5-2020

An Examination of the Neural Basis of Self-Reflectivity in Schizophrenia

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An Examination of the Neural Basis of Self-Reflectivity in Schizophrenia

by

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A Dissertation submitted in partial satisfaction of
the requirements for the degree
Doctor of Philosophy in Clinical Psychology

May 2020

Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Philosophy.

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ACKNOWLEDGMENTS

I would first like to thank my committee chair, Dr. Colleen Brenner, for your support and guidance throughout this process. Thank you to my committee members, Dr. David Vermeersch, Dr. Elizabeth Cisneros, and Dr. Grace Lee for your advice and direction. A special thank you to my family and loved ones for their endless support and words of encouragement. I also want to thank the Loma Linda University Behavioral Medicine Center for working with researchers to recruit participants from the FOCUS program. Finally, thank you to all of the participants who took the time out of their busy schedules to participate and make this study possible.

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ABSTRACT OF THE DISSERTATION

An Examination of the Neural Basis of Self-Reflectivity in Schizophrenia

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Loma Linda University, May 2020
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Metacognition is a term that refers to the act of thinking about thinking. The self-reflective aspect of metacognition specifically, has been shown to be impaired in patients diagnosed with schizophrenia. The Default Mode Network (DMN) is a set of cortical regions that demonstrate coordinated activation during the resting state of the brain. The DMN has been linked with various aspects of self-awareness and has been hypothesized as a possible source of dysfunction in patients diagnosed with schizophrenia. The current study bridged these findings by using electrophysiological measures to investigate the neural basis of self-reflectivity in a psychiatric group. A Repeated Measures ANOVA with a between-subjects factor of group (healthy controls and the psychiatric group) and within-subjects factors of task (resting-state EEG and self-referential resting-state EEG) and region (frontal and central) was used to evaluate group differences between healthy controls and the psychiatric group, for each frequency band and task at frontal and central electrode sites separately. Of the 13 participants, the majority identified as Caucasian (38.5%) and female (53.8%), with a mean age of 33.60 for the healthy control group (SD = 15.27) and 37.63 for the psychiatric group (SD = 11.22). A main effect of group was found in the theta frequency band, indicating that the psychiatric group showed increased

theta activity compared to healthy controls during resting-state EEG. There were no significant group by task interactions. Analyses also revealed a significant, strong positive correlation between MAS-A ratings of self-reflectivity and beta frequency band activity in the central region during self-referential resting-state EEG for healthy control participants. Lastly, analyses revealed a statistically significant, strong negative correlation between MAS-A ratings of self-reflectivity and theta frequency band activity in the central region during resting-state EEG for the psychiatric group. Continued research using electrophysiological measures to investigate the neural basis of self-reflectivity in patients diagnosed with schizophrenia is vital to increasing their ability to engage effectively in treatment and create the insight needed to view themselves as an active participant in their own families and communities.

CHAPTER ONE

LITERATURE REVIEW

The term metacognition is composed of several aspects of mental activity that involve thinking about cognitions carried out through a range of mental activities, from recognizing thoughts and emotions to the ability to use cognitions to form a representation of the self and others (Dimaggio, Hermans, & Lysaker, 2010; Lysaker et al., 2011; Semerari et al., 2003; Vohs et al., 2014; Vohs et al., 2016). Self-reflectivity is an aspect of metacognition that refers to the ability to comprehend one's own mental state, such as thinking about one's own thoughts and feelings (Lysaker et al., 2011;Vohs et al., 2016). Recently, researchers have emphasized that metacognition may be a potential target for treatment in individuals experiencing psychotic symptoms (Lysaker et al., 2011; Salvatore et al., 2012; Trauelsen et al., 2016; Vohs et al., 2014). Self-reflectivity specifically has been demonstrated as an aspect of metacognition impaired in individuals diagnosed with schizophrenia. Researchers have hypothesized that increasing self-reflectivity in individuals diagnosed with schizophrenia may increase their ability to relate to others and participate in commonly practiced treatment modalities (Lysaker et al., 2010; Salvatore et al., 2012). However little research has been done to investigate the neural basis of self-reflectivity in patients diagnosed with schizophrenia. Learning more about the neural underpinnings of self-reflectivity in individuals diagnosed with schizophrenia is needed in order to further investigate self-reflectivity as a possible target for treatment of patients diagnosed with schizophrenia.

The following literature review will begin by examining the concept of metacognition and, more specifically, self-reflectivity, as it relates to healthy individuals.

Next, I will discuss how deficits in metacognition and self-reflectivity may contribute to psychological disorders. A general overview of psychosis will then be provided as well as an overview of the relationship between metacognition and psychotic symptoms. I will continue by specifically discussing the deficits in self-reflectivity reported by individuals diagnosed with schizophrenia and why they are considered targets for treatment. I will then present an overview of the measures commonly used to evaluate levels of self-reflectivity. Next, I will provide an overview of resting electroencephalography (EEG) and examine resting EEG and the Default Mode Network (DMN) as potential measures of the neural functioning underlying self-reflectivity. I will continue by describing the use of resting EEG with individuals diagnosed with schizophrenia. Finally, I will summarize the relevant research regarding self-reflectivity in patients diagnosed with schizophrenia. I will conclude by identifying the gaps in the current literature examining self-reflectivity in patients diagnosed with schizophrenia and describing the importance of using resting EEG to explore the relationship between the DMN and self-reflectivity. This information is invaluable to the evaluation of self-reflectivity as a possible target for the treatment of patients diagnosed with schizophrenia.

Self-Reflectivity

Metacognition is a spectrum of mental activity that involves thinking about cognition (Lysaker et al., 2011; Semerari et al., 2003; Vohs et al., 2016). This spectrum of activity can range from acts in which a person recognizes specific thoughts, to acts in which a person integrates a collection of thoughts, feelings, intentions, and connections between events into complex representations (Dimaggio, Hermans, & Lysaker, 2010;

Vohs et al., 2016). Metacognitive capacities allow individuals to engage in the meaning-making necessary for sustaining connections with family, friends, and one's larger community, and for setting and pursuing goals across long periods of time (Semerari et al., 2003; Vohs, et al., 2016). Self-reflectivity is an aspect of metacognition that involves the act of thinking about one's own thoughts and feelings (Lysaker et al., 2011). Self-reflectivity refers to both cognitive and emotional experiences and is related to other aspects of metacognition including those which require an awareness of the internal states of others or the use of metacognitive knowledge to solve social dilemmas (Lysaker, Ringer, Maxwell, McGuire, & Lecomfe, 2010c). Researchers have suggested that there are multiple levels of self-reflectivity (Huddy, Roberts, Jarrett, & Valmaggia, 2016; Lysaker et al., 2011). More specifically, self-reflectivity has been hypothesized as involving nine complex steps ranging from the persons acknowledgement that they have mental functions to the person's ability to integrate into a coherent and complex personal narrative their different modes of cognitive and/or emotional functioning (Semerari et al., 2003; Lysaker et al., 2005b). Researchers define a personal narrative as the formation of a personal understanding of one's own life as an unfolding story in which one is a meaningful agent, connected to others, facing realistic challenges and possessing basic human values (Lysaker et al., 2012; Lysaker et al., 2010c). Lysaker and colleagues (2010) emphasized that personal narratives should supply meaning and allow for connections with others, paving the way for managing distress, living with challenges, and sustaining general wellness. Furthermore, emphasizing the development of a more coherent personal narrative has been reported as a possible target for treatment (Lysaker & Buck, 2008; Lysaker et al., 2011; Lysaker et al., 2010). The overall coherence and richness of a personal narrative has been linked to wellness and healthy functioning (Lysaker et al., 2012). A richer personal narrative may allow persons to better relate to others and to meaningfully function in their communities (Lysaker et al., 2010c).

Dimaggio and colleagues (2010) have hypothesized that health and social adaption might depend on the existence of a certain number of internal voices, a minimum degree of internal diversity, and the freedom to act differently as the context changes. A healthy self-concept involves the existence of a multiple self, where different aspects of an individual's personality are activated depending on the demands of interpersonal situations and environmental problems that arise (Bell & Wittkowski, 2009; Dimaggio et al., 2010). Researchers have suggested that a key aspect of metacognitive capacity is the ability to continuously integrate the different representations of the self with one another into a coherent narrative as these representations change according to social demands (Dimaggio et al., 2010; Semerari et al., 2003). With difficulties determining how one is thinking and coping or thinking about the motives of others, the social landscape may appear confusing and impossible to navigate (Dimaggio et al., 2010; Lysaker et al., 2010; Lysaker & Lysaker 2006). Improvement in self-reflection, assimilation of problematic voices in the broader self-narrative, or an increase in metacognitive skills has been associated with good outcomes (Dimaggio et al., 2010; Lysaker, Buck, & Ringer, 2007a). For example, Bell and Wittkowski (2009) reported that individuals who were better able to distinguish between their different self-aspects experienced less stress, depression, and physical symptoms after experiencing stressful life events. Furthermore, researchers demonstrated that individuals with higher levels of self-reflection or integration are likely to forge more successful levels of adaptation than those identified as having poor self-reflection (Bell & Wittkowski, 2009; Dimaggio et al., 2010).

Both a restricted variety of aspects of an individual's personality as well as an excessive number of personality aspects crowded together in the stream of consciousness are linked with significant psychopathology (Dimaggio et al., 2010). Lysaker and Lysaker (2006) reported that pathology would be a consequence of a lack of dialogues, with distinct aspects of the self remaining dissociated or conflicting, or of the presence of dominant aspects of the self, shutting out other aspects of the self. Dimaggio and Colleagues (2010) have noted that many with severe psychopathology lack the ability to recognize aspects of the self and to integrate them within a personal narrative. Many with significant psychopathology also display a kind of disorganization in which different aspects of the self emerge uncontrollably (Dimaggio et al., 2010; Lysaker & Lysaker, 2006). Furthermore, researchers have suggested that many with significant psychological disorders have access to a severely restricted number of aspects of self (Dimaggio et al., 2010; Vohs et al., 2016). Poor self-reflection has been found in a series of case studies and research on clinical samples (Dimaggio et al., 2010; Lysaker et al., 2012). For example, Dimaggio and colleagues (2010) reported in depression, personality disorders, and schizophrenia, difficulties are manifested in the inability to construct a rich representation of one's own mind, and this is associated with greater severity of symptoms and poorer social functioning. Conditions such as schizophrenia, personality disorders, and dissociative disorders may also be associated with a disorganization of communication between different parts of the self failing to recognize or acknowledge one another (Dimaggio et al., 2010). Additionally, deficits in self-awareness, coupled with deficits in the ability to see others as having their own unique perspectives, have been linked to the gravest levels of social withdrawal (Dimaggio et al., 2010; Lysaker, Buck, Hammoud, Taylor, & Roe, 2006a). Vohs and colleagues (2016) emphasized that deficits in the ability to form complex representations of the self and others might leave individuals with schizophrenia less able to recognize and respond to the challenges of their illness and the larger demands of everyday life. Therefore, having a developed account of one's experience of life in the midst of mental illness might reflect an essential domain of recovery (Lysaker et al., 2012).

Psychosis

Psychosis has been defined as the experience of voices, visions, special messages, and alternative realities (Jones & Shattell, 2016). Pervasive symptoms throughout the course of psychotic disorders are a major obstacle to a person's ability to return to a reasonable level of functioning and quality of life (Lyne, Joober, Schmitz, Lepage, & Malla, 2017). For many, the experience of psychosis includes fluctuations between everyday reality and unusual experiences and beliefs (James & Shattell, 2016). Unrelenting psychotic symptoms may result in a sense of defeat and helplessness, leading to social and personal withdrawal (Lyne et al., 2017). Morgan and colleagues (2017) emphasized that poor social circumstances and relative disadvantages experienced by people with psychotic illnesses render them highly vulnerable to social and economic changes, and lower levels of physical health. Similarly, Stain and colleagues (2012) reported that young people exhibiting a first episode of psychosis experience reduced social support and opportunities for social participation, including smaller social networks and having fewer people to turn to in a crisis compared to their peers without a mental illness. Jones and Shattell (2016) emphasized that an individual's experience of psychosis is both an incredibly individualized experience as well as an experience rooted in their complex intersections with identity, culture, and fundamental processes of thought and perception. Therefore, healing for individuals experiencing psychotic symptoms involves a much more holistic process of personal and cultural acceptance and understanding (Conus et al., 2017; Jones & Shattell, 2016; Morgan et al., 2017).

Interest in overall metacognitive deficits in psychotic illnesses has continued to gain momentum, likely due to their possible impact upon psychosocial functioning and the suggestion that these processes may mediate the impact of neurocognitive and related disturbances on patient outcomes (Vohs et al., 2014). Researchers have emphasized that individuals experiencing both early and later phases of psychosis have impairments in a number of metacognitive capacities including self-reflectivity (Jones & Shattell, 2016; Vohs et al., 2016). Jones and Shattell (2016) suggested that most of the time, psychotic experiences could not be separated from the self: therefore, to experience psychosis is to experience a radically changed self. People struggling with severe inner distress often have a markedly reduced capacity to relate and interact with others in adequate ways (Haug et al., 2013). Compromised overall metacognitive capacity in individuals with prolonged psychosis has been linked to learning difficulties, poorer motivation, and poorer psychosocial functioning (Vohs et al., 2014). Vohs and colleagues (2014) found that people with a first-episode psychosis had even lower overall metacognitive abilities compared to those with prolonged psychosis and psychiatric controls. Additionally, there is accumulating evidence that overall metacognition is specifically associated with negative symptoms in people with psychosis (Trauelsen et al., 2016; Vohs et al., 2014). For instance, Trauelsen and colleagues (2016) reported that those experiencing first-episode psychosis with high levels of negative symptoms, had difficulties recognizing and formulating their inner states. Lysaker and colleagues (2012) also demonstrated that personal narrative development is more closely associated with negative symptom severity over time, particularly for persons diagnosed with schizophrenia.

