ABSTRACT

Title of Dissertation:	ELECTROPHYSIOLOGY OF SOCIAL REWARD PROCESSING IN SCHIZOPHRENIA
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Poor social outcomes have been long observed in schizophrenia. Most studies have identified social cognition as an important contributor to social functioning. Recent research suggests that some people with schizophrenia do not appropriately respond to social rewards, including facial expression of positive affect. The aim of the current study was (1) to use electroencephalogram (EEG) and the event related potential (ERP) technique to examine how people with schizophrenia (SZ) and healthy control (HC) participants anticipate and respond to social (smiles) and nonsocial (money) types of feedback; (2) to examine how deficits in social reward processing are associated with motivation and pleasure deficits and social functioning; and (3) to examine differential contributions of social cognition and social reward processing in understanding functioning. Social and monetary incentive delay tasks were used to characterize reward

processing. The stimulus preceding negativity (SPN) was evaluated as an index of reward anticipation, and the reward positivity (RewP) was evaluated as an index of reward sensitivity.

Results indicated that HC participants (n = 22) showed significantly more anticipation of reward feedback than neutral feedback, as indexed by the SPN. SZ participants (n = 25) showed similar anticipation regardless of whether there was a potential to win a reward. SZ participants were more sensitive to social rewards than HC participants, as indexed by a larger RewP. We were unable to measure the RewP on the money task; however, exploratory analyses on a P2 component suggested there were no group differences in nonsocial reward sensitivity. Within the SZ group, reduced social reward anticipation was related to greater motivation and pleasure deficits but not social functioning. Social cognition was not significantly related to social functioning or social reward processing in the SZ sample.

This is the first study to measure the electrophysiological correlates of social and nonsocial reward processing in schizophrenia. Findings provide preliminary evidence of a generalized anticipatory deficit in schizophrenia that is related to impairments in motivation and pleasure. Reward sensitivity to social rewards appears to be intact. Future experimental design considerations are discussed.

ELECTROPHYSIOLOGY OF SOCIAL REWARD PROCESSING IN SCHIZOPHRENIA

by

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Chapter 1: Introduction

Schizophrenia is a severe mental illness that affects approximately 1.1% of the world's population (World Health Organization, 2015). Clinical presentations vary with the extent to which people experience positive symptoms (i.e., hallucinations, delusions), negative symptoms (i.e., deficits in experience and expression), and cognitive impairment (i.e., processing speed, working memory, abstract thinking). Illness onset typically occurs in late adolescence or young adulthood between the ages of 18-25, with an earlier age of onset of men than women. Disturbances in social and role functioning become apparent during a prodromal phase where sub-diagnostic features begin to appear (Millan et al., 2016). Diagnosis generally occurs after the first psychotic episode, which consists of auditory hallucinations and paranoid delusions in its most common form. The emerging illness is disruptive to the pursuit of life goals, at least for some period of time. Stressful life events can exacerbate symptoms even after periods of stabilization. With each relapse, the risk of developing persistent psychotic symptoms and long-term impairment increases (Stephenson, 2000). The cause of deterioration is largely unknown but is likely a neurodevelopmental process in which multiple genetic, biological, and environmental risk factors collectively interfere with normal brain maturation (Insel, 2010).

Schizophrenia is a major public health problem and a leading cause of suffering and disability. The lifetime debilitation from the illness places a significant burden on the individual, their caregivers, and society due to the need for long-term economic and psychosocial support. Quality of life is significantly limited by antipsychotic medication side effects (e.g., weight gain, tremors) and lifestyle factors (e.g., unemployment, smoking, and social disadvantage), which increase rates of morbidity (e.g.,

cardiovascular disease, type II diabetes) and early mortality (Fitch, Iwasaki, & Villa, 2014; Draine, Salzer, Cullhane, & Hadley, 2002). In 2013, the economic burden of schizophrenia in the United States was estimated at $155.7 billion in direct and indirect costs (Cloutier et al., 2016). Indeed, schizophrenia has been ranked the 8th leading cause of disability worldwide (Mathers, Lopez, & Murray, 2006).

Social Impairment

Social impairment is a defining characteristic of schizophrenia that profoundly impacts one's ability to function appropriately and effectively in the world. Many individuals with schizophrenia have social skill deficits, which makes routine interactions challenging (Mueser & McGurk, 2004; Morrison, Bellack, Wixted, & Mueser, 1990) and interferes with the fulfillment of basic social roles across a variety of domains, including education, vocation, and independent living (Harvey et al., 2012; Hooley, 2010). Social impairment is most pronounced for those who have a longer duration of untreated psychosis (Marshall et al., 2005). Social skills can be further compromised by intermittent periods of hospitalization during which individuals are removed from their everyday lives, making it increasingly difficult to understand and respond to others in the absence of regular interaction. As such, many individuals with schizophrenia have narrow social networks that are generally restricted to family members, have fewer meaningful interpersonal relationships, and have a lower likelihood of marriage compared with healthy individuals (Goldberg, Rollins, & Lehman, 2003; MacCabe, Koupil, & Leon, 2009).

Individuals with schizophrenia experience social deficits prior to illness onset, suggesting that it is an important vulnerability marker of the disorder (Tarbox & Pogue-

Geile, 2008; Cornblatt et al., 2012; Cannon et al., 1997). Premorbid social skill deficits in adolescence can result in poor social integration, low social support, and interpersonal conflict (Mueser et al., 1993; Cornblatt et al., 2012; Ballon, Kaur, Marks, & Cadenhead, 2007; Horan et al., 2006). Relatedly, youth with a first-degree relative with schizophrenia also show less social interest, immaturity, and problems with peers (Addington, Penn, Woods, Addington, & Perkins, 2008; Dworkin et al., 1991, 1993; Hans et al., 2000). There is also evidence that social impairment persists despite the remission of other symptoms (Robinson et al., 2004; Harvey et al., 2012; Harrison et al., 2001). Taken together, social impairment seems to be a primary feature of the disorder rather than a secondary consequence of illness-related factors, such as positive symptoms, stigma, chronicity of illness, or medication.

Social impairment may also importantly contribute to the development of the disorder (Häfner et al., 2003). The stress-diathesis model proposes that exposure to stress, through its effect on cortisol production, acts upon a pre-existing vulnerability for schizophrenia and triggers psychosis (Nuechterlein & Dawson, 1984). The age period during which psychosis develops is highly stressful in its own right due to increasing educational and social demands, accompanied peer pressures (e.g., recreational drug use, risk-taking), and the expectation to learn adult roles. Family members can add to this stress by communicating with criticism, hostility, or emotional over-involvement (high expressed emotion), which predicts relapse and worse prognosis (Kavanagh, 1992). Therefore, it is altogether likely that social difficulty causes additional stress that potentially accelerates illness progression. The reciprocal relationship between social dysfunction and stress is especially troubling because supportive relationships might

otherwise protect individuals from the effects of stressful life events (Corrigan & Phelan, 2004).

Causes of Social Impairment

Social Cognitive Deficits. Translational research that aims to understand causes of social impairment in schizophrenia has largely focused on social cognition, the set of cognitive processes dedicated to understanding the social world. Penn and colleagues (1997) described individuals with schizophrenia to have social cognitive deficits in the following domains: (1) emotion perception (i.e., the ability to perceive and understand emotions); (2) attributional bias (i.e., inferences about the causes of positive and negative events); (3) theory of mind (i.e., inferences about the intentions, dispositions, and beliefs in others); and (4) social perception (i.e., understanding social roles, societal rules, and social context). Social cognition predicts social dysfunction above and beyond that of general neurocognition (Couture et al., 2006; Green, Horan, & Lee, 2015; Fett et al., 2011), and may function as a mediator between neurocognition and social functioning (Schmidt, Mueller, & Roder, 2011). Over the past two decades, there has been a particular emphasis on the perceptual aspects of how facial expressions inform mental state inferences and impressions (see Gur & Gur, 2015 for a review). Individuals with schizophrenia generally perform worse than healthy individuals when asked to identify or discriminate facial affect, at all stages of the illness (Addington et al., 2012; van Rijn et al., 2011), due to a more effortful approach to processing social stimuli that involves over activation of the prefrontal cortex (Fakra, Salgado-Pineda, Delaveau, Hariri, & Blin, 2008). It seems that individuals with schizophrenia do not readily understand the

emotions and intentions of others, which likely makes it difficult to effectively function in the social world.

Social Motivation Deficits. Humans have a fundamental need for interpersonal relatedness and intimacy (Baumeister & Leary, 1995), and yet some individuals with schizophrenia lack this normative drive. Social motivation deficits in schizophrenia are reflected in the negative symptoms of the disorder, including: (1) social anhedonia, a disinterest and lack of pleasure from social activities, and (2) asociality, a reduced frequency of social contact. Social anhedonia was first described in early seminal writings by Emil Kraepelin (1919/1971) and Eugen Bleuler (1950). Expanding upon this work, Paul Meehl (1962) proposed that social anhedonia was as an important construct for schizophrenia-spectrum liability. Later research supported this theory, demonstrating that there is a high prevalence of social anhedonia among family members of individuals with schizophrenia (Katsanis, Iacono, & Beiser, 1990), and that elevated levels of the social anhedonia in the general population predict schizophrenia-spectrum disorders (Kwapil, 1998; Gooding, Tallent, & Matts, 2005). The nature and extent of social anhedonia and asociality in schizophrenia has been well-established using self-report and interview measures (Berenbaum, & Oltmanns, 1992; Chapman et al., 1976), and demonstrate that deficits are stable over time and symptom status (Blanchard, Horan, & Brown, 2001; Horan, Blanchard, Clark, & Green, 2008) and predict poor functioning (Blanchard, Mueser, & Bellack, 1998; Milev, Ho, Arndt, & Andreasen, 2005).

The Interplay of Social Ability and Motivation. Social-cognitive deficits and social motivation deficits are both salient features of schizophrenia that are present before illness onset and uniquely predict social dysfunction (Millian, Fone, Steckler, & Horan,

2014; Bora & Pantelies, 2013). These two facets of the illness are modestly correlated (Kalin et al., 2015; Robertson et al., 2014; Couture, Granholm, & Fish, 2011); however, studies are often cross-sectional, thus it is unclear which is primary. On the one hand, individuals with schizophrenia may become less socially motivated over time as a direct result of social cognitive deficits. That is, the reduced ability to understand others results in unsatisfactory social interactions, leading to social isolation and withdrawal. Consistent with this idea, there is emerging evidence to show that motivation mediates social cognition and functional outcomes (Green, Hellemann, Horan, Lee, & Wynn, 2012; Gard, Fisher, Garrett, Genevsky, & Vinogradov, 2009; Mehta, et al., 2015; Fervaha et al., 2015). Conversely, social motivation may be the more primary feature of the disorder that reduces the desire for social involvement from a young age. Social isolation may precipitate a cascade of events that disrupts brain networks supporting social cognition (Barr et al., 2004; Chugani et al., 2001; Kaufman et al., 2000), similar to what is thought to happen in Autism (see Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Either way, it is evident that one must have both social-cognitive ability and motivation to successfully function.

How Do We Improve Social Outcomes? Improving social outcomes in schizophrenia likely requires a multi-faceted approach that targets both social cognition and social motivation. Where social-cognitive deficits have been extensively studied in the past two decades, less is known about the causes of poor social motivation. Antipsychotic medications are used as the first line of treatment to reduce positive symptoms (Lieberman et al., 2005); however, they do not sufficiently improve social deficits and negative symptoms (Swartz et al., 2007; Keefe et al., 2007). Psychosocial

interventions provide a necessary treatment adjunct to help individuals with schizophrenia achieve recovery. Many well-established psychosocial interventions, such as social skills training (SST; Kurtz & Mueser, 2008), cognitive behavioral therapy (CBT; Kern, Glynn, Horan, & Marder, 2009), and their combination (CBSST; Granholm et al., 2007, 2014), reflect the status of the literature and do not necessarily encourage social affiliation. As such, treatment benefits tend to be short-lived, in part, because individuals do not always continue to use skills beyond the treatment setting (Elis, Caponigro, & Kring, 2013). It is likely that these interventions improve social ability, but that ability is only useful to the extent to which individuals are motivated to seek social contact. This underscores the need to better understand mechanisms underlying social motivation to develop effective interventions that fully restore social function (Mueser et al., 2013; Jukel & Morosini, 2008).

Social Reward Processing

A promising avenue for psychosocial rehabilitation may involve targeting social reward processes to offset enduring deficits in social motivation. Social interaction is a rewarding aspect of the human experience. Aside from the enjoyment and pleasure that is derived from social intimacy, there are physical and mental health benefits associated with social connectedness. Those who are more socially connected live longer than those who are isolated (Holt-Lunstad, et al., 2010), have fewer chronic health problems (Caspi, Harrington, Moffitt, Milne, & Poulton, 2006), better cognitive performance (Cacioppo & Hawkley, 2009), improved psychological well-benig (Lincoln, 2000), and higher self-esteem (Lee & Robbins, 1998).

