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An investigation into event-related responses to emotional faces in early course psychosis

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Thesis

AN INVESTIGATION INTO EVENT-RELATED RESPONSES TO EMOTIONAL FACES IN EARLY COURSE PSYCHOSIS

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ABSTRACT

Background

Impairments in detecting emotional faces and in the brain's response to emotional faces have been well documented in psychosis spectrum disorders, especially in individuals with chronic schizophrenia (SZ) and chronic schizoaffective disorder (SZA). However, there has been less research into individuals who are early in their course of psychosis (ECP). In this study, we examined the brains event-related potential (ERP) responses to various static emotional faces in participants with ECP and healthy controls.

Methods

Ten healthy controls and eighteen individuals with ECP completed an emotional face recognition task. Sad, happy, and neutral faces were presented for 1000 ms, and participants then indicated what emotion they believed was displayed. Using electroencephalography (EEG), evoked potential data was obtained using a 128-channel EEG system. ERP data was then analyzed and averaged from channels in the occipital and temporal regions to elucidate the average P100 and N170 amplitudes for each group.

Results

Independent t-tests found that group differences in average N170 amplitudes differed significantly in the sad condition ($p < 0.032$) with the ECP group having more negative amplitudes than HC participants (HC mean = 0.54, sd = 1.72; ECP mean = -1.09, sd = 3.03). However, N170 amplitudes did not differ significantly between groups in the happy or neutral conditions. P100 average amplitude also displayed no significant differences across any emotional condition. SFS totals and anti-psychotics use also had no significant effect on ERP amplitude differences.

Conclusions

Emotional face recognition is a complex cognitive process, and paired with a highly heterogenous disorder, results can vary across studies. A significantly higher N170 amplitude in ECP versus control group suggests that a negativity bias could correlate to better recognition of adverse emotional expressions. Future large-scale investigations will be necessary to further solidify these findings.

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LIST OF ABBREVIATIONS

BIDMC ..... Beth Israel Deaconess Medical Center

BPD I ..... Bipolar Disorder I

CHR ..... Clinical High-Risk

CPZ ..... Chlorpromazine

DSM-III..... Diagnostic and Statistical Manual of Mental Health Disorders, Third Edition

DSM-IV .... Diagnostic and Statistical Manual of Mental Health Disorders, Fourth Edition

DSM-V..... Diagnostic and Statistical Manual of Mental Health Disorders, Fifth Edition

ECP ..... Early Course Psychosis

EEG ..... Electroencephalography

ERP ..... Event-Related Potential

FAP ..... Facial Affect Perception

FEP ..... First Episode Psychosis

FFA ..... Fusiform Face Area

fMRI ..... Functional Magnetic Resonance Imaging

HC ..... Healthy Control

IOG ..... Inferior Occipital Gyrus

LH ..... Left Hemisphere

MEG..... Magnetencephalography

OFA..... Occipital Face Area

PANSS ..... Positive and Negative Syndrome Scale

PET ..... Positron Emission Tomography

RH ..... Right Hemisphere

SAAMHSA ..... Substance Abuse and Mental Health Services Administration

SFS ..... Social Functioning Scale

STS ..... Superior Temporal Sulcus

SZA ..... Schizoaffective Disorder

INTRODUCTION

Schizophrenia and Its Diagnostic History

Schizophrenia is a psychotic disorder that has a prevalence of 3.3 per 1000 people worldwide. While it is not a curable disease, most individuals can decrease their symptoms through antipsychotics and other therapies (Bhati, 2013). Through most of the twentieth and early twenty-first centuries, schizophrenia was narrowed down to a specific diagnostic criterion to improve clinical reliability and standardization in research studies (Tsuang et al., 2000). According to the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV), schizophrenia is defined as presenting with two or more of the following symptoms for at least one month: delusions, hallucinations, disorganized speech, catatonic or disorganized behavior, or negative symptoms (SAAMHSA, 2016).

A delusion is a belief that has no justification by evidence to an individual. Most of the time, there is substantial evidence against these beliefs, which are tightly held by the believer (Coltheart et al., 2007). Delusions fall into two categories: monothematic and polythematic. Monothematic delusions are a single delusional belief, or a small cluster of beliefs related to one theme. Polythematic delusions exhibit a variety of beliefs that cover many different topics, most famously documented in mathematician John Nash, who believed he would become the Emperor of Antarctica, his name was Johann von Nassau, and that he was the left foot of God on Earth (Coltheart et al., 2007). On the other hand, hallucinations are false perceptions that have no external stimulation (Gearing et al., 2011). All senses can be present in hallucinations, but the most prominently studied and

often most common and debilitating are in visual or auditory domains (Teeple et al., 2009).

Another core symptom of schizophrenia is disorganized speech; however, it is harder to conceptualize than delusions and hallucinations. In the DSM-V, disorganized speech is defined as switching from one topic to another with no apparent connection, answering unrelated to a question, or nearly incomprehensible speech (American Psychiatric Association, 2013). Most importantly, there must be a severe enough impairment to stunt effective communication (SAAMHS Administration, 2016).

Catatonic or disorganized behavior is a set of symptoms that has been contested in being categorized as a symptom versus a subgroup of schizophrenia throughout the years. This behavior can vary from immature and childlike to aggressive and potentially violent, again causing impairment in communication and social functioning (SAAMHS Administration, 2016). The behavior can also include excessive or unusual movements, freezing in place, or not responding to instructions or external stimuli (Tsuang et al., 2013).

The final core category of schizophrenia symptoms is negative symptoms. This broad grouping is defined mainly by individuals being unable to carry out routine tasks such as personal hygiene. Also, this includes withdrawing from others, a flat affect of emotion, or speaking in a monotone (Tandon et al., 2013). An important note with all these symptom categories is that, individually, they can be attributed to different mental health disorders. However, it is their combination and timing that defines schizophrenia or other psychosis diagnosis (SAAMHS Administration, 2016). This is where most of the

changes in the DSM have come from over the years, especially when creating more concrete, data-driven rating scales and operational definitions that are accepted internationally (Mitra et al., 2016).

In addition to the presence of these symptoms, poor social functioning is a prominent feature of psychotic disorders. For many, it is more disruptive to their daily lives than the positive symptoms present throughout illness onset. It is hypothesized that social functioning deficits are present well before the first symptoms of psychosis (Addington et al., 2008).

The symptoms considered to characterize schizophrenia have varied throughout time and across different cultures, especially when placing importance on specific symptoms (Andreasen & Flaum, 1991). In the 1970s, the creation of the DSM-III saw the narrowest definition of schizophrenia emerge, creating a classification that was unique to schizoaffective, schizophreniform, and other psychosis non-specified disorders (American Psychiatric Association, 1980). This was done in part to align American psychiatry with British and other European physicians who believed Americans were using too broad of a definition that tended to misdiagnose manic depression as schizophrenia (Tsuang et al., 2013). Also, during this time, there was a considered effort to improve the reliability of evaluation and diagnostic criteria for psychosis disorders, making course and duration of illness essential factors in addition to identifying symptomology. This led to the DSM-III definition defining schizophrenia as a disorder lasting at least six months, characterized by delusions and hallucinations during active periods of illness (Andreasen & Flaum, 1991).

In continuing with the desire for more universal diagnostic criteria, the DSM-IV reflected the increase in structured interviews and rating scales, making a more empirical and data-based approach possible. This period also saw a rise in the importance of negative symptoms and their presence in diagnoses (Maj, 1998). In this definition, an individual needs to have two or more of the symptoms (delusions, hallucinations, disorganized speech, catatonia, or negative symptoms) present. However, there are a few distinct differences to the DSM-V. Most importantly, only one symptom was required if the delusions were considered "bizarre" or the hallucination contained two people talking to one another (American Psychiatric Association, 2013). This created problems because deciding what constitutes a bizarre from a non-bizarre delusion was up to interpretation, leading to this aspect being dropped in the latest edition (Maj, 1998).

Table 1. Diagnostic Criteria for Schizophrenia from DSM-IV and DSM-V
Diagnostic Criteria for Schizophrenia and Psychosis disorders from the DSM-IV (American Psychiatric Association, 1994) and the DSM-V (American Psychiatric Association, 2013).

DSM-IV	DSM-V
Disorder Class: Schizophrenia and Other Psychotic Disorders	*Disorder Class:* Schizophrenia Spectrum and Other Psychotic Disorders
Symptoms: Two (or more) of symptoms must be present for a significant period in 1-month (less if treatment is successful) 1. delusions 2. hallucinations 3. disorganized speech 4. disorganized or catatonic behavior 5. Negative symptoms *Only one symptom required if delusions are bizarre, or hallucinations contain two or more voices*	*Symptoms:* At least one of the symptoms must be from 1, 2, or 3 on the list
Negative symptoms include affective flattening, alogia, or avolition	Negative symptoms include diminished emotional expression or avolition
Duration: Must be continuously symptomatic for a minimum of 6 months. At least one month must be symptomatic (or less with successful treatment) with a disturbance from 1-4. There may be prodromal or residual periods during this time.	*Duration:* SAME

With the creation of the DSM-V, experts started to move away from describing mental illnesses as categories and began to focus more on a spectrum approach for specific diagnoses (Adam, 2013). This once again fell within the pattern of expanding and contracting the boundaries of schizophrenia throughout the years. However, rather

than looping more individuals into one box, they are now starting to be aligned on a continuum that reflects the interactions between mood and psychosis (Andreasen & Flaum, 1991). While the clinical criteria remain in a categorical context defining schizophrenia from schizoaffective and mood disorders, the continuing efforts of researchers and physicians alike are working towards a gradient system, which is reflected in the name change to "Schizophrenia Spectrum and Other Psychotic Disorders" (SAAMHS Administration, 2016). As research evolves and refines these hypotheses, this continuum reflects the complicated interactions within the brain that are still largely unknown.

Early Course Psychosis

Early course psychosis (ECP) is defined as the first few years of psychotic symptoms present the first few years after illness onset (Lewandowski et al., 2020). While many individuals are between 18-35 years old, ECP refers to the duration of illness rather than early-onset psychosis, which refers to first episode psychosis (FEP) occurring before the age of eighteen (Larsen et al., 1996). Two conflicting theories define ECP, which differ based on when illness onset is considered (Yung & McGorry, 1996).
In the literature, ECP has three phases: the clinical high-risk (CHR) period, the prodromal period, and acute psychosis (Tsuang et al., 2000).

Through all the diagnostic refinements, one of the more elusive aspects still not well defined is the CHR period, especially the criteria to be considered CHR (Tsuang et al., 2000). This is of particular interest in recent studies because understanding deficits and precursors in early course psychosis and schizophrenia is critical for more effective

intervention and management. Early detection and treatment can significantly improve the prognosis of the disorder, helping to mitigate the long-term impact on the affected population, their families, and society (Tsuang et al., 2000).