Metacognitions have been associated with symptoms of various psychological disorders, which researchers suggest may indicate that metacognitions are vulnerable to multiple forms of psychopathology (Hagen, Solem, Opstad, Hansen, & Hagen, 2017). However research specifically concerning the relationship between psychosis and the self-reflective aspect of metacognition in patients diagnosed with schizophrenia has been scarce. Schizophrenia has been associated with a diminished sense of life as a comprehensible ongoing story and difficulty perceiving oneself as an active agent meaningfully connected to others (Lysaker et al., 2006a). Salvatore and colleagues (2012) reported that many with schizophrenia have difficulties with aspects of self-awareness such as describing their emotions and thoughts and establishing psychologically valid cause-and-effect chains among events, thoughts, emotions, and actions. The inability to establish a cause-and-effect chain between thoughts, emotions, and actions may gravely impact an individual's ability to participate in commonly practiced treatment modalities, such as Cognitive Behavioral Therapy (CBT; Salvatore et al., 2012). Additionally, deficits in self-awareness and related aspects of metacognition are linked with greater levels of social and vocational dysfunction in schizophrenia (Lysaker et al., 2010a; Salvatore et al., 2012). Impairments in metacognition have been found in both early and later phases of schizophrenia and are linked with both objective and subjective indicators of wellness, independent of symptom severity (Hasson-Ohayon et al., 2015). Lysaker and colleagues (2012) emphasized that individuals diagnosed with schizophrenia experience unusually severe decrements in their ability to make sense of their life in a coherent, plausible, and narrated manner. Researchers have also reported that individuals diagnosed with schizophrenia have increased difficulties with challenging beliefs that may be inaccurate (Dimaggio et al., 2010; Lysaker et al., 2005a). However, while deficits in metacognition in general has been linked to a range of poor outcomes in schizophrenia (Tas et al., 2014), there is less known about the specific impact of self-reflectivity deficits in those with schizophrenia.

Schizophrenia is estimated to cost $23 billion in direct costs and nearly $40 billion in indirect costs annually because of the chronicity, severity, and marked psychosocial impairment that may characterize the illness (Liffick, Mehdiyoun, Vohs, Francis, & Breier, 2017). Stain and colleagues (2012) emphasized that historically, the focus on symptom reduction in typical treatments for psychosis has led to the neglect of the basic human rights of people with psychosis, particularly the right to education, work, marry, raise a family, and participate in the community. Researchers have recently advocated for redesigning services to better meet the needs of young people currently experiencing a first-episode of psychosis (Barr et al., 2015; Jones & Shattell, 2016; Salvatore et al., 2012). Specific interventions typically offered by early interventions for psychosis include individual CBT, family therapy, career interventions, medication in the form of a low- dose antipsychotic regime, and social support around education, employment, and housing (Barr, Ormrod, & Dudley, 2015). However, before many patients can use cognitive restructuring or other CBT techniques typically used in early interventions for psychosis, they may have to first develop a level of metacognitive abilities sufficient to question their own cognitive beliefs (Salvatore et al., 2012). Therefore, researchers have emphasized that improving aspects of metacognition should be considered as targets of treatment for individuals with psychotic symptoms (Lysaker et al., 2011; Salvatore et al., 2012; Trauelsen et al., 2016; Vohs et a., 2014). Lysaker and colleagues (2011) suggested that the beginning of therapy should involve an assessment of clients' capacity for self-reflectivity. Following such an assessment, interventions should be tailored so they are appropriate for a patient's current capacity for self-reflectivity (Lysaker et al., 2011). Therefore more research is needed in order to better understand self-reflectivity in individuals diagnosed with schizophrenia and to further investigate self-reflectivity as a possible target for treatment of individuals diagnosed with schizophrenia.

Attention has also turned to whether helping persons with schizophrenia develop self-acceptance and self-awareness and a richer sense of personal identity through their unique personal histories or narratives might promote recovery (Salvatore et al., 2012). A more thorough personal narrative might represent the opportunity to experience oneself as an active agent prevailing in the face of adversity, which may lead to a reduction in symptoms of psychosis (Salvatore et al., 2012). Quantitative assessments of the fullness and coherence of personal narratives of patients diagnosed with schizophrenia have been linked to aspects of various elements of recovery such as social function, hope, self-esteem and symptom level (Lysaker et al., 2010c). Lysaker and colleagues (2002) developed the Indiana Psychiatric Illness Interview (IPII) to assess illness narratives. The

IPII is a semi-structured interview conceptually divided into four sections (Lysaker et al., 2002; Lysaker et al., 2006c). Each section is used to elicit enough information to understand the story the participant is telling about mental illness, not to confirm or disagree with that story (Lysaker et al., 2002). The IPII is unique from other psychiatric interviews in that the interviewer does not elicit content and therefore responses can be analyzed in terms of the larger story being told and not the presence or absence of specific behaviors and experiences (Lysaker et al., 2010c; Lysaker et al., 2006c). A number of measures have been used to assess the content of the resulting IPII transcripts (Lysaker et al., 2002; Lysaker et al., 2005). For instance, The Narrative Coherence Rating Scale (NCRS) is a six-item rating scale used to assess the coherence of illness narratives (Lysaker et al., 2002). The NCRS is completed following a review of the IPII transcript (Lysaker et al., 2002). Additionally, The Scale to Assess Narrative Development (STAND) was developed to assess narrative coherence during psychotherapy with patients specifically diagnosed with schizophrenia (Lysaker et al., 2006c). The STAND assesses four key aspects of recovery as they might emerge in client narratives (Lysaker et al., 2010; Lysaker et al., 2006c; Lysaker, Wickett, Campbell, and Buck, 2003). Lysaker and colleagues (2003) demonstrated that the STAND can be rated reliably, is internally consistent, and may be able to detect changes over time.

Semerari and colleagues (2003) created the Metacognitive Assessment Scale (MAS) to specifically assess metacognitive deficits in psychotherapy. The MAS is divided into four scales: understanding of one's own mind, understanding of other's minds, decentration, and mastery (Lysaker et al., 2005a; Lysaker et al., 2010b; Semerari et al., 2003). Lysaker and colleagues (2005a) further applied an abbreviated version of the MAS (MAS-A) to be used specifically with individuals diagnosed with schizophrenia. Higher scores on the MAS-A subscales reflect greater abilities to construct integrated representations of self and others and to use that knowledge to respond to social and psychological challenges (Lysaker & Dimaggio, 2014). The MAS-A defines self-reflectivity as a construct that involves nine increasingly complex steps ranging from a patient's ability to acknowledge they have emotions to a patient's ability to integrate their cognitions and emotions into a coherent and complex narrative (Lysaker et al., 2011). Researchers have demonstrated that self-reflectivity can be rated reliably among participants with schizophrenia both on the basis of psychotherapy transcripts and semi-structured interviews, such as the IPII (Lysaker et al., 2007a; Lysaker et al., 2005a). The MAS and MAS-A have been consistently and reliably used to analyze IPII transcripts because IPII transcripts present a situation in which metacognitions are elicited in an open-ended manner (Lysaker et al., 2005a; Lysaker et al., 2010b). Researchers have linked poorer MAS-A scores with lower levels of functional competence, subjective sense of recovery, therapeutic alliance, the ability to deflect stigma, and histories of impulsive violence in forensic patients (Lysaker et al., 2011b; Lysaker et al., 2010a; Lysaker et al., 2010b). Good internal consistency and good overall reliability have been repeatedly demonstrated in use of the MAS-A with individuals diagnosed with schizophrenia (Lysaker et al., 2005a; Lysaker et al., 2002; Lysaker et al., 2010b; Lysaker et al., 2007a).

Electroencephalography

Electroencephalography (EEG) is one method that has been used to investigate the neural basis of the self-referential aspect of metacognition. EEG is a powerful technique used to objectively measure changes in the activity levels of the brain (Lavoie et al., 2012). EEG provides a measure of large-scale cellular network activity with high temporal resolution (Ranlund et al., 2014;Vohs et al., 2016). Oscillations of electrical activity recorded by EEG reflect synchronized neuronal activity (Nuñez, Panetsos, Avendaño, 2000). Furthermore, power within specified frequency bands indicates the average magnitude of oscillations over a specific time range (Kam, Bolbecker, O'Donnell, Hetrick, & Brenner, 2013). Amplitude, phase, and synchrony of the EEG activity are dependent upon the synchronization and integrity of neural networks (Vohs et al., 2016). EEG synchronization appears to support the communication between distinct neural regions, which may facilitate coherent cognition and behavior (Ward, 2003). The frequencies most often studied in humans are the delta (0-3 Hz), theta (4-7 Hz), alpha (8-12 Hz), beta (12-24 Hz), and gamma (30-50 Hz) frequency bands (Boutros et al., 2008;Vohs et al., 2016). EEG is highly sensitive to changes in arousal and consciousness associated with waking, sleeping, and dreaming; as well as pathological states of consciousness (Uhlhaas & Singer, 2013). For instance, delta frequency bands are most commonly observed in EEG patterns of deep sleep (Travis, Arenander, & DuBois, 2004). Ward (2003) reported that theta power increases during memory tasks, especially during encoding. Alpha EEG has been associated with long-range, top-down processes and general arousal, while gamma EEG has been associated with local, bottom-up, sensory processing (Travis et al., 2004). A frequently used avenue for quantifying disturbances in brain activity is resting state EEG (Vohs et al., 2016). Disruptions in resting EEG may reflect disturbances in the neural interactions that support cognition and arousal in the absence of task-related activity (Kam et al., 2013; Lorenzo et al., 2015). For instance, gamma activity has been linked to sensory information encoding and perceptual and cognitive processes even during resting state (Singer, 1999;Vohs et al., 2016). In the gamma-band range, reduced task-related, but intact resting-state connectivity has also been reported (Andreou et al., 2015). Furthermore, Ward (2003) suggested that interactions of gamma and theta activity might be involved in memory function. While there is not a precise allocation of frequency of brain activity to the particular functions they subserve, disruptions in resting state EEG have been shown to reliably differentiate neuropsychiatric populations from healthy control samples (Thibodeau, Jorgensen, & Kim, 2006).

The Default Mode Network (DMN) has been identified as a set of cortical regions that show coordinated activation in the resting state and coordinated deactivation during task execution (Andreou et al., 2015; Gruberger et al., 2015; Qin, & Northoff, 2011; Robinson, Wagner, & Northoff, et al., 2016). Researchers have described the DMN as an anatomically defined brain system that preferentially activates when individuals are not focused on the external environment (Buckner et al., 2008; Li, Mai, & Liu, 2014). Researchers have generally observed the DMN during resting state EEG or resting Functional Magnetic Resonance Imaging (fMRI; Robinson et al., 2016) Li and colleagues (2014) reported that regions of the DMN are also activated during tasks that required participants to understand and interact with others, such as perceiving and interpreting other’s emotion status, showing empathy to other people, inferring other’s belief and intention, and performing moral judgments on other’s behavior. Furthermore, the DMN was shown to participate in constructing self-relevant mental simulations that were exploited by a wide range of cognitive functions including remembering the past, thinking about the future, and conceiving the current viewpoint of others (Li et al., 2014). Bellana and colleagues (2017) also suggested that areas within the DMN operate in a more complex manner, exhibiting positive or negative fluctuations of activity depending on the current task requirements. Furthermore, the activation of the DMN during resting state could reflect the engagement of similar cognitive or component processes during mind wandering, which may include thinking about events from the past, imagining events that will occur in the future, or more generally constructing situation models (Bellana et al., 2017). Rest-related human tendency to continuously think, whenever the mind is not otherwise engaged in attention-demanding tasks, has long been recognized as a fundamental element of the human awareness of a ‘self’ (Gruberger et al., 2015; Qin & Northoff, 2011). Patterns of brain functioning have also helped delineate different descriptions of self-awareness, such as ownership, agency, cognitive unity, and self-reflectivity (Travis et al., 2004). Travis and colleagues (2004) emphasized that the similarity between neural networks associated with states of self-reflectivity and resting baseline suggests that there are distinct brain states associated with more outward, object and task-oriented modes of processing versus more inward, self-oriented modes of processing. Furthermore, Andrews-Hanna and colleagues (2010b) reported that tasks that encourage subjects toward internal mentation, including autobiographical memory, thinking about one's future, theory of mind, self-referential and affective decision making, tend to activate regions within the DMN. Francis and colleagues (2017) hypothesized that disrupted DMN connectivity may therefore impair one's ability to think reflectively about the self, and to integrate self-awareness and self-concept into the broader world. Due to the overlap in activity between regions that are suggested to be involved in self-relatedness processing and DMN regions, it has been hypothesized that the self may be more or less identical with the resting state activity observed in DMN (Qin & Northoff, 2011). Therefore measurement of DMN activity presents as a valuable approach for evaluating overall metacognition and the self-reflective aspect of metacognition more specifically.