Individuals differ in their desire for social affiliation based on neurobiological mechanisms that influence the experience of positive affect from interpersonal sources (Depue & Morrone-Strupinsky, 2005). The reward system thereby plays a pivotal role in the development of social attachments by reinforcing regular engagement with those to whom we have a connection (Vrtička, Bondolfi, Sander, & Vuilleumier, 2012; Bowlby, 1969). Social behavior is shaped over time based on how much individuals value interpersonal experiences, learn from them, and make decisions and plan for future encounters (Behrens, Hunt, & Rushworth, 2009; Behrens, Hunt, Woolrich, & Rushworth, 2008). Facial displays of emotion are one source of information that helps to reinforce social behavior (Blair, 2003). Displays of happiness, such as smiles, elicit positive feelings and signal that the individual is safe to approach, whereas frowns elicit negative feelings and signal that the personal should be avoided. To behave adaptively in the social world, it is important to learn from the consequences of social actions and adjust ongoing behavior to maximize rewards (e.g., praise, approval, acceptance, cooperation) and avoid punishments (e.g., rejection) (Behrens et al., 2008).

Social versus Nonsocial Reward Processing. Basic research indicates that general reward processing involves a brain network that consists of the orbitofrontal (OFC) and ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), striatum, amygdala, and dopaminergic midbrain (Delgado, 2007). Ruff and Fehr (2014) outline two competing perspectives as to how the brain derives reward from social sources: (1) the social-valuation specific hypothesis, and (2) the extended common currency hypothesis. The “social-valuation specific hypothesis” suggests that the brain has dedicated neural circuitry to evaluate social aspects of the environment. That is, the

valuation of social and nonsocial rewards involves similar computations but with different specialized neurons that are located within the same reward regions or in different brain regions altogether. In contrast, the "extended common currency theory" suggests that there is a unified neural circuit that assigns value to social and non-social stimuli alike. Both types of rewards result in identical activity, although there may be differences in functional connectivity of these shared valuation areas with brain regions from which social and nonsocial information is recruited.

Based on a review of the extant literature, it is unlikely that social rewards are processed in a fully separate neural circuit from nonsocial rewards, as the majority of findings support the use of common brain regions in the valuation of both reward types, including the ventral striatum, vmPFC, amygdala, and insula (e.g., Bhanji & Delgado, 2014; Izuma, Saito, & Sadato, 2008). With that said, several types of social decisions have been associated with responses in regions outside the classic reward circuitry, such as the dorsolateral prefrontal cortex (dlPFC), temproparietal junction (TPJ), and dorsomedial prefrontal cortex (dmPFC), that may be unique to social information processing (Adolphs, 1999, 2010; Saxe, 2006; Amodio & Frith, 2006). Thus, it would appear that social and nonsocial reward processing share similar circuitry, but there may be additional brain regions involved in the later.

Stages of Reward Processing. Reward processing can be separated into anticipatory and consummatory phases, each with dissociable functions and neural circuits (Berridge, Robinson, & Aldridge, 2009). Anticipatory pleasure is related to reward motivation and goal-directed activity for desired outcomes ("wanting") and is mediated by the mesolimbic dopamine system (Robinson, & Berridge, 2000), including

dopaminergic projections from the ventral tegmental area (VTA) to the nucleus accumbens (NAcc) in the ventral striatum (O'Doherty, Buchanan, Seymour, & Dolan, 2006). Consummatory or "in-the-moment" pleasure reflects the hedonic impact of a reward ("liking"). Associated brain regions for reward consumption include the orbitofrontal prefrontal cortex, thalamus, amygdala, and cingulate cortex (Nieuwenhuis et al., 2005). Importantly, neural networks for the anticipation and consumption of reward have been dissociated with social rewards (i.e., smiling faces) (Rademacher et al., 2010, 2014).

Motivation and Reward Processing in Schizophrenia

It is well established that multiple aspects of reward processing are abnormal in schizophrenia (Gold, Waltz, Prentice, Morris, & Heerey, 2008; Barch & Dowd, 2010). Results have shown that individuals with schizophrenia have an intact ability to experience pleasure from a wide variety of evocative stimuli (i.e., liking), but have difficulty using information from previous experience to guide future goal-directed behavior (i.e., wanting) (Cohen & Minor, 2010; Kring & Caponigro, 2010; Kring & Elis, 2013; Waltz & Gold, 2007; Juckel et al., 2006). One explanation for why this may happen is that action systems in the brain do not have a clear line of communication with reward value representations (Heerey & Gold, 2007). Recent evidence suggests that motivational deficits in schizophrenia are not just driven by a failure to accurately represent and update the value of actions, but also by a failure to accurately represent the costs of actions (see Gold, Waltz, & Frank, 2015 for commentary). That is, they show a reduced willingness to expend effort to obtain higher levels of rewards (e.g., Gold et al., 2013; McCarthy, Treadway, Bennett, & Blanchard, 2016; Treadway, Peterman, Zald, &

Park, 2015; Barch, Treadway, & Schoen, 2014). Interestingly, individuals with schizophrenia are able to learn from aversive outcomes (Gold et al., 2012). The result is that some individuals learn to avoid actions that may produce negative outcomes, but do not learn to select actions that could produce positive ones.

Motivation for Social Rewards in Schizophrenia. Most of the research to date in the schizophrenia literature has involved nonsocial rewards, and much less is known about the treatment of social rewards. Some have questioned whether there is a "social-specific" hedonic deficit in schizophrenia given the central role of social abnormalities in the pathogenesis of the disorder (see Cohen, Najolia, Brown, & Minor, 2010). That is, despite preserved hedonic capacity in a nonsocial context, individuals with schizophrenia may fail to experience pleasure in the moment during social interactions. There is mixed evidence to support this hypothesis. One study found that individuals with schizophrenia had less positive and more negative affect than healthy volunteers in response to laboratory social affiliation tasks with an experimenter (McCarthy et al., 2018). However, other studies have shown that individuals with schizophrenia have equal levels of experienced emotions compared with healthy volunteers during role-plays (Horan & Blanchard, 2003; Blanchard et al., 2015), and do not differ in their appraisals of the interaction partner or their desire for future interaction (Blanchard et al., 2015). Studies using Ecological Momentary Assessment (EMA) similarly demonstrate that individuals with schizophrenia report enjoyment in the moment from social interaction (Kimhy et al., 2014; Oorschot et al., 2013; Granholm et al., 2013). There is also evidence that individuals with schizophrenia are motivated by social encouragement (Fulford, Treadway, & Woolley, 2018), providing further support of normative positive affect.

Thus, it would seem that most people with schizophrenia, on average, are capable of experiencing pleasure in an interpersonal context (i.e., liking). Nonetheless, negative symptoms are associated with less affiliative feelings of interpersonal closeness towards social partners (Blanchard et al., 2015; McCarthy et al., 2018).

Another explanation as to why some individuals with schizophrenia have low social motivation is that social activities are not anticipated to be enjoyable (i.e., wanting and learning) (see Gard et al., 2014). This may occur because there is difficulty forming mental representations of social reward from social cognitive inferences (e.g., from facial expressions) to guide social behaviors. Several studies have borrowed methods from behavioral economics to test this theory, such as the Trust Game (Campellone, Fisher, & Kring, 2016; Campellone, Truong, Gard, & Schlosser, 2018; Fett et al., 2016) and the Cyberball game (Engel et al., 2016). Results show that individuals with schizophrenia are less sensitive to positive social outcomes from social partners as reflected by their decision-making during these games (but also see Hanewald et al., 2017[1]). A recent study expanded upon these findings by examining preferences for different types of social (genuine and polite smiles) and nonsocial (money) feedback from computerized opponents during a decision-making game (Catalano, Heerey, & Gold, In press). Results showed that individuals with schizophrenia learned to make choices that yielded money rewards, but did not show the same preference to select opponents based on genuine smile feedback. These findings provide preliminary evidence of a deficit in social reward

[1] Hanewald and colleagues (2017) conducted a study to examine reaction times on a social and monetary incentive delay task as an index of reward anticipation for these reward types. They found that individuals with schizophrenia were able to adapt their behavior to successfully obtain social and nonsocial rewards, as did healthy participants.

valuation that may impact behavior during social interaction. In summary, social reward processing may be a promising mechanism to help explain disruptions in social motivation; however, continued research is necessary to explore which aspects are impaired in schizophrenia.

An Electrophysiological Approach

There is growing interest in the use of electroencephalography (EEG) to study reward processing due to its millisecond temporal resolution that can precisely delineate reward-related brain responses during distinct phases, such as: (1) reward anticipation or "wanting" (i.e., incentive salience for an upcoming reward or action), (2) reward outcome or "liking" (i.e., the experience of pleasure upon receiving a reward), and (3) reward learning (i.e., predictive associations used to guide future behavior) (Berridge et al., 2009). Where fMRI has excellent spatial resolution, it only provides broad temporal characterizations of these stages because it utilizes BOLD signals, which are delayed secondary consequences of neural activity (Logothetis, 2008). Thus, EEG is a superior tool to understand the timing of psychological processes associated with reward anticipation and reward outcome.

Reward Anticipation. Reward anticipation can be studied with the stimulus-preceding negativity (SPN), a slow cortical potential that is maximal in the 200 ms prior to feedback (Brunia, 1988; Brunia & Damen, 1988; Damen & Brunia, 1987). The SPN manifests as a centroparietal negativity and is anatomically associated with activation in the lateral prefrontal cortex and the insula (Knutson & Greer, 2008). Some research has shown that the SPN has a right hemisphere preponderance, reflecting activity of the right insula cortex (Brunia, de Jong, van den Berg-Lenssen, M. M., & Paans, 2000; Tsukamoto

et al., 2006). It does not require motivated effort or pursuit, but rather involves simply waiting for feedback. The SPN aids in the transition from cue processing to motivated approach behavior (Brunia, van Boxtel, & Böcker, 2012; van Boxtel, & Böcker, 2004; Foti & Hajcak, 2012). Recent studies have shown that the amplitude of the SPN can be induced by monetary reward or punishment (Masaki et al., 2006; Novak, Novak, Lynam, & Foti, 2016; Novak & Foti, 2015). In schizophrenia, there is evidence of reduced SPN amplitude when asked to anticipate nonsocial rewards, and this lack of response may have some association with self-reported anhedonia (Wynn, Horan, Kring, Simons, & Green, 2010). It is not known how the SPN will respond to the anticipation of social rewards in schizophrenia. Of note, the SPN is altered in other psychiatric disorders that are characterized by social reward abnormalities, such as Autism and depression (Stavropoulos & Carver, 2014; Cox et al., 2015; Kohls et al., 2013; Novak et al., 2016).

Reward Outcome. Studies of feedback evaluation have focused on the feedback-related negativity (FRN)[2]. The FRN is a negative-going deflection in the EEG that is maximal at frontocentral sites approximately 250 ms post-feedback (Miltner, Braun, & Coles, 1997; for review, see Glazer et al., 2018; San Martin, 2012; Nieuwenhuis et al., 2004). The FRN reflects a scalp-recorded index of a neural system for reinforcement learning (Holroyd & Coles, 2002). According to Schultz and Dickinson (2000), unexpected events evoke reward prediction errors (RPEs), which are encoded in the brain at cortical and subcortical levels. RPEs are driven by phasic alterations of dopamine that reflect the difference between the expected value of a reward and the value of what was

[2] Other names for the FRN include the feedback negativity, FN, or feedback error-related negativity, FERN.

actually received. The receipt of a high-value, unexpected reward yields a positive prediction error, which signals to repeat the action in order to gain future rewards. The omission of an expected reward yields a negative prediction error, which leads to the extinction of that learned behavior (Sutton & Barto, 1998).

The FRN reflects the summation of RPEs generated during decision-making that signals when choices yield outcomes that are "worse than expected". Negative outcomes (e.g., losses or punishments) evoke a larger deflection in the EEG compared with neutral or positive feedback (e.g., rewards or gains) (Miltner et al., 1997; Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). The FRN is correlated with brain activity in reward-related regions, such as the striatum and medial frontal cortex (Becker, Nitsch, Miltner, & Straube, 2014; Carlson et al., 2011; Foti, Carolson, Sauder, & Proudfit, 2014), and is potentially generated by the ACC (Carlson et al., 2011; Foti, Weinberg, Dien, & Hajcak, 2011).

There are several studies that examined the FRN in schizophrenia. The first study to examine the FRN was conducted by Morris and colleagues (2008), which used a probabilistic learning task to show that individuals with schizophrenia have diminished differentiation between correct and incorrect feedback. It was unclear from the experimental design whether this finding was a reflection of deficient learning, reward insensitivity, or both. To clarify the scope of feedback processing impairments in schizophrenia, Horan and colleagues (2012) used a simple monetary gamble task. This study demonstrated that individuals with schizophrenia and controls had a comparable FRN differentiation between reward and non-reward feedback, suggesting that the sensitivity to external reward feedback and pleasurable stimuli is intact in schizophrenia.