Like a fever manifesting before an illness, the prodromal phase of ECP refers to the early symptoms preceding the first acute episode (Yung & McGorry, 1996). Prodromal symptoms are not specified for schizophrenia or another psychotic disorder, so most often, the illness onset must be found retrospectively. This period is not as well laid out as chronic psychosis diagnoses because many individuals go undiagnosed with prodromal symptoms until after a first psychotic episode occurs (Larsen et al., 1996).

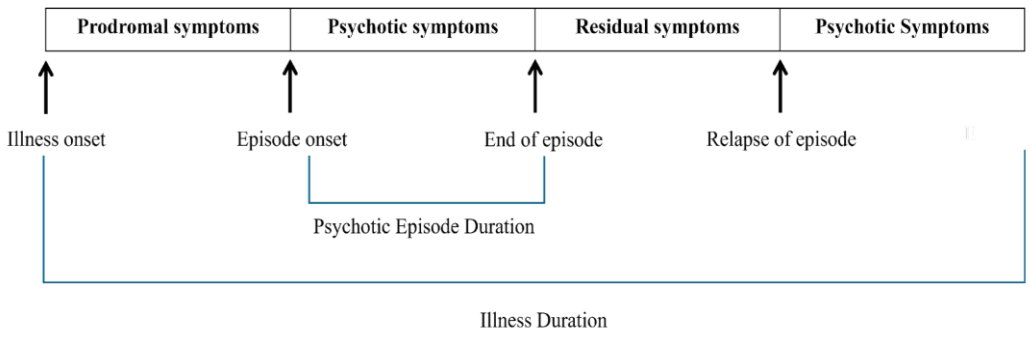


Figure 1. Diagram of Psychosis Disorder Progression
Flowchart of the progression through the different stages from prodromal symptoms to recurring psychosis symptoms (Keshavan et al., 1992).

There has been extensive study into chronic schizophrenia and other psychotic disorders; however, there is less research into ECP. One of the main reasons for this is that it is hard to obtain a diagnosis early in the disorder's progression, so there is a much smaller pool of individuals. Often, the first admission for psychosis may not be the actual first episode, or the severity of symptoms may not be fully apparent in the prodromal

phase (Keshavan & Schooler, 1992). Due to these complications, it is often the case that researchers categorize individuals within 2-5 years in illness duration as early-course, or they consider how long individuals have been actively taking antipsychotics (Prakash, 2021).

Social deficits are one of the strongest predictors of converting to active psychosis from the high-risk period, and there is also a positive correlation between decreasing cognition and social functioning (Cannon et al., 2008). A recent study that followed up with patients 2-8 years after a psychotic disorder diagnosis found that a poorer initial social functioning rating correlated with decreased cognitive functioning and social problem-solving as the illness progressed (Addington & Addington, 2008). Social problem-solving involves various facets of interpersonal communication, but it is especially evident in the processing of emotional faces.

Early Course Psychosis Social Functioning and Emotions

Recognizing and accurately identifying different emotional facial expressions is integral for developing communication skills and social cognitive abilities. As a result, it may dramatically impact social functioning (Streit et al., 2003). Impaired ability to identify emotional faces has been thoroughly researched in chronic schizophrenia and schizoaffective disorder (Turetsky et al., 2007). In chronic illness cases, it has also been shown that individuals have more difficulty distinguishing between faces and objects than their neurotypical counterparts (Shah et al., 2018). If an individual has difficulty registering what emotion a person is presenting to them, let alone having trouble recognizing their face, then it would stand to reason that social abilities would also be

impaired (Kanwisher & Yovel, 2006). The interaction between cognition and social functioning is complex, and this relationship is an essential place for future study (Turetsky et al., 2007).

What are emotions?

Scientists such as Paul Ekman believe there are basic emotions (fear, disgust, happiness, sadness, surprise, anger) thought to be universal across cultures (Ekman, 1992). Emotions are still highly contested in their empirical definition, the criteria to be considered an emotion, and many of their identification's cognitive and social aspects (Adolphs et al., 2019). While common sense is used amongst humans to categorize emotions, this is not a solid foundation for building an elucidated scientific theory of their beginnings. At their most basic definition, some scientists agree that emotions are functional cognitive states of the brain that describe complex behaviors (Adolphs et al., 2019). Therefore, with this theory, emotions are functional states defined by what they do rather than how they are created in the brain. However, this definition relies on groups of people reaching a consensus on what an emotion looks and feels like rather than creating an operational definition through experimentation, ensuring empirical validity (Ekman, 1992). While this route is the epicenter of many psychiatric disorders having problems integrating into society, it is not a purely objective stance.

The problem with creating a scientifically sound definition of emotion is defining boundaries for physiological responses as categorized emotions or just a part of bodily function. Heart rate or sweat production changes have no emotional meaning on their own, and they can also be associated with many different emotions. In order to find more

objective proof of emotion categorization beyond physical attributes, there must be an investigation into the brain and other brain structures (Shackman & Wager, 2019).

At the physiological response level, emotions are theorized in two camps. On the one hand, some researchers believe that each primary emotion, which is also contested, has distinct feelings, facial expressions, and autonomic activity patterns (Ekman, 1992). The other camp emphasizes differences in autonomic activity and behavior for some emotions, but they also hypothesize that there is overlap across many emotions. However, both groups and most scientists agree that neural networks in the brain oversee many emotions rather than a one-to-one isolated mechanism (Shackman & Wager, 2019).

Emotional face processing in the brain

There are many theories on how the brain processes facial expressions and emotions, but there are a few leading theories of importance. Starting broadly with the brain's ability to identify a face, the fusiform face area (FFA), located within the fusiform gyrus, is hypothesized to play a prominent role in facial recognition (Sellal, 2022). The FFA is a small region found within the inferior surface of the temporal lobe, and it has only been studied more intensely within the last 30 years (Valentine, 1988). The discovery of this brain region through functional magnetic resonance imaging (fMRI) changed the landscape of face perception from a domain-general hypothesis where one pathway operates within many processes to a domain-specific theory (Kanwisher & Yovel, 2006). This area also proved that the recognition of faces is distinct from the processing of objects. When shown faces that are inverted at 90 degrees, facial recognition is impaired within the FFA (Valentine, 1988).

With the FFA specialized for recognizing a face from another object, there are still steps missing in the pathway where the characteristics of the face are perceived. The occipital face area (OFA) is a face-selective region located on the lateral surface of the occipital lobe near the inferior occipital gyrus (IOG) (Pitcher et al., 2011). This region's neuronal response to faces has been studied through positron emission tomography (PET) and fMRI studies relating face and object perception (Steeves et al., 2009). These studies have found that OFA is often more extensive and more frequently seen in the right hemisphere (RH) than the left hemisphere (LH), which is a consistent finding with other face-selective regions as well (Pitcher et al., 2011). This structure is believed to receive neuronal input from the visual cortex and acts as the intermediary between the early visual cortex and the FFA. Also acting as a mediator between the early visual cortex and the superior temporal sulcus (STS), the OFA is particularly integral in the epicenter of facial recognition and perception pathways (Pitcher et al., 2011).

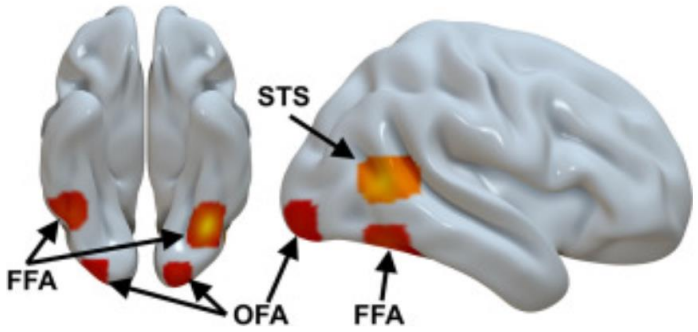


Figure 2. Inferior and Right Lateral Views of the FFA, OFA, and STS
Visual representations of the OFA and FFA in the inferior view and the FFA, OFA, and STS in the right lateral view (Barton et al., 2021).

Another vital brain region in facial expression perception is the STS. The STS plays a larger role in other cognitive pathways, including language, audio-visual integration, and motion perception (Iidaka, 2012). The posterior portion of the STS is most closely associated with the core networks for facial expression and eye-gaze shifts (Schobert et al., 2018). Unlike the FFA and OFA, the STS is hypothesized to have a specialty in processing facial information related to biological motion. Meanwhile, the OFA and FFA are associated with invariant aspects of various facial expressions and identifiers (Pitcher et al., 2011).

While these brain regions have been identified as having different specialties within facial processing, another important aspect is how they interact within a more extensive network and their time course when a facial stimulus is presented. Studies using magnetoencephalography (MEG) found that identifying a face and its subsequent emotion occurred in stages of activation after the onset of the stimulus, correlating with activation of different brain regions in a hierarchical order (Streit et al., 2003). Several studies have shown that OFA and FFA are more involved in individual facial identification, whereas STS is more engaged in the social context of faces. Emotions are learned culturally, so learned sources are more likely to influence the STS (Liu et al., 2010). Further elucidating the functional differences between FFA and OFA, the FFA was found to have the strongest activation when participants were discerning between faces with differing facial aspects (Gauthier et al., 2000).

Electroencephalography

With many different instruments available for recording and studying cortical activity, the electroencephalogram (EEG) is the most widely used. EEGs are one of the best mediums to investigate and interpret brain activity and dysregulation, and they were invented in the last century (Sur & Sinha, 2009). This invention offered the opportunity to gain insight into the brain's electrical activity in a noninvasive manner. It is also relatively inexpensive and more portable than other devices such as fMRI, MEG, and PET (Buzsáki et al., 2012). In contrast to other imaging modalities, EEG can detect discrete temporal changes in neuronal activity with millisecond-precision. It can be combined with other imaging modalities to enhance its spatial capability, making it highly versatile in research settings.

Neuronal brain activity creates transmembrane currents that can be measured externally on the scalp. The brain has many different electrical current contributors, including calcium and sodium spikes and synaptic transmembrane current (Buzsáki et al., 2012). The most important electrical measurement comes from the dendrites of pyramidal neurons during the electron flow from synaptic excitation (Teplan, 2002). Together, these sources generate a potential, and the difference in potentials across parts of the brain creates electric fields. The fields can be recorded by placing external electrodes on the scalp to interpret neuronal communication (Buzsáki et al., 2012). The advantage of gaining insight into brain activity from electrical field recordings is that the biophysics of these interactions is well understood. Therefore, the mathematical models that have been developed are more reliable (Oostenveld & Praamstra, 2001).