Altered DMN connectivity has been consistently reported within schizophrenia and the degree of this dysfunction may relate to an individual's prospects for improvement, specifically due to its relationship with overall metacognitive capacity (Francis et al., 2017; Littow et al., 2015). Holt and colleagues (2011) reported that many introspective mental processes, including self-reflection, rely on coordinated activity of two reciprocally connected, midline cortical regions: the medial prefrontal cortex (mPFC) and the posterior cingulate gyrus (PCC). Research in non-psychotic populations has demonstrated that mPFC may play an important role in mediating metacognitive ability in general (Francis et al., 2017). The mPFC is a major component of the DMN and is associated with processes related to metacognition, such as self-referential thinking (Francis et al., 2017). Furthermore, Gruberger and colleagues (2015) hypothesized that if spontaneous thinking is self-related, then disruptions of mPFC activity during rest would be expected to result in subsequent alterations in the sense of self. Holt and colleagues (2011) found that patients with schizophrenia showed abnormally elevated activation of the right and left middle and dorsal-posterior cingulate cortex (m/pCC) during self-reflection and abnormally reduced responses during self-reflection within the right ventral mPFC. Additionally, Bellana and colleagues (2017) reported that activation of midline regions of the DMN, such as the PCC and mPFC, often associated with the processing of self-referential information, have been reliably reported during rest. Therefore, EEG power within defined frequency bands may be related to both functional and anatomical resting state networks that modulate self-referential thought and autobiographical memory (Vohs et al., 2016). Phenomenologically-oriented researchers propose that a disturbance of the basic sense-of-self aspect of metacognition is at the clinical core, and is therefore a phenotypic trait marker of the schizophrenia spectrum (Nelson, Whitford, Lavole, & Sass, 2014). However, little work has been done to examine the neurobiology of overall metacognition, or self-reflectivity more specifically, in patients diagnosed with schizophrenia (Francis et al., 2017). The current study aims to fill these gaps in the literature by using resting-state EEG to investigate the possible neural basis of self-referential processing in patients diagnosed with schizophrenia.

Disordered brain connectivity at the cortical level, generally defined as a failure of effective functional integration within and between brain areas, has been proposed as a core deficit of schizophrenia (Lorenzo et al., 2015). The disruption of functional connectivity was particularly pronounced in patients with auditory hallucinations (Nelson et al., 2014). Nelson and colleagues (2014) emphasized that the excessive activity of the brain's resting state may drive excessive awareness of internal processes, which are generally tacit and unnoticed, possibly leading to their externalization in the form of psychotic symptoms. Resting state EEG has been shown to reliably differentiate neuropsychiatric populations from healthy control samples (Kam et al., 2013; Thibodeau, Jorgensen, & Kim, 2006). EEG power in the delta, theta and beta bands has been shown to be positively correlated with negative symptoms in first episode psychotic patients (Zimmerman et al., 2010). However, research evaluating impairments in delta, theta, beta, as well as alpha and gamma frequency bands in schizophrenia patients has provided conflicting results (Narayanan et al., 2014). For instance, disrupted gamma activity has been linked to common illness features of schizophrenia, such as poor information integration and performance on feature binding and encoding, maintenance, and recall tasks (Spencer et al., 2004; Vohs et al., 2016). Researchers have also hypothesized that altered gamma activity observed in schizophrenia may also be linked to a disruption in the ability to form complex ideas about oneself and others and to see the world from multiple perspectives (Vohs et al., 2016). Kam and colleagues (2013) reported that augmented low-frequency power in the delta and theta frequency bands is consistently found in the resting state EEG of those with schizophrenia compared to healthy controls. Lavoie and colleagues (2012) also stated that the most consistent observation obtained from spectral analysis in medicated as well as unmedicated schizophrenia patients is an increase in slow wave (delta) activity. Andreou and colleagues (2015) found evidence for increased resting state theta band connectivity across orbitofrontal areas, the anterior and posterior midline and the left temporoparietal junction in patients with schizophrenia. Increased beta activity has also been observed in patients with schizophrenia, but with less consistency (Lavoie et al., 2012). Furthermore, some researchers have reported that schizophrenic patients demonstrate decreased alpha frequency activity (Clementz, Sponheim, Iacono, & Beiser, 1994; Schug et al., 2011). However, Ranlund and colleagues (2014) reported no evidence of alpha impairments in patients experiencing psychotic symptoms. Therefore more research is needed to better understand impairments in resting state EEG activity across frequency bands in patients diagnosed with schizophrenia and to further investigate the relationship between DMN and self-reflectivity in patients diagnosed with schizophrenia.

The Current Study

Metacognition is a term that refers to the act of thinking about thinking (Lysaker et al., 2011). Self-reflectivity is one aspect of metacognition that specifically refers to thinking about one's own cognitive and emotional experiences (Lysaker et al., 2011). Deficits in metacognition in general have been broadly observed in schizophrenia and theorized as the first of four core features of schizophrenia (Francis et al., 2017; Hasson-Ohayon et al., 2015; Lysaker et al., 2005a). Individuals diagnosed with schizophrenia have demonstrated specific difficulties with various aspects of self-awareness, such as describing their own emotions and thoughts (Lysaker et al., 2006a; Salvatore et al., 2012). While patients diagnosed with schizophrenia have demonstrated difficulties engaging in tasks requiring self-reflectivity, little research has been done to better understand deficits specifically in the self-reflective aspect of metacognition in patients diagnosed with schizophrenia. Furthermore, little to no research has examined the neurobiology of self-reflectivity in patients diagnosed with schizophrenia, despite being identified as a source of impairment and a possible target for treatment (Francis et al., 2017). The Default Mode Network (DMN) is a set of cortical regions that demonstrate coordinated activation during the resting state of the brain (Andreou et al., 2015; Gruberger et al., 2015; Robinson, et al., 2016; Qin, & Northoff, 2011). Researchers have demonstrated an overlap between DMN regions and brain regions that are suggested to be involved in self-referential thinking, such as the PCC and mPFC (Andrews-Hanna et al., 2010b; Bellana et al., 2017; Travis et al., 2004; Qin & Northoff, 2011). Deficits in DMN connectivity have been hypothesized to contribute to cognitive dysfunction in schizophrenia (Andreou et al., 2015; Francis et al., 2017). Additionally, researchers have demonstrated that patients diagnosed with schizophrenia experience abnormal responses in the m/PCC and mPFC during self-reflective tasks (Holt et al., 2011). However, while regions of the DMN have demonstrated involvement in self-referential thinking as well as a possible source of dysfunction in patients diagnosed with schizophrenia, little to no research has examined the specific relationship between the DMN and self-reflectivity in patients diagnosed with schizophrenia.

Psychotic symptoms have been associated with social, emotional, and personal withdrawal in patients (Lyne et al., 2017; Lysaker et al., 2005b). Money, social engagement, and employment are the most important challenges identified by people suffering from a psychotic illness (Morgan et al., 2017). Lower metacognitive functioning overall in individuals with prolonged schizophrenia has been associated with a range of poor outcomes including increased negative symptoms, decreased motivation, and worse overall psychosocial function (Francis et al., 2017; Lysaker et al., 2005a;Vohs et al., 2014). Salvatore and colleagues (2012) emphasized that difficulties in understanding mental states causes some patients experiencing psychosis to enter a hypermentalizing mode, in which they are overwhelmed with a variety of ideas about what is occurring interpersonally leading them to disengage from others and withdraw socially. Improvements in metacognition have been associated with better social adjustment and less severe symptoms (Dimaggio et al., 2010). Researchers have hypothesized that a relatively rich and valid narrative of one's strengths and weaknesses may allow individuals diagnosed with schizophrenia to make meaning of and share some of their experiences as well as healthy aspects of themselves with others, which in turn allows these individuals to better relate to others and function in their communities (Lysaker et al., 2010a). Furthermore, increasing a patient's ability to describe or question their own thoughts and emotions may also increase their ability to engage in commonly practiced treatment modalities, such as CBT (Salvatore et al., 2012). A new avenue for treatment may therefore involve not only patients' symptoms and social functioning, but also their ability to engage in self-reflectivity and think about themselves as agents in the world (Salvatore et al., 2012). The measurement of DMN activity presents as a valuable approach for evaluating the neural basis of self-reflectivity in individuals diagnosed with schizophrenia. Altered DMN connectivity has been consistently reported within schizophrenia and the degree of this dysfunction may relate to an individual's prospects for improvement, due in part to its relationship with overall metacognitive capacity (Francis et al., 2017; Littow et al., 2015). Unfortunately, research examining the neurobiology of self-reflectivity specifically in patients diagnosed with schizophrenia has been scarce (Francis et al., 2017). Therefore, more research is needed to better understand self-reflectivity and the relationship between the DMN and self-reflectivity in patients diagnosed with schizophrenia in order to further investigate self-reflectivity as a possible target for treatment of patients diagnosed with schizophrenia.

CHAPTER TWO

STUDY AIMS AND HYPOTHESES

Study Aims

The current study had two aims. First, the current study aimed to explore the electrophysiological correlates of self-referential processing in a psychiatric group compared to healthy controls. Additionally, the current study also aimed to investigate the relationship between electrophysiological measures of self-reflectivity and interview ratings of self-reflectivity. Previous researchers have reported decreased metacognitive capacity in patients diagnosed with schizophrenia (Francis et al., 2017; Hasson-Ohayon et al., 2015; Lysaker et al., 2005). The self-reflective aspect of metacognition specifically, has been shown to be impaired in patients diagnosed with schizophrenia (Lysaker et al., 2006a; Salvatore et al., 2012). The DMN has been linked with various aspects of self-awareness and has been hypothesized as a possible source of dysfunction in patients diagnosed with schizophrenia as well (Andreou et al., 2015; Andrews-Hanna et al., 2010b; Bellana et al., 2017; Francis et al., 2017). The current study bridged these findings by using electrophysiological measures to investigate the neural basis of self-reflectivity in a psychiatric sample.

Study Hypotheses

Hypothesis 1: Resting state EEG

It was hypothesized that the psychiatric group will show decreased alpha and beta frequency band activity and increased gamma and theta frequency band activity compared to healthy controls during resting-state EEG.

Hypothesis 2: Self-referential thinking and resting-state EEG

It was hypothesized that alpha, beta, gamma, and theta frequency band activity will significantly increase in healthy controls when asked to think about themselves compared to their resting-state EEG activity, and alpha, beta, gamma, and theta frequency band activity in the psychiatric group will not significantly change.

Hypothesis 3: Resting-state EEG and MAS-A Rating

It was hypothesized that MAS-A score will be correlated with alpha, beta, gamma, and theta frequency band activity during resting-state and self-referential EEG in healthy controls and in the psychiatric group, but the correlations will be stronger for healthy controls.

CHAPTER THREE

METHODS

Participants

Participants for the current study were recruited through three different mechanisms. Patients receiving treatment at the Loma Linda University Behavioral Medicine Center (LLUBMC) in the Adult Partial Hospitalization FOCUS group were eligible to be referred by the treatment team. Additionally, flyers and advertisements, including both online and print advertisements, were posted in the community and within specific targeted groups such as local National Alliance on Mental Illness (NAMI) groups. Individuals referred through the LLUBMC FOCUS program were screened in the Brain Potential Laboratory after signing the informed consent form, to assess for the exclusionary criteria. For individuals recruited from the community, a research assistant completed the screening questions in order to assess for the exclusionary criteria over the phone. To be eligible for the current study, participants had to be adults between the ages of 18-55, had to be able to understand written and verbal English, and must have had at least 20/40 corrected vision or better. In order to be eligible for the psychiatric sample, individuals had to endorse symptoms of psychosis or schizophrenia spectrum disorders. In order to be eligible as a healthy control participant in the current study, individuals must not have endorsed any symptoms of psychosis or schizophrenia spectrum disorders and must not have had a first-degree relative with symptoms of psychosis. In order to be eligible for the specific EEG component of the current study, participants must not have been engaged in current illicit drug-use, must not have had a history of neurological disorders or serious head injury accompanied by a loss of consciousness for more than five minutes, or have had a self-reported learning disorder. A power analysis using G Power software determined at least 26 participants were needed to detect a medium-sized effect (0.30) at a 95% significance level when using a repeated-measures ANOVA to examine the interaction between a between-subjects variable and two within-subjects variables with two groups and four measurements. In total, 13 participants had complete data and met criteria for the current study; therefore the current study did not achieve adequate statistical power.

Procedures

The procedures utilized in the current study were part of a larger study conducted by the Brain Potential Laboratory. The current study was broken into three testing sessions. During the first testing session, written informed consent was obtained once the participants had been escorted to the Brain Potential Laboratory assessment room. After signing the informed consent document, participants were administered the first set of study measures, including a demographics questionnaire, portions of the Structured Clinical Interview for DMS 5 (SCID), the Positive and Negative Syndromes Scale (PANSS), the Schizophrenia Hope Scale, the Brief International Functional Capacity Assessment (BIFCA), and the MATRICS cognitive battery. The second testing session took place approximately one week after the conclusion of the first testing session. Testing session two contained the Indiana Psychiatric Illness Interview, along with several questionnaires (the Perceptual Aberration Scale, the Hinting Task, and the Interpersonal Reactivity Index (IRI)) as well as various EEG tasks. After completing the second testing session, participants received a $25 gift card as compensation for their participation in the first two testing sessions. The third testing session took place approximately three weeks after the conclusion of the second testing session. During the third testing session participants were asked to complete three final measures, including the PANSS, the Schizophrenia Hope Scale, and the Patient Activation Scale. After completing the third testing session, participants received a second $25 Wal-Mart gift card as compensation for their participation.

Measures

The Indiana Psychiatric Illness Interview.