Morris and colleagues (2011) also confirmed this pattern of findings in a subsequent study. Recently, it was found that there is intact feedback processing (FRN) in schizophrenia that has good test-retest reliability over a four-week period, indicating that it is stable over time (Llerena et al., 2016).

The FRN is abnormal in several psychiatric disorders associated with altered reward-sensitivity, such as depression and anxiety (Foti & Hajcak, 2009; Simons, 2010). However, the FRN appears to function normally in schizophrenia, at least when individuals are provided nonsocial feedback (Morris et al., 2008, 2011; Horan et al., 2012; Llerena et al., 2016). These findings are not surprising, as most individuals with schizophrenia show relatively intact in-the-moment hedonic experiences (Kring & Moran, 2008).

Recent work has identified a reward positivity (RewP), which has the same timing as the FRN, but is a positive-going deflection in the EEG that is sensitive to gain instead of loss outcomes (for reviews see Proudfit, 2015; Sambrook & Goslin, 2015). This work has shown that the smaller FRN following gain feedback is explained by the superposition of the positive-going RewP (Bernat, Nelson, Steele, Gehring, & Patrick, 2011; Holroyd et al., 2008; Foti et al., 2009). Furthermore, time-frequency analysis approaches have found that the FRN occurs in the theta frequency band (3-7 Hz) and the RewP occurs in the delta frequency band (0-3 Hz) (Bernat et al., 2011). Thus, findings from this work suggest that theta-FRN and delta-RewP are two independent, co-occurring processes[3].

[3] The FRN and RewP can both be measured with difference waves. The FRN is calculated as a loss minus gain difference, resulting in a fronto-central negativity. The RewP is calculated as a gain minus loss difference, resulting in a fronto-central positivity.

Emerging research has shown that the RewP can be elicited by nonsocial (e.g., money) and social rewards (Kujawa et al., 2014; Sun & Yu, 2014; van der Veen et al., 2016). Moreover, the RewP is associated with behavioral and self-report measures of reward sensitivity (e.g., Bress & Hajcak, 2013) and extraversion (Cooper, Duke, Pickering, & Smillie, 2014; Smillie, Cooper, & Pickering, 2011). To our knowledge, there is no study that has used the RewP as an index of reward sensitivity in schizophrenia, and it is not known whether the RewP will be differentially modulated by social and nonsocial rewards in this clinical group.

Incentive Delay Tasks. One of the most well validated tasks to capture different phases of reward processing is a cued incentive-delay task. These tasks require that the participant successfully complete some action (e.g., button press) after the presentation of a cue to earn a prospective reward. There are two types of incentive delay tasks: (1) the monetary incentive delay task (MID) (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Knutson, Westdorp, Kaiser, & Hommer, 2000), which uses monetary feedback; and (2) the social incentive delay task (SID) (Rademacher et al., 2010, 2014; Spreckelmeyer et al., 2009), which uses social feedback in the form of positive facial expressions (smiles). Incentive delay tasks are widely used as an assessment tool to capture reward anticipation and reward outcome, and have successfully been implemented in conjunction with EEG to elucidate related brain function using both social feedback (SID tasks: Flores, Münte, & Doñamayor, 2015; Cox et al., 2015; Stavropoulos & Carver, 2014; Kohls et al., 2011) and monetary feedback (MID tasks:

For this reason, sometimes these component names are used interchangeably in the literature (for details see Proudfit, 2015).

Novak et al., 2015, 2016; Angus et al., 2017; Santesso et al., 2011; Broyd et al., 2012) as incentives.

Importantly, the MID/SID tasks have been used to compare social and nonsocial reward processes between diagnostic groups. This comparison has been especially instrumental in the Autism literature, where it has been demonstrated that individuals with Autism have low social reward valuation compared with healthy individuals, and spared nonsocial reward valuation (Cox et al., 2015; Stavropoulos & Carver, 2014; Kohls et al., 2011). Indeed, individuals with Autism-spectrum disorders show typical FRN responses to nonsocial stimuli (Larson et al., 2011; McPartland et al., 2012), but show an impaired FRN response to social stimuli compared with healthy individuals (Stavropoulos & Carver, 2014). In terms of reward anticipation, there is evidence of a reduced SPN exclusively for social rewards among children with Autism (Kohls et al., 2011; Stavropoulos & Carver, 2014). Similar results were found using MID/SID tasks in a sample of individuals with high autistic traits (Cox et al., 2015), where they exhibited attenuated P3 amplitudes (a measure of attention to reward outcomes) and SPN amplitudes under social reward conditions, and no significant differences in P3 amplitude with non-social incentives. Taken together, these findings show the utility of incentive delay tasks in studying group differences in reward sensitivity across different reward phases as indexed by the FRN (a reverse calculation of the RewP) and the SPN.

Moreover, the MID tasks have been used to reliably detect individual differences in reward sensitivity within several psychiatric groups. Unfortunately, there have been no ERP studies that have examined individual differences in reward sensitivity using the SID task, only the MID task (e.g., Bress & Hajcak, 2013). First, Novak and colleagues

(2016) used the MID to explore individual differences in reward sensitivity among individuals with internalizing (depressive symptoms) and externalizing (impulsivity: sensation seeking) psychopathology. Findings suggested that high levels of sensation seeking were related to increased RewP amplitudes, and faster reaction times overall. Increased symptoms of depression predicted decreased RewP amplitudes. This study was important because it demonstrated that individual differences in reward functioning are stage-specific and can be measured with electrophysiological measures. Second, Vignapiano and colleagues (2016) used the MID task to examine group differences in reward sensitivity among individuals with schizophrenia and healthy individuals, and also examined the relationship between P3 and negative symptoms within the schizophrenia group. Results indicated that, compared with healthy participants, individuals with schizophrenia had trouble using information related to reward magnitude and reward value of future events as studies by the fb-P3. Total negative symptoms were not related to CNV or P3 amplitude; however, there were significant correlations between social anhedonia and P3 amplitude. It is unclear if these symptoms will be significantly correlated with facets of social reward sensitivity (SNP, RewP). Furthermore, this study was limited in that it only examined the P3. Lastly, a study found that RewP amplitude was correlated with anhedonia among individuals with cocaine use disorders using the MID (Parvaz, Gabbay, Malaker, & Goldstein, 2016).

To summarize, EEG has millisecond temporal resolution that is well suited to study different phases of reward processing, including reward anticipation (indexed by the SPN) and reward outcome (indexed by the RewP). These ERP components can be reliably measured using the MID and SID tasks, which have been useful in comparing

social and nonsocial forms of feedback across multiple diagnostic groups, and individual differences within groups.

Conclusions from the Literature

Social impairment is a core feature of schizophrenia that interferes with functioning across multiple life domains. Current psychosocial treatments may be limited in their ability to restore social function because some individuals with schizophrenia lack social motivation, thus limiting the impact of learned therapeutic skills. The study of social reward processing is a promising, emerging area of research that may explain the reduced drive for social motivation in schizophrenia. Previous research indicates that aspects of reward processing related to the enjoyment of rewards may be relatively spared, whereas anticipatory and motivational aspects of reward processing may be more dysfunctional and may be closely linked to negative symptoms (Gold et al., 2008, 2012; Barch & Dowd, 2010). It remains unclear to what degree these reward abnormalities impact social experience. The ERP technique has excellent temporal resolution and is therefore an ideal methodology to decompose the time-course of social versus nonsocial reward processing.

The Present Study

The present study was designed to evaluate the behavioral and electrophysiological correlates of social and nonsocial reward processing between individuals with schizophrenia and healthy participants, and to link them with unique facets of social behavior. To this end, we used the monetary incentive delay task (MID) (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Knutson et al., 2000) and social incentive delay task (SID) (Spreckelmeyer et al., 2009; Rademacher et al., 2010, 2014) to

measure responses to nonsocial and social rewards, respectively. Reward processing was studied at two different outcome phases: (1) reward anticipation (the "wanting" or desire to obtain future rewards); and (2) reward delivery (the "liking" or enjoyment of a reward). In particular, the SPN and the RewP were used to index reward anticipation and reward sensitivity, respectively. To our knowledge, no investigation has directly examined the electrophysiology of different phases of social and nonsocial reward processing in schizophrenia using these ERP indices. Our aims and hypotheses are as follows:

Primary Aim: To examine the electrophysiological correlates of social and nonsocial reward processing between individuals with schizophrenia and healthy participants.

Aim 1A: To examine electrophysiological correlates of social and nonsocial reward anticipation between individuals with schizophrenia and healthy participants.

Hypothesis 1A: It was hypothesized that individuals with schizophrenia would exhibit an attenuated stimulus preceding negativity (SPN) during the anticipation of both social and nonsocial rewards, relative to healthy participants.

Aim 1B: To examine electrophysiological correlates of social and nonsocial reward sensitivity between individuals with schizophrenia and healthy participants.

Hypothesis 1B: It was hypothesized that individuals with schizophrenia would exhibit an attenuated reward positivity (RewP) in response to social feedback, but an intact RewP in response to nonsocial feedback, relative to healthy participants.

Aim 2: To examine the relation between social reward processing, motivation and pleasure deficits, and broader social functioning within the schizophrenia group.

Hypothesis 2A: Reduced RewP amplitudes were hypothesized to be associated with more severe motivation and pleasure deficits (CAINS MAP) and worse real-world social functioning (SFS total score).

Hypothesis 2B: Reduced SPN amplitudes were hypothesized to be associated with more severe motivation and pleasure deficits (CAINS MAP) and worse real-world social functioning (SFS total score).

Aim 3: To examine differential contributions of social cognition and social reward processing in understanding social functioning.

Hypothesis 3: It was hypothesized that poor social cognition (TASIT) would be related to worse social functioning (SFS total score) and social reward processing deficits (reduced SPN and RewP amplitudes).

Chapter 2: Methodology

Participants

Twenty-six individuals with schizophrenia or schizoaffective disorder (SZ) and 23 healthy control participants (HC) completed study procedures. Individuals with SZ were recruited from outpatient clinics at the MPRC and local community mental health clinics. All SZ participants were on a stable medication regimen of constant doses and types for at least four weeks prior to testing and were deemed clinically stable by their

mental health clinician prior to enrollment. Diagnosis was established using a consensus best estimate approach, combining information from past medical records, mental health clinicians, and the SCID-I (First et al., 1997) according to the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV). All SZ participants were prescribed one or more antipsychotic medications at the time of testing: clozapine (n = 6), risperidone (n = 1), olanzapine (n = 1), aripiprazole (n = 3), fluphenazine (n = 2), haloperidol (n = 3), paliperidone (n = 1), quetiapine (n = 1), clozapine + risperidone (n = 1), clozapine + haloperidol (n = 1), clozapine + aripiprazole (n = 1), clozapine + minocycline (n = 1), risperidone + aripiprazole (n = 1), quetiapine + fluphenazine (n = 2), quetiapine + fluphenazine + clozapine (n = 1).

HC participants were recruited through random digit dialing of households in nearby zip codes, word of mouth among recruited participants, and through online and newspaper advertisements. HC participants were screened with the SCID-I (First et al., 1997) and the Structured Interview for DSM-III-R Personality Disorders (SIDP-R) (Pfohl et al., 1989) and were excluded if they met criteria for a psychotic disorder; bipolar disorder; and paranoid, schizotypal or schizoid personality disorder. None of the participants met criteria for a mood episode at the time of testing. HC participants also denied family history of psychosis among their first-degree relatives and current use of psychotropic medications. Additional exclusion criteria for the study were substance abuse or dependence disorders within the last six months, history of significant head injury or trauma, and significant medical or neurological disease.

Measures

Master's level research assistants administered the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I; First et al., 1995) to determine history and/or presence of Axis I disorders according to the *Diagnostic and Statistical Manual of Mental Disorders* 4th ed. (*DSM-IV*), and to confirm diagnostic inclusion and exclusion criteria. Additional study measures characterized the sample in terms of clinical symptoms, social functioning, personality traits (social anhedonia), neurocognition, and social cognition. Only the SZ group completed ratings of clinical symptoms and social functioning. All raters achieved agreement with the gold standard for each interview measure (i.e., no more than 2 items with a difference of more than 1 rating point from the gold standard). To maintain reliability, highly skilled clinicians held on-site meetings to supervise assessments and resolve discrepancies of ratings from the current study.

Clinical Symptoms. The Clinical Assessment Interview for Negative Symptoms (CAINS; Kring, Gur, Blanchard, Horan, & Reise, 2013*)* is a thirteen-item clinician-rated interview that captures the two factors of negative symptoms: motivation and pleasure (MAP; 9 items) and expression (EXP; 4 items) (Blanchard & Cohen, 2006; Horan, Kring, Gur, Reise, & Blanchard, 2011) (see Appendix A). The CAINS has good internal consistency for the overall CAINS scale (α =0.76), as well as for the two factor scales of expression (α = 0.88) and motivation and pleasure (α = 0.74). The CAINS demonstrates good inter-rater reliability (EXP, average ICC = .77; MAP, average ICC = .93), adequate test-retest reliability (average ICCs = .69 for both scales), good convergent validity, and good discriminate validity (Kring et al., 2013).