It is important to note that these potential readings are interpreted from a reference electrode on the scalp, typically near the center of the top of the head (Jackson & Bolger, 2014). In addition to the reference electrode from which all active electrode potentials are derived, there is also a grounding electrode. The ground electrode provides the reference and active electrodes with a baseline grounding signal counter-phase to the voltages in both the reference and active electrodes (Teplan, 2002).

With the electrodes of EEG caps sitting externally, the electrical activity recorded comes mainly from outer cortical structures. Therefore, the EEG cannot provide much insight into deeper subcortical structures, such as the limbic or hypothalamic systems (Jackson & Bolger, 2014). Further analysis, with the help of fMRI imaging, can help pinpoint activity in brain regions deeper than the outer cortical layer. However, this has only been possible with the standardization of electrode placement (Oostenveld & Praamstra, 2001).

EEGs are administered by placing electrodes on the scalp, usually through a snug-fitting webbed cap. The resistance between the electrode and the electrical field readings on the scalp must be low, so an electrolyte bridge through gel or a salt solution is typically applied to each electrode (SAAMHS Administration, 2016). In the early days of EEG recordings, it became clear that there was a need for a standard placement of electrodes to correctly identify which brain regions are producing different kinds of electrical activity (Oostenveld & Praamstra, 2001). In the late 1950s, the International Federation in Electroencephalography and Clinical Neurophysiology created a standardization called the 10-20 electrode placement system (Teplan, 2002). This system

divided the head into proportional distances from well-known skull landmarks, such as nasion and preauricular points. With a proportional system, the distances between electrodes could be increased or decreased to accommodate individual heads' different shapes and sizes (Teplan, 2002). The system labeled electrodes according to four different brain regions: F (frontal), C (central), P (posterior), T (temporal), and O (occipital). The left side of the head is labeled with odd numbers, the right side corresponds to even numbers, and the subscript Z replaces numbers along the midline of the skull. This montage is still used in modern EEGs, often with denser 128 or 256 electrode caps, providing more spatial awareness of brain region activity (Teplan, 2002).

Event Related Potential

A time-locked EEG or event-related potential (ERP) can help bridge the relationship of neural activity to sensory and cognitive processes. ERPs are small changes in voltage (typically measured in microvolts) produced by specific brain areas as a time-locked response to a stimulus. They allow for a noninvasive mechanism to study cognitive or sensory processes before an individual is even aware of their response (Sur & Sinha, 2009). The time-locked event can be evoked from different types of stimuli. It could be external stimuli (i.e., hearing sounds or seeing faces), a behavioral response (i.e., button press, speech, or motor movement), or it could be an internal cognitive process (i.e., decision-making) (Sur & Sinha, 2009).

In the brain, it is theorized that ERPs are the summed activity of postsynaptic potentials from aligned cortical pyramidal neurons that fire simultaneously (Sur & Sinha, 2009). In contrast to the ongoing EEG activity, ERP amplitudes are typically smaller, so

they are averaged across multiple stimulus presentations (“trials”) and groups of electrodes to be more thoroughly elucidated from background noise (Teplan, 2002). However, ERPs offer great insight into the discrete temporal characteristics of information processes from bottom-up and top-down mechanisms.

In humans, the waveform of an ERP is divided into two stages (Sur & Sinha, 2009). The early waves peak within the first 100-200 milliseconds and are more sensory, dependent on the physical aspects of the provided stimulus. The second stage is after the early waves and pertains to an individual's cognitive evaluation of the stimulus. However, it is essential to note that this evaluation occurs before the person is even aware of their judgment. In the emotional expression processing of a face, the early waves typically correspond to identifying that the stimulus is a human face through physical aspects (or early initial encoding of information), and the later waves reflect the identification of the emotion and an individual's initial cognitive response to that emotion (Sur & Sinha, 2009).

A face is detected within a visual field rapidly, and a familiar face is registered even faster by the brain, all happening within a few hundred milliseconds. Within this period, the brain will garner a swath of information to categorize an individual, including facial expressions and connected emotions (Caharel et al., 2005). While a behavioral task alone can assess what a person has perceived, an EEG can decipher the dynamic cognitive processing of the brain in real-time. The information gathered by an EEG during a behavioral task can produce a time course of facial processing from the onset of

visual stimulation to the behavioral response hundreds of milliseconds later (Rossion & Jacques, 2012).

Many different peaks can be seen in response to various sensory, cognitive, or motor stimuli, and their name also varies based on their approximate latency and amplitude. Each peak is labeled with either "P" or "N," identifying if it is a positive- or negative-going wave, respectively. The letter is then followed by the number corresponding to the peak latency. This aspect varies across sources because latency can vary from group to group (Sur & Sinha, 2009). However, ERPs are highly replicable across studies and populations, allowing for such categorizations to support communication and consensus-building between researchers.

P1 or P100 is a positive deflection that peaks around 80-120 msec after the stimulus. Most studies suggest this component may reflect the sensation-processing behavior of an individual (Sur & Sinha, 2009). More specifically, this component is hypothesized to represent early-stage visual information processing. The best readings for P100 are measured over the occipital cortex, specifically near the midline (Shah et al., 2018).

In contrast, N170 is a negatively deflected peak found 150-200 msec after stimulus onset. It is observed mainly when a difference is perceived in the stimulus (Sur & Sinha, 2009). This component is one of the most well-studied in visual ERPs, mainly because of its tie to a large deflection when human faces are the presented stimulus (Marzi & Viggiano, 2007). N170 is best measured over the occipitotemporal region, with a more prominent peak in the right than left hemisphere (Shah et al., 2018). This is

hypothesized to be due to the larger STS brain region in the right brain region (Schobert et al., 2018).

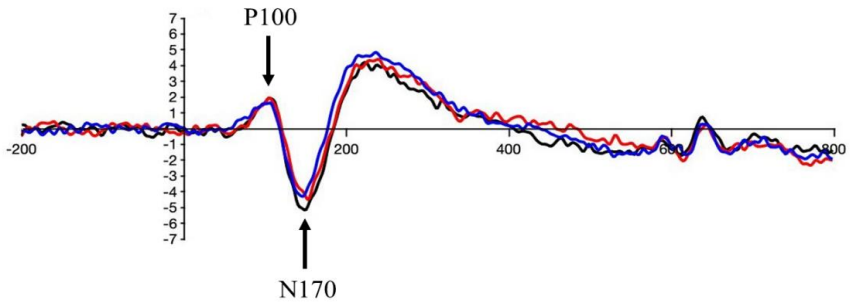


Figure 3. Example of an ERP with Labeled Components
An example graph from the study highlights the two main ERP components: the first positive peak (P100) and the first negative peak (N170). Time is shown along the x-axis in milliseconds, while response amplitude is shown along the y-axis in microvolts.

Components of an ERP present after 300 ms are thought to be related to higher-order cognitive processes, separating them from the early sensory amplitudes (Shah et al., 2018). P300, which occurs around 300 ms after stimulus onset, reflects discrimination and recognition of different stimuli (Teplan, 2002). P300 is a convergence of attention to a stimulus and updating memory for future recognition of the same image. The deflection's latency also depends on the speed of cognition to classify a stimulus; therefore, it has been shown to be smaller for familiar objects (Teplan, 2002). Shorter latencies have also been correlated with increased cognitive abilities and performance about longer latencies (Sur & Sinha, 2009). Regarding the amplitude of the wave, with the relationship to attention, the P300 wave is larger with increased attention to the presented stimulus (Sur & Sinha, 2009).

Emotional Face Processing and ERPs

Determining the emotional expression of a person's face has been traditionally thought of as a higher-order cognitive process (Turetsky et al., 2007). The processing of a face and its emotion are independent processes, sensory and structural processing, and then cognitive processing of the emotion (Caharel et al., 2005). In early studies, "facial affect perception" (FAP) was thought to be associated only with ERP amplitudes occurring 400 – 600 ms post-stimulus (Turetsky et al., 2007). However, evidence is mounting that FAP happens in the 170 – 250 ms range after structural encoding of the face stimulus (Turetsky et al., 2007). Together, both structural encoding and higher-order cognitive processing are well-defined components that are consistent across psychiatric disorders and neurotypical individuals. Regardless of deficits or abnormalities in emotional face processing, these robust components will be evident in the ERP (Caharel et al., 2005).

More recent studies have taken this theory further to demonstrate that different emotions can manipulate an ERP response. Most notably, adverse affects, such as sadness or anger, correlate to a more robust response than neutral facial expressions (Caharel et al., 2005). P100, a sensory-based ERP component, is thought to be less affected by different facial expression stimuli and deals more with recognizing a face versus an object (Shah et al., 2018). Most research has found a larger P100 amplitude when a face is presented as a stimulus rather than an object (Shah et al., 2018). On the other hand, studies have mixed results on the effect of emotional faces on N170 amplitudes, with many finding a difference between amplitudes of neutral versus

emotional faces (Turetsky et al., 2007). However, the effect of different emotions, such as happiness, sadness, or anger, is poorly elucidated. These inconsistencies are likely due to the physical properties of the presented facial stimulus (i.e., brightness, contrast) (Shah et al., 2018), demonstrating the importance of controlling for perceptual features when designing an ERP task.

Scales of Social Functioning and Psychosis Symptoms

When EEGs and other tests are administered, there is often a clinical scale component to relate to emotional task results. These quantifiable scales measure levels of social and global impairment or current symptoms, bringing in another piece of the puzzle to how psychosis affects daily life (Addington et al., 2008).

The Social Functioning Scale (SFS) is a clinical questionnaire used to assess the social functioning of patients with psychotic disorders (Birchwood et al., 1990). Within the SFS are seven sub-scores: withdrawal/social engagement, interpersonal communication, independence-performance, independence-confidence, recreation, prosocial [activity], and employment/occupation, as well as the overall total (Addington et al., 2008). Each sub-score contains different items, rated in various ways (i.e., rating 0 – 3, yes/no answers, Likert scales, or numeric answers) (Lecomte et al., 2014). While the scale covers many aspects of social functioning in detail, it was created in 1990 and does not account for some aspects of modern communication. The SFS does not account for social activity through social media, online forums, videogame chatrooms, or chatting with people on cell phones (Lecomte et al., 2014). While these technologies are no

replacement for in-person communication and friendships, there must be an acknowledgment of these online social interactions.

The Global Assessment of Functioning (GAF; Axis 5 of DSM-IV-TR) is another tool used to assess an individual's ability to function in daily life. On a scale from 1 to 100, this score reflects a patient's overall functioning from the previous month and is rated by the diagnosing clinician. The criteria for this score are based on the patient's clinical, social, and professional state from the prior 30 days (Lecomte et al., 2014).