The Indiana Psychiatric Illness Interview (IPII) is a semi-structured interview developed in order to assess illness narratives (Lysaker et al., 2002). The IPII is an individual interview typically lasting between 30 and 90 minutes (Lysaker et al., 2002). The interview is either typed verbatim throughout the course of the interview or recorded and later transcribed (Lysaker et al., 2002). The interview consists of four sections (Lysaker et al., 2002). In the first section participants are asked to tell the story of their lives, providing as much detail as they can (Lysaker et al., 2002). In the second section, participants are asked if they think they have a mental illness and if so, what they think it is (Lysaker et al., 2002). The third section asks how their interpersonal and psychological life has and has not been affected by their condition (Lysaker et al., 2002). Lastly, participants are asked if their condition controls their life and if so how, and how they control their condition (Lysaker et al., 2002). The interviewer may not offer comments that assist in clarification or impose structure to the narrative in any way (Lysaker et al., 2002). Therefore, the IPII was an ideal measure for the current study because it offers a narrative of the self that can be analyzed in terms of metacognition (Lysaker et al., 2002).

***The Metacognition Assessment Scale- Abbreviated*.**

The Metacognition Assessment Scale (MAS) was created by Semerari and colleagues (2003) in order to evaluate the metacognitive profiles of psychotherapy patients. Lysaker and colleagues (2005a) later modified the MAS to create the Metacognition Assessment Scale-Abbreviated (MAS-A) specifically for use with patients diagnosed with schizophrenia. The MAS-A is a rating scale used to assess metacognition as it arises in personal narratives, such as the IPII (Lysaker et al., 2005a; Semerari et al., 2003). The MAS-A contains four subdomains, which evaluate understanding one's own mind, understanding of others minds, decentration, and mastery (Francis et al., 2017; Lysaker et al., 2005a). Each item within a subdomain receives a score ranging from zero to one and the individual subscales are added to create a total score ranging from zero to 29 (Lysaker et al., 2005a). Higher MAS-A scores indicate a higher ability to engage in metacognitive acts (Lysaker et al., 2012). The current study utilized the score from the understanding of one's own mind subdomain in order to examine levels of self-reflectivity in the psychiatric group and healthy controls. Cohen's κ was calculated to determine if there was agreement between the two raters of the understanding one's own mind subscale used in the current study. Results indicated that there was decent inter-rater reliability, $\kappa = 0.641$, $p < .05$ for this 4-item assessment.

Positive and Negative Syndrome Scale.

The Positive and Negative Syndrome Scale (PANSS) is a 30 item rating scale used for measuring the prevalence of positive and negative syndromes in patients diagnosed with schizophrenia (Kay, Fiszbein, & Opler, 1987; Lysaker et al., 2010c). Kay and colleagues (1987) assembled the PANSS scales on the basis of theoretical and psychometric considerations. Each item is rated on a scale ranging from one to seven, with higher scores indicating greater psychopathology (Kay, Fiszbein, & Opler, 1987; Lysaker et al., 2010c). The PANSS was used in the current study to characterize the psychiatric sample. The PANSS demonstrated adequate reliability in the current study, with a Chronbach's alpha of 0.91.

Electrophysiological Assessment.

EEG was used to collect resting state brain wave activity for approximately three minutes while the participant sits comfortably with their eyes closed. Resting state brain activity was also collected after participants were asked to think about themselves while sitting comfortably with their eyes closed for an additional three minutes. EEG data was processed using BrainVision Analyzer software (Brain Products, GmbH, Gilching, Germany). Consistent with previous studies examining changes in resting state EEG, Frontal (Fz) and Central (Cz) electrode sites were used in statistical analysis (Vohs et al., 2016). The data was segmented into 2.048 s epochs and submitted to Fast-Fourier Transformations (FFT). Similar to procedures used by previous researchers evaluating resting state EEG in psychiatric samples, each participants data was averaged across epochs for each electrode site in order to compute the mean absolute power for theta (4-7

Hz), alpha (8-12 Hz), beta (12-24 Hz), and gamma (30-50 Hz) frequency bands (Kam et al., 2013;Vohs et al., 2016).

Statistical Analysis

A log transformation was applied to the EEG data to normalize the distribution and reduce the number of outliers. Individual subjects with EEG values over three times the inter-quartile range after natural log transformations were applied were used to identify outliers in each frequency band for each electrode site. There was homogeneity of variances in the alpha, gamma, and theta frequency bands, as assessed by Levene's test for equality of variances ($p > .05$). However, results indicated that the assumption of homogeneity was violated in the beta frequency band at the central region during the self-referential EEG task ($p <.05$). Mauchly's test of sphericity indicated that the assumption of sphericity was automatically met because each of the within-subjects variables only had two levels; therefore there is only one paired difference.

Frontal and central electrode sites in each frequency band were averaged in order to compute frontal and central electrode regions. Specifically, F3, F4, Fp1, Fp2, and Fz electrode sites were averaged to create the frontal region and C3, C4, Cp1, Cp2, Cp5, and Cp6 electrode sites were averaged to create the central region (Figure 1). Electrodes F7 and F8 were not included in the calculation of the frontal region average in order to reduce possible contamination by eye movement (Acharya, Hani, Thirumala, & Tsuchida, 2016). Additionally, FC sites were not included in order to ensure frontal and central sites were analyzed separately. Lastly, Fp and Cp sites were included in the calculation of the average for each region since parietal activity would not be analyzed as a separate region in the current study.

A Repeated Measures Analysis of Variance (ANOVA) with a between-subjects factor of group (healthy controls and psychiatric group) and within-subjects factors of task (resting-state EEG and self-referential resting-state EEG) and region (frontal and central) was used to evaluate EEG data for alpha, beta, gamma, and theta frequency bands separately. To test Hypothesis one, a main effect of group was used to determine group differences across frequency bands. To test Hypothesis two, a group by task interaction was used to evaluate resting-state frequency band activity in healthy controls and the psychiatric group when asked to engage in self-referential thinking. The mean EEG power values and standard deviations for healthy control participants and the psychiatric group at each frequency band in frontal and central regions during resting-state and self-referential resting-state EEG are presented in Table 1. Additionally, a Repeated Measures ANOVA with a between subjects factor of group (healthy controls and psychiatric group) and within-subjects factors of task (resting-state EEG and self-referential resting-state EEG) and electrode site (F3, F4, Fp1, Fp2, Fz, C3, C4, Cp1, Cp2, Cp5, Cp6) was used to identify specific electrode sites impacting the effects at each region.

To test Hypothesis three, Pearson correlation coefficients were used to evaluate correlations between MAS-A rating and self-referential resting-state and resting-state activity at alpha, beta, gamma, and theta frequency bands in healthy controls and the psychiatric group. A Fisher's r-to-z transformation was used to assess the significance of the difference between the two correlation coefficients (MAS-A rating and resting-state activity at each frequency band) between healthy controls and the psychiatric group during resting-state and self-referential resting-state EEG. Z scores were compared using the formula provided by Cohen and Cohen (1983). All statistical analyses were performed using statistical software IBM SPSS Statistics 22.

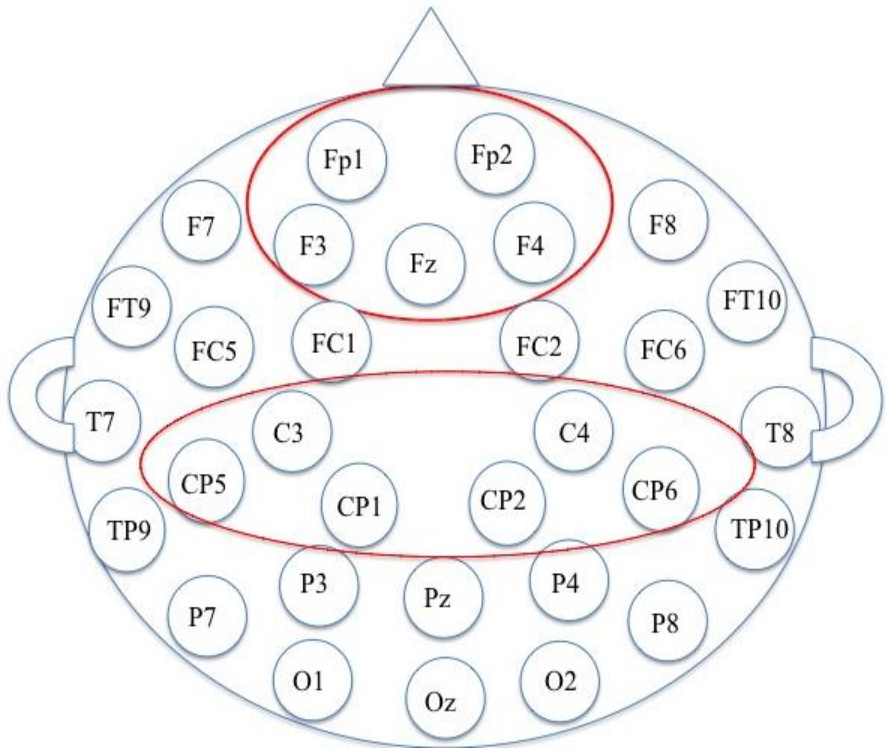

Figure 1. Electrode locations. Electrodes circled in red represent those utilized in the current study to create the frontal and central regions.

Table 1. Mean EEG Power Values and Standard Deviations by Frequency Band, Region, and Task for the Psychiatric Group and Healthy Controls

			Psychiatric Group		Healthy Controls	
Frequency Band	Region	Task	Mean	SD	Mean	SD
Alpha	Frontal	Resting-State	1.319	0.429	0.641	0.641
		Self-Referential	1.071	0.439	0.418	0.511
	Central	Resting-State	1.191	0.446	1.250	1.018
		Self-Referential	1.096	0.585	1.021	1.041
Beta	Frontal	Resting-State	0.992	0.631	0.938	0.389
		Self-Referential	0.743	0.535	0.548	0.304
	Central	Resting-State	0.681	0.271	1.149	0.431
		Self-Referential	0.532	0.226	0.772	0.592
Gamma	Frontal	Resting-State	0.894	0.869	1.247	0.877
		Self-Referential	0.820	0.799	0.775	0.496
	Central	Resting-State	0.204	0.812	0.427	0.745
		Self-Referential	0.020	0.517	0.188	0.608
Theta	Frontal	Resting-State	1.419	0.745	0.407	0.523
		Self-Referential	1.169	0.714	0.361	0.610
	Central	Resting-State	0.763	0.339	-0.066	1.033
		Self-Referential	0.589	0.372	-0.059	0.698

CHAPTER FOUR

RESULTS

Participants

There were 28 participants that began the study. Out of those 28, 13 participants had both resting-state and self-referential resting-state EEG data and were therefore eligible for the current study. Given the small sample size, the decision was made to include individuals diagnosed with bipolar disorder with psychotic features and schizoaffective disorder in addition to individuals diagnosed with schizophrenia in the current analyses. Thus, the final dataset included 13 participants, five in the healthy control group and eight in the psychiatric group. Of note, 16 participants had both MAS-A ratings and resting-state EEG data available and 12 participants had both MAS-A ratings and self-referential resting-state EEG data available. The decision was made to include the maximum number of subjects in the correlation analyses. Therefore correlations between MAS-A rating and resting-state activity included 16 participants and correlations between MAS-A rating and self-referential resting-state activity included 12 participants. Table 2 provides a list of relevant demographic information. The majority of the participants identified as Caucasian (38.5%; n=1 in the healthy control group; n=4 in the psychiatric group) and female (53.8%; n=5 in the healthy control group; n=2 in the psychiatric group), with a mean age of 33.60 for the healthy control group (SD = 15.27) and a mean age of 37.63 for the psychiatric group (SD = 11.22). There was not a significant difference in age between the healthy control and psychiatric groups $t(11) = 0.550$, $p = 0.594$. However, there was a significant difference in the gender distribution between groups, $x^2(1) = 6.964$, $p < .05$. The healthy control group consisted of only female participants (n = 5) and the psychiatric group consisted of two female participants and six male participants. Average highest level of education completed was 14.50 years for the healthy control group and 12.75 for the psychiatric group. There was not a significant difference in years of education between groups, $t(11) = -1.798$, $p = 0.134$. In terms of clinical symptomology, 20 % of healthy control participants and 100% of participants in the psychiatric group endorsed symptoms of a mood disorder. 75% of participants in the psychiatric group endorsed symptoms of a psychotic disorder and none of the healthy control participants endorsed symptoms of a psychotic disorder. In the psychiatric group, 50% of participants had a diagnosis of schizophrenia, 25% had a diagnosis of either bipolar I or bipolar II disorder with psychotic features, 12.5% had a diagnosis of schizoaffective disorder, and 12.5% were diagnosed with other psychotic disorder. In the healthy control group, 60% had no previous psychiatric diagnosis and 40% were diagnosed with a depressive disorder. Of note, information regarding clinical symptomology was not collected for one healthy control participant in the current study. However demographic information regarding age, gender, diagnosis, and years of education were collected for all participants included in the current study. The current study had a mean self-reflectivity rating of 4.72 (SD = 0.795) as measured by the MAS-A in the psychiatric group and a mean self-reflectivity rating of 5.57 (SD = 1.69) as measured by the MAS-A in the healthy control group.