The Brief Psychiatric Rating Scale (BPRS; Overall & Gorman, 1962; Ventura et al., 1993) is a 20-item clinician-rated interview assessing the severity of psychiatric symptoms over the past week (see Appendix B). Symptoms are rated on a seven-point Likert scale, ranging from 1 (not present) to 7 (extremely severe). The scale has four subscales based on a factor structure derived by Kopelowicz and colleagues (2008), including positive symptoms, negative symptoms, and disorganization. The BPRS has well-established psychometric properties in schizophrenia (Anderson, et al., 1989; Morlan & Tan, 1998; Overall & Gorham, 1962).

The Calgary Depression Scale for Schizophrenia (CDSS; Addington, Addington, Maticka-Tyndale, & Joyce, 1992) is a nine-item clinician-rated interview that evaluates depressive symptoms over the past two weeks (see Appendix C). Items are rated on a four-point Likert scale ranging from 0 (absent) to 3 (severe), and are aggregated to yield a total that is discriminant from positive, negative, and extrapyramidal symptoms. The CDSS has excellent psychometric properties, including good internal consistency, inter-rater reliability, sensitivity, and specificity (Addington, Addington, & Atkinson, 1996; Addington, Addington, & Maticka-Tyndale, 1994; Collins, Remington, Coulter, & Birkett, 1996; Lancon et al., 2001, Addington et al., 1992), as well as good convergent validity and discriminant validity (Addington et al., 1992). The CDSS is the recommended scale to estimate depression severity in schizophrenia (Collaborative Working Group on Clinical Trial Evaluations, 1998). A score of 6 or higher is the cut-off for clinically significant depression (Addington et al., 1992).

Social Functioning. The Social Functioning Scale (SFS; Birchwood, Smith, Cochrane, & Wetton, 1990) (see Appendix D) is a 79-item measure that assesses social

behavior across seven domains: 1) social engagement/withdrawal (e.g., time spent alone, initiation of conversations, social avoidance); 2) interpersonal behavior (e.g., number of friends, romantic partner, quality of communication); 3) pro-social activities (e.g., engagement in common social activities); 4) recreation (e.g., time spent pursuing hobbies, interests, pastimes); 5) independence-competence (e.g., ability to perform skills necessary for independent living); 6) independence-performance (e.g., performance of skills necessary for independent living); and 7) occupation/employment (e.g., engagement in productive employment or structured program of daily activity). Data were collected from the participants' self-rating/reports. Items were scored on a four-point scale, with higher scores indicating a higher level of function. The total score was computed by summing the seven subscale scores. Raw scores from each of the subscales were converted to scale score equivalents with a mean of 100 and a standard deviation of 15 for comparability and interpretation (Birchwood et al., 1990). The SFS has been shown to be a reliable, valid, and sensitive measure of social functioning in schizophrenia (Barrowclough & Tarrier, 1990; Birchwood et al., 1990). In a RAND panel, the SFS scored highest among the social functioning scales on practicality, reliability, sensitivity, and comprehensiveness (Leifker et al., 2011).

Trait Measures. The Revised Social Anhedonia Scale (RSAS; Eckblad, Chapman, Chapman, & Mishlove, 1982) was administered to assess individual differences in the capacity to experience pleasure from interpersonal sources (see Appendix E). This self-report questionnaire is comprised of 40 true/false items that describe common social situations (e.g., “I prefer watching television to going out with other people,” keyed true). Total scores range from 0 to 40 (the lower the score, the less severe the anhedonia). The

RSAS has good internal consistency with alpha coefficients between 0.79 and 0.84 (Blanchard, Mueser, & Bellack, 1998; Mishlove & Chapman, 1985), and high test-retest reliability over both 90-day and one-year periods (Blanchard, Horan, & Brown, 2001; Blanchard et al., 1998). The Asocial Beliefs Scale (ABS; Grant & Beck, 2010) consists of 15 RSAS items with face validity for assessing attitudes of social disinterest (e.g., "Having close friends is not as important as most people say"). The Infrequency Scale (INFS) was included to identify individuals who responded randomly (Chapman & Chapman, 1983). The INFS consists of 13 true/false items that are universally answered in one direction (e.g., “I believe that most light bulbs are powered by electricity,” keyed true). In line with previous studies, data were excluded from two participants (1 SZ; 1 HC) because they endorsed 3 or more items in the unexpected direction (Kwapil, 1998).

Neurocognition. Premorbid intelligence was assessed using the Wide Range Achievement Test—Fourth Edition (WRAT-4; Wilkinson & Robertson, 2011), which assesses correct pronunciation of English words that are irregularly spelled (M = 100, SD = 15). Because of their irregularity, pronunciation of these words cannot be determined using standard phonological principles. Instead, the ability to pronounce these words correctly requires prior exposure to them. Many individuals with schizophrenia display intact word recognition relative to other cognitive domains (Crawford et al., 1992). As such, tests of word recognition are a useful way to estimate premorbid intelligence for those who are currently unemployed or unable to continue with school due to illness onset. WRAT-4 scores have been shown to remain stable across repeated testing (Johnstone & Wilhelm, 1996).

Social Cognition. The Awareness of Social Inference Test (TASIT; McDonald, Flanagan, Rollins, & Kinch, 2003) was administered to assess how social cognition is related to social reward processing and social functioning. The TASIT was developed for use with individuals with traumatic brain injuries; however, it has been validated for use with schizophrenia populations as well (Sparks et al., 2010; Pinkham, Penn, Green, & Harvey, 2016). Participants watched videoed scenes in three parts: (1) the Emotion Evaluation Test (EET), (2) the Social Inference-Minimal, and (3) the Social Inference-Enriched. The EET tests basic emotion recognition, whereas the SI-M and the SI-E test theory of mind[4].

The Emotion Evaluation Test (EET) consists of 28 short video clips in which an actor portrays one of seven basic emotions (happy, sad, fear, disgust, surprise, anger, and neutral). Participants identify emotions from facial expressions, tone of voice, and body gestures. The Social Inference-Minimal (SI-M) consists of 15 videoed scenes, each lasting 15-60 seconds, and assesses the ability to understand when a conversational inference, such as sarcasm, is being made. The dialogue in each scene is ambiguous; therefore, the participant must infer meaning from paralinguistic cues. Actors used simple sarcasm when they said the opposite of what was meant, and paradoxical sarcasm when they sounded nonsensical unless it was understood that they were sarcastic. The Social

[4] One might argue that individuals with schizophrenia are less able to enjoy social rewards (smiling expressions) due to emotion perception abnormalities (see pg. 7). However, evidence from a prior experiment in our lab showed that individuals with schizophrenia can recognize when social partners display positive affect but do not value these expressions to the same extent as healthy participants (Catalano, Heerey, & Gold, In press). Thus, it is unlikely that perceptual deficits fully explain decreased social reward valuation. Nonetheless, we included measures of social cognition to explore such hypotheses.

Inference-Enriched (SI-E) consists of 16 videoed scenes where the viewers were provided contextual information that explained the nature of the conversational exchange. In each scene there is a literally untrue comment. Participants are tested on their ability to detect deception in social encounters (white lies or sympathetic lies) and sarcasm. For both the Social Inference-Minimal and Social Inference-Enriched subtests, participants answered four types of yes/no questions at the end of each scene: the first asked the participant to think about what one actor in the scene knows (beliefs); the second asked what the actor was trying to say to the other person (meaning); the third asked about the actor's intentions (e.g., to insult, to reassure, etc.); and the fourth asked what the character was feeling. The videotape was paused between each scene to allow the participant time to answer. The primary outcome for each subtest is the proportion of correct responses across the trials.

EEG Experimental Task. Participants performed an adapted version of a monetary incentive delay task (MID; Knutson et al., 2000, 2005) and a social incentive delay task (SID; Rademacher et al., 2010, 2014; Spreckelmeyer et al., 2009), while the electroencephalogram (EEG) was recorded (see Figure 1). We used versions of these tasks similar to those that have been used in prior EEG studies (e.g., Flores et al., 2015; Novak & Foti, 2015; Novak et al., 2016; Angus et al., 2017; Broyd et al., 2012; Santesso et al., 2011). These tasks were designed to assess electrophysiological responses to reward anticipation and delivery. Experimental stimuli were presented on a 24" LED color monitor, centrally placed at a viewing distance of 100 cm. E-Prime version 1.2 (Psychology Software Tools, Inc.) was used to present the stimuli.

An overview of the trial structure for the MID and SID tasks, including the sequence and timing of stimuli, are shown in Figure 2. There were two conditions: (1) a reward condition, and (2) a neutral condition[5]. A cue was presented at the beginning of each trial for 400 ms. Rewards are available on trials that began with a circle with a line through the middle (reward condition; possible gain) but were not available on trials that began with a triangle (neutral condition; always break-even). The cue was followed by an anticipatory period that varied in length from 2000 to 2500 ms with a fixation mark (+) presented on the center of the screen. In order to win, participants had to respond to the target ("Go") as quickly as possible by pressing the right or left button on a game controller. Participants were encouraged to respond as quickly as possible to the target regardless of the incentive that was being offered during that trial (neutral or reward)[6]. Following target offset, the fixation mark was presented for 1300 ms while participants anticipate feedback about their response. On reward trials, if they hit the button in time (i.e., while the target was still on the screen), they would receive either a smile (SID) or 25 cents (MID)[7]. If they did not hit the button in time (i.e., before or after the target), they

[5] A loss condition was not included because our research question is specific to social motivation, and we wanted to rule out the impact of punishment/penalty on behavior. Moreover, research indicates that breaking even elicits a relative negativity compared to gains, thus the loss condition is not necessary to isolate the RewP (Holroyd, Hajcak, & Larsen, 2006).

[6] This classic manipulation is referred to as a time estimation task and it is frequently used to study electrophysiological indices of reward (FRN/RewP) (Miltner et al., 1997).

[7] Incentive Delay tasks can be designed to offer different reward magnitudes, such as different money amounts (MID tasks), or different smile intensities (SID tasks). We chose not to vary reward magnitudes for two reasons. First, research from our lab suggests that low intensity smiles are not salient incentives to motivate behavior in healthy individuals and people with schizophrenia (Catalano, Heerey, & Gold, In press). Second, additional trials would have been necessary to test hypotheses related to high versus low reward magnitudes, which would have significantly increased the total length of the experiment and potentially minimized participant attention and motivation.

would receive no reward, and would instead see a neutral/non-expressive face (SID) or a gray circle (MID). No earnings were received on neutral trials regardless of their behavior.

The task included four blocks (2 MID and 2 SID), which were counterbalanced in order. Participants were told before each block which rewards they would be playing for (smiles or money). Blocks consisted of 70 trials (50 reward, 20 neutral) presented in a random order. There were 140 MID trials (100 reward, 40 neutral) and 140 SID trials (100 reward, 40 neutral), for a grand total of 280 trials (200 reward, 40 neutral). Participants' goal was to win as many rewards as possible. Participants were able to take breaks after each block. They were informed of their cumulative money winnings at the end of the MID blocks (they did not receive additional money for the SID task). A screen at the end of the task indicated the total performance bonus earned.

Participants were given the opportunity to practice before the experiment. The practice block consisted of 20 trials (10 MID trials [2 neutral and 8 reward] and 10 SID trials [2 neutral and 8 reward]). Performance on the practice determined initial task difficulty. Task difficulty was adjusted on an individual basis by varying the duration of the target window to keep the success rate at approximately 65%[8]. The target duration started at 200 ms and was dynamically adjusted, such that the target window increased (+10 ms) after three unsuccessful responses and decreased (-10 ms) after three successful

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Therefore, we elected to only use large rewards. Our monetary reward amount (25¢) was selected based on a previous MID/SID study that used €0.10 (11.7¢) as a low reward and €0.20 (23.4¢) as a high reward (Flores et al., 2015).

[8] The success rate was selected from the extant literature at the time of study design. Flores and colleagues (2015) validated the use of MID/SID tasks with EEG and used an approximate hit rate of 65%. Of note, other tasks designed to elicit the RewP use a hit success rate of 50% (e.g., the doors task; see Proudfit, 2015).

responses on incentivized trials. The difficulty threshold at the end of the practice block was carried over to the main task, and was adjusted thereafter in the same fashion.

Social Stimuli. The stimuli used in the SID task were color photographs taken from the Chicago Face Database (Ma, Correll, & Whittenbrink, 2015), a free stimulus set of faces and norming data validated for use in scientific research. Actors consisted of racially diverse males and females between the ages of 18 and 40 years. Only the actors' heads and shoulders were visible and eye gaze was directed toward the viewer. Each actor had two poses: neutral/non-expressive and an open-mouth smiling expression. These images were validated in a separate study (Ma et al., 2015), where two judges rated how believable the expressions were on a 1-9 Likert scale (1 = not at all believable; 9 = very believable). Valence ratings for the smiling facial expressions were not available. We used images from 28 actors (14 White, 14 Black). There were 14 males and 14 females, evenly divided between the two races. Multiple images were used to avoid confounds resulting from use of a single face, gender, or race. Face images were counterbalanced across social/monetary contingencies, as well as reward/neutral conditions.