The Positive and Negative Syndrome Scale (PANSS), while not an important scale for determining social functioning, is an integral part of schizophrenia and psychosis research. The PANSS was published in 1987 by Stanley Kay, Lewis Opler, and Abraham Fiszbein, and it is a scale used for measuring the severity of schizophrenia symptoms, and it also contains some measures related to social functioning (Kay et al., 1987). It is a 30-item measure that adapted items from the Brief Psychiatric Rating Scale (BPRS) and the Psychology Rating Schedule (PRS). The PANSS has a 7 -point rating scale: 1 = absent, 2 = minimal, 3 = mild, 4 = moderate, 5 = moderate-severe, 6 = severe, 7 = extreme. The final score of the PANSS is a composite of all the items in the three subscales: positive scale, negative scale, and general psychopathology scale (Kay et al., 1987). The PANSS is typically administered in person, with the observation of a patient's physical demeanor offering further insight into their symptoms beyond their actual answers to the questions (Kay et al., 1987).

SPECIFIC AIMS / OBJECTIVES

There are many hypotheses into why patients with psychosis disorders, on average, have impaired social functioning and lower quality of life than their neurotypical counterparts. We investigated two ERP components that could be used to explain this deficit. ERPs are time-locked responses to a stimulus, and observed deficits could be attributed to an individual's processing dysfunction. The research into chronic psychosis subjects and their associated emotional face-processing deficits is well elucidated. However, there have been very few studies on ECP individuals and whether ERP deficits are present early on or develop later in the course of illness. By understanding the role of P100 and N170 deficits in ECP, researchers could use them further to assess the associated brain regions as potential therapeutic targets or diagnostic biomarkers.

This study has two main objectives. The first is to analyze differences between ECP and HC participants in their ability to recognize and process emotional face expressions. We will investigate using EEG data to analyze group differences in average ERP measurements, specifically in P100 and N170 amplitudes. This study will collect average P100 and N170 amplitudes from happy, sad, and neutral face paradigms for all subjects. We hypothesize that ECP participants will show impaired recognition of faces and impaired processing of emotional facial expressions, represented by smaller P100 and N170 amplitudes compared to HCs.

The second objective is to study the relationship between social functioning, antipsychotic use, and emotional face processing in the ECP and HC participants. We will investigate this by correlating the P100 and N170 average amplitudes with the total

score from the SFS for each subject. We will then compare the impact of antipsychotic use and chlorpromazine (CPZ) equivalent dosing on SFS totals and P100 and N170 amplitudes. We hypothesize that ECP individuals will display a relationship between decreased SFS totals and decreased P100 and N170 amplitudes. We also hypothesize that antipsychotic use will not have a significant effect on SFS total or P100 and N170 amplitudes.

METHODS

Participants

This study comprises 28 participants, 18 individuals with ECP and 10 non-psychiatric controls. The diagnoses amongst the ECP cohort included: bipolar I disorder (BPD I) with psychotic features (n = 2), schizophrenia (n = 4), schizoaffective disorder (SZA) (n = 7), and other psychosis disorder (n = 5). Participants were recruited from ongoing studies of ECP and Beth Israel Deaconess Medical Center's (BIDMC) ECP clinic (ASPIRE) in Boston, Massachusetts. All participants provided informed consent, and the Institutional Review Board of BIDMC approved the protocol.

All ECP participants met the criteria for an idiopathic psychotic disorder based on the Structured Clinical Interview for DSM-V disorders.[42] ECP participants were defined as being within five years of their diagnosis with a psychotic disorder. Healthy controls (HC) are screened for no family or personal history of bipolar, psychosis, or recurrent depression disorders. To quantify psychosis symptoms and social functioning, the PANSS and SFS were administered to all ECP participants, and the SFS was administered to the HCs.

Table 2. **Table of Participant Demographics**

	Overall	Control	ECP
	28	10	18
Sex (%)			
Female	17 (63.0)	5 (50.0)	12 (70.6)
Male	10 (37.0)	5 (50.0)	5 (29.4)
Race (%)			
Asian, East Southeast	2 (7.1)	1 (10.0)	1 (5.6)
Asian, Western	1 (3.6)	0 (0.0)	1 (5.6)
Black or AA	2 (7.1)	0 (0.0)	2 (11.1)
Multi-Racial	4 (14.3)	1 (10.0)	3 (16.7)
White	19 (67.9)	8 (80.0)	11 (61.1)
Group Diagnosis (%)			
BPD I w/ psych	2 (7.1)	0 (0.0)	2 (11.1)
HC	10 (35.7)	10 (100.0)	0 (0.0)
Psychosis	5 (17.9)	0 (0.0)	5 (27.8)
Schizophrenia	4 (14.3)	0 (0.0)	4 (22.2)
SZA	7 (25.0)	0 (0.0)	7 (38.9)
Mean Age (SD)	24.11 (5.23)	25.4 (5.52)	23.39 (5.08)

Emotional Face Task and EEG Acquisition

Each participant was fitted with the proper-sized EEG cap from Electrical Geodesics, Inc. (EGI). The 128-channel Hydrocel Geodesic Sensor Net was soaked in an electrolyte solution for five minutes before being placed on the participant's head. This helped to form an electrolyte bridge between the electrode and the electrical readings on the scalp. To properly place the EEG cap on each person's head, the vertex of the head

was identified by finding a cross between the halfway point of the preauricular points and the halfway point of the nasion and the occipital region of the head. This cross is where the reference electrode is centered to align all participants' caps so that similar brain regions are recorded by the proper electrodes on the map. In an effort to minimize EEG background noise, the participant completed the emotional face task in a sound and light-shielded room, and all electrode impedances were minimized to below 50kΩ.

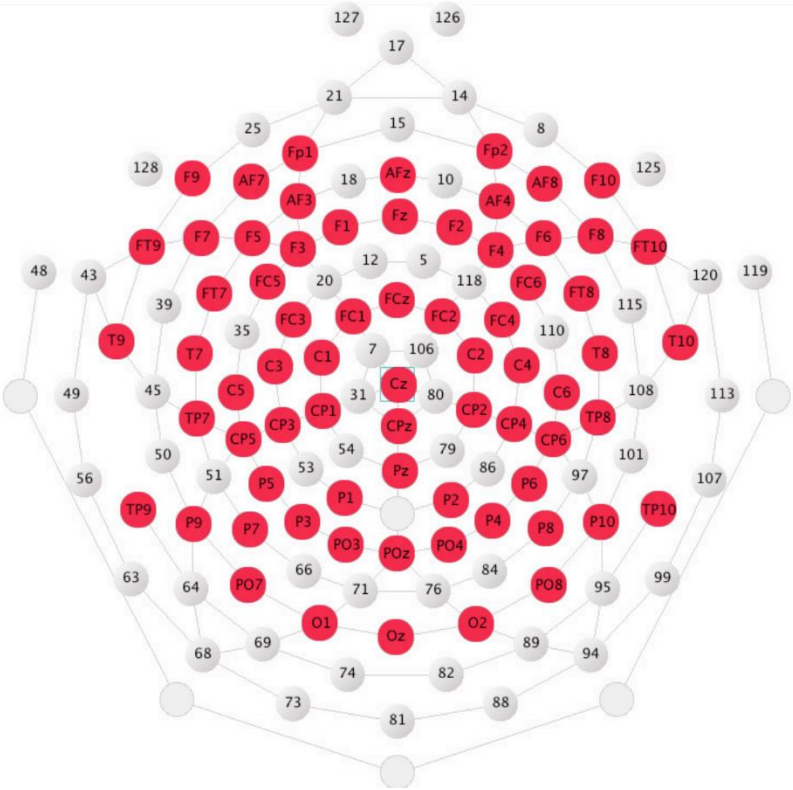


Figure 4. Layout of the Hydrocel Geodesic 128-channel EEG cap
Electrode layout depicting the 10-10 equivalent electrodes (red) overlayed on the expansion into the 128-electrode EEG cap (gray) (Luu and Ferree 2005). Electrode 17 is placed above the nose, 81 in the back of the head, and 48/119 are on the left and right, respectively.

During the EEG, all participants were shown static human facial stimuli from the NimStim set of facial expressions. Neutral, sad, and happy faces from male and female-presenting actors were used. The expressions are depicted by twenty actors, totaling 120 images with 40 images per emotion. Stimuli were equalized in brightness and contrast, and the images were viewed in a random order.

Figure 5. Example Faces from NimStim set of Emotional Faces
Examples of the sad, neutral, and happy faces used in the emotional face task taken from the NimStim set of facial expressions (Tottenham et al., 2019).

The static face paradigm was presented using Neurobehavioral Systems (NBS) software. For each image, participants viewed the emotional stimuli for 1000 ms, then proceeded by an inter-stimulus interval (ISI). During the ISI, the participants identify the emotion of the previous image by pressing one of the three buttons.

Initial EEG Processing

Preprocessing of the EEG data followed previously published methods.[49] The initial raw data was inspected manually for faulty sensor recordings and interpolated in EGI Tools with no more than 6 (5% of total) channels interpolated for each recording.

The data was also transformed into an average reference and filtered from 0.1 to 100 Hz with a 60 Hz notch filter.

Extraneous artifacts such as eye blinks, heart rate and muscle tension were removed or minimized using the ICA toolbox in EEGlab from Matlab. Through this component removal, no more than 7 ICA artifacts were removed per subject. This software was also used to downsample the data to 500 Hz, and epochs with amplitudes greater or less than 120 μV at a sensor were thrown out. At least 25 trials were included in each subject's ERP, per emotional condition, and the number of trials in each did not significantly differ, with an average of 36.09 trials in the happy condition, 36.76 trials in the sad condition, and 36.77 trials in the neutral condition.

ERP Processing and Analysis

Similar to previous studies, the sensor data was downsized to electrode clusters where the P100 and N170 amplitude responses were maximal. Since this study used a denser 128-sensor EEG cap versus other studies that used 64-sensor caps, more electrodes were included in the averaging for both components to give a more accurate average amplitude for the brain region. P100 sensors were chosen from around the midline of the occipital region on the scalp surrounding O1, O2, and Oz electrodes (66, O1, 71, 74, Oz, 76, 82, O2, 84). N170 sensors were grouped into two clusters centered around the P7 (50, P5, P7, 59, P9) and P8 (91, P10, P8, P6, 101) sensors, and they were also combined for an overall N170 amplitude average. ERPs were constructed from 200 ms pre-stimulus to 800 ms post-stimulus, and the two components' average amplitudes (P100 and N170) were extracted at 80 – 120 ms and 150 – 200 ms, respectively. The

average amplitude between these latencies was used to find the amplitude of each component for every subject, readying the data for statistical analyses.