Table 2. Demographics' of the Current Sample

Demographic	%	*N*
Healthy Control Gender		
Female	100	5
Male	0	0
Psychiatric Group Gender		
Male	75	6
Female	25	2
Race		
Caucasian	38.5	5
Other	30.8	4
No Response	15.4	2
African American	7.7	1
Latino	7.7	1
Psychiatric Group Diagnoses		
Schizophrenia	50	4
Bipolar II with Psychotic Features	12.5	1
Bipolar I with Psychotic Features	12.5	1
Schizoaffective Disorder	12.5	1
Other Psychotic Disorder	12.5	1
Healthy Control Group Diagnoses		
No Diagnosis	60	3
Major Depressive disorder	20	1
Persistent Depressive Disorder	20	1
Highest Grade Completed	Mean	SD
Psychiatric Group	12.75	0.89
Healthy Control Group	14.6	2.19
Age		
Psychiatric Group	37.63	11.22
Healthy Control Group	33.6	15.27

Psychiatric Symptom Characterization

Characterization of psychotic symptoms was captured by the Positive and Negative Syndrome Scale (PANSS). The average symptom severity ratings for Positive Symptoms in the psychiatric group were 18.75 (SD = 4.86). The average symptom severity ratings for Negative Symptoms in the psychiatric group were 14.75 (SD = 6.20). Lastly, the average symptom severity ratings for General Symptoms in the psychiatric group were 32.75 (SD = 8.23). Pearson correlations were computed to assess the relationship between PANSS ratings of positive and negative symptoms and resting-state and self-referential resting-state EEG data in the psychiatric group (Table 3). Results revealed no significant correlations between positive and negative symptoms as measured by the PANSS and resting-state or self-referential resting-state EEG data in the psychiatric group in the alpha, beta, gamma or theta frequency bands.

Table 3. Pearson Correlation Values Between PANSS Data and EEG Data for the Psychiatric Group

Frequency Band	Region		Positive Symptoms	Negative Symptoms	General Symptoms
Alpha	Frontal	Resting-State	-0.014	-0.052	-0.171
		Self-Referential Resting-State	-0.120	0.353	-0.031
	Central	Resting-State	-0.236	-0.111	0.114
		Self-Referential Resting-State	0.228	0.160	0.364
Beta	Frontal	Resting-State	-0.276	-0.121	-0.464
		Self-Referential Resting-State	-0.412	0.044	-0.404
	Central	Resting-State	-0.399	-0.169	-0.050
		Self-Referential Resting-State	-0.219	0.156	0.352
Gamma	Frontal	Resting-State	-0.302	-0.209	-0.536
		Self-Referential Resting-State	-0.618	-0.259	-0.688
	Central	Resting-State	-0.196	0.237	0.070
		Self-Referential Resting-State	-0.529	0.137	-0.091
Theta	Frontal	Resting-State	0.286	0.138	0.004
		Self-Referential Resting-State	0.144	0.048	-0.197
	Central	Resting-State	-0.099	-0.315	-0.123
		Self-Referential Resting-State	0.069	0.076	0.000

Note. There were no significant Pearson correlations between PANSS ratings and EEG Power across frequency bands

Alpha Frequency Band

Repeated Measures ANOVA revealed no significant main effect of group in the alpha frequency band, $F(1,11) = 1,432$, $p = 0.257$, no significant main effect of task, $F(1,11,) = 2.054$, $p = 0.180$, and no significant group x task interaction, $F(1,11) = 2.889$, $p = 0.117$. There were no other statistically significant two or three- way interactions (Table 4).

Pearson correlation analyses indicated no significant correlations between MAS-A ratings of self-reflectivity and alpha frequency band EEG activity during resting-state or self-referential resting-state EEG for healthy controls (Frontal $r(4)= 0.043$, $p =0.926$; Frontal Self-Referential $r(2) = 0.826$, $p = 0.085$; Central $r(4) = 0.174$, $p=0.710$; Central Self-Referential $r(2) = 0.766$, $p = 0.131$) or the psychiatric group (Frontal $r(6) = 0.243$, $p=0.528$; Frontal Self-Referential $r(4) = 0.683$, $p = 0.091$; Central $r(6) = -0.490$, $p =0.181$; Central Self-Referential $r(4) = -0.499$, $p = 0.254$). Additionally, there was not a statistically significant difference in correlations between healthy controls and the psychiatric group (Frontal z = -0.32, $p = 0.751$; Frontal Self-Referential z = 0.05, $p = 0.960$; Central z =1.1, $p = 0.271$; Central Self-Referential z= 1.53, $p = 0.126$). Table 5 contains Pearson correlations between MAS-A ratings of self-reflectivity and frequency band EEG activity during resting-state and self-referential resting-state EEG for healthy controls and the psychiatric group.

Beta Frequency Band Activity

Repeated Measures ANOVA revealed no significant main effect of group in the beta frequency band, $F(1,11) = 0.485$, $p = 0.501$, no significant main effect of task,

$F(1,11) = 0.015$, $p = 0.905$, and no significant group x task interaction, $F(1,11) = 1.904$, $p = 0.195$. However, there was a significant main effect of region, $F(1,11) = 14.758$, $p < .05$, partial $\eta^2 = 0.573$. Pairwise comparisons revealed that beta frequency band activity was significantly higher in the frontal region than the central region with a mean difference of 0.291, 95% CI [0.124, 0.458], $p < .05$. There were no other statistically significant two or three- way interactions (Table 4).

A separate Repeated Measures ANOVA was conducted using a between subjects factor of group (healthy control vs psychiatric) and within subjects factors of electrode site (F3, F4, Fp1, Fp2, Fz) and task (resting-state EEG and self-referential resting-state EEG) to identify which individual electrodes were driving the above main effect of region. Mauchly's test of sphericity indicated that the assumption of sphericity was violated ($p < .05$). Therefore Greenhouse-Geisser corrections were interpreted. There was no significant main effect of electrode site in the frontal region, $F(4, 44) = 2.663$, $p = .102$, indicating that all electrode sites contributed equally to the main effect of region.

Pearson correlation analyses indicated a statistically significant, strong positive correlation between MAS-A ratings of self-reflectivity and beta frequency band activity in the central region $r(1) = 0.911$, $p < .05$ during self-referential resting-state EEG for healthy control participants (Figure 2). Furthermore, a Fisher's r-to-z transformation indicated that there was a statistically significant difference in correlations between healthy controls and the psychiatric group in the central region during self-referential resting-state EEG, $z = 2.09$, $p < .05$ (Table 5).

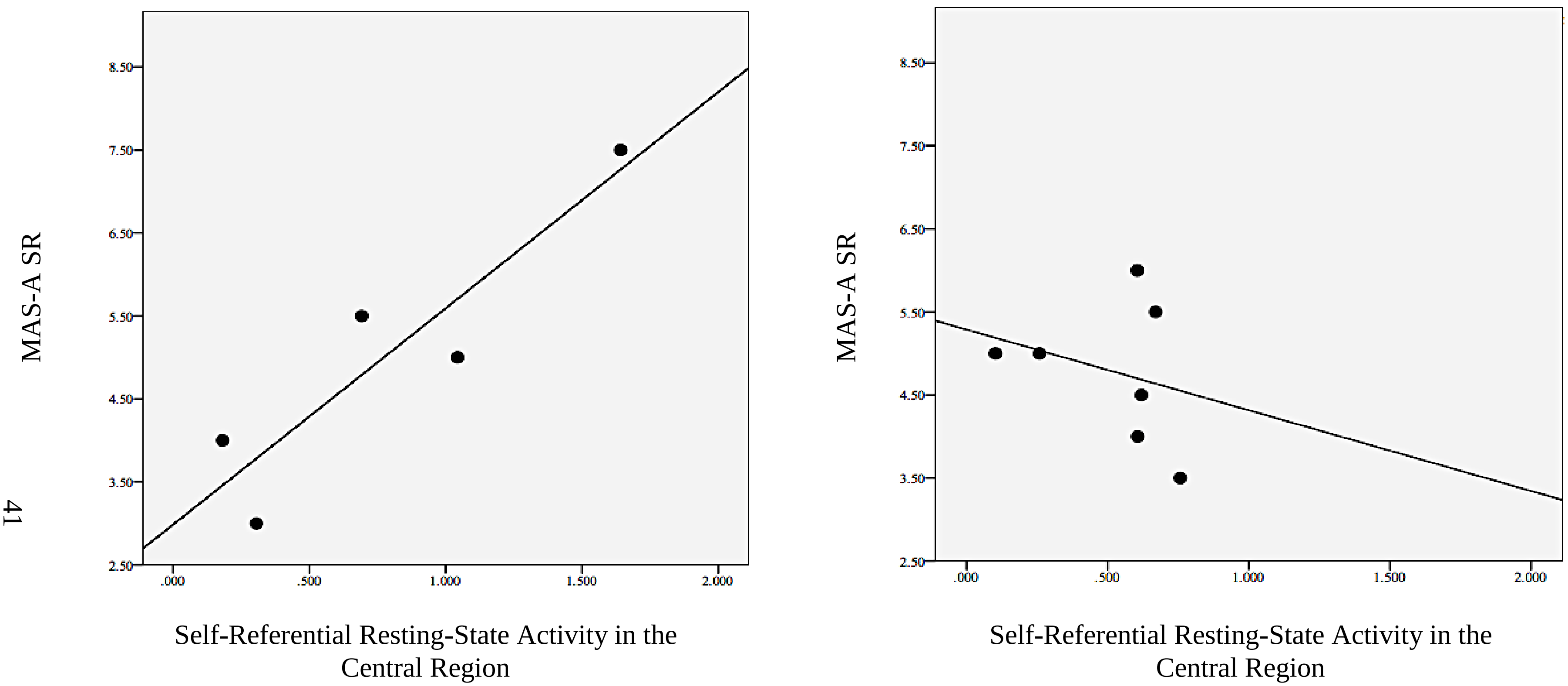

Figure 2. Left: Scatterplot representing the significant, strong positive correlation between MAS-A ratings of self-reflectivity and beta frequency band activity in the central region during self-referential resting-state EEG for healthy control participants. Right: Scatterplot representing the non-significant correlation between MAS-A ratings of self-reflectivity and beta frequency band activity in the central region during self-referential resting-state EEG for the psychiatric group. Sample size for the healthy control group, n = 5. Sample size for the psychiatric group, n = 7.

Gamma Frequency Band Activity

Repeated Measures ANOVA revealed no significant main effect of group in the gamma frequency band, $F(1,11) = 0.283$, $p = 0.605$, and no significant group x task interaction, $F(1,11) = 0.009$, $p = 0.925$. However, results did indicate a significant main effect of task, $F(1,11) = 10.941$, $p < .05$, partial $\eta^2 = 0.499$. Pairwise comparisons revealed that gamma frequency band activity was significantly higher during the resting-state EEG task than the self-referential resting-state EEG task with a mean difference of 0.724, 95% CI [0.242, 1.206], $p < .05$ (Figure 3). There were no other statistically significant two or three- way interactions (Table 4).

Pearson correlation analyses indicated no significant correlations between MAS-A ratings of self-reflectivity and gamma frequency band EEG activity during resting-state or self-referential resting-state EEG for healthy controls (Frontal $r(4)= -0.528$, $p =0.223$; Frontal Self-Referential $r(2) = -0.318$, $p = 0.602$; Central $r(4) = -0.740$, $p=0.057$; Central Self-Referential $r(2) = -0.405$, $p = 0.498$) or the psychiatric group (Frontal $r(4)= 0.127$, $p =0.744$; Frontal Self-Referential $r(2) = 0.280$, $p = 0.544$; Central $r(4) = -0.130$, $p=0.739$; Central Self-Referential $r(2) = 0.068$, $p = 0.885$). While not statistically significant, it should be noted that correlations between MAS-A ratings of self-reflectivity and gamma frequency band activity in the central region, $r(4) = -0.740$, $p=0.057$ during resting-state EEG for healthy control participants was trending toward significance (Table 5). Additionally, there was not a statistically significant difference in correlations between healthy controls and the psychiatric group (Frontal z = -1.11, $p = 0.267$; Frontal Self-Referential z = -0.71, $p = 0.478$; Central z = -1.27, $p = 0.204$; Central Self-Referential z= -0.45, $p = 0.652$).

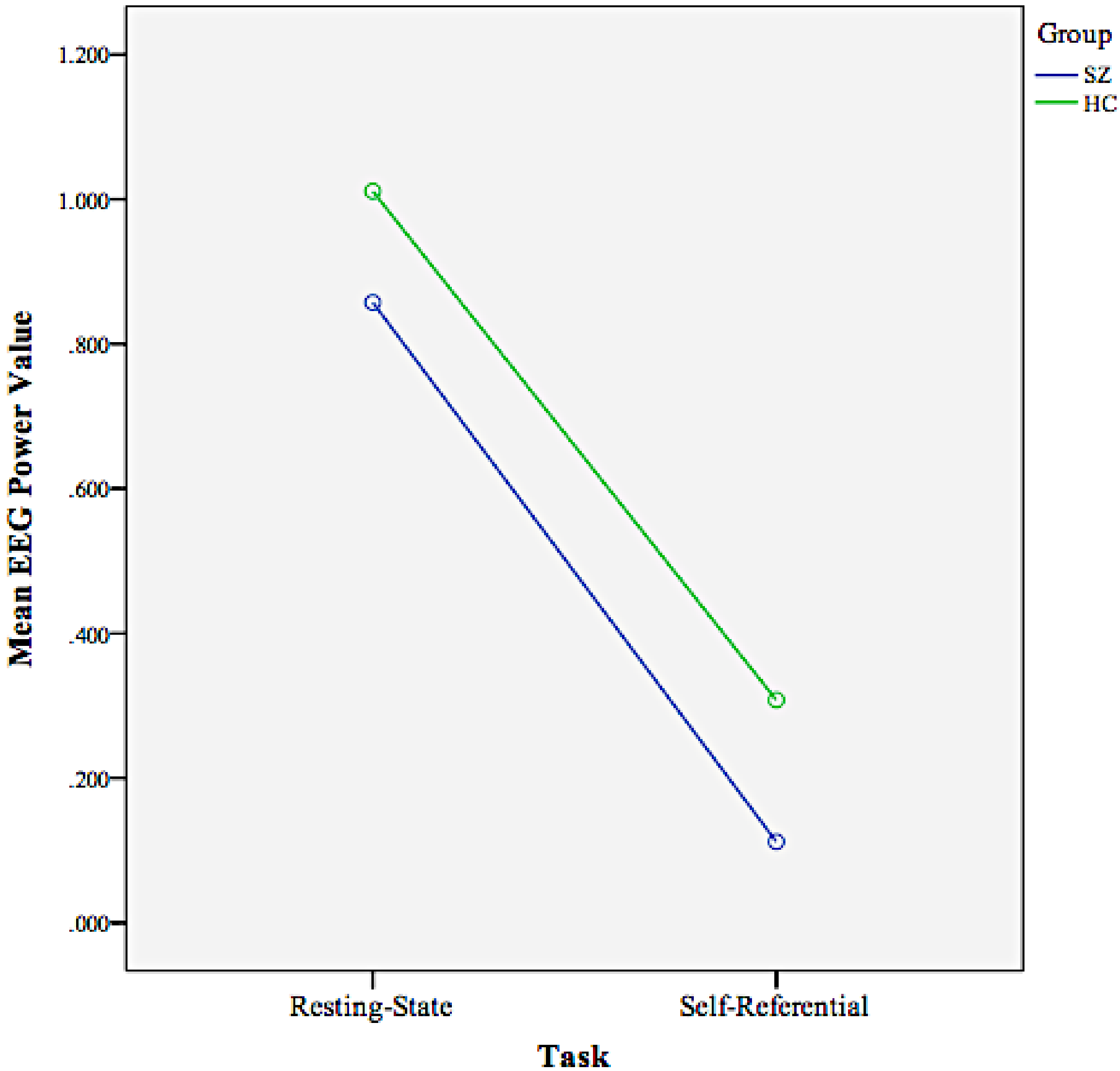

Figure 3. Plot representing the significant main effect of task in the gamma frequency band. Pairwise comparisons revealed that gamma frequency band activity was significantly higher during the resting-state EEG task than the self-referential resting-state EEG task with a mean difference of 0.724, 95% CI [0.242, 1.206], $p < .05$.

Theta Frequency Band Activity

Repeated Measures ANOVA revealed a significant main effect of group in the theta frequency band, $F(1,11) = 7.648$, $p < .05$, partial $\eta^2 = 0.410$. Pairwise comparisons indicated that theta frequency band activity was significantly higher in the psychiatric group than in healthy controls with a mean difference of 0.825, 95% CI [0.168, 1.148], $p < .05$ (Figure 4). Analyses revealed no significant group x task interaction, $F(1,11) = 0.173$, $p = 0.686$. However, results did indicate a significant main effect of task, $F(1,11) = 6.661$, $p < .05$, partial $\eta^2 = 0.377$. Pairwise comparisons revealed that theta frequency band activity was significantly higher during the resting-state EEG task than the self-referential resting-state EEG task with a mean difference of 0.532, 95% CI [0.078, 0.986], $p < .05$ (Figure 5). There were no other statistically significant two or three- way interactions (Table 4).

Pearson correlation analyses indicated a statistically significant, strong negative correlation between MAS-A ratings of self-reflectivity and theta frequency band activity in the central region, $r(5) = -0.683$, $p < .05$ during resting-state EEG for the psychiatric group (Figure 6). However, there was not a statistically significant difference in correlations between healthy controls and the psychiatric group (Table 5; Frontal z = -0.61, $p = 0.542$; Frontal Self-Referential z = 0.23, $p = 0.818$; Central z = 1.77, $p = 0.077$; Central Self-Referential z= 0.69, $p = 0.490$).

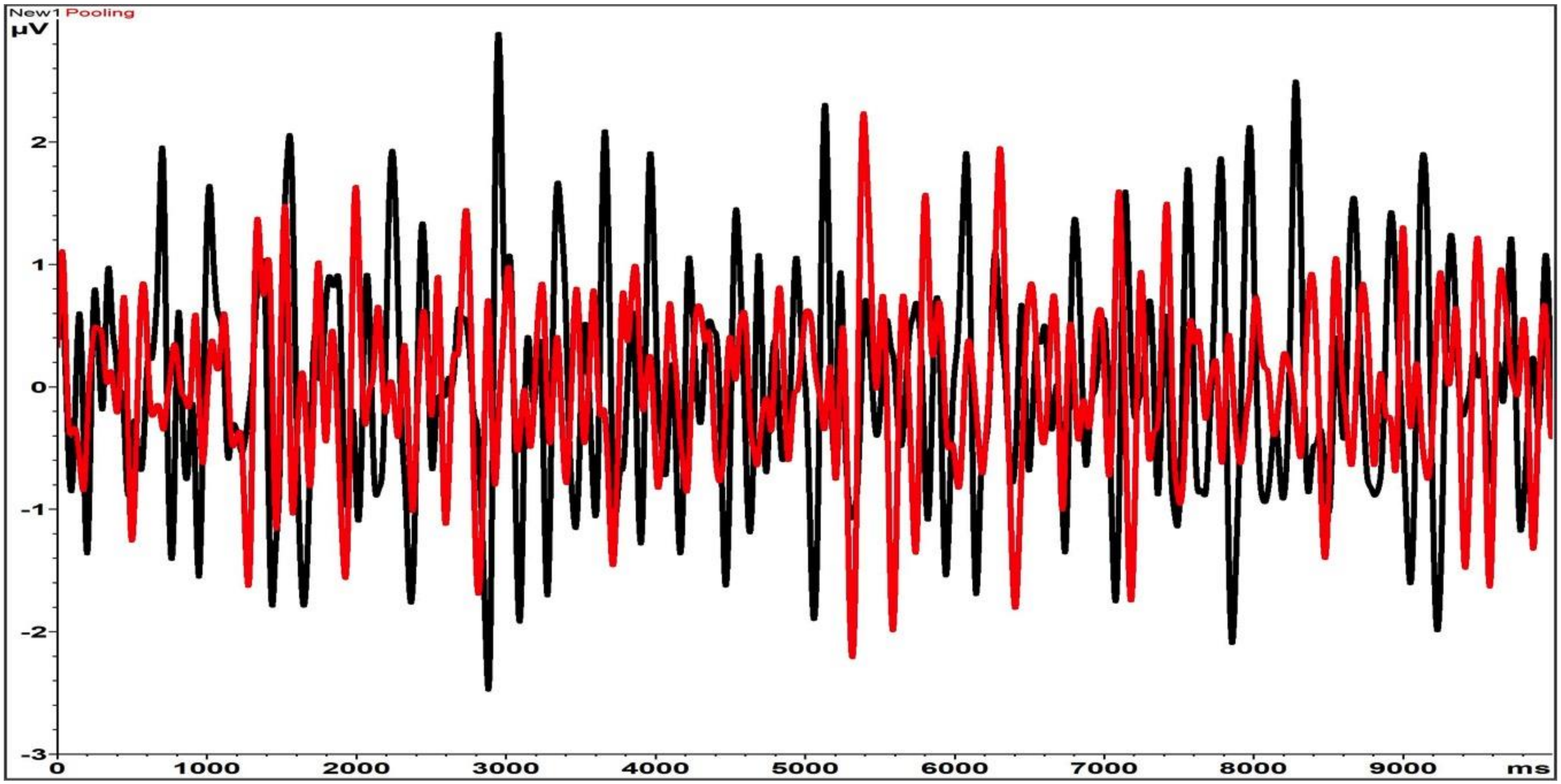

Figure 4. Waveforms demonstrating the significant main effect of group in the theta frequency band (4-7 Hz). The black line represents theta frequency band activity in the healthy control group and the red line represents theta frequency band activity in the psychiatric group. Pairwise comparisons indicated that theta frequency band activity was significantly higher in the psychiatric group than in healthy controls with a mean difference of 0.825, 95% CI [0.168, 1.148], $p < .05$.

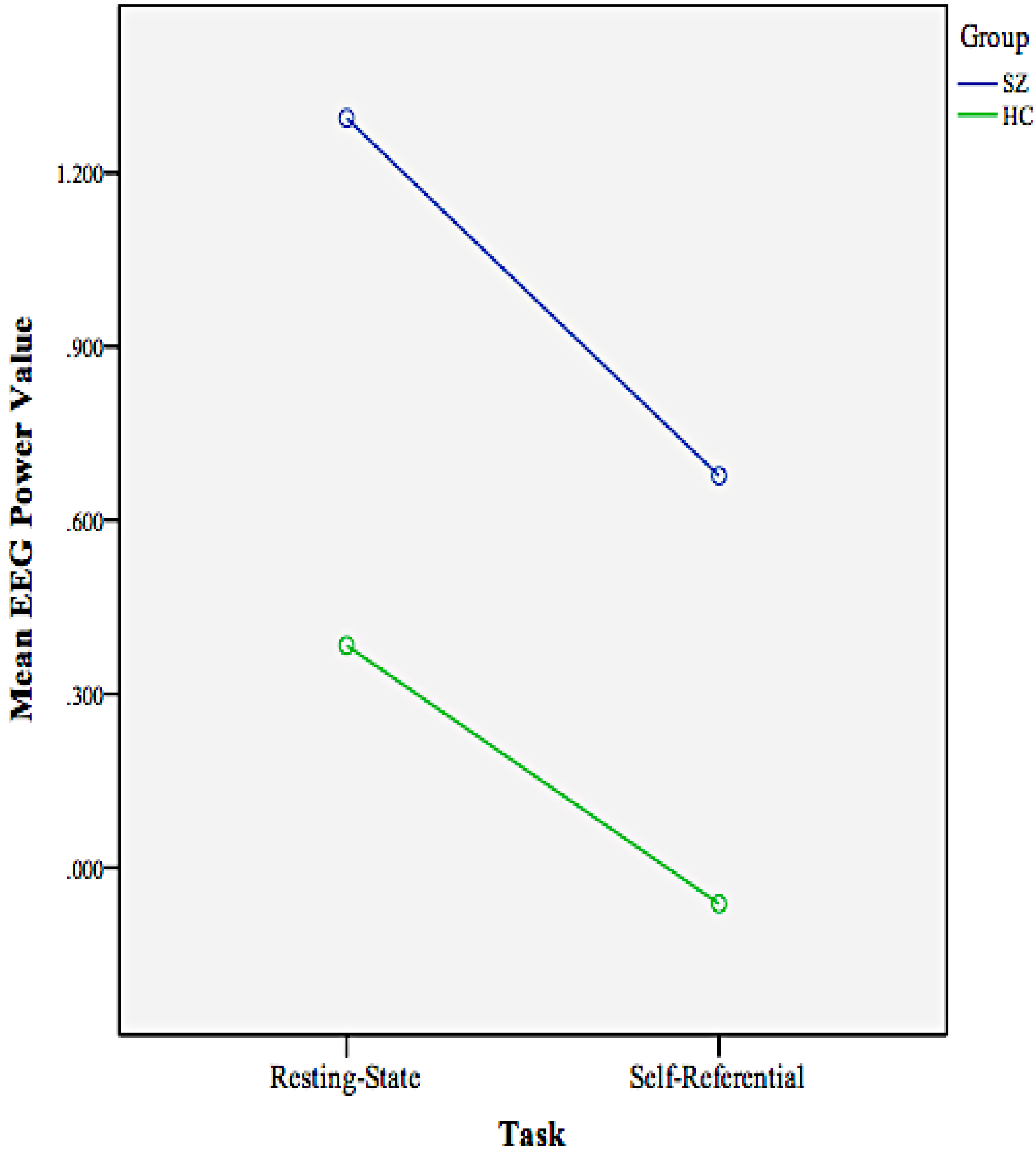

Figure 5. Plot representing the significant main effect of task in the theta frequency band. Pairwise comparisons revealed that theta frequency band activity was significantly higher during the resting-state EEG task than the self-referential resting-state EEG task with a mean difference of 0.532, 95% CI [0.078, 0.986], $p < .05$.

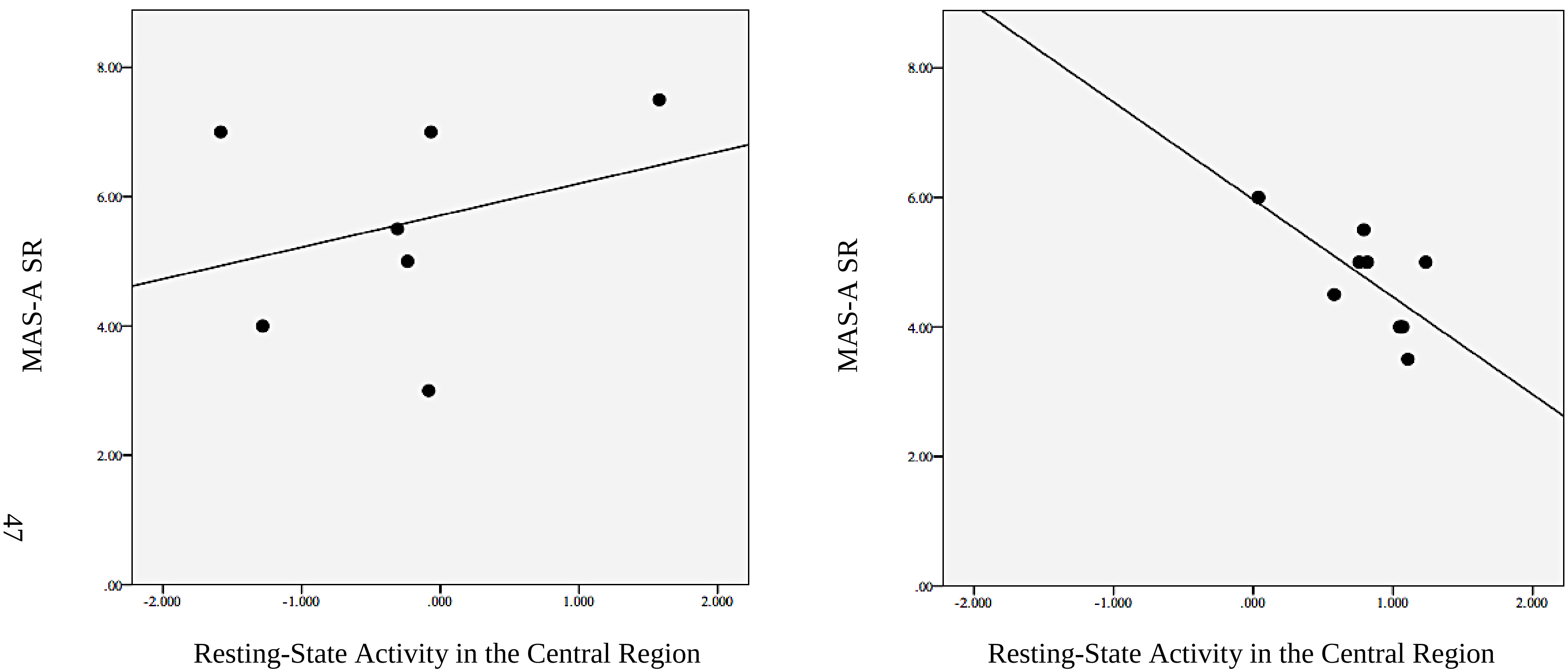

Figure 6. Left: Scatterplot representing the non-significant correlation between MAS-A ratings of self-reflectivity and theta frequency band activity in the central region during resting-state EEG for the healthy control group. Right: Scatterplot representing the significant, strong negative correlation between MAS-A ratings of self-reflectivity and theta frequency band activity in the central region during resting-state EEG for the psychiatric group. Sample size for the healthy control group, n = 7. Sample size for the psychiatric group, n = 9.

Table 4. Repeated Measures ANOVA Results for Alpha, Beta, Theta, and Gamma Frequency Bands

Frequency Band	df	F	*p*	η^2
Alpha				
Group	1,11	1.432	0.257	0.115
Task	1,11	2.054	0.18	0.157
Region	1,11	3.622	0.083	0.248
Group x Task	1,11	2.889	0.117	0.208
Region x Group	1,11	0.069	0.798	0.006
Region x Task	1,11	0.555	0.472	0.048
Group x Task x Region	1,11	0.661	0.433	0.057
Beta				
Group	1,11	0.485	0.501	0.042
Task	1,11	0.015	0.905	0.001
Region	1,11	**14.758**	**0.003**	0.573
Group x Task	1,11	1.904	0.195	0.148
Region x Group	1,11	1.482	0.249	0.119
Region x Task	1,11	0.457	0.513	0.04
Group x Task x Region	1,11	0.26	0.623	0.023
Gamma		1.419	0.238	0.407
Group	1,11	0.283	0.605	0.025
Task	1,11	**10.941**	**0.007**	0.499
Region	1,11	3.249	0.099	0.228
Group x Task	1,11	0.009	0.925	0.001
Region x Group	1,11	0.706	0.419	0.6
Region x Task	1,11	0.29	0.601	0.026
Group x Task x Region	1,11	2.29	0.158	0.172
Theta				
Group	1,11	**7.648**	**0.018**	0.41
Task	1,11	**6.661**	**0.026**	0.377
Region	1,11	1.39	0.263	0.112
Group x Task	1,11	0.173	0.686	0.015
Region x Group	1,11	0.971	0.346	0.081
Region x Task	1,11	0.246	0.63	0.022
Group x Task x Region	1,11	0.008	0.931	0.001

Note. Bolded values are significant at $p < .05$

Table 5. Pearson Correlation Values Between MAS-A Data and EEG Data for the Psychiatric Group and Healthy Controls

Frequency Band	Region	Task	Psychiatric group MAS-A	Healthy Controls MAS-A	Difference in Z scores
Alpha	Frontal	Resting-State	0.243	0.043	-0.32
		Self-Referential	0.683	0.826	0.05
	Central	Resting-State	-0.490	0.174	1.1
		Self-Referential	-0.499	0.766	1.53
Beta	Frontal	Resting-State	0.366	-0.314	1.1
		Self-Referential	0.701	0.292	-0.66
	Central	Resting-State	-0.233	-0.126	0.17
		Self-Referential	-0.272	**0.911**	**2.09**
Gamma	Frontal	Resting-State	0.127	-0.528	-1.11
		Self-Referential	0.280	-0.318	-0.71
	Central	Resting-State	-0.130	-0.740	-1.27
		Self-Referential	0.068	-0.405	-0.45
Theta	Frontal	Resting-State	0.286	-0.097	-0.61
		Self-Referential	0.395	0.551	0.23
	Central	Resting-State	**-0.683**	0.296	1.77
		Self-Referential	0.112	0.609	0.69

Note. Bolded values are significant at $p < .05$.

CHAPTER FIVE

DISCUSSION

The current study had two aims. The first was to explore the electrophysiological correlates of self-referential processing in a psychiatric group compared to healthy controls. The second was to investigate the relationship between electrophysiological measures of self-reflectivity and interview ratings of self-reflectivity. The current study used a repeated measures ANOVA to evaluate group differences between healthy controls and a psychiatric group for each frequency band (alpha, beta, gamma, theta) and for each task (resting-state and self-referential resting-state) at frontal and central electrode sites separately (F3, F4, Fp1, Fp2, Fz, C3, C4, Cp1, Cp2, Cp5, Cp6).

It was hypothesized that the psychiatric group would show decreased alpha and beta frequency band activity and increased gamma and theta frequency band activity compared to healthy controls during resting-state EEG (Hypothesis 1). Hypothesis one was partially supported. A significant main effect of group was found in the theta (4-7 Hz) frequency band, indicating that the psychiatric group showed increased theta activity compared to healthy controls during resting-state EEG. However, there were no significant main effects of group in the alpha (8-12 Hz), beta (20-30 Hz), or gamma (30 – 50 Hz) frequency bands.

It was also hypothesized that alpha, beta, gamma, and theta frequency band activity will significantly increase in healthy controls when asked to think about themselves during resting-state EEG and alpha, beta, gamma, and theta frequency band activity in the psychiatric group will not significantly change (Hypothesis 2). Hypothesis two was not supported because there were no significant interactions between group and task in any frequency bands. Therefore contrary to our hypothesis, EEG activity did not significantly increase in healthy controls when asked to think about themselves.

Results of the current study are consistent with previous research indicating that theta frequency band magnitude may represent a trait characteristic of schizophrenia associated with neurocognitive deficits (Andreou et al., 2015). Kam and colleagues (2013) reported that a consistent finding in resting-state EEG in patients diagnosed with schizophrenia is augmented low frequency power at delta and theta frequency bands. Clementz and colleagues (1994) found increased theta frequency band activity during resting-state EEG in participants diagnosed with schizophrenia as well as participants diagnosed with bipolar disorder compared to healthy controls. Furthermore, previous researchers have reported that participants diagnosed with schizophrenia showed higher connectivity in the theta frequency band during resting-state EEG compared to healthy controls (Lorenzo et al., 2015). Researchers have also suggested that aberrant theta-band connectivity may be a target for electrophysiology-based treatments for patients diagnosed with schizophrenia as well as individuals at high-risk for psychosis (Andreou et al., 2015). Therefore, the results of the current study demonstrating that the psychiatric group showed increased theta activity compared to healthy controls during resting-state EEG may further indicate that increased resting-state theta frequency band activity is a characteristic of patients experiencing psychotic symptoms.

One possible explanation for the lack of significant differences in alpha, beta, or gamma frequency bands between the psychiatric group and healthy controls in the current study may be due to the symptomology of the healthy control sample. Approximately, 40% of healthy control participants in the current study endorsed symptoms of depression. Previous researchers have reported various EEG abnormalities in patients experiencing symptoms of depression (Akar et al., 2915; Allen & Cohen, 2010; Fitzgerald & Watson, 2018). The current study had a mean EEG power in the alpha frequency band of 0.641 (SD = 0.641) in the frontal region and 1.250 (SD = 1.018) in the central region during resting-state EEG in the healthy control group (Table 1). Previous researchers have reported mean EEG power values in the alpha frequency band between 1.22 and 1.88 in the frontal region and between 1.34 and 2.89 in the central region in healthy control participants (Chen et al., 2019; Kam et al., 2013; Woltering et al., 2012). Therefore, mean EEG power values in the alpha frequency band in the current study were lower than those typically reported in healthy control participants. These results are consistent with those reported by previous researchers, indicating a specific decrease in alpha frequency band activity in patients diagnosed with schizophrenia as well as patients with a history of major depression (Allen & Cohen, 2010).

Additionally, the current study had a mean EEG power in the gamma frequency band of 1.247 (SD = 0.877) in the frontal region and 0.427 (SD = 0.745) in the central region during resting-state EEG in the healthy control group (Table 1). Previous researchers have reported mean EEG power values between 0.10 and 0.37 in the frontal region and between 0.08 and 0.15 in the central region in healthy control samples during resting-state EEG (Chen et al., 2019; Kam et al., 2013). Therefore, mean EEG power values in the gamma frequency band in the current study were higher than those typically reported in healthy control participants. These results are consistent with those reported by Akar and colleagues (2015) that found that participants diagnosed with major depressive disorder had significantly higher EEG complexities in the gamma frequency band compared to healthy control participants. Fitzgerald and Watson (2018) hypothesized that gamma frequency band oscillations may present as a novel biomarker of major depression.

Lastly, the current study had a mean EEG power in the beta frequency band of 0.938 (SD = 0.389) in the frontal region and 1.149 (SD = 0.438) in the central region during resting-state EEG in the healthy control group (Table 1). Previous researchers have reported mean EEG power values between 0.35 and 0.61 in the frontal region and between 0.36 and 0.69 in the central region in healthy control participants during resting-state EEG (Chen et al., 2019; Kam et al., 2013; Woltering et al., 2012). Therefore, mean EEG power values in the beta frequency band in the current study were also higher than those typically reported in healthy control participants. Newson and Thiagarajan (2019) reported that a review of resting-state EEG studies indicated that significant increases in beta frequency band activity were commonly reported in participants diagnosed with depression. Therefore, the lack of significant differences in resting-state EEG activity in the alpha, beta, and gamma frequency bands between healthy controls and the psychiatric group in the current study may be due to the presence of depressive symptoms in the healthy control sample.

The results of the current study also revealed a significant main effect of region in the beta frequency band. Pairwise comparisons indicated that beta frequency band activity was significantly higher in the frontal region than the central region. Previous researchers have reported that beta frequency band activity in frontal regions differed for patients diagnosed with schizophrenia and relatives of patients diagnosed with schizophrenia compared to healthy controls (Venables et al., 2009). Researchers have also reported increased beta frequency band activity in frontal regions specifically in elderly healthy control participants (Zappasodi et al., 2006). Venables and colleagues (2009) suggested that increased beta frequency band activity over frontal and temporal regions may reflect a genetic liability for schizophrenia. Lastly, researchers have also reported that coherence of beta waves in the left frontal region positively predicted executive functions in a sample of healthy control participants (Basharpoor, Heidari, Molavi, 2019). Therefore the results of the current study are consistent with those of previous studies indicating increased beta frequency band activity in the frontal region in patients diagnosed with schizophrenia as well as healthy control participants during resting-state EEG.

Analyses also revealed a significant main effect of task in the gamma and theta frequency bands. Pairwise comparisons indicated that frequency band activity was significantly higher in the resting-state EEG task than in the self-referential resting-state EEG task in both the gamma and theta frequency bands. As previously stated, the current study also found a significant main effect of group in the theta frequency band, indicating that theta frequency band activity was higher in the psychiatric group compared to healthy control participants. Although there was no significant group by task interaction in the theta frequency band, both of these results are consistent with those reported by previous researchers demonstrating that theta frequency band activity is increased in patients diagnosed with schizophrenia during resting-state EEG (Andreou et al., 2015; Venables et al., 2009). Furthermore, increased theta frequency band activity during resting-state EEG has also been correlated with decreased DMN activity. Previous researchers have reported negative correlations between medial prefrontal activity as measured by Functional Magnetic Resonance Imaging (fMRI), and theta oscillations during a resting-state task and suggested that theta frequency band activity can be seen as an EEG index of default mode network activity (Scheeringa et al., 2008; Mu & Han, 2010). Therefore, the increased activity in the theta frequency band during resting-state EEG compared to self-referential resting-state EEG may indicate that the default mode network was less activated in the theta frequency band during resting-state EEG.

Additionally, previous researchers have demonstrated that increased gamma frequency band activity at rest may reflect cortical hyperexcitability in patients diagnosed with schizophrenia, which would signify increased noise and cortical inefficiency (Venables et al., 2009; Vohs et al., 2016). Vohs and colleagues (2016) reported that hyperactivity in the gamma frequency band may be linked to the disruption of cognitive integration and ultimately the ability to form complex ideas about oneself and others. Furthermore, Mu and Han (2010) demonstrated event-related desynchronization specifically associated with self-referential trait adjectives in gamma frequency band activity. Therefore, the increased activity in the gamma frequency band during resting-state EEG compared to self-referential resisting-state EEG may further indicate that increased gamma frequency band activity is linked with less self-referential processing.

The DMN is most active when the brain is *not* focused on a task and is regularly observed to deactivate during attention demanding cognitive tasks (Scheeringa et al., 2008). For instance, Grady and colleagues (2009) found that participants demonstrated reduced activity in the DMN when asked to engage in four visual tasks. Raichle and colleagues (2001) also reported that brain regions known to be associated with the DMN, such as the PCC and mPFC, show decreased activity when focused attention is required, such as when participants are asked to view a passive visual stimulus. Andrews-Hanna and colleagues (2010b) stated that when left alone and undisturbed, people tend to engage in self-relevant internal cognitive processes that likely activate DMN subsystems such as the PCC and mPFC. Similarly, previous researchers have revealed that the DMN exhibits greater activity during passive epochs compared to controlled, externally directed tasks or active task conditions (Andrews-Hanna et al., 2010b; Bucker et al., 2008). In the current study, examiners explicitly directed participants to think about themselves during the self-referential resting-state EEG task. Therefore, a possible explanation for the lack of significant findings in alpha, beta, gamma, and theta frequency band activity during the self-referential resting-state EEG task may be that the current study created a directed task by instructing participants to engage in self-referential thinking, thereby deactivating the default mode network.

However, the results of the current study are consistent with previous literature indicating a relationship between gamma and theta frequency band activity. Previous researchers have hypothesized that gamma frequency oscillations are nested within theta oscillations in the hippocampus in rodents (Belluscio et al., 2012; Pahor & Jausˇovec, 2014). Lisman and Buzsaki (2008) suggested that theta and gamma oscillations work together to form a neural code. Additionally, Holz and colleagues (2010) demonstrated that a comparison between new and familiar information is associated with cross-frequency theta-gamma phase synchronization in healthy control participants. Lastly, researchers have reported that resting-state theta-gamma cross-frequency coupling is associated with measures of intelligence (Pahor & Jausˇovec, 2014). Therefore, results of the current study may further demonstrate that a relationship exists between gamma and theta frequency band activity.

The current study did not find any significant correlations between PANSS ratings of positive and negative symptoms and resting-state EEG or self-referential resting-state EEG data in the psychiatric group. In the current study, the average rating of positive symptoms was 18.75 and the average rating of negative symptoms was 14.75 in the psychiatric group. Previous researchers have generally reported average PANSS ratings of positive and negative symptoms between 15 and 19 (Brosey & Woodward 2016; Corbera et al., 2014; Couture et al., 2010). Therefore, this lack of association does not appear to be related to differences in symptom severity between our sample and those commonly reported in the literature. The lack of significant correlations despite the presence of positive and negative symptoms in the psychiatric group may be due to the small sample size of the current study. As previously stated, the final data set included 13 participants, eight in the psychiatric group and five in the healthy control group. Therefore, a higher sample size may be needed in order to reliably detect a significant correlation outside of random chance.

Lastly, it was hypothesized that interview ratings of self-reflectivity would be correlated with alpha, beta, gamma, and theta frequency band activity during resting-state and self-referential resting-state EEG in healthy controls and in the psychiatric group, but the correlations will be stronger for healthy controls (Hypothesis 3). Hypothesis three was partially supported. Pearson correlation analyses revealed a significant, strong positive correlation between MAS-A ratings of self-reflectivity and beta frequency band activity in the central region during self-referential resting-state EEG for healthy control participants. Therefore, healthy control participants that demonstrated higher levels of self-reflectivity as measured by the MAS-A, had higher activity in the beta frequency band in the central region during the self-referential resting-state EEG task. Furthermore, there was a statistically significant difference in correlations between healthy controls and the psychiatric group during self-referential resting-state EEG. These results indicate that correlations between MAS-A ratings of self-reflectivity and self-referential resting-state EEG activity in the beta frequency band in the central region were significantly higher in healthy controls than the psychiatric group.

The results of the current study are consistent with findings reported by previous researchers demonstrating that power in the beta frequency band positively correlates with DMN activity (Kam et al., 2013). Specifically, Hlinka and colleagues (2009) demonstrated that increased DMN connectivity was associated with an increase in high-frequency beta band power in a group of healthy control participants. Additionally, Laufs and colleagues (2003) identified beta frequency band activity as a signature of activity in the brain that underlies the DMN. Therefore, the results of the current study may further indicate that beta frequency band activity is correlated with DMN activity. Furthermore, previous researchers have reported that mind wandering is associated with activity in the regions that form the DMN (Christoff et al., 2009). Kam and colleagues (2013) suggested that the association between DMN activity and mind wandering might indicate more frequent attention to internal thoughts. Therefore, the positive correlation between levels of self-reflectivity as measured by the MAS-A and increased beta frequency band activity during self-referential resting-state EEG in the current study may also indicate that beta frequency band activity and DMN activity increased in healthy control participants during the self-referential resting-state EEG task as a result of their increased attention to internal thoughts.

Analyses also revealed a statistically significant, strong negative correlation between MAS-A ratings of self-reflectivity and theta frequency band activity in the central region during resting-state EEG for the psychiatric group. Therefore, higher resting-state EEG activity in the theta frequency band in the central region was associated with lower ratings of self-reflectivity as measured by the MAS-A in the psychiatric group. However, there was not a statistically significant difference in correlations between healthy controls and the psychiatric group. The negative correlation between resting-state EEG activity in the theta frequency band and ratings of self-reflectivity as measured by the MAS-A in the psychiatric group, has also been supported by previous research. Hlinka and colleagues (209) found that theta frequency band functional connectivity was negatively correlated with DMN activity. Additionally, Scheeringa and colleagues (2008) reported negative correlations between theta frequency band activity and blood oxygenation level dependent (BOLD) signals in areas of the DMN. Therefore, the negative correlation between resting-state EEG activity and ratings of self-reflectivity as measured by the MAS-A in the psychiatric group may suggest that the DMN was less activated in the theta frequency band in the psychiatric group during resting-state EEG and as a result, participants engaged in less self-reflectivity.

One possible explanation for the lack of significant group differences in correlations between MAS-A ratings of self-reflectivity and EEG activity in the alpha, gamma, or theta frequency bands between the psychiatric group and healthy controls when asked to think about themselves during resting-state EEG, could be due to the relatively low ratings of self-reflectivity found in the healthy control sample. The current study had a mean self-reflectivity rating of 4.72 (SD = 0.795) as measured by the MAS-A in the psychiatric group and 5.57 (SD = 1.69) in the healthy control group. Previous researchers have reported average MAS-A ratings of self-reflectivity between 4.0 and 4.32 in patients diagnosed with schizophrenia (Aydin et al., 2016; Hasson-Ohayon et al., 2014; Vohs et al., 2014) and between 6.77 and 8.28 for healthy control participants (Hasson-Ohayon et al., 2014; Popolo et al., 2017). Therefore, average MAS-A ratings of self-reflectivity in healthy control participants in the current study were lower than those typically reported by previous researchers. As previously stated, 40% of healthy control participants in the current study endorsed symptoms of depression. Researchers have found that compared to healthy controls, patients experiencing symptoms of depression struggled to understand the relationship between thoughts, feelings, behavior, and interpersonal processes as measured by the self-reflectivity subscale on the MAS-A (Ladegaard Larsen, Videbech, & Lysaker, 2014). Furthermore, researchers have also reported that neuroimaging studies of depressed patients have identified abnormalities in neural networks known to support higher-order social cognition and suggested to be a part of the DMN, such as the mPFC (Ladegaard et al., 2014; Fitzgerald, Laird, Maller, & Daskalakis, 2008). Therefore the presence of depressive symptoms in the healthy control group in the current study could have impacted their ability to engage in the level of self-reflective thinking typically observed in healthy control participants.

Furthermore, some researchers have linked increased self-reflectivity in patients diagnosed with schizophrenia with specific treatment modalities. For instance, Lysaker and colleagues (2006b) found that engaging in a cognitively-based, vocational rehabilitation program increased levels of metacognition in patients diagnosed with schizophrenia. Previous researchers have also demonstrated that, in a single case study of an individual diagnosed with schizophrenia, as narrative structure improved in psychotherapy so did metacognition (Lysaker et al, 2005b). Furthermore, Minor and Lysaker (2014) suggested that improving disorganized symptoms in patients diagnosed with schizophrenia may also impact metacognition. The current study did not gather a detailed treatment history from participants. Therefore it is possible that participants in the psychiatric group engaged in previous treatment modalities that have been linked with increased levels of metacognition.

Limitations

Although the current study had many strengths, it also had some limitations. First, although efforts were made to engage all patients enrolled in the LLUBMC FOCUS program as well as patients diagnosed with schizophrenia and healthy controls from the community, our final sample size only consisted of 13 participants. Therefore the current study did not achieve adequate statistical power and results may not be generalizable to the broader population. Additionally, there was a significant difference in the gender distribution between the psychiatric group and the healthy control group. As a result of the small sample size, it was decided not to use gender as a covariate in the current study. Previous researchers have demonstrated significant differences in resting-state EEG data between males and females (Jausˇovec and Jausˇovec, 2010). Specifically, researchers reported that females demonstrated higher beta and gamma activity compared to males (Kam et al., 2013; Zappasodi et al., 2006). Therefore, gender may have impacted resting-state EEG activity in the current study. Furthermore, the hypotheses of the current study were based on the literature for patients diagnosed with schizophrenia, however the final sample included individuals diagnosed with schizoaffective disorder and bipolar disorder with psychotic features in addition to individuals diagnosed with schizophrenia. Including individuals diagnosed with schizoaffective disorder and bipolar disorder with psychotic features may have increased the heterogeneity of the data, making it more difficult to find group differences between the psychiatric group and healthy control participants. Additionally, 40% of the healthy control participants in the current study endorsed symptoms of depression. Previous researchers have reported that patients diagnosed with depression struggle with aspects of metacognition and demonstrate alterations in alpha, beta, and gamma frequency band activity (Allen & Cohen, 2010; Fitzgerald et al., 2008; Ladegaard et al., 2013). Therefore, it is possible that the presence of depressive symptoms resulted in difficulties engaging in self-reflectivity as well as resting-state EEG abnormalities that are not typically seen in healthy control participants. Finally, participants were required to find the time and space in their schedule to participate in the current study, at times after attending an eight-hour day of therapeutic programming in the LLUBMC FOCUS program. Therefore, additional efforts to provide protected time and space to participate in the current study (e.g., a half day of programming or weekend appointments) may have resulted in a larger sample size and may have yielded a more diverse sample that varied in their symptomology.

Clinical Considerations

To the best of our knowledge, this is the first study conducted to explore the electrophysiological correlates of self-referential processing in a psychiatric sample compared to healthy controls, and to investigate the relationship between electrophysiological measures of self-reflectivity and interview ratings of self-reflectivity. Although this study was an important first step, additional research is needed to better understand electrophysiological measures of self-reflectivity. Previous researchers have identified an overlap between DMN regions and brain regions that are suggested to be involved in self-referential thinking (Qin & Northoff, 2011). Therefore, evaluating electrophysiological measures of self-reflectivity may present as an opportunity to identify a possible source of dysfunction in patients diagnosed with schizophrenia. Future research should also aim to investigate the neurobiology of self-reflectivity specifically in patients diagnosed with schizophrenia in order to further investigate self-reflectivity as a possible target for treatment. For example, incorporating treatments that promote the development of self-reflectivity in patients diagnosed with schizophrenia, such as metacognition reflection and insight therapy (MERIT; Lysaker, Kukla, & Vohs, 2019) may allow patients to increase their ability to describe or question their own thoughts and emotions and may also increase their ability to effectively engage in commonly practiced treatment modalities, such as CBT. More research is needed to explore how the use of treatments that increase self-reflectivity may facilitate a patient’s ability to effectively engage in treatment modalities that require more metacognitive capacity. Additionally, longitudinal studies may be needed to examine the effects of increasing self-reflectivity in patients diagnosed with schizophrenia on resting-state EEG activity as well as the impact on positive and negative symptoms and overall functioning over time. Finally, research that is more inclusive of a diverse sample of patients diagnosed with schizophrenia and healthy controls is needed to better understand the neurobiology of self-reflectivity in patients and healthy controls from diverse backgrounds with varied symptomology.

Historical emphasis on symptom reduction in treatments for psychosis have led some to argue that the basic human rights of people with psychosis have been neglected (Stain et al., 2012). While symptom reduction is an important goal for treatment, increasing the quality of life of individuals experiencing psychotic symptoms is crucial to increasing their ability to successfully build interpersonal relationships and interact in their communities in a way that moves beyond a baseline level of functioning. By utilizing electrophysiological measures to investigate the neural basis of self-reflectivity, the current study not only adds to the literature that identifies self-reflectivity as a possible source of dysfunction for individuals experiencing psychotic symptoms, it further argues for increasing a patient's ability to engage in self-referential thinking to become a target for treatment. In doing so, the current study advocates for typical treatments for individuals experiencing psychotic symptoms to move beyond symptom reduction and aim to increase the overall quality of life of people with psychosis.

Conclusions

The current study strengthens the literature regarding self-reflectivity in patients diagnosed with schizophrenia by not only examining a possible neural basis of self-reflectivity, but also by examining the relationship between electrophysiological measures of self-reflectivity and interview ratings of self-reflectivity. Self-reflectivity is crucial in building connections with others and functioning in communities (Lysaker et al., 2010a). Continued research using electrophysiological measures to investigate the neural basis of self-reflectivity in patients diagnosed with schizophrenia is vital to increasing their ability to engage effectively in treatment and create the insight needed to view themselves as an active participant in their own families and communities.

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