Procedures

The study was conducted as part of a larger NIMH funded grant (R01 MH080066-06A1) directed by Dr. James Gold to understand the nature of reinforcement learning deficits in schizophrenia. The University of Maryland-Baltimore Institutional Review Board approved the protocol (#HP-00072330). All participants provided written informed consent prior to testing. SZ participants demonstrated comprehension of study requirements, risks, and rights using the Evaluation to Sign Consent form (ESC)

(DeRenzo, Conley, & Love, 1998) (see Appendix F). Inclusion and exclusion criteria were verified upon enrollment. Testing was divided into two visits to prevent fatigue. Participants completed the EEG task during one visit, and completed all other tasks during the second visit. The total testing battery took approximately 2 -3 hours to complete. Participants were compensated $20 per hour plus a performance bonus (see above).

EEG Recording and Data Processing

Psychophysiological Data Acquisition. During the administration of the EEG task, participants were seated in a comfortable chair in a room with controlled lighting and sound to minimize artifacts. The EEG was recorded using an actiCAP and the actiCHamp amplifier system (Brain Products, Munich, Germany). Recordings were taken from 64 Ag/AgCl electrodes embedded in a fabric cap arranged based on the International 10-20 system, with a ground electrode was placed at FPz. The EEG data were recorded using PyCorder recording software and referenced online to the average activity at the left and right mastoids. The vertical electrooculogram (VEOG) was recorded from electrodes placed above and below the left eye to detect blinks and vertical eye movements. The horizontal EOG (HEOG) was recorded from two electrodes placed lateral to the external canthi and was used to detect horizontal eye movements. All electrode impedances were maintained below 25 kOhm. The EEG/EOG was digitized at 1,000 Hz with 24 bits of resolution.

Data Preprocessing. Offline data processing was conducted in Matlab (The MathWords, Inc., Natick, MA) using the EEGLab (Delorme & Makeig, 2004) and ERPLab (Lopez-Calderon & Luck, 2014) toolboxes. Continuous EEG data were down

sampled to 256 Hz and high-pass filtered with a cutoff at .1 Hz (Butterworth impulse response function, half-power cutoff, 12 dB/octave roll-off). An independent components (ICA) analysis was conducted to remove components from the data introduced by eye movements (Jung et al., 2000). Following ocular correction, data was segmented by condition (cue: neutral [always break even] and reward [potential gain]), reward phase (anticipation and delivery), and task (incentive type: money and smiles). For the reward anticipation phase, the signal was segmented from -1700 to 100 ms relative to feedback onset. For the reward outcome phase, the signal was segmented from -200 to 1000 ms relative to feedback onset. The epoched data was then low-pass filtered at 30 Hz (Butterworth impulse response function, half-power cutoff, 24 dB/octave roll-off). Artifact rejection was performed on the retained segments by using a series of algorithms built into ERPLab. Epochs were rejected if (1) the voltage difference was greater than 150 uV at any point in the epoch, or (2) peak-to-peak amplitudes exceeded 100 uV within a 200 ms moving window. A visual inspection of the data was conducted to remove any remaining artifacts.

Data Reduction. ERPs were scored with time window averages for each reward condition (cue: neutral [always break even] and reward [potential gain]), reward phase (anticipation and delivery), and task (MID and SID). The reward anticipation phase was baseline corrected to -900 to -700 ms relative to feedback onset. This time window was selected to avoid differential overlap from surrounding ERPs related to target onset, which is consistent with previous SPN studies (Ait Oumeziane et al., 2017; Walentowska et al., 2017). The reward outcome phase was baseline corrected to the 200 ms period preceding feedback (-200 to 0 ms). Overall grand average waveforms (collapsed across

groups) were created to determine whether ERP time windows and scalp distributions were consistent with the literature, or whether we needed to select measurement parameters specific to our task and sample[9]. Grand averages were then calculated separately for each ERP for the SZ and HC groups. We opted to measure our ERPs as mean/area amplitude, which is argued to be superior to peak-based measures in cases in which the number of trials contributing to the ERP or the signal-to-noise ratio of the data differs between groups, which is often the case in clinical research (Kappenman & Luck, 2016).

Feedback Anticipation (SPN). Figure 3 presents overall grand-averaged waveforms collapsed across groups at midline electrode sites (F3/F4, C3/C4, and P3/P4) during the feedback-anticipation phase. Previous studies have examined the SPN between -200 and 0 ms prior to feedback onset from electrode sites F3/F4, C3/C4, P3/P4, (Kotani, Kishida, Hiraku, Suda, Ishii, & Aihara, 2003; Ohgami et al., 2004, 2006; Morís, Luque, & Rodríguez-Fornells, 2013). Visual inspection of topographic maps from the overall grand average revealed that the SPN was maximal at parietal sites (P3 and P4), so we used this electrode cluster for analyses. Trials with no behavioral response or where responses were made before the target were not included in analyses.

Feedback Delivery (RewP). Figure 4 presents overall grand-averaged ERP waveforms collapsed across groups that are time-locked to the reward feedback at midline electrodes (FCz, Cz, CPz, and Pz). These waveforms are presented for comparison with traditional RewP plots in other studies. Visual inspection of the ERP

[9] Overall grand averages are appropriate to inform measurement selections because they can be made specific to the task and sample without biasing the results in favor of a statistically significant between-groups effect (Luck 2014).

waveforms shows that our experimental manipulation did not elicit the RewP in the money condition (MID task); there was only a weak RewP present at electrode Pz. Instead, gain and no gain trials elicited differences around 120 ms (negativity), 200 ms (positivity) and 250 ms (negativity), which in terms of latency could be referred to as the "N1", "P2", and "N2", respectively.[10] This early activity appears to be contamination from surrounding ERPs in the theta range (3-7 Hz), which precludes us from measuring the RewP in the delta range (0-3 Hz) using traditional time-domain methods.

We isolated delta activity to visually examine the RewP using a 3rd order low-pass Butterworth filter at 2 Hz (see San Martin, 2012 for a review of this technique)[11] (see Figure 8). There is a small hint of a RewP, but the P2 component is still present. Therefore, for the MID task, we conducted exploratory analyses with the P2 component to understand arousal and attentional capture while receiving money feedback (Carretié et al., 2001; Schutter et al., 2004; Potts et al., 2006; San Martin et al., 2010; Flores et al., 2015). We used the difference wave to measure the P2 from a cluster around FCz where the difference between gain and no gain trials was maximal in the overall grand average waveform. A time window 125 to 265 ms was used for analyses, selected from the overall grand average waveform.

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[10] The N1 is a marker of visual-attentional processing and is sensitive to stimulus characteristics, such as luminance (Vogel & Luck, 2000). It therefore likely that the money image on gain trials differentially captured attention compared with the grey circle image on no-gain trials. The P2 is found in response to rewards that are large in magnitude (Goyer, Woldorff, & Huettel, 2008), suggesting that the money reward was relatively larger than the social reward. The N2 is associated with frequency information (Baker & Holroyd, 2011). It is possible that the large money reward influenced the frequency of feedback across trial types.

[11] We selected a 2 Hz low-pass filter rather than 3 Hz because the identified time frequency range for RewP-delta activity is below 2.5 Hz (Bernat, Nelson, & Baskin-Sommers, 2015).

The RewP was elicited in the social task. Previous studies have examined the RewP between 250-350 ms from electrode FCz (Proudfit, 2015). However, visual inspection of our overall grand average difference wave revealed that our RewP occurred between 200-500 ms and peaked at approximately 350 ms (see Figure 4). We therefore used the 200-500 ms time window for analyses. A difference waveform was used to isolate the RewP by subtracting gain condition average activity from no gain condition average activity (Proudfit, 2015)[12]. Neutral trials (or "break-even" trials) were not included in the RewP analysis, as only a single outcome was ever possible. For each participant, the RewP was quantified as the mean amplitude in the time window of 200-500 ms relative to the baseline voltage specified above. The electrode cluster for analysis included nine electrodes centered around CPz, where the RewP was maximal based on visual inspection of topographic maps (see Figure 4). This was confirmed by measuring the peak amplitudes from midline electrode difference waves between 200-500 ms: FCz, 2.695 μV, 351.56 ms; Cz, 2.688 μV, 351.56 ms; CPz, 2.733 μV, 355.47 ms; Pz, 2.351 μV, 371.09 ms).

Data Analysis

Analyses were performed using the Statistical Program for Social Sciences version 23.0 (SPSS, Chicago, Illinois, USA). We performed one-way analysis of variances (ANOVAs) and chi-square (χ^2) analyses on demographic and clinical variables. Next, variables of interest were examined for missing values, normality of distributions, and outliers. Data checks were conducted to assure that the data met the statistical

[12] Difference waves are the traditional approach to isolate processes that are differentially active for distinct trial types and to eliminate components that do not differ across conditions (Luck, 2014).

assumptions. For all analyses, significance levels were set at $\alpha < 0.05$, 2-tailed. Effect size is presented as either partial eta-squared (η^2) or Pearson's correlation coefficient (*r*).

Aim 1: Our first aim was to examine social and nonsocial reward processing between SZ and HC groups. Behavioral data was evaluated as a secondary measure of reward anticipation. We calculated the proportion of trials that participants successfully responded to the target (hit rates) and how quickly they responded to the target (reaction times). Hit rate data was evaluated using a 2 Group (SZ, HC) X 2 Incentive Type (money, smiles) X 2 Condition (reward [potential gain], neutral [always breakeven]) repeated measures ANOVA. Reaction time data was similarly evaluated using a 2 Group (SZ, HC) X 2 Incentive Type (money, smiles) X 2 Condition (reward [potential gain], neutral [always breakeven]) repeated measures ANOVA.

Next, we analyzed the SPN mean amplitude as an electrophysiological correlate of reward anticipation. We conducted a 2 Group (SZ, HC) X 2 Condition (reward [potential gain], neutral [always breakeven]) X 2 Incentive Type (money, smiles) repeated measures ANOVA, with SPN mean amplitude (P3/P4) as the dependent variable (Hypothesis 1A). Similarly, we analyzed RewP mean amplitude as an electrophysiological corelate of reward sensitivity. For the SID task, we conducted a one-way ANOVA, with diagnostic group (SZ, HC) as the between groups factor, and RewP amplitude (CPZ cluster) as the dependent variable (Hypothesis 1B).

Because we could not measure the RewP during the MID task, exploratory analyses were conducted on the reward-related P2 component. A one-way ANOVA was conducted with diagnostic group (SZ, HC) as the between groups factor and P2 mean

amplitude (FCz cluster) as the dependent variable. Exploratory Pearson's correlations compared reaction times and reward-related ERPs across the SID and MID tasks.

Aim 2: Our second aim was to examine the relation between social reward processing, motivation and pleasure deficits, and social functioning. Pearson's correlations were calculated within the SZ group to determine whether ERP mean amplitudes (RewP and SPN) were significantly associated with motivation and pleasure deficits symptoms (CAINS MAP), social functioning (SFS total score) (Hypotheses 2A and 2B).

Aim 3: Our third aim was to examine the relation between social cognition (TASIT), social reward processing, and social functioning (SFS total score) within the SZ group. One-way ANOVAs compared group means (% correct) on each TASIT subscale. Pearson's correlational analyses were conducted for SZ participants to determine whether ERP amplitudes (RewP and SPN) were associated with different facets of social cognition (TASIT) and social function (SFS total score) (Hypothesis 3).

Chapter 3: Results

Sample Characteristics

Twenty-six SZ participants and 23 HC participants were tested. Two participants (1 HC and 1 SZ) were eliminated from the sample because more than 50% of their trials contained artifacts, yielding a final sample of 47 participants (SZ n =25; CN n = 22)[13]. In

[13] This exclusion criterion is standard in our lab and the schizophrenia ERP literature (e.g., Wynn, Horan, Kring, Simons, & Green, 2010; Horan, Wynn, Kring, Simons, & Green, 2010). Sample sizes of approximately 20-25 participants per group are also common.

the remaining sample, artifacts led to the rejection of 9.416% of trials in the SZ group and 6.434% of trials in the HC group, $F(1, 45) = 1.307$, $p = .259$. All results reflect this final sample.

The demographic features of the SZ and HC groups are shown in Table 1. The groups were of similar age, gender, and race. SZ participants had fewer years of education than HC participants, an expected finding given that the onset of the illness generally occurs in early adulthood. SZ and HC participants did not differ in their estimates of premorbid intelligence (WRAT), with both groups scoring within the average range. This is unusual given the known cognitive deficits in schizophrenia (Gold & Weinberger, 1995). The groups did not differ in parental years of education. In the SZ sample, 80% of participants reported that they were unemployed, and 76% of participants denied being married or having a romantic partner.

Clinical characteristics of the SZ group are summarized in Table 1. Symptom ratings were in the absent or mild range for global psychiatric symptoms (BPRS total), positive symptoms (BPRS positive cluster), disorganized symptoms (BPRS disorganized cluster), and depressive symptoms (CDSS)[14]. Importantly, there were low levels of motivation and pleasure deficits (CAINS MAP) and trait-levels of social anhedonia (RSAS). In fact, RSAS and asocial beliefs (ABS) scores did not significantly differ between groups[15]. The social functioning of our SZ group is summarized in Table 2 for

[14] Research suggests that depression is associated with a blunted dopamine response to rewards (Whitton, Treadway, & Pizzagalli, 2015). We note that, in the current SZ sample, only 8.000% of participants endorsed clinically significant depression according to the CDSS.

[15] MAP scores from our sample were lower on average ($M = 11.920$, $SD = 5.552$) than what is typically seen in other studies ($M = 15.05$, $SD = 6.55$; Strauss & Gold, 2016). RSAS scores were similarly low on average ($M = 9.360$, $SD = 5.251$) compared with

descriptive purposes. Overall, these data suggest that our SZ group is unusually similar to the HC participants in terms of social anhedonia and premorbid intelligence and have clinical symptoms that reflect less severe levels of pathology compared to other clinical samples in the published literature.

Behavioral Data

Hit rate. Hit rates were evaluated to determine how often participants successfully responded to the target (see Table 3). Our time-estimation manipulation was designed to keep the task difficulty at 65% on reward trials. To test this, one-sample t-tests were run for each group (SZ and HC) on each task (money and social) comparing the hit rates against a value of .65. Hit rates were not significantly different from .65 for either group on either task (p's > .162).

Next, we evaluated whether hit rates varied across groups, trial conditions, and incentive types. Groups should not differ in their mean hit rates because the task was programmed so that participants would win on approximately 65% of reward trials. Similarly, hit rates should be consistent across money and social tasks. We would, however, expect to see that participants were putting forth more effort (as indicated by increased hit rates) on reward trials compared with neutral trials because there was a greater payoff.

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other studies (M = 15.11, SD = 5.75; Blanchard et al., 1998). We note that, although our sample has low levels of pathology, there are not anomalous relationships among measures compared with the broader literature (see Table 6). Motivation and pleasure deficits (CAINS-MAP) and social anhedonia (RSAS) showed a similar association with prior studies (r = .29) (Kring et al., 2013), and CAINS MAP were significantly correlated with worse social functioning (SFS Total) (r = -.497, p = .011).

We conducted a 2 Group (SZ, HC) X 2 Incentive Type (money, smiles) X 2 Condition (reward [potential gain], neutral [always breakeven]) repeated measures ANOVA with the hit rate as the dependent variable. Main effects were not significant for Incentive Type, $F(1, 45) = 0.344$, $p = .561$, (η^2 partial = .008), or Group, $F(1, 45) = .004$, $p = .949$, (η^2 partial = .000). There was not a significant Group X Condition interaction effect, $F(1, 45) = 0.363$, $p = .550$, (η^2 partial = .008), nor a Group X Incentive Type interaction effect, $F(1, 45) = 0.308$, $p = .582$, (η^2 partial = .007). The three-way interaction of Incentive Type X Condition X Group revealed trend-level differences in hit rates, $F(1, 45) = 2.979$, $p = .091$, (η^2 partial = .062).

As expected, there was a significant main effect of Condition, $F(1, 45) = 64.996$, $p < .001$ (η^2 partial = .591), which was qualified by a significant Condition X Incentive Type interaction effect, $F(1, 45) = 4.296$, $p = .044$, (η^2 partial = .087). As shown in Figure 5, there was a steeper decline in performance in the absence of an incentive during the money task compared with the social task. Pairwise comparisons revealed that participants had higher hit rates when there was an opportunity to earn money as opposed to breaking even, $F (1, 45) = 60.508$, $p < .001$, (η^2 partial = .573), a mean difference of .174, 95% CI (.129, .219). Participants also had higher hit rates when there was the opportunity to earn smiles as opposed to breaking even, $F (1, 45) = 36.274$, $p < .001$, (η^2 partial = .446), a mean difference of .127, 95% CI (.085, .170). There was only a trend-level significant difference between hit rates on money reward trials and social reward trials, $F(1, 45) = 3.399$, $p = .072$, (η^2 partial = .070), a mean difference of .017, 95% CI (-.002, .037). Hit rates were comparable for neutral trials on both tasks.

Reaction times. Reaction times were evaluated to determine how quickly participants responded to the target to obtain rewards (see Table 3). It was expected that SZ participants would have slower overall reaction times compared with HC participants, consistent with prior research (Hanewald et al., 2017) and evidence of psychomotor slowing in SZ (Morrens, Hulstijn, & Sabbe, 2007). We predicted that SZ participants would put forth less effort to win rewards (as evidenced by slower reaction times) compared with HC participants, even after controlling for slower overall reaction times in the SZ group.

We conducted a 2 Group (SZ, HC) X 2 Incentive Type (money, smiles) X 2 Condition (reward [potential gain], neutral [always breakeven]) repeated measures ANOVA with reaction times as the dependent variable. First, we looked at the between-subjects effects. As expected, there was a significant main effect of Group, $F(1, 45) = 6.598$, $p = .014$ (η^2 partial = .128), suggesting that SZ participants ($M = 327.620$ ms, $SD = 13.418$) had slower overall reaction times than HC participants ($M = 274.953$ ms, $SD = 13.990$). However, there was not a significant Group X Condition interaction effect, $F(1, 45) = .180$, $p = .673$ (η^2 partial = .004), Group X Incentive Type interaction effect, $F(1, 45) = 2.832$, $p = .099$, (η^2 partial = .059), nor was there a significant three-way interaction of Incentive Type X Condition X Group, $F(1, 45) = .144$, $p = .707$, (η^2 partial = .003). These results suggest that, although SZ participants had slower reaction times, they were still motivated to adapt their behavior to the experimental demands to win rewards.

Next, we looked at the within-subjects effects. There were significant main effects for Condition, $F(1, 45) = 33.380$, $p < .001$, (η^2 partial = .426), and Incentive Type, $F(1, 45) = 4.169$, $p = .047$, (η^2 partial = .085), which were qualified by a significant Condition

X Incentive Type interaction effect, $F(1, 45) = 4.752$, $p = .035$, (η^2 partial = .096) (see Figure 5). Pairwise comparisons revealed that participants had similar reaction times on neutral trials across the social and nonsocial tasks, $F(1, 45) = .154$, $p = .697$, (η^2 partial = .003), a mean difference of -2.266 ms, 95% CI (-13.905, 9.374). Interestingly, participants responded more quickly when there was an opportunity to earn money (M = 261.359, SE = 8.621) as opposed to smiles (M = 275.166, SE = 9.698), $F(1, 45) = 15.819$, $p < .001$, (η^2 partial = .260), a mean difference of -13.906 ms, 95% CI (-20.948, -6.864). Overall, these data suggest that participants were willing to put forth more effort (by reacting more quickly to the target) to ensure money rewards.

Money earned. If SZ participants were not motivated to put forth effort to win rewards, they would have earned less total money than HC participants at the end of the task. We note that the groups did not significantly differ in terms of their total money earnings (HC M = 16.489, SD = 1.153; SZ M = 16.570, SD = 1.226; $F(1, 45) = 0.054$, p = .817).

ERP Waveforms

Feedback anticipation. We examined SPN amplitude as an electrophysiological index of social and nonsocial reward anticipation between SZ and HC participants (see Table 3). Of note, the SPN is a negative waveform; therefore, more negative values reflect larger amplitudes. We hypothesized that SZ participants would exhibit less anticipation of rewards (both social and nonsocial) compared with HC participants, as evidenced by an attenuated SPN. Figure 6 shows the ERP waveforms on reward and neutral trials for each group during the 900 ms before feedback onset, and associated topographic maps at 10 ms before feedback onset.

We conducted a 2 Group (HC, SZ) X 2 Condition (reward [potential gain], neutral [always breakeven]) X Incentive Type (money, smiles) repeated measures ANOVA with the SPN mean amplitude as the dependent variable. Main effects were not significant for Incentive Type, $F(1, 45) = 1.423$, $p = .239$, (η^2 partial = .031), or Group, $F(1, 45) = 0.178$, $p = .675$, (η^2 partial = .004). The Incentive Type X Group interaction was also not significant, $F(1, 45) = .142$, $p = .708$, (η^2 partial = .003), indicating that groups did not significantly differ on their overall SPN amplitudes for the money and social tasks. The Incentive Type X Condition X Group three-way interaction effect did not reach significance, $F(1, 45) = .336$, $p = .565$, (η^2 partial = .007).

There was a significant main effect for Condition, $F(1, 45) = 4.567$, $p = .038$, (η^2 partial = .092), which was qualified by a significant Condition X Group interaction effect, $F(1, 45) = 6.470$, $p = .014$, (η^2 partial = .126) (see Figure 7). Pairwise comparisons revealed no significant differences in the estimated marginal means on reward trials (M = -.675, SE = .412) and neutral trials (M = -.818, SE = .629) for SZ participants, $F(1, 45) = .088$, $p = .768$, (η^2 partial = .002), a mean difference of .144, 95% CI (-.830, 1.117). However, there was a significant difference on reward trials (M = -1.865, SE = .439) and neutral trials (M = -.211, SE = .671) for HC participants, $F(1, 45) = 10.297$, $p = .002$, (η^2 partial = .186), a mean difference of -1.654, 95% CI (-2.692, -.616). These results suggest that HC participants showed significantly more anticipation of reward feedback than neutral feedback, whereas the SZ participants showed similar anticipation regardless of whether there was a potential to win a reward.

Feedback delivery. We planned to examine the RewP mean amplitude as an electrophysiological index of social and nonsocial reward sensitivity between SZ and HC

participants. We hypothesized that SZ participants would exhibit an attenuated RewP for social rewards, but an intact RewP in response to nonsocial feedback, relative to HC participants. Unfortunately, we were unable to measure the RewP in the money task due to contamination from surrounding ERPs (see Figure 4). Thus, we were only able to examine the RewP in the social task, and a P2 component in the money task (see Table 3).

Figure 9 shows (A) ERPs to gain and no gain feedback recorded at channel CPz, (B) the associated difference waves and scalp maps at 350 ms, and (C) delta-RewP waveforms for SZ and HC groups. A one-way ANOVA was conducted to determine whether there were group differences in RewP mean amplitudes for social rewards. Contrary to our prediction, we found that SZ participants (M = 2.007, SD = 2.251) had a larger RewP for social rewards than HC participants (M = 0.228, SD = 3.354), $F(1, 45)$ = 4.662, p = .036, (η^2 partial = .094). To test whether HC and SZ groups experienced the social feedback as rewarding, we conducted one-sample t-tests for each group to determine whether RewP mean amplitudes were significantly different than zero. RewP amplitude was significantly different from zero for the SZ group, one-sample $t(1,24)$ = 4.459, p <.001, but was not significantly different from zero for the HC group, $t(1, 21)$ = .754, p = .754. These results suggest that the SZ group were more sensitive to the receipt of social rewards than HC participants.

Figure 8 shows (A) ERPs to gain and no gain feedback recorded at channel FCz, (B) the associated difference waves and scalp maps at 190 ms, and (C) delta waveforms for SZ and HC groups. An exploratory analysis was conducted on the P2 component to assess group differences in arousal and attentional capture while receiving money

feedback. A one-way ANOVA was conducted to determine whether there were group differences in P2 mean amplitudes for money rewards. Results indicated that groups did not significantly differ in terms of their sensitivity to money rewards, $F(1, 45) = .877$, $p = .354$, (η^2 partial = .019).

Correlations with behavior and ERPs. Pearson's correlations were conducted to explore whether electrophysiological and behavioral indices of reward processing were related. Correlations for the HC group are presented in Table 4. Reaction times were significantly correlated on social and nonsocial tasks. Reward anticipation was also significantly correlated on social and nonsocial tasks. Surprisingly, HC participants had greater reward anticipation when they were slow to react to the target on both tasks. Also of note, we did not find a significant correlation between reward anticipation and reward sensitivity on either task.

Correlations for the SZ group are presented in Table 5. Similar to the HC participants, reaction times were significantly correlated across the social and nonsocial tasks. SZ participants also showed comparable reward anticipation while awaiting social and nonsocial feedback. Unlike HC participants, there was not a significant correlation between reaction times and reward anticipation for SZ participants. Lastly, there was a trend-level correlation between reward anticipation and reward sensitivity for both tasks, suggesting that greater anticipation was associated with greater reward sensitivity.

Correlations with social reward processing, negative symptoms, social functioning. Our third aim was to examine the relation between electrophysiological correlates of social reward processing (RewP and SPN), motivation and pleasure deficits

(CAINS MAP), and overall social functioning (SFS total score) within the SZ group. The correlation matrix for all primary clinical and social variables is presented in Table 6.

First, we hypothesized that low social reward sensitivity would be related to more severe motivation and pleasure deficits and worse social functioning. Our hypotheses were not supported (p's > .527). Second, we hypothesized that low social reward anticipation would be related to more severe motivation and pleasure deficits and worse social functioning. Consistent with our hypothesis, we found that motivation and pleasure deficits (CAINS MAP) were significantly correlated with less social reward anticipation[16] (see Figure 10). Social functioning (SFS total) was not significantly correlated with social reward anticipation, although in the correct direction, $r(26) = -.312$, $p = .129$. Our results demonstrate that motivation and pleasure deficits are more closely related to social reward anticipation than social reward sensitivity.

Social-Cognitive Performance

Table 7 summarizes social-cognitive performance for the SZ and HC groups. Levene's test for equality of variances was violated for each of these tests, so t statistics are reported with equal variances not assumed. On the EET, SZ participants did not significantly differ from HC participants in identifying negative emotions or positive emotions, when evaluated separately. However, SZ participants showed worse overall emotion perception abilities. SZ participants also had significant theory of mind deficits relative to HC participants. SZ participants were able to correctly identify when actors

[16] Negative SPN values reflect greater social reward anticipation. Therefore, we predicted that SPN amplitude would be positively correlated with motivation and pleasure deficits (CAINS MAP) and negatively correlated with real-world social functioning (SFS total score).

were being sincere, but otherwise showed widespread problems understanding conversational inferences, such as when actors were lying or being sarcastic.

Correlations with social cognition, social reward processing, and clinical variables. We sought to examine the relation between social cognition (TASIT), social reward processing (RewP and SPN amplitudes), negative symptoms (CAINS), and social functioning (SFS total) within the SZ group. Pearson's correlations are shown in Table 6. We did not find any significant correlations between these variables (*p*'s > .120).

Chapter 4: Discussion

This study investigated the electrophysiological correlates of social and nonsocial reward processing between individuals with schizophrenia and healthy participants, using an adapted version of the monetary incentive delay task (MID) (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Knutson et al., 2000) and the social incentive delay task (SID) (Spreckelmeyer et al., 2009; Rademacher et al., 2010, 2014). Our multistage experimental design allowed us to examine unique event related potentials (ERPs) associated with different phases of reward processing. Specifically, we examined reward anticipation, indexed by the stimulus preceding negativity (SPN), and reward sensitivity, indexed by the reward positivity (RewP). Our second aim was to examine whether deficits in social reward processing were related to more severe motivation and pleasure deficits and worse social functioning among individuals with schizophrenia. Our third aim was to explore the differential contributions of social reward processing and social cognition in understanding social functioning. This is the first study, to our knowledge, to evaluate the electrophysiological correlates of social and nonsocial reward processing in people with schizophrenia and healthy participants.

Before analyzing reward-related ERPs, we examined behavior during the incentive delay task as a measure of incentive motivation and effort. Hit rates were calculated as the proportion of trials that participants correctly responded to the target during the allocated time frame. The task was designed so that participants would win on 65% of reward trials. Results indicated that our experimental manipulation was successful—participants put forth significantly more effort to respond to the target when there was an opportunity to win a reward compared to when no reward was available. Furthermore, there was a more drastic decline in performance between reward and neutral trials when participants were attempting to win money, suggesting that money was a more salient reward than smiles. We then calculated how quickly participants responded to the target (reaction time). Across the full sample, participants were quicker to react when there was an opportunity to win money compared with smiles, providing further evidence that money was the more salient reward. In terms of group differences, individuals with schizophrenia had slower overall reaction times, yet their reaction times on reward trials did not significantly differ from healthy participants. Hanewald and colleagues (2017) similarly found that individuals with schizophrenia exhibited motivated behavior on another version of the monetary and social incentive delay task. Taken together, these results indicate that implicit reinforcement learning is intact in schizophrenia, whereby individuals are able to represent the value of reward cues and adapt their behavior to maximize payoffs (Heerey et al., 2008; Barch et al., 2017). It should also be acknowledged, however, that participants were given explicit instructions as to what each cue represented before the task, so minimal learning was required.

Next, we examined the stimulus preceding negativity (SPN) as an electrophysiological index of affective-motivational anticipation of rewards. The SPN manifests as a slow negative waveform at centro-parietal sites that intensifies as the person is waiting for "good" feedback and is less intense for neutral feedback (Brunia, van Boxtel, & Böcker, 2012; van Boxtel, & Böcker, 2004; Foti & Hajcak, 2012). We hypothesized that individuals with schizophrenia would have a reduced SPN amplitude while anticipating social and nonsocial feedback, relative to healthy participants. Results indicated that healthy participants had a significantly larger SPN amplitude while awaiting reward feedback compared with neutral feedback; however, individuals with schizophrenia had a SPN that did not differentiate between reward and neutral trials. Our results converge with a study by Wynn and colleagues (2010), who also found evidence of a reduced SPN in schizophrenia when participants were asked to anticipate emotional and non-emotional images. These data extend the broader reward literature in schizophrenia (Cohen & Minor, 2010; Kring & Caponigro, 2010; Kring & Elis, 2013; Waltz & Gold, 2007; Juckel et al., 2006) to show that there are broad anticipatory deficits for social and nonsocial rewards alike.

Groups were also compared on reward sensitivity. Our ERP index was the reward positivity (RewP), a positive-going ERP component at fronto-central sites that is maximal 250-350 ms post-feedback, with positive outcomes (rewards or gains) evoking a larger deflection compared with neutral or negative feedback (Holroyd, Hajcak, & Larsen, 2006; Holroyd, Pakzad-Vaezi, & Krigolson, 2008; Holroyd, Krigolson, & Lee, 2011; Doñamayor et al., 2012; Weinberg, Riesel, & Proudfit, 2014). We hypothesized that individuals with schizophrenia would exhibit an attenuated RewP in response to social

rewards, but a normative RewP to nonsocial rewards, relative to healthy participants. This hypothesis is consistent with a social specific hedonic deficit in schizophrenia (Cohen et al., 2010). Instead, we found that individuals with schizophrenia exhibited a larger RewP amplitude to social rewards compared with healthy participants. Although this was not what we predicted, our results converge with findings from recent studies that show individuals with schizophrenia can experience social enjoyment (Horan & Blanchard, 2003; Blanchard et al., 2015; Kimhy et al., 2014; Oorschot et al., 2013; Granholm et al., 2013; Fulford, Treadway, & Woolley, 2018). We extend these findings by showing that hedonic capacity for social rewards is evident at the level of electrophysiology. It was surprising that individuals with schizophrenia had a greater RewP than healthy participants. A study by McCarthy and colleagues (2017) had similar findings, wherein individuals with schizophrenia had higher initial positive responses to a social affiliation partner. It is possible that individuals with schizophrenia have impoverished social environments (Goldberg, Rollins, & Lehman, 2003; MacCabe, Koupil, & Leon, 2009), and thus have different initial reactions to novel social rewards than healthy participants. This explanation is speculative, and future research will need to determine the replicability of this group difference.

Unfortunately, we were unable to use the data from the money task to reliably measure group differences in reward sensitivity for nonsocial rewards. Examination of the raw ERP waveforms from the money task revealed a large fronto-central positivity in the gain condition that began around 150 ms and peaked around 190-200 ms post stimulus onset. The positivity we observed, in terms of latency, could be referred to as the P2 (or P200). Additionally, in the gain condition, there was a negativity that peaked at

120 ms post stimulus onset, reflective of a N1 component. Together, these two components reflected a N1/P2 complex in the theta range. The N1/P2 complex was quite robust and appeared to suppress the RewP in the delta range (Bernat et al., 2015). Indeed, the RewP typically shows a small difference between gain and no-gain conditions at 200 ms that becomes more pronounced in the 250-400 ms range. Even after filtering theta frequency from our data, we saw the most drastic differences between gain and no gain conditions at 200 ms, suggesting that our RewP measurement was confounded by the N1/P2 complex. As such, our experimental manipulation did not elicit the traditional RewP in the money condition as we had planned, and we therefore did not use this data as a contrast with social reward processing. Exploratory analyses, however, revealed that there were no significant group differences on P2 mean amplitudes.

There are several reasons why we may have found a N1/P2 in addition to the RewP in the money condition, but not in the social condition. First, the quarter image on gain trials may have differentially captured attention compared with the grey circle image on no-gain trials. The P2 effect is typically associated with stimuli that have greater attention capture and allocation (Potts et al., 2006; San Martin et al., 2010; Flores et al., 2015). Similarly, the N1 is a marker of visual-attentional processing and is sensitive to stimulus characteristics, such as luminance (Vogel & Luck, 2000). It is possible that the visual properties of quarter image made it more captivating than the grey circle image. Another reason why we may have seen the N1/P2 complex in the money condition is because the magnitude of the money reward was quite large (see Goyer, Woldorff, &

Huettel, 2008)[17]. Indeed,the P2 is thought to reflect greater arousal levels due to the valence of a stimulus (Carretié et al., 2001; Schutter et al., 2004), whereas the RewP reflects the mismatch between reward prediction and outcome (Potts et al., 2006). It is therefore possible that participants were not actively updating reward prediction errors necessary for learning the consequences of their behavior (the function of the RewP), but instead participants were orienting their attention to the large reward when it appeared on the screen. Lastly, contextual factors are known to affect feedback processing (Gehring & Willoughby, 2002; Gibbons et al., 2013; Goyer et al., 2008), such as the presence of alternative outcomes (Holroyd et al., 2004). It is possible that we saw the N1/P2 complex because participants viewed smiles to be a relative punishment when juxtaposed with the money because the social reward magnitude was relatively small and intangible, comparatively.

Another unpredicted finding in the money condition was contamination by component overlap with the N200. The N200 is a frontal-central negativity that peaks about 260 ms following the onset of an infrequent stimulus, referred to as the "oddball effect" (Patel & Azzam, 2005). The N200 and the FRN were originally thought to be the same component because they overlapped in timing and topography (Holroyd, 2004). This idea was later refuted because it was demonstrated that their functions are different (Baker & Holroyd, 2011). That is, the N200 is associated with frequency information (whether the feedback is frequent or infrequent) and the FRN is associated with valence

[17] When comparing our raw ERP waveforms to those from Flores and colleagues (2015), the study from which our methods were derived, it is of note that they also found a robust P2 effect in the "high reward" condition relative to the "low reward" and "non-reward" conditions.

information (whether the feedback is positive or negative). When these two components coincide, the presence of both waveforms can complicate feedback interpretations (Krigolson, 2017). Our task was fixed so that participants earned rewards on 65% of trials. This threshold was based on the extant literature at the time of study design (Flores et al., 2015); however, many RewP tasks use a 50% threshold to eliminate N200 contamination (e.g., Proudfit, 2015). Moreover, in the current study, the frequency of feedback may not have been consistent across money and social tasks because the money reward was more salient (see behavioral data), which impacted reward frequency across the different trial types.

We compared reaction times and reward-related ERPs across the social and nonsocial tasks. Participants' reaction times were comparable on both tasks. This was not surprising, as the task structure was the same, merely with different incentive types. Similarly, participants' reward anticipation was significantly correlated on the two tasks, suggesting that participants' ability to anticipate reward feedback is largely consistent regardless of incentive type. Reward sensitivity on the two tasks was not significantly correlated, perhaps because the reward magnitudes were discrepant. Next, we evaluated how reaction times were related to reward-related ERPs. We expected that participants would show more anticipation of rewards when they were faster to respond to the target (i.e., "I hit the target, I'm going to win!"). Surprisingly, we found the opposite pattern: healthy participants showed greater reward anticipation when they were slow to react to the target (i.e., "I was too slow, I wonder if I'm going to win?"). In the schizophrenia group, reward anticipation was not related to reaction times during the task, providing further evidence of an anticipatory deficit. This might suggest that, although individuals

with schizophrenia were motivated to obtain rewards (as evidenced by their behavioral data), they do not reflect on their actions in the interim period leading up to the feedback in the same manner as healthy participants.

Another perplexing finding was that we expected that greater reward anticipation (SPN) to be associated with greater reward sensitivity (RewP); however, this was not the case for either group. This finding is inconsistent with evidence from fMRI studies, which show that activation in the nucleus accumbens (NAcc) of the ventral striatum during reward anticipation increases with expected reward value (Knutson et al., 2005; Spreckelmeyer et al., 2009), reflecting positive affect associated with the prospect of receiving a reward (Knutson & Greer, 2008). Nonetheless, our finding is consistent with the broader ERP literature showing that the SPN and RewP are not always correlated (Ait Oumeziane et al., 2017; but also see Zheng et al., 2017).

Our second aim was to examine correlations between social reward processing, negative symptoms, and social functioning. Use of the CAINS allowed us to examine the differential contributions of motivation and pleasure deficits and expressivity deficits (Kring et al., 2013). We predicted that deficits in social reward processing, as indexed by reward-related ERPs, would be associated with greater motivation and pleasure deficits and worse social functioning. Results indicated that social reward sensitivity (RewP) was not related to motivation and pleasure deficits or social functioning. However, less social reward anticipation (SPN) was related to more severe motivation and pleasure deficits. Our data are consistent with previous work by Wynn and colleagues (2010), who found that reductions in SPN amplitudes had some association with self-reported anhedonia, although in their study this relationship did not reach statistical significance. It was

unexpected that social functioning was not related to social reward anticipation using the self-report instrument. Ecological momentary assessment (EMA) might provide more precise information about real-time enjoyment in social interactions, frequency of social engagement, or desire for social contact. Overall, our findings add to the general reward literature, demonstrating that aspects of reward processing involving the enjoyment of rewards is relatively spared in schizophrenia, whereas anticipatory and motivational aspects of reward processing may be more dysfunctional and may be more closely related to negative symptoms (Gold et al., 2008, 2012; Barch & Dowd, 2010).

Lastly, our third aim was to explore the differential contributions of social reward processing and social cognition in understanding social functioning. Social-cognitive abilities were assessed using the TASIT. Individuals with schizophrenia performed significantly worse on theory of mind measures compared with healthy participants, which is consistent with previous research (Sparks et al., 2010). Schizophrenia participants correctly identified when actors were being sincere, but otherwise showed widespread problems understanding conversational inferences, such as when others were lying or being sarcastic. Next, we found that individuals with schizophrenia significantly differed from healthy participants in their ability to identify affective states, consistent with the broader literature (see Gur & Gur, 2015 for a review). The literature provides some evidence that individuals with schizophrenia have the most difficulty understanding negative emotions (Sparks et al., 2010; Kohler et al., 2003; Mandal et al., 1998; Edwards et al., 2002; Heimberg et al., 1992), in part because these expressions are more complex (Hager & Ekman, 1982) and are encountered less frequently during interactions (Fridlund, 1994). These results are interesting given that our sample reported a stronger

desire for close relationships compared with other clinical samples. Overall, our results suggest that individuals with schizophrenia have difficulty understanding the emotions and intentions of others, even among those who have a desire for social connection.

Social-cognitive performance was not related to our clinical variables. At the very least, we expected that social-cognitive impairments would be significantly correlated with social functioning (see Couture et al., 2006; Green, Horan, & Lee, 2015; Fett et al., 2011), which was not the case. Additionally, we hypothesized that worse theory of mind would be correlated with motivation and pleasure deficits, providing further evidence that individuals are less motivated to seek out social contact when they have difficulty understanding the intentions of others (Kalin et al., 2015; Robertson et al., 2014; Couture et al., 2011). However, only emotion perception was modestly correlated with motivation and pleasure deficits (r = -.178), and this association did not reach statistical significance. Finally, we hypothesized that negative symptoms would be associated with worse social functioning (Kalin et al., 2015; Kring et al., 2013). Indeed, we found that motivation and pleasure deficits are associated with a decline in social functioning, while expressivity deficits were not. These results highlight the utility of using a two-factor negative symptom scale differentiating between experiential (motivation and pleasure) and expressivity deficits (Blanchard & Cohen, 2006; Horan, Kring, Gur, Reise, & Blanchard, 2011).

Limitations

Several limitations of the study must be acknowledged. First, our schizophrenia sample was atypical with regards to symptom ratings, social anhedonia, and premorbid intelligence. Symptom ratings were on the low end of the clinical interview scales, and

mean scores from these scales were lower than other clinical samples (see Strauss & Gold, 2016 for comparison). Another striking difference was that groups did not differ in their trait-levels of social anhedonia, with schizophrenia participants reporting levels that were much lower than other published studies (see Blanchard et al., 1998; Horan et al., 2006 for comparison). Groups were also not differentiated by their premorbid intelligence, which is highly unusual given that schizophrenia is characterized by widespread cognitive impairments (Gold & Weinberger, 1995). All of this suggests that our schizophrenia sample was relatively high functioning, with less severe negative symptoms and cognitive impairments, thereby restricting the generalizability of our findings.

Relatedly, the average age of our schizophrenia sample was 33-years-old. There may be advantages to studying social reward processes in younger, first-episode psychosis samples who have a shorter illness duration. Namely, it may be easier to experimentally control for environmental factors that reduce social motivation, in order to focus on the biological mechanisms specific to the illness. For example, individuals with schizophrenia may become less motivated to seek social interaction over time due to impoverished social environments and a lack of opportunity for social connection (Goldberg, Rollins, & Lehman, 2003). It is also possible that individuals remove themselves from their social environments after experiencing stigma and discrimination (Link, Struening, Neese-Todd, Asmussen, & Phelan, 2002).

Next, the results of our study, like nearly every study in the schizophrenia cognition literature, necessarily confound the impact of diagnosis, symptom severity, and the unknown impact of medication on reward processes. All of our schizophrenia

participants were taking at least one antipsychotic during the study. Research shows that antipsychotic medications block dopamine receptors and have the potential impact motivational processes (Barch & Dowd, 2010). For ethical reasons, drug-withdrawal for research purposes is rarely permitted. And if only medication-free individuals were included, it would undermine external validity. Some researchers compute chlorpromazine (CPZ) equivalents of antipsychotic medication types and dosages to use as a covariate in statistical analyses to control for medication effects. However, Miller and Chapman (2001) advise against this when the covariate is confounded by sub-group membership. Indeed, medications differ in their potency and ability to block dopamine receptors, and medications vary in their target receptor sites and neurotransmitters. Moreover, providers differentially prescribe medications to target specific clinical symptoms (e.g., positive or negative symptoms). For all the above reasons, controlling for antipsychotic medication effects is inappropriate and would lead to uninterpretable findings.

Another limitation is that, given our small sample size, we were limited in statistical power to explore possible gender differences related to reward processing. There is emerging ERP research to suggest that women are more sensitive to social and nonsocial rewards (i.e., a larger RewP) compared with men (Distefano et al. 2018). This may also be an interesting and important direction for future research in schizophrenia given that men with schizophrenia tend to have more negative symptoms and worse social functioning (Abel, Drake, & Goldstein, 2010), which likely impacts social reward processes.

Lastly, the specificity of our findings is unclear because our clinical sample consisted solely of individuals with schizophrenia, and we did not attempt to understand how social reward processes are impacted by individual differences social anhedonia across the full dimensional continuum from healthy to pathological. Additionally, the Research Domain Criteria (RDoC) framework has been proposed to advance the classification of mental disorders by examining dimensions of symptomatology across diagnostic categories (Insel, 2010). A direction for future research may be to look at social reward processes among people with other clinical disorders known to have social deficits, including Autism, Williams syndrome, depression, social anxiety, and schizophrenia. With that said, this may add noise given that people with these disorders likely have different social environments and preferences.

Directions for Future ERP Reward-Related Research

Methodological issues must be taken into consideration when designing future EEG studies that attempt to parse apart psychological processes associated with reward processing. First, there should be an equal probability of receiving gain and no gain feedback to ensure that the impact of stimulus frequency (N200) on the ERP is equivalent across conditions (Krigolson, 2017). The easiest way to correct this problem is to adjust the time estimation manipulation so there is a 50% success rate across reward conditions. Another way to control for stimulus frequency would be to use a different task entirely. The Doors Task (Proudfit, 2015) is a simple guessing task where participants are instructed to choose one of two doors with a reward behind it, and thus there is a 50-50 probability of winning. It is a well-established reward paradigm known to elicit the RewP

(e.g., Bress & Hajcak, 2013; Bress et al., 2013) and has been adapted in recent years to have a social condition (Distefano et al., 2018).

Second, future experiments should be designed so that there are equal or comparable reward magnitudes across money and social tasks to isolate the RewP (and prevent P2). One solution may be to use stimuli that have similar physical characteristics yet represent social and monetary phenomenon. For example, Ait Oumeziane and colleagues (2017) used a "thumbs up" (gain) image or "thumbs down" (loss) image to simulate "likes" on Facebook (social condition); in the money condition, they used an arrow pointing up (gain) or an arrow pointing down (loss). Another solution may be to try and make the social exchange more realistic. Indeed, our social stimuli were an approximation of the social rewards encountered in everyday life, which challenges ecological validity. fMRI researchers have begun to develop innovative methods to bring live social interactions into the lab to make social feedback more salient (see Redcay & Warnell, 2018), which may be adapted for EEG research. With that said, it is possible that the electrophysiological responses will always be bigger for money rewards because it is a tangible reward, unlike social rewards that lose their utility outside the experimental setting (e.g., Stavropoulos & Carver, 2014). This raises the question of whether social and nonsocial rewards should be studied together or on separate occasions in EEG studies.

Another direction for future ERP reward-related research in schizophrenia would be to use more advanced methodological approaches. Recent work employing time-frequency analysis has shown that processes indexed by the FRN and RewP are confounded in the time domain but can be better represented as separable processes in the

theta (3-7 Hz) (fronto-central) and delta (0-3 Hz) (central parietal) frequency bands (Bernat, Williams, & Gehring, 2005; Bernat, Nelson, Steele, Gehring, & Patrick, 2011; Bernat, Malone, Williams, Patrick, & Iacono, 2007). As such, time-frequency signal processing may provide an alternate approach for characterizing distinct psychological processes associated with feedback processing. This method may be especially useful in parsing apart the differential effects of punishment (theta-FRN) and reward (delta-RewP), which is of interest given evidence that individuals with schizophrenia can learn from negative outcomes and not positive ones (Gold et al., 2012). We choose not to include a loss condition in the current study because we were specifically interested in motivational approach behaviors associated with social rewards.

Lastly, future research examining social reward processing in schizophrenia could examine other sub-stages and their associated electrophysiological correlates. For example, it may be helpful to understand how people respond to the prospect of earning a social reward. The cue-P300 is a positive-going ERP component that peaks between 300-500 ms and reflects allocation of attention to reward cues (Flores et al., 2015; Novak & Foti, 2015; Goldstein et al., 2006; Broyd et al., 2012). The cue-P300 may be a useful index related to reward anticipation in schizophrenia because it could provide information as to whether there was adequate orientation to the reward cue in order for later processing stages to occur. Another anticipatory ERP that may be of interest is the contingent negative variation (CNV), a slow, negative-going ERP that is maximal at central electrodes and peaks just before the behavioral response. The CNV would provide an index of approach-motivated action preparation for rewards.

Conclusions

The current study provided initial electrophysiological evidence of anticipatory deficits for social and nonsocial reward types, reflecting a broad impairment in anticipatory processes. Importantly, anticipatory deficits for social stimuli were significantly correlated with motivation and pleasure deficits in the schizophrenia sample. Our findings also provided initial electrophysiological evidence of intact sensitivity to social rewards in schizophrenia. Despite some methodological issues that precluded us from measuring the RewP in the money task, this study demonstrates that the incentive delay tasks are appropriate to study social and nonsocial reward processing in this clinical population, with some experimental adjustments. Findings provide a useful foundation on which to compare distinct phases of social reward processing in schizophrenia.

Table 1. Participant demographic and clinical characteristics.

	SZ (n = 25)	HC (n = 22)	Statistic	p
Age	33.480 (7.848)	35.364 (9.550)	$F(1, 45) = 0.551$	.462
Male, n(%)	64.000%	68.182%	$\chi^2 = 0.091$	.763
Race, n(%)			$\chi^2 = 0.297$	.862
African-American	36.000%	40.909%	--	--
Caucasian	56.000%	54.545%	--	--
Other	8.000%	4.545%	--	--
Education	13.760 (1.640)	15.273 (2.120)	$F(1, 45) = 7.582$	.008
Parental Education	14.080 (2.528)	13.546 (3.266)	$F(1, 45) = 0.399$	.531
WRAT	102.400 (12.497)	106.227 (10.897)	$F(1, 45) = 1.236$	.272
Clinical Symptoms				
CAINS Total	16.480 (8.282)	--	--	--
MAP	11. 920 (5.552)	--	--	--
EXP	4.560 (4.321)	--	--	--
BPRS Total	33.692 (7.210)	--	--	--
Positive	2.163 (1.241)	--	--	--
Negative	1.606 (0.605)	--	--	--
Disorganized	1.169 (0.217)	--	--	--
CDSS Total	2.440 (2.347)	--	--	--
SFS Total	135.58 (25.916)			
RSAS Total	9.360 (5.251)	8.909 (5.245)	$F(1, 43) = 0.001$	.970
Asocial Beliefs Scale	4.240 (2.833)	3.864 (2.997)	$F(1, 43) = 0.021$	.886

Note. WRAT = Wide Range Achievement Test- Word Reading standard score (M = 100, SD = 15); CAINS = Clinical Assessment Interview for Negative Symptoms total score; MAP = Motivation and pleasure subscale; EXP = Expression subscale; CDSS = Calgary Depression Scale for Schizophