions. On the other hand, neutral but not scrambled supraliminal N170 latencies were positively correlated with Cognitive Perceptual and Unusual Perceptions scores.

P300 peaks were not correlated with schizotypy as hypothesized. The P300 duration difference (supraliminal-subliminal) effect was correlated with Interpersonal and Cognitive Perceptual schizotypy. In the positively-oriented parietal region, P300 peak differences for scrambled images were negatively correlated with Interpersonal

Constricted Affect and Social Anxiety. In the negatively-oriented inferior frontal region, peak differences for angry faces were negatively correlated with Interpersonal No Close Friends and Suspiciousness.

Similarly, the P300 face-specific difference (neutral-scrambled) effect was correlated with positive symptom-like experiences. The difference between parietal subliminal neutral vs. scrambled P300 peaks negatively correlated with Cognitive Perceptual schizotypy, particularly Unusual Perceptions, Ideas of Reference, and Suspiciousness. However, these correlations between P300 difference scores and SPQ scales had relatively high probability values (*p*s>.025).

This difference (neutral-scrambled) was also correlated negatively with Social Functioning Independence-Competence for inferior frontal subliminal P300 peaks. This correlation had a low probability value (*p*=.008) but was relatively isolated - other SFS scales were not correlated with the neutral-scrambled peak difference for subliminal or supraliminal stimuli.

The emotion-specific difference (angry-happy) effect was also correlated negatively for inferior frontal supraliminal P300 peaks with Interpersonal schizotypy, particularly No Close Friends, as well as with Suspiciousness. The Interpersonal correlations had relatively low probability values (Interpersonal *p*=.016; No Close Friends *p*=.009).

This emotion-specific difference (angry-happy) effect was also correlated negatively with overall social functioning and Recreation and Prosocial activities in particular for subliminal parietal P300 peak differences. These correlations also had

relatively low probability values (Total SFS p=.016, Recreation p<.0005, but Prosocial p=.084).

Inferior frontal P300 latencies were positively correlated for supraliminal neutral stimuli with overall social functioning (p=.025) , Interpersonal Communication (p=.006), Prosocial activities (p=.042), and Social Engagement and Withdrawal) (p=.090).

The exact specifications of hypothesis 4a-i were not fully-supported, but the general hypothesis that N170 and P300 would be related to schizotypy and social functioning were well-supported. The most compelling findings are summarized next.

In particular, later N170 latencies for subliminal neutral and scrambled stimuli were associated with Cognitive Perceptual, Interpersonal, and Social Anxiety dimensions of schizotypy. Later latency for N170 is associated with stimulus manipulations such as inverted faces but not objects (Bentin et al., 1996) and stimulus dissimilarity (Rossion & Jacques, 2008), and earlier N170 is noted for faces compared to objects (Itier & Taylor, 2004). N170 latency differences have not typically been analyzed in SMI, but have had mixed results in a few studies (Campanella et al., 2006; Wynn et al., 2013). Unfortunately, to this author's knowledge, previous studies in schizotypy have not analyzed N170 latencies.

P300 peak differences showed many relationships with schizotypy and social functioning.

The face-specific difference (neutral-scrambled) was correlated with Cognitive-Perceptual schizotypy such that greater enhancement of subliminal P300 for faces was associated with decreased schizotypy. These effects had relatively high probability values. This comparison is more commonly made in the literature for subliminal

emotional faces (e.g., Balconi & Lucchiari, 2007), but the conditional effect is in line with the concomitant idea that P300 is enhanced for social and emotional stimuli compared to non-social scrambled images, and this is a more dramatic manipulation than the comparison of neutral to emotional faces. Moreover, neutral faces are only "neutral" in comparison to exaggerated emotional faces. Compared to scrambled images, they are quite social and emotional. Enhanced subliminal P300 for faces than scrambled images may then represent a normative conditional effect for which deviation, or specifically a lack of enhancement, represents abnormal information processing at a level preceding conscious perception. To reiterate, these findings clearly require replication to be interpreted due to their relatively high probability values. However, the context of correlations with raw peak amplitudes and other conditional differences with measures across the spectrum bolster the potential validity of these findings.

The emotion-specific (angry-happy) difference for supraliminal P300 was correlated with Interpersonal schizotypy and Suspiciousness such that greater magnitude angry vs. happy P300 peaks were associated with greater schizotypy (and, technically greater happy than angry P300 peaks were associated with decreased schizotypy, but the correlation appears to be driven by values in the angry > happy and angry = happy range; see Figure 4.71). As previously mentioned angry-happy supraliminal P300 was associated with increased verbal emotion identification abilities. Although schizotypy was not correlated with verbal emotion identification, it is possible that either or both of these P300 results are Type 1 errors, but it is also possible they are both valid and represent different aspects of the information processing indicated by face P300. Interpersonal schizotypy and Suspiciousness both involve anxiety related to social stimuli

and often avoidance thereof. The relationship between P300 with either attentional avoidance or, conversely, facilitated vigilance toward emotional stimuli is debated (e.g., Shah et al., 2013). Abnormal attentional processes, particularly hypervigilance, toward emotional stimuli could conceivably facilitate performance in recognizing emotions in the degraded recordings of the VEIT. Most previous research has utilized angry vs. neutral face comparisons, and this study found only a reliable conditional difference for angry vs. happy faces. So, these particular comparisons are unprecedented and clearly require replication and expansion.

Finally, later frontal supraliminal P300 latencies for neutral stimuli were associated with greater social functioning, particularly Interpersonal Communication, which indexes number of close relationships and perceived communication ability. As previously mentioned, later latency was also associated with improved face memory. Given that the P300 latency may reflect stimulus evaluation and increase with working memory load, this correlation may reflect relatively increased resource allocation in the evaluation of consciously-perceived face stimuli (Kok, 2001). The fact that it was only related for neutral faces supports this hypothesis, as the neutral faces are quite ambiguous whereas the emotional faces are unequivocal. On the other end of the correlation, SMI is associated with both decreased social functioning and increased misinterpretation or quick, unreflective emotional judgments of neutral face stimuli, and deficits in affect perception have been linked to decreased social functioning (Penn et al., 2006; Edwards et al., 2002; Brekke, Kay, Kee, & Green, 2005). However, later peak latencies for oddball P300 have been related to maladaptive personality types (Hansenne, 1999).

Hypothesis 4a-ii was not supported for schizotypy. SPQ scales were not correlated with N170 peak differences. The precise hypothesized relationships were not observed for social functioning, but subliminal neutral N170 peaks and the difference between these peaks and scrambled peaks were each positively correlated with performance of independent social functioning roles. So, the magnitude of the neutral face N170 and the face-specific difference (neutral-scrambled) were associated with social functioning. This is the opposite of the hypothesized effect, as N170 is a negative waveform. So, less negative (lower magnitude) peaks were associated with greater social functioning, as was decreased modulation of N170 by faces compared to scrambled images. These effects had relatively low probability values (p=.010 and p=.018, respectively), but they were isolated (i.e., other stimulus types, supraliminal presentation, and all other social functioning scales were not correlated).

Hypothesis 4a-iii was not assessed for schizotypy because the hypothesized face emotion effect (angry-happy) was not observed for N170 peaks.

Exploratory (Un-hypothesized) P1 Results.

There were several notable correlation patterns with P1 that show evidence of validity.

P1 peaks for neutral stimuli correlated negatively with face memory, overall social functioning, and reported prosocial behaviors, and the difference between neutral and scrambled peaks (face-specific difference) was correlated negatively with overall social functioning and reported prosocial behaviors. So, more positive P1 peaks for neutral stimuli were associated with poorer face memory and social functioning, and

relatively more positive peaks for neutral stimuli compared to scrambled stimuli were also associated with poorer functioning. In fact, the highest scores on SFS Prosocial were obtained by participants with the greatest enhancement of scrambled compared to neutral stimuli.

The Cognitive Perceptual scale of the SPQ-BRU was not correlated with P1 peaks or latencies, but the subscale Unusual Perceptions was positively correlated with P1 peaks for neutral stimuli. So, more positive P1 peaks for neutral stimuli were associated with a greater degree of positive symptom-like experiences.

Overall, P1 was not explored in great detail due to its lack of conditional effects. So, in the effort for reducing Type 1 error, subliminal and emotional P1 peaks and latencies were not analyzed. However, the observed correlations between P1 supraliminal neutral and scrambled peaks with external measures are compelling. P1 has shown mixed results in social cognition and SMI research, with a common lack of external correlations for P1 in the SMI literature (e.g., Wynn et al., 2008; Obayashi et al., 2009) but also several studies suggesting reduced P1 is associated with illness and reduced cognitive abilities (e.g., Foxe, Doniger, & Javitt, 2001; Haenschel et al., 2007). The present results are in the opposite direction of the typical findings, although these specific comparisons are unprecedented to the knowledge of this author. It is possible that greater P1 amplitude in fact does confer more efficient early visual processing and that the present results are paradoxically related to social functioning, symptom-like experiences, and face memory as a result of sampling bias. Another possible interpretation is that in this particular study, relatively greater P1 indicated less-efficient early visual processing, similar to the lack of attenuation or inhibition noted in psychiatric illnesses for early sensory processing (e.g.,

Braff, Geyer, & Swerdlow, 2001). This interpretation would most likely imply a familiarity or priming effect. Although priming effects on supraliminal stimuli were not significant in this study, it is possible that the manipulation of blank vs. non-blank subliminal primes did not in fact account for priming. In other words, having a prime stimulus, whether blank or not, in each stimulus block may have induced a priming effect. Finally, the conditional effect of faces vs. scrambled images has been found to be the opposite of N170 in some studies. P1 may be magnified by scrambled images as opposed to faces due to different spatial frequencies (Morgan et al., 2008). Although P1 was not different by stimulus type, the component's amplitude may simply function in the opposite direction.

Limitations

Several limitations of this study are apparent. The limitations in the results have been mentioned above in the summary and interpretation of results, but there are several bigger-picture issues worth noting.

The most glaring limitation of the present study is that the goal is to define a protocol for measuring individual differences over the course of treatment, and yet the present study only includes a single time point. It is not expected that this study's participants could feasibly be recruited for a follow-up study, and changes in facilities make it impossible that if they could be recruited, the data could be compared directly to the first time point. Future studies should plan for multiple observations and at least three time points to allow analysis of random effects of change over time (Peer et al., 2007).

The second major limitation is that it was not possible to recruit a large number of participants with a very high degree of schizotypy. A continuous model of schizotypal traits does not map exactly onto Meehl's conceptualization of schizotypy and schizotaxia, but a linear approach is the best approximation given the available participants and timeframe of this study (Lenzenweger, 2006). Nonetheless, the present results provide convincing evidence that there is meaningful variance between relatively psychiatrically healthy individuals in schizotypy, social functioning, and even neuropsychological performance that are related to information processing as indicated by electrophysiology. One main implication of this study is that analogue research into the biosystemic relationships relevant to SMI is not only possible but also fruitful and promising. In addition to providing the possibility of better mapping psychopathology onto the human condition rather than a marginalized psychiatric minority, this also confers the ability to develop, pilot, and hone assessment and possibly even treatment techniques in analogue samples before application to clinical research. Plus, the primary psychopathological construct in this study, schizotypy, and the age group studied happen to overlap considerably with efforts at understanding and treating early stages of psychosis, prodromal phases, and at-risk populations (Koychev et al., 2012; Phillips & Seidman, 2008; Rossi & Daneluzzo, 2002). These results may more directly map onto these fields of research and clinical work.

The non-ERP measures used in this study were chosen for their popularity in SMI research, and where possible, instruments known to vary meaningfully in both SMI and non-SMI samples were chosen. However, several measures appear to have suffered ceiling effects, and some may not even measure the same constructs as they do in SMI

(e.g., schizotypal Social Anxiety). More psychometric research is necessary to develop instruments with known dimensions of variance across SMI and non-SMI samples, or commensurate measures (e.g., Bauer & Hussong, 2009). Future studies should carefully select measures that will at least reliably represent the population sampled.

A relative measurement issue was noted in the SPQ-BRU, in that the Magical Thinking subscale did not load strongly onto the Cognitive Perceptual factor. The distribution of scores on this scale was skewed, and correlations with ERPs were noticeably absent, nonsignificant, and often near zero or in the opposite direction of other scales. This suggests either the scale was not reliably measured in these samples, the ERPs do not reliably indicate information processes related to Magical Thinking in positive schizotypy, or both. Given the substantially decreased loading for Magical Thinking on its parent factor, it is likely that the scale itself did not function as expected. It is possible that participants found these particular questions off-putting or overly blatant or that these traits are indicative of Magical Thinking as it relates to schizotypy at higher levels but not lower levels of the dimension. Future studies should employ more comprehensive confirmatory analytic methods such as Item Factor Analysis (or Item Response Theory) to empirically assess reliability across different levels of the factor and produce specific hypotheses and recommendations for improvement.

Passive viewing of the stimuli of interest was chosen to reduce the confound of attentional control, but it is possible that the conditional waveforms derived and their relationships with external measures were limited by the lack of response conditions. For example, P300 responses to visual oddball tasks typically are reduced compared to active tasks (Bennington & Polich, 199). However, ERP tasks that are reliably related to

attention and executive functions are well-known and utilized in SMI research (Turetsky et al., 2007). One purpose of the present study was to develop a modified ERP task that reliably elicits waveforms indicating processes other than attention and executive functioning. The present ERP task shows evidence of eliciting ERPs related to attention as well as more social and emotion-specific processes, but future studies should also include more classical ERP tasks to validate the discriminant and convergent validity of the present task.

A notable issue in the present study may be summarized in one word, "scope." The enormity of ERP data combined with a biosystemic assessment battery is obvious in the length and complexity of the present paper, but they also provide a plethora of possibilities. A relatively simplistic approach was taken to reduce the number of comparisons moderately and produce a feasible thesis. However, spectral analysis, laterality, correlations between external measures and conditional effects that were not significant, alternative approaches to empirical temporal component derivation, empirical spatial derivation, analysis of other factors or components, analysis by demographic groups, and many other valid approaches may be taken in future projects with this data or follow-up studies.

A final issue is that the biosystemic relationships that are prominent in SMI don't always replicate in non-SMI samples. This may be due to a completely different system in people with SMI, but there are several cases that seem clearly related. For example, one would assume that face memory or face identification abilities would be related to face emotion recognition. Theoretically, the individual differences in people without SMI may be very slight, and the sources of error in any of the constructs may be inflated. In

the present study, this might manifest as an interaction wherein level of schizotypy moderates the relationships between other measures, such that people with more schizotypy have higher magnitude correlations between measures. A much larger sample and substantially more sensitive measures would be required to identify this interaction and compare the measures to brain processes. However, the powerful within-subject comparisons provided by ERP assessment may obviate this issue to some degree.

Protocol Development Considerations

The effects that most robustly differentiate conditions, most clearly match biosystemic relationships found in SMI, differ in early and later processes, show a face-specific and emotion-specific effect, and correlate with schizotypy are considered the targets for a new ERP protocol. An additional goal of this protocol will be reduced experiment duration and increased trails per condition.

Subliminal presentation was a primary issue in stimulus design, and several effects suggest that the subliminal manipulation may not have been one-hundred percent effective. Backward masking designs are relatively simple and have been in use for decades (Raab, 1963). However, with increasing familiarity with the literature and experience using the technique, there are certain details that may have been improved in the present study. In particular, the spatial dissimilarity of the mask used in this study compared to the face stimuli that were being masked may have reduced the backward masking effect, leaving more of a residual image on the retina than intended. Participants never stated that they knew the subliminal "flashes" were the same as the supraliminal images, but after being debriefed, many stated that they suspected this. A design such as

that of Kiss and Eimer (2007), where the target image is masked with a scrambled version of that image would provide substantially more reliable masking. Given that the scrambled image would then be presented 13ms after the target image, the ERP for the scrambled image could not be analyzed separately. However, there are many different degrees and types of scrambling, and different matched scrambled images could easily be presented as targets and similarly masked. Also, objects have often been used as a control stimulus in comparison to faces, and these would obviate the aforementioned issue, though the categorical and processing manipulation would be altered (e.g., Itier & Taylor, 2004). Notably, the degree to which subliminal images are not noticeable may not make any difference in the task's ability to demonstrate differences in early visual processing for people with SMI, as these differences have been shown across tasks with different types and degrees of masking (Green, Lee, Wynn, & Mathis, 2011).

In addition to the issues of subliminal presentation, use of objects as a control stimulus, while introducing more specific categorical processing, would have the advantage of possibly being more configurally similar to faces than scrambled images, thus avoiding the difficult to interpret scrambled image specific P300 effects. However, these results were correlated with neuropsychological tests to a greater degree than earlier components or face stimuli, and as such it may be more productive to manipulate the degree of scrambling rather than using objects to provide controlled manipulation of this useful conditional component (e.g., Sadr & Sinha, 2004). The latter approach would also preserve the specific conditional effects with valuable criterion-related validity observed in the present study between P300 and emotion recognition tasks.

Considerations concerning the assessment battery have been discussed above, but the ERP Debriefing should be modified in future studies. A more formalized and carefully documented debriefing process would allow qualitative and quantitative analysis of the participants' actual experience of the experiment.

Given the results of the present study, the most important effects for discriminating conditional effects and relationships with external measures were angry, neutral, and scrambled faces across subliminal and supraliminal presentations. However, the priming condition was not useful. Additionally, results involving scrambled images implied that graded scrambled images are necessary for interpretation, and the subliminal manipulation may need to be improved. Finally, in an experiment with no manipulation of the stimulus screen location, the fixation point serves little purpose. Given these considerations, a proposed new protocol is described below.

The protocol described in the figure below includes subliminal and supraliminal presentations of angry, happy, partially-scrambled, and fully-scrambled images. Instead of a fixation point or blank mask, the target images are forward and backward masked by another type of fully-scrambled face. Specifically, a tiling program within the freeware GNU Image Manipulation Program, v.2.8.6 easily adjusts the size and saturation of square tiles of the original image that are randomly re-distributed and rotated. Additionally, the "spread" program provides random shifting of individual pixels. As such, two different types of scrambling can be achieved that create different amounts of face and emotion ambiguity, but are both essentially the same technique (randomly redistributing pixels or groups of pixels by a manipulatable distance from their original location). These programs allow the experimenter to scramble images to the degree that

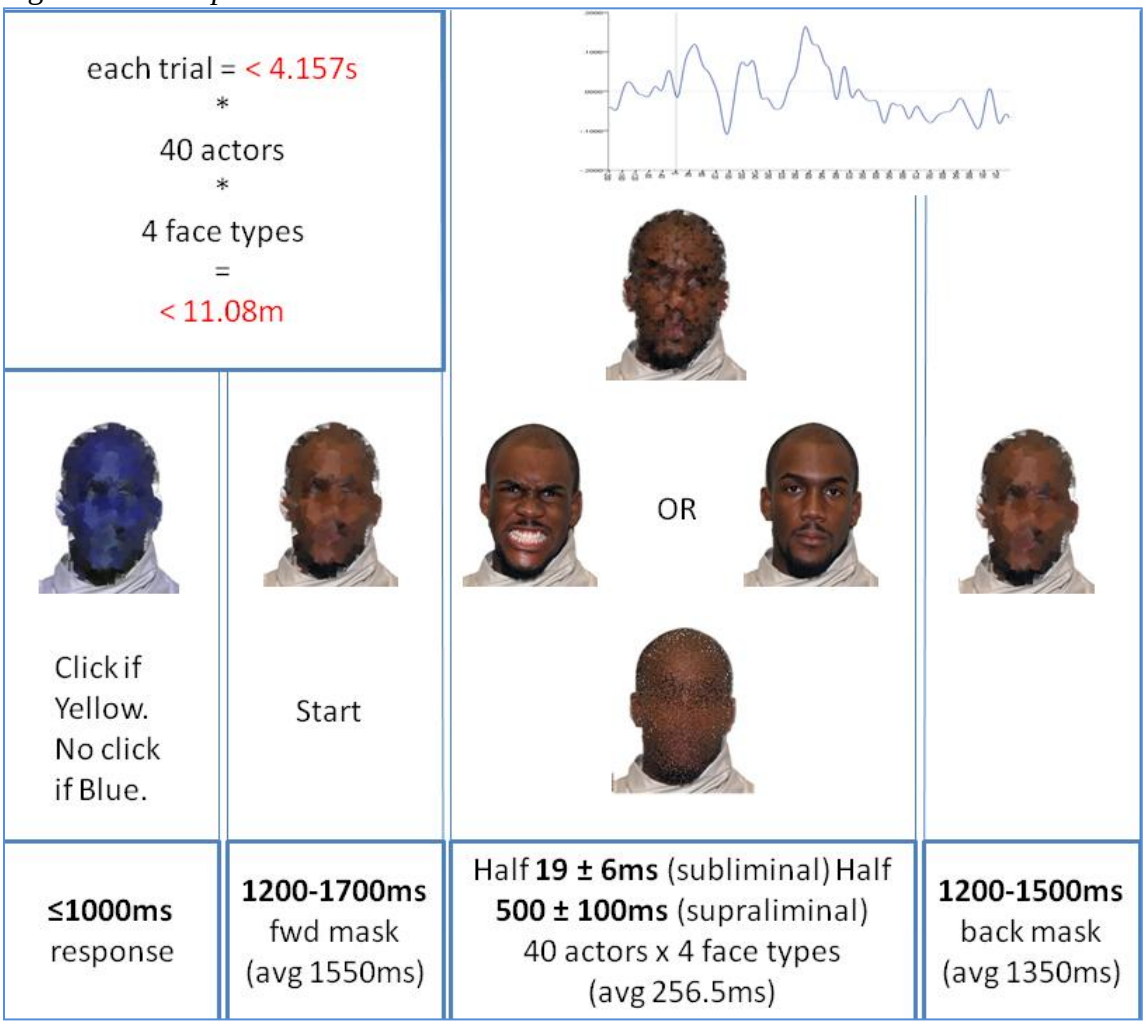
they are degraded, but facial expression and identity are recognizable, that face identity is recognizable but not expression, and that face identity is essentially not recognizable. Using a scrambled mask for forward and backward masking would remove the "flash" present in the previous subliminal presentation as well as increase the specificity of the configural stimulus manipulations. This design will also reduce the chance of startle responses, as were noted for at least one of the participants in the previous protocol. Further, the scrambled face mask will decrease the novelty or curiosity invoked by the scrambled image. Similarly, half of the target images will be scrambled and half unaltered face images, reducing the chance of an oddball effect.

Another consideration is that the scrambled images may be better categorized as "degraded," rather than "scrambled." It's possible that "scrambled" images, with larger blocks of the image moved such that facial features are evident but not in a facial structure, may produce different results (e.g., Bentin et al., 1996). However, "degraded" face stimuli have been used in face ERP studies with similar effects to that of "scrambled" images (e.g., Rossion & Caharel, 2011).

There is one confound that may be unavoidable - that neutral faces are rarely interpreted as truly "neutral." This is a confound in the very idea of measuring differentiable social and emotional components, as social stimuli are automatically interpreted for emotional valence. However, the angry face condition provides a foil for this comparison, whereby the exaggerated emotional condition allows control for extreme emotional valence and threat-perception, which is closely conceptually linked to anxiety and suspiciousness, among other traits, central to schizotypy (Rasmussen, 2005). Although it is not indicated in the figure, another important consideration is the duration

of the target stimulus. Varying the subliminal stimulus duration within a window that is not expected to be consciously perceptible by any participants (i.e., 13 to approximately 25ms) and supraliminal stimulus duration, for example from 400-600ms, would decrease any possible systematic intrusion by the backwards mask and any possible habituation to the "rhythm" of the experiment. The proposed experiment is substantially shorter (63% of the original duration), doubles the number of trials per condition, appears more tightly controlled, and is likely to take advantage of the criterion-related validity of the electrophysiological measures used in the present study.

Figure 4.75. *Proposed ERP Protocol.*



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Appendix 1.

SPQ-BR Original Items (Cohen et al., 2010) plus 1st-Person ("I") vs. 2nd-Person ("You") Wording

SPQ-BR Item	Factor	Sub-factor	I/you
1. Do you sometimes feel that people are talking about you?	CP	IR	you
2. Do you sometimes feel that other people are watching you?	CP	IR	you
3. When shopping, do you get the feeling that other people are taking notice of you?	CP	IR	you
4. I often feel that others have it in for me.	CP	SU	I
5. Do you sometimes get concerned that friends or co-workers are not really loyal or trustworthy?	CP	SU	you
6. Do you often have to keep an eye out to stop people from taking advantage of you?	CP	SU	you
7. Do you feel that you cannot get "close" to people?	IP	CF	you
8. I find it hard to be emotionally close to other pe21ople.	IP	CF	I
9. Do you feel that there is no one you are really close to outside of your immediate family, or people you can confide in or talk to about personal problems?	IP	CF	you
10. I tend to keep my feelings to myself.	IP	CA	I
11. I rarely laugh and smile.	IP	CA	I
12. I am not good at expressing my true feelings by the way I talk and look.	IP	CA	I
13. Other people see me as slightly eccentric (odd).	DO	EB	I
14. I am an odd, unusual person.	DO	EB	I
15. I have some eccentric (odd) habits.	DO	EB	I
16. People sometimes comment on my unusual mannerisms and habits.	DO	EB	I
17. Do you often feel nervous when you are in a group of unfamiliar people?	IP or SA	SA	you
18. I get anxious when meeting people for the first time.	IP or SA	SA	I
19. I feel very uncomfortable in social situations involving unfamiliar people.	IP or SA	SA	I
20. I sometimes avoid going to places where there will be many people because I will get anxious.	IP or SA	SA	I
21. Do you believe in telepathy (mind-reading)?	CP	MT	you
22. Do you believe in clairvoyance (psychic forces, fortune telling)?	CP	MT	you
23. Have you had experiences with astrology, seeing the future, UFO's, ESP, or a sixth sense?	CP	MT	you
24. Have you ever felt that you are communicating with another person telepathically (by mind-reading)?	CP	MT	you
25. I sometimes jump quickly from one topic to another when speaking.	DO	OS	I
26. Do you tend to wander off the topic when having a conversation?	DO	OS	you
27. I often ramble on too much when speaking.	DO	OS	I
28. I sometimes forget what I am trying to say.	DO	OS	I
29. I often hear a voice speaking my thoughts aloud.	CP	UP	I
30. When you look at a person or yourself in a mirror, have you ever	CP	UP	you

seen the face change right before your eyes?			
31. Are your thoughts sometimes so strong that you can almost hear them?	CP	UP	you
32. Do everyday things seem unusually large or small?	CP	UP	you

Appendix 2.

SPQ-BRU Items

item #	Higher -Order	Sub-factor	text
1	CP	IR	I sometimes feel that people are talking about me.
2	CP	IR	I sometimes feel that other people are watching me.
3	CP	IR	When shopping, I get the feeling that other people are taking notice of me.
4	CP	SU	I often feel that others have it in for me.
5	CP	SU	I sometimes get concerned that friends or co-workers are not really loyal or trustworthy.
6	CP	SU	I often have to keep an eye out to stop people from taking advantage of me.
7	IP	CF	I feel that I cannot get 'close' to people.
8	IP	CF	I find it hard to be emotionally close to other people.
9	IP	CF	I feel that there is no one I am really close to outside of my immediate family, or people I can confide in or talk to about personal problems.
10	IP	CA	I tend to keep my feelings to myself.
11	IP	CA	I rarely laugh and smile.
12	IP	CA	I am not good at expressing my true feelings by the way I talk and look.
13	DO	EB	Other people see me as slightly eccentric (odd).
14	DO	EB	I am an odd, unusual person
15	DO	EB	I have some eccentric (odd) habits.
16	DO	EB	People sometimes comment on my unusual mannerisms and habits.
17	*IP*	SA	I often feel nervous when I am in a group of unfamiliar people.
18	*IP*	SA	I get anxious when meeting people for the first time.
19	*IP*	SA	I feel very uncomfortable in social situations involving unfamiliar people.
20	*IP*	SA	I sometimes avoid going to places where there will be many people because I will get anxious.
21	CP	MT	I believe in telepathy (mind-reading).
22	CP	MT	I believe in clairvoyance (psychic forces, fortune telling).
23	CP	MT	I have had experiences with astrology, seeing the future, UFO's, ESP, or a sixth sense.
24	CP	MT	I have felt that I was communicating with another person telepathically (by mind-reading).
25	DO	OS	I sometimes jump quickly from one topic to another when speaking.
26	DO	OS	I tend to wander off the topic when having a conversation.

27	DO	OS	I often ramble on too much when speaking.
28	DO	OS	I sometimes forget what I am trying to say.
29	CP	UP	I often hear a voice speaking my thoughts aloud.
30	CP	UP	When I look at a person or at myself in a mirror, I have seen the face change right before my eyes.
31	CP	UP	My thoughts are sometimes so strong that I can almost hear them.
32	CP	UP	Everyday things seem unusually large or small.

Appendix 3.

Edinburgh Handedness Inventory:
Participant

Experimenter

Please indicate your preferences in the use of hands in the following activities by putting (+) in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put (++). If in any case you are really indifferent, put (+) in both columns.

Some of the activities require both hands. In these cases, the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

	PARTICIPANT HAND PREFERENCE:	Left	Right
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Broom (upper hand)		
9	Striking match		
10	Opening box (lid)		
11	Which foot do you prefer to kick with?		
12	Which eye do you use when using only one?		

Leave blank for the experimenter:

	L.Q	Decible

Participant		

Appendix 4.

Voice Emotion Identification Task

INSTRUCTIONS: You will hear a series of 21 sentences. Each sentence will be said in one of six emotions including ***happiness, anger, fear, sadness, surprise, & shame***. Listen to each sentence and circle on your answer sheet the one emotion that best describes the speaker's tone of voice. Focus on the *emotion* in the speaker's voice, *not the content* of the sentence because the content will not help you identify the emotion. Listen carefully because the sentences are brief. SELECT ONLY ONE ANSWER FOR EACH ITEM. DO NOT LEAVE ANY ITEMS BLANK. IF YOU ARE NOT SURE OF YOUR ANSWER, PLEASE TAKE YOUR BEST GUESS.

1. Happy Angry Afraid Sad Surprised Ashamed
2. Happy Angry Afraid Sad Surprised Ashamed
3. Happy Angry Afraid Sad Surprised Ashamed
4. Happy Angry Afraid Sad Surprised Ashamed
5. Happy Angry Afraid Sad Surprised Ashamed
6. Happy Angry Afraid Sad Surprised Ashamed
7. Happy Angry Afraid Sad Surprised Ashamed
8. Happy Angry Afraid Sad Surprised Ashamed
9. Happy Angry Afraid Sad Surprised Ashamed
10. Happy Angry Afraid Sad Surprised Ashamed
11. Happy Angry Afraid Sad Surprised Ashamed
12. Happy Angry Afraid Sad Surprised Ashamed
13. Happy Angry Afraid Sad Surprised Ashamed
14. Happy Angry Afraid Sad Surprised Ashamed
15. Happy Angry Afraid Sad Surprised Ashamed

16.	Happy	Angry	Afraid	Sad	Surprised	Ashamed
17.	Happy	Angry	Afraid	Sad	Surprised	Ashamed
18.	Happy	Angry	Afraid	Sad	Surprised	Ashamed
19.	Happy	Angry	Afraid	Sad	Surprised	Ashamed
20.	Happy	Angry	Afraid	Sad	Surprised	Ashamed
21.	Happy	Angry	Afraid	Sad	Surprised	Ashamed

END OF VOICE IDENTIFICATION TEST.

Appendix 5.

Social Functioning Scale

(Markers Version)
Max Birchwood (1990)

Social Engagement \ Withdrawal (circle or underline the correct answers)

1. On average what time do you get up?

Average weekday: Before 9 am
9 – 11 am
11 am – 1pm
After 1 pm

Average weekend: Before 9 am
9 – 11 am
11 am – 1 pm
After 1 pm

2. **How many hours of the waking day do you usually spend alone?** (e.g. In your room alone, walking alone, watching T.V. alone)
   Very little time / 0 – 3 hours alone
   Some of the time /3 – 6 hours alone
   Quite a lot of the time / 6 – 9 hours alone
   A great deal of the time / 9 – 12 hours
   Practically all the time / more than 12 hours

3. How often will you start a conversation at home?
   Almost never / rarely / sometimes / often

4. **How often will you leave the house for any reason?**
   Almost never / rarely / sometimes / often

5. **How do you react to the presence of strangers?**
   Avoid them / feel nervous / accept them / like them

Interpersonal Communication (tick or underline the correct answers)

1. **How many friends do you have at the moment?** (people whom you see regularly, talk with, do activities with, etc)
   none / one friend / two friends / three or more friends

2. **Do you have someone you find it easy to discuss feelings / difficulties with?**
   yes no

3. **How often have you confided in them?**
   almost never / rarely / sometimes / often

4. **Do other people discuss their problems with you?**
   almost never / rarely / sometimes / often

5. **If not married, do you have a boyfriend / girlfriend?**
   yes / no / married

6. **Have you had arguments with friends, relatives or neighbours recently?**
   none / 1 or 2 minor / continued minor or 1 major / many major

7. **How often are you able to have a conversation with someone?**
   almost never / rarely / sometimes / often

8. **How easy or difficult do you find talking to people at present?**
   very easy / quite easy / average / quite difficult / very difficult

9. **Do you feel uneasy with groups of people?**
   almost never / rarely / sometimes / often

10. **Do you prefer to spend time on your own?**
    often / sometimes / rarely / almost never

Prosocial

Over the past three months, how often have you participated in any of the following? (place a check in the appropriate boxes)

	Never	**Rarely**	**Sometimes**	**Often**

Cinema				
Theatre / concert etc				
Watching indoor sport				
Art gallery / museum				
Exhibition				
Visiting places of interest				
Meeting , talk etc				
Evening class				
Visiting relatives				
Being visited by relatives				
Visiting friends*				
Being visited by friends*				
Parties				
Formal occasions				
Disco etc				
Nightclub / social club				
Playing an indoor sport				
Playing an outdoor sport				
Club / society				
Pub				
Eating out				
Church activity				

(*includes boy / girlfriend/partner)

Any other activity?	**Rarely**	**Sometimes**	**Often**

Recreation

Over the past three months, how often have you done any of the following?
(place a check in the appropriate boxes)

	Never	**Rarely**	**Sometimes**	**Often**
Playing musical instruments				
Sewing, knitting				
Gardening				
Reading				
Watching television				

Listening to records / radio				
Cooking				
D.I.Y. activities				
Fixing things (car, bike etc)				
Walking / rambling				
Driving/cycling (for leisure)				
Swimming				
Hobby (collecting things)				
Shopping				
Artistic or craft activity				

Any other activity?	**Rarely**	**Sometimes**	**Often**

Independence-Competence

Place a check in each row to show how able you are at doing or using the following:

	Adequately, no help needed	Need help or prompting	Unable or only with lots of help	Not known
Public transport				
Handling money correctly				
Budgeting				
Cookery for self				
Weekly shopping				
How to look for a job				
Washing own clothes				

Personal hygiene				
Washing, tidying etc				
Purchasing from shops				
Leaving the house alone				
Choosing and buying clothes				
Taking care of personal appearance				

Independence-Performance

Place a check in each row to show how often you have done the following *over the past three months:*

	Never	**Rarely**	**Sometimes**	**Often**
Buying items from shop alone				
Washing pots, tidying up etc				
Regular washing and bathing				
Washing own clothes				
Looking for a job				
Doing the food shopping				
Prepare and cook a meal				
Leaving the house alone				
Using buses, trains etc				
Using money				
Budgeting				
Choosing and buying clothes				
Taking care of personal appearance				

Employment / Occupational / Educational Functioning

1. **Are you in regular employment** (this includes Industrial therapy, rehabilitation or retraining courses)?
   YES / NO

IF YES:
What sort of job? _____
How many hours a week do you work?_____
How long have you had this job?_____

IF NO:
When were you last in employment?_____
What sort of job was it?_____
How many hours a week did you work?_____

If not employed:
Are you registered disabled?
YES / NO (please underline)

Do you attend hospital as a day patient?
YES / NO (please underline)

Do you think you are capable of some sort of employment?
Definitely Yes / Would have difficulty / Definitely no

How often do you make attempts to find a job?
Almost never / Rarely / Sometimes / Often

1. **If not employed how do you usually occupy your day?**

Morning	
Afternoon	
Evening	

Appendix 6.

Demographics Questionnaire

Thank you for your participation. Please respond to the following items to the best of your ability.

Do NOT use the BACK, FORWARD, or REFRESH buttons during this survey, and please do not change the web page in this window while completing any part of the survey. Doing so could invalidate your results or hinder your ability to receive credit.

Please enter your date of birth.
(mm/dd/yyyy):

Select your biological sex
- Male
- Female

Select your current year in college.
- Freshman
- Sophomore
- Junior
- Senior
- Graduate Student
- Other (please describe)

Select your current marital status.
- Single, never married
- In a committed relationship, not co-habiting
- In a committed relationship, living together
- Engaged
- Married
- Separated
- Divorced
- Widowed

Do you consider yourself to be…
- Heterosexual or straight
- Homosexual orientation
- Bisexual orientation

People are different in their sexual attraction to other people. Which best describes your feelings?
- Only attracted to females
- Mostly attracted to females
- Equally attracted to females and males
- Mostly attracted to males
- Only attracted to males
- Not sure

Select your cultural identity (choose all that apply).

- European American/White
- African American/Black
- American Indian
- East Asian/Pacific Islander
- Hispanic
- Latino
- Other (please describe)

Select the area that best describes where you were raised.

- Urban
- Suburban
- Rural

Select the best representation of your military history.

- Never in military
- Reserves currently
- Served in military - No incident
- Served in military - With incident

Select the best representation of your legal history (choose all that apply).

- No history of legal problems
- Currently on parole/probation
- Arrest(s) not related to drugs/alcohol/substances
- Arrest(s) related to drugs/alcohol/substances

Select the highest level of education earned by any parent/guardian.

- Grammar School
- High School or Equivalent
- Vocational/Technical School (2 year)
- Some College
- College Graduate (4 year)
- Master's Degree (MS)
- Doctoral Degree (PhD, MD, JD, etc)
- Other

Select your current marital status.

- Single, never been married
- Married
- Separated
- Divorced, not remarried
- Co-habitating
- Widowed

Select your parents' current marital status (choose all that apply).

- Married to each other
- Separated
- Divorced, not re-married
- Mother remarried or in a long-term partnership
- Father remarried or in a long-term partnership
- Mother deceased
- Father deceased

Have you ever received outpatient psychotherapy?

- Yes, for many years
- Yes, for a few months
- No

Has any member of your first-degree family (mother, father, sibling) had outpatient psychotherapy?

- Yes, for many years
- Yes, for a few months
- No

Have you ever received inpatient treatment for a psychiatric, emotional, or substance abuse disorder?

- Yes
- No

Has any member of your first-degree genetic family (mother, father, sibling) had inpatient treatment for a psychiatric, emotional, or substance use disorder?

- Yes
- No

Has any member of your second-degree genetic family (aunts, uncles, grandparents, nephews, nieces) had inpatient treatment for a psychiatric, emotional, or substance use disorder?

- Yes
- No

Have you ever been prescribed any psychotropic medication?

- Yes
- No

Are you currently prescribed any psychotropic medication?

- Yes
- No

Has any first-degree family member (mother, father, sibling) been prescribed psychotropic medication?

- Yes

- No

As a child (younger than 18 years of age), did you ever experience:

- Physical abuse
- Emotional abuse
- Sexual abuse
- Physical or emotional neglect
- None of the above
- Prefer not to answer

Have you ever incurred any type of head injury (concussion, stroke, shrapnel, etc.)?

- Yes
- No

If so, did this head injury result in loss of consciousness?

- Yes
- No
- N/A

Do you have a history of seizures?

- Yes
- No

Please indicate your parents'/guardians' current household income in U.S. dollars.
Under $10,000

- $10,000 - $19,999
- $20,000 - $29,999
- $30,000 - $39,999
- $40,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - $150,000
- Over $150,000

Please indicate your parents'/guardians' household income in U.S. dollars while you were in elementary school

- Under $10,000
- $10,000 - $19,999
- $20,000 - $29,999
- $30,000 - $39,999
- $40,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - $150,000
- Over $150,000