R (version 4.3.2) was used to conduct independent t-tests to assess the differences in P100 and N170 amplitudes across the emotional conditions between the ECP and HC groups. Cohen's d standardized mean difference with a 95% confidence interval was also conducted to determine effect size for these groups across conditions. A significant p-value was designated as less than 0.05 for these tests.

RESULTS

Group v P100 and N170 Amplitudes

After conducting independent t-tests on P100 and N170 averaged amplitudes between the ECP and HC groups, there was a significant difference between amplitude and group in one emotional condition. In the sad condition, N170 average amplitudes between ECPs and HCs differed significantly ($p = 0.032$, 95% CI = [-0.06, 1.54]) with a large Cohen's d effect size estimate ($d = 0.75$). In the neutral condition, the average N170 amplitudes were slightly above the significance threshold (see Table 3 below). There was no significant difference in P100 amplitudes between groups across any of the emotional conditions. Cohen's d effects sizes for most emotional conditions across both ERP components were large. There was also not a significant effect of facial expression on the P100 or N170 ($F(df1,df2) = 1.283$, $p = 0.286$) or group by face expression interaction ($F(df1,df2) = 1.934$, $p = 0.155$).

Though the two groups did not differ significantly in the happy or neural expression conditions, N170 amplitudes were slightly larger in the ECP group than the HC group (HC mean = 0.54, sd = 1.72; ECP mean = -1.09, sd = 3.03). In the p100 component, HC amplitudes were higher than the ECP group (HC mean = 2.64, sd = 2.03; ECP mean = 1.433, sd = 2.85).

Table 3. Table of statistical tests measuring group differences in P100 and N170 Amplitudes Across Emotional Conditions
Measurements of EP v HC differences across happy, sad, and neutral conditions for P100 and N170 amplitudes using p-values and Cohen's d effect size with 95% CI.

	t	***df***	***p***	***d***	**95% CI**
P100 Happy	0.89	24.11	0.383	0.32	[-0.46, 1.09]
P100 Neutral	0.86	19.53	0.401	0.33	[-0.45, 1.11]
P100 Sad	1.68	21.61	0.108	0.63	[-0.17, 1.41]
N170 Happy	1.35	25.15	0.188	0.47	[-0.31, 1.25]
N170 Sad	2.27	25.88	.032*	0.75	[-0.06, 1.54]
N170 Neutral	1.77	25.99	0.089	0.59	[-0.20, 1.38]

Boxplots comparing the emotional conditions with the P100 and N170 average amplitudes were created to display the differences between the groups, particularly in the statistically significant N170 sad condition.

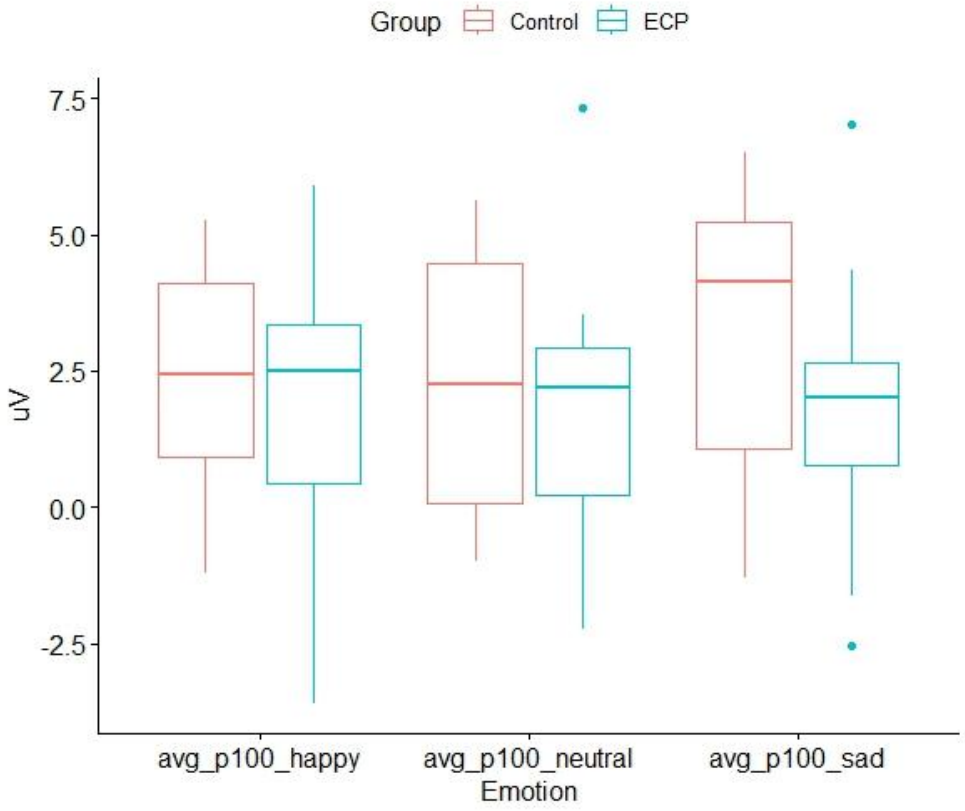


Figure 6. Group Differences in P100 Amplitudes Across All Emotional Conditions
Boxplot depicting the average amplitude of P100 (in μV) in the happy, sad, and neutral conditions for HC (orange) and ECP (blue) participants.

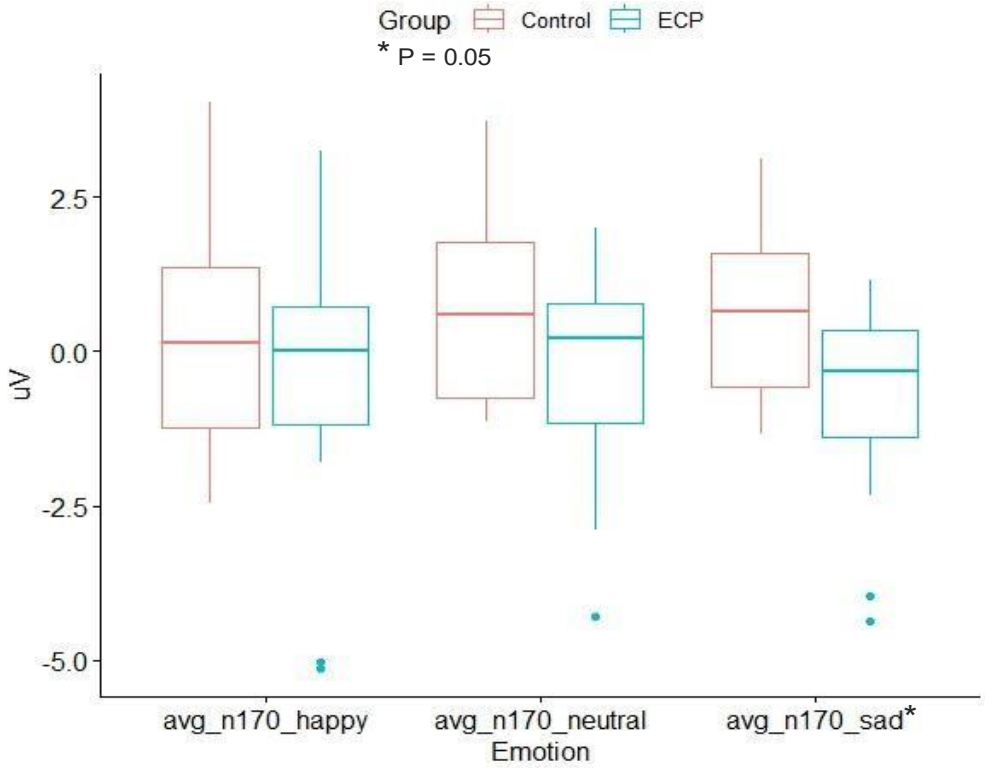


Figure 7. Group Differences in N170 Amplitudes Across All Emotional Conditions
Boxplot depicting the average amplitude of N170 (in µV) in the happy, sad, and neutral conditions for HC (orange) and ECP (blue) participants.

SFS Total v Group and N170/P100 Amplitudes

Group Differences in SFS Total

SFS total score was significantly higher in the HC group v ECP participants ($p = 0.0055$). A boxplot was created to compare the two groups.

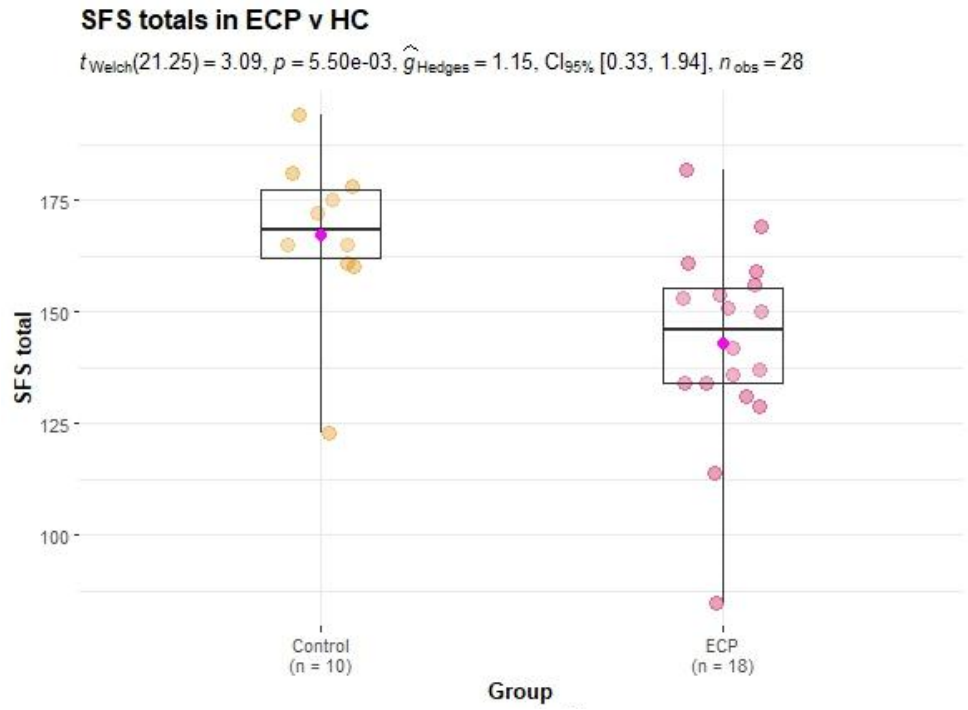


Figure 8. Graph of SFS totals ECP v HC
Boxplot depicting differences in SFS totals between HC (yellow) and ECP (pink) participants.

ERP Amplitude Differences v SFS Total

SFS total score was not significantly correlated with the average amplitude of P100 or N170 in any emotional condition between groups (p = 0.41). Scatterplots were created to illustrate how spread out the data was for both groups across all conditions and ERP components.

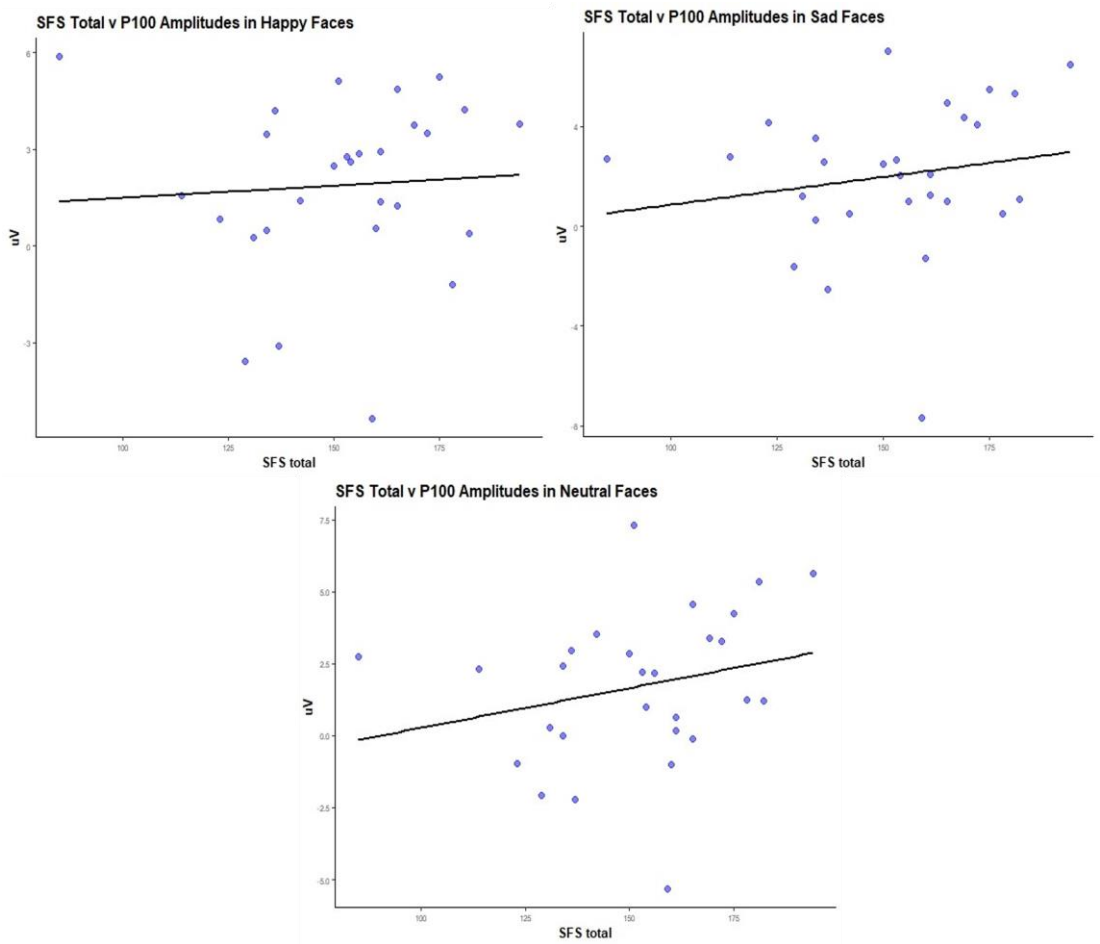


Figure 9. SFS total v P100 Amplitudes in Happy, Sad, and Neutral Conditions
Scatterplots illustrating the relationship between SFS total (x-axis) and P100 amplitudes (y axis; in µV) for all participants in the happy, sad, and neutral expression conditions.

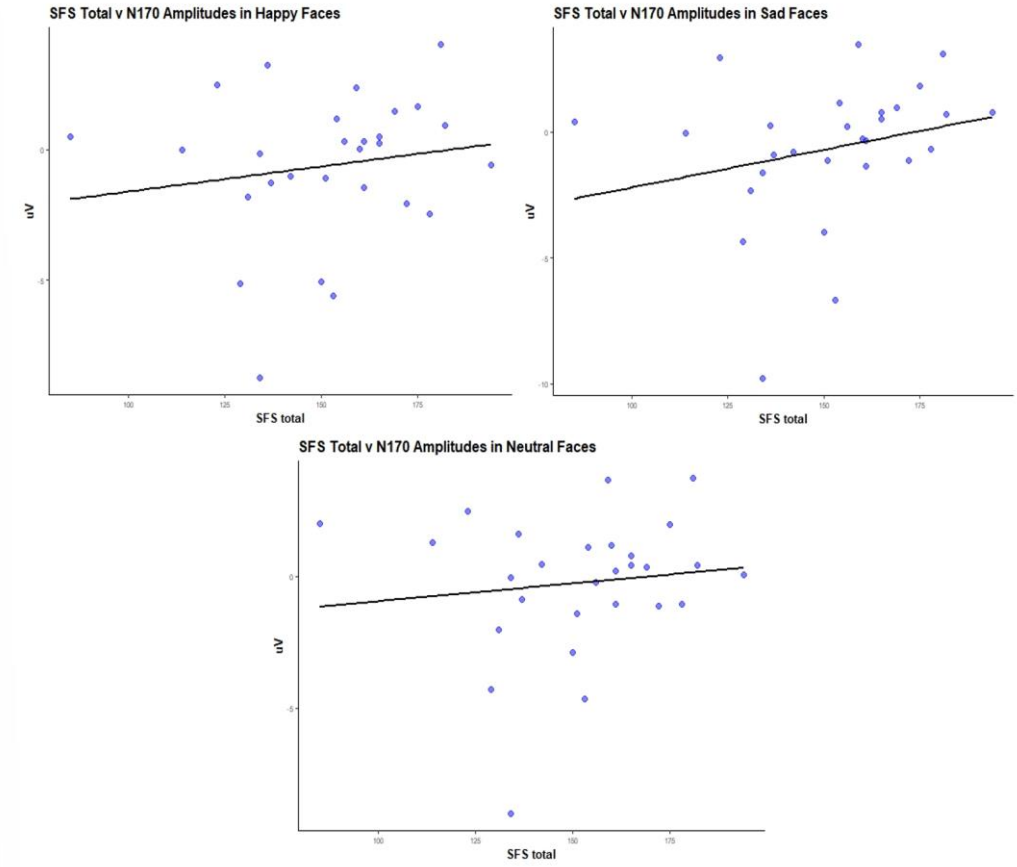


Figure 10. SFS total v N170 Amplitudes in Happy, Sad, and Neutral Conditions
Scatterplots illustrating the relationship between SFS total (x-axis) and N170 amplitudes (y-axis; in μV) for all participants in the happy, sad, and neutral expression conditions.

Antipsychotic Use v SFS Total and ERP Component Amplitudes

Antipsychotic use (CPZ) v SFS total in ECP participants were not significantly correlated ($p = 0.343$, 95% CI = [-0.54, 1.38]). In addition, there was no statistical significance of antipsychotic use on average P100 or N170 amplitudes across the emotional conditions in ECP subjects.

Table 4. Table of statistical tests measuring group differences in P100 and N170 Amplitudes Across Emotional Conditions

Measurements of differences in antipsychotic use across happy, sad, and neutral conditions for P100 and N170 average amplitudes using p-values and Cohen's d-effect size with 95% CI.

	t	***df***	***p***	***d***	**95% CI**
P100 Happy	-0.93	8.84	0.379	-0.5	[-1.46, 0.47]
P100 Neutral	-0.35	7.1	0.739	-0.2	[-1.15, 0.75]
P100 Sad	-0.46	7.02	0.657	-0.27	[-1.22, 0.69]
N170 Happy	0.44	15.84	0.666	0.2	[-0.76, 1.14]
N170 Sad	0.85	15.76	0.41	0.38	[-0.58, 1.33]
N170 Neutral	0.43	15.42	0.673	0.19	[-0.76, 1.14]
SFS total	0.98	16	0.343	0.42	[-0.54, 1.38]

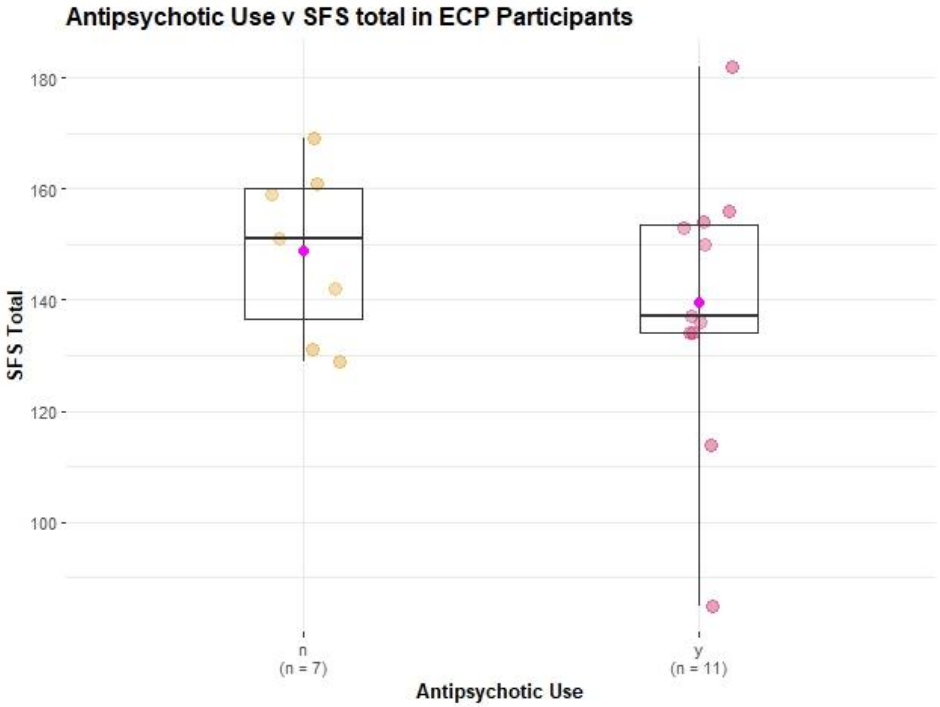


Figure 11. Antipsychotic Use v SFS Total in ECP Participants
Boxplot illustrates differences in antipsychotic use vs. SFS total within the ECP participants group: No (yellow) and yes (pink).

DISCUSSION

This thesis analyzed two different aims for ECP individuals and their ability to recognize emotional faces. The first hypothesis focused on group differences in P100 and N170 amplitudes across emotional conditions, and the results contrast some of the literature in providing a statistically significant increase in N170 ECP amplitudes in the sad condition. While this result contrasts prior research into emotional face recognition in chronic psychosis as well as some of the early literature on CHR patients (Osborne et al. 2021), it also highlights the work that still needs to be done in ECP.

The results from the first aim provide preliminary insight into the cortical processing of emotionally relevant stimuli in ECP and its relationship with social functioning. Furthermore, examining the potential effect of antipsychotic use also tested if antipsychotic medications could account for or compensate for ERP deficits. Results suggested that early processing of sad faces (N170) is impaired in ECP, but overall, results did not show substantial support for face-evoked ERP abnormalities in ECP.

Concerning the second aim, SFS total score was not significantly associated with group differences in P100 or N170 amplitudes, suggesting that other neural processes could be more impactful on this aspect of behavior. There are so many facets to the social functioning scale that lie outside of FAP. With SFS total scores already lower in ECP patients than HC, there may be other areas that cause more of an effect than being able to visually process emotional content in a face. Other factors could include understanding verbal communication and body language, socioeconomic factors, as well as influence from the after effects of the COVID-19 pandemic. Global health concerns and reduced

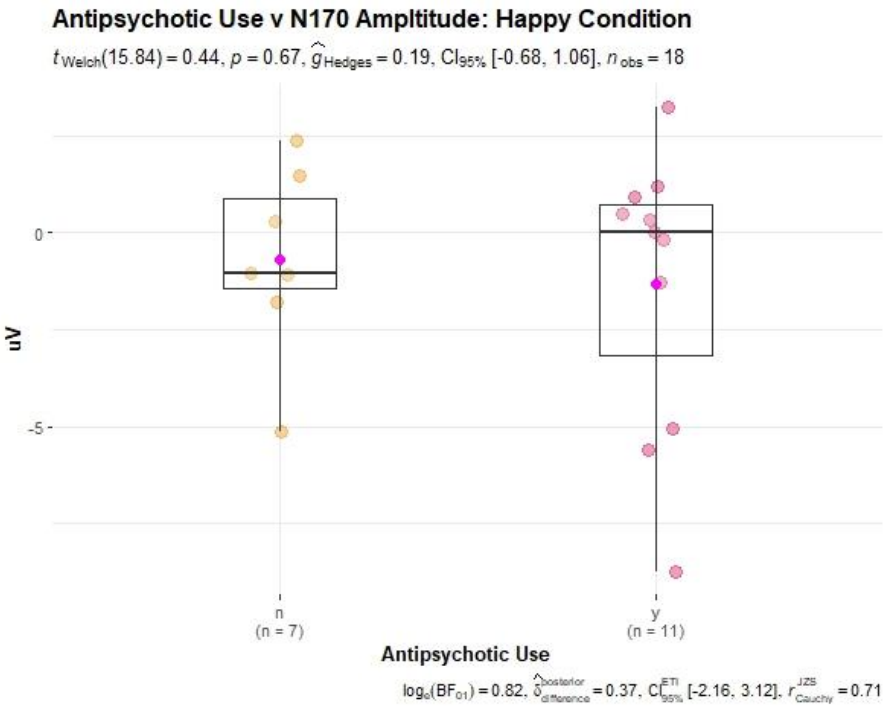
socialization opportunities could have an impact on SFS scores. As previously stated, virtual socialization is not included in the SFS, so the total score may not reflect the full breadth of community an individual has cultivated in a post-COVID society.

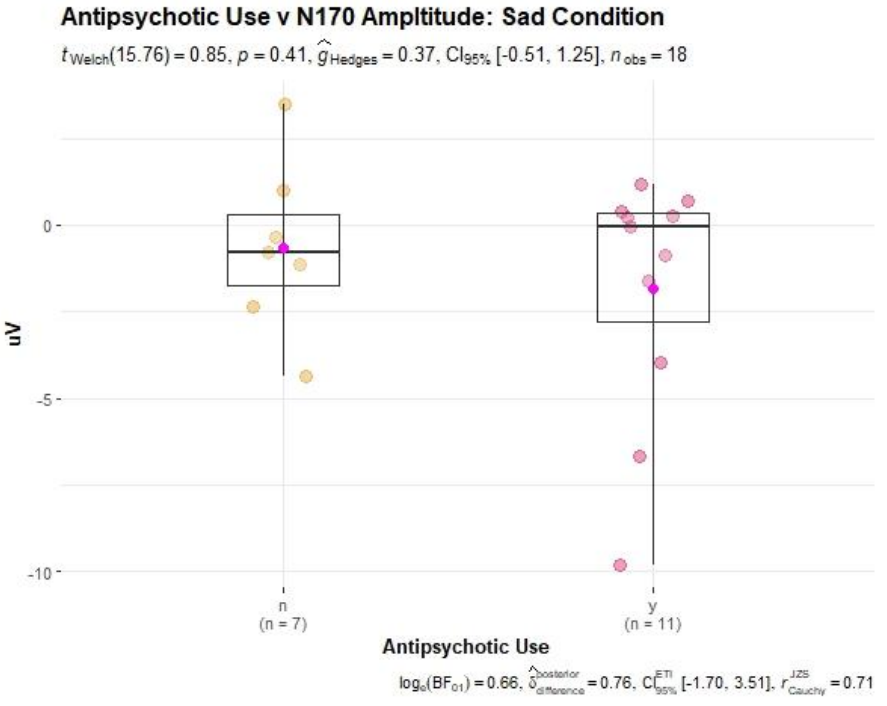
Limitations

There are a few limitations to consider with this study. The sample size is small, with the total study sample consisting of 28 participants and the subgroups containing less than 20 people. Therefore, the statistical power to detect P100 and N170 amplitude differences between groups and the emotional conditions is low. In order to properly power the t-tests, each group would need 31 people (N170 ES = 0.64) (McCleery et al., 2015). The error rate also increases in a small data sample, possibly leading to incorrect or slightly skewed p-values. Therefore, the power of this study to be extrapolated to the larger ECP community is lessened. However, this study offers preliminary insight into neural processing in this group, and data collection is ongoing.

Similar to the small sample group size, only three emotional expressions (happy, sad, neutral) were chosen out of all possible emotional expressions (disgust, anger, fear, surprise). While this study can offer results describing deficits in these specific emotions, the limited emotion subgroups impair the ability to ascribe this data as general emotional face deficits. Furthermore, emotional face perception deficits in ECP could be more specific to emotions not included in this study. Prior studies found significant impairments in N170 in chronic psychosis populations for fearful, angry, and ashamed facial expressions (McCleery et al., 2015).

The effect of antipsychotics on social functioning and emotional face processing has mixed support in prior research (Hempel et al., 2008). Like other medications, antipsychotics can have different effects on every individual, and their effectiveness in treating psychosis symptoms also may differ, especially when combined with other medications. Also, medication adherence could also affect the outcome if some participants do not take their pills regularly but self-report that they are compliant. Future studies could look at the interactions between different medications and their combined effects on emotional face recognition or test neural processing in unmedicated populations to further examine these possibilities.


Antipsychotic Use v N170 Ampltitude: Happy Condition
$t_{Welch}(15.84) = 0.44$, $p = 0.67$, $\hat{g}_{Hedges} = 0.19$, $CI_{95\%}$ [-0.68, 1.06], $n_{obs} = 18$
uV
0
-5
n
(n = 7)
y
(n = 11)
Antipsychotic Use
$\log_e(BF_{01}) = 0.82$, $\hat{\delta}^{posterior}_{difference} = 0.37$, $CI^{ETI}_{95\%}$ [-2.16, 3.12], $r^{JZS}_{Cauchy} = 0.71$


Antipsychotic Use v N170 Ampltitude: Sad Condition
$t_{Welch}(15.76) = 0.85$, $p = 0.41$, $\hat{g}_{Hedges} = 0.37$, $CI_{95\%}$ [-0.51, 1.25], $n_{obs} = 18$
uV
0
-5
-10
n
(n = 7)
y
(n = 11)
Antipsychotic Use
$\log_e(BF_{01}) = 0.66$, $\hat{\delta}^{posterior}_{difference} = 0.76$, $CI^{ETI}_{95\%}$ [-1.70, 3.51], $r^{JZS}_{Cauchy} = 0.71$

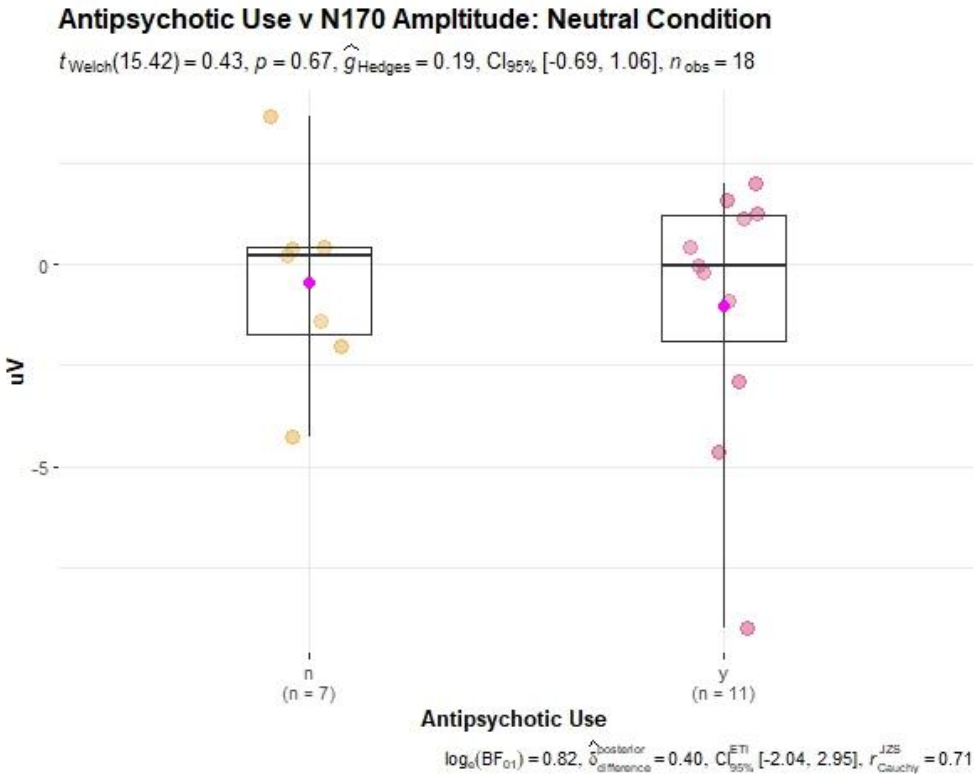
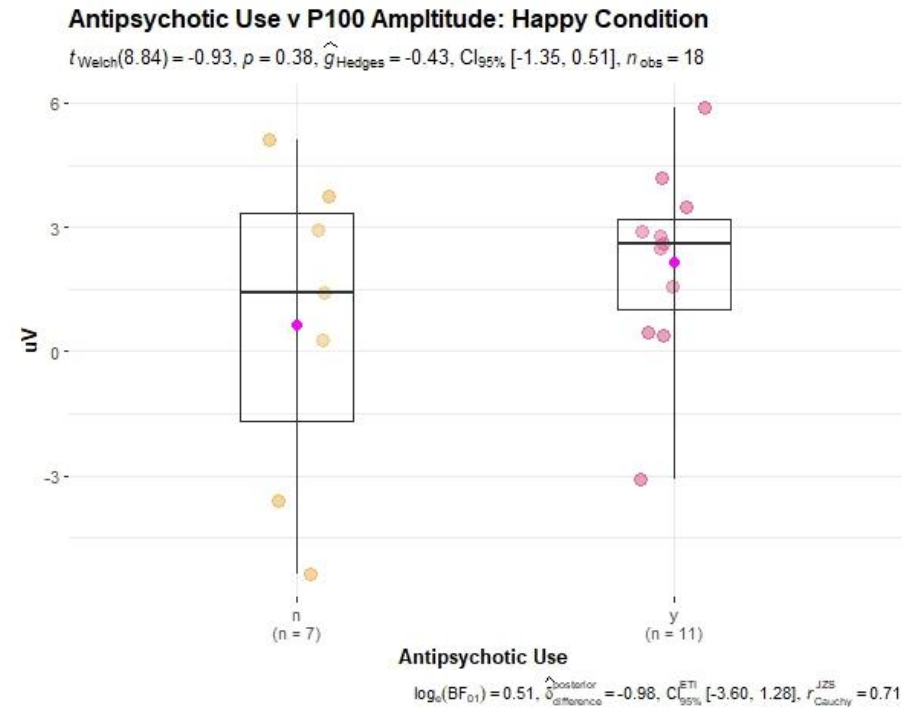
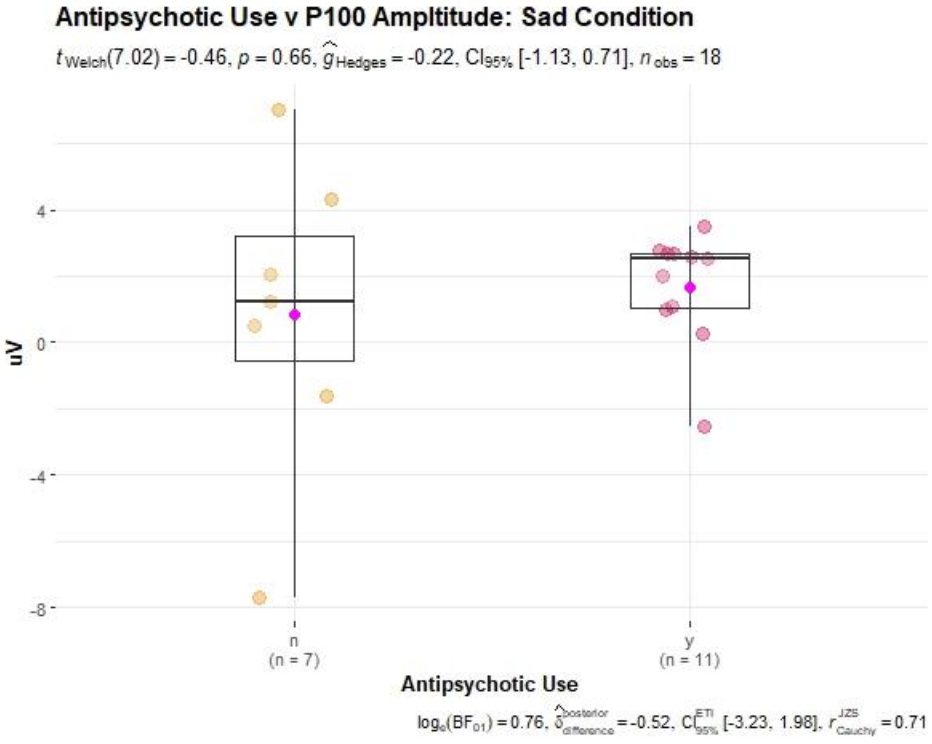


Figure 12. Antipsychotic Use v N170 Amplitude in All Emotional Conditions
Boxplots depicting the difference in antipsychotic use (No = yellow, yes = pink) in the ECP group versus the change in average N170 amplitudes for happy, sad, and neutral conditions.


Antipsychotic Use v P100 Ampltitude: Happy Condition
$t_{Welch}(8.84) = -0.93$, $p = 0.38$, $\widehat{g}_{Hedges} = -0.43$, $CI_{95\%}$ [-1.35, 0.51], $n_{obs} = 18$
uV
6
3
0
-3
n
(n = 7)
y
(n = 11)
Antipsychotic Use
$\log_e(BF_{01}) = 0.51$, $\hat{\delta}^{posterior}_{difference} = -0.98$, $CI^{ETI}_{95\%}$ [-3.60, 1.28], $r^{JZS}_{Cauchy} = 0.71$


Antipsychotic Use v P100 Ampltitude: Sad Condition
$t_{Welch}(7.02) = -0.46$, $p = 0.66$, $\widehat{g}_{Hedges} = -0.22$, $CI_{95\%}$ [-1.13, 0.71], $n_{obs} = 18$
uV
4
0
-4
-8
n
(n = 7)
y
(n = 11)
Antipsychotic Use
$\log_e(BF_{01}) = 0.76$, $\hat{\delta}^{posterior}_{difference} = -0.52$, $CI^{ETI}_{95\%}$ [-3.23, 1.98], $r^{JZS}_{Cauchy} = 0.71$

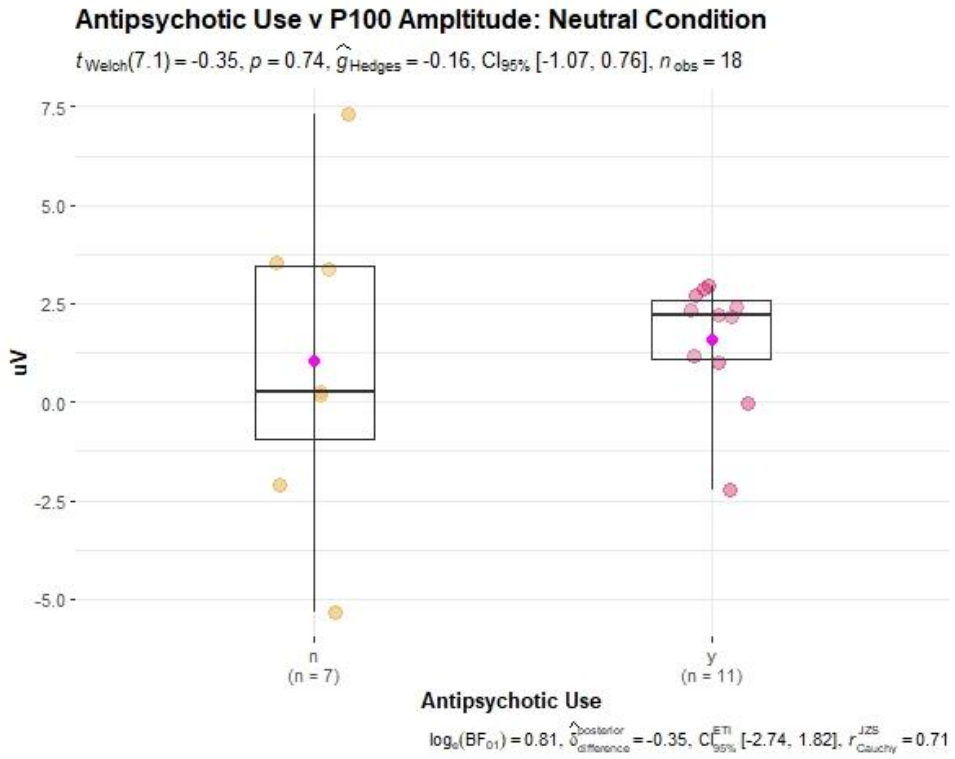


Figure 13. Antipsychotic Use v P100 Amplitude in All Emotional Conditions
Boxplots depicting the difference in antipsychotic use (No = yellow, yes = pink) in the ECP group versus the change in average P100 amplitudes for happy, sad, and neutral conditions.

In previous studies, gender has been shown to affect P100 amplitudes in specific emotional subgroups. In fearful or angry faces, women have displayed larger P100 amplitudes in response to these stimuli when compared to men.[52] While these emotional paradigms were not used in this study, it does give insight into possible differences between genders in emotional face processing. In the ECP group, 70.6% of the subjects were female compared to 50% in the HC group, so that gender could impact results, especially with a small sample size.

Future Directions and Considerations

For future studies, we could look at valence ratings of faces to test the possibility of a difference in how participants view the emotional face stimuli from the standardized NimStim set (Tottenham et al., 2019). The task would be preceded by a survey of how pleasant/happy or unpleasant/sad people perceive a face from the set, affecting N170 response amplitudes.

Another avenue for future study would be to investigate the accuracy and speed of detecting each emotional face within the task and expand the number of emotions used in the paradigm. Research suggests that people with schizophrenia and other psychotic disorders have difficulty with correctly identifying emotions, with them specifically skewing into identifying emotions as more negative (Schneider et al., 2006). Impaired emotion discrimination could impact facial recognition and ERP component amplitudes, especially towards a negative affect. Behavioral data were collected during this ERP study, so future investigations will examine emotion recognition.

Beyond future studies of emotional face recognition in ECP individuals, there is also a possibility for future therapeutic opportunities. Transcranial direct current stimulation (tDCS) is a noninvasive neuromodulation technique used to treat different cognitive deficits (Rassovsky et al., 2015). This approach can be used to target EEG measures or brain regions, such as the OFA and FFA, in order to normalize deficits related to emotional face processing. In that case, there is potential for these measures to be candidate targets for future simulation studies.

Psychosis is a complex disease that has a significant impact on social functioning. Chronic cases have been well studied in emotional face processing, but there is little research on ECP. We hope that there will be future studies that build off these findings to help better understand the interplay of emotional face processing, social functioning, and psychosis.

LIST OF JOURNAL ABBREVIATIONS

BMJ.....British Medical Journal

JAMA..... The Journal of the American Medical Association

NEJM ..... New England Journal of Medicine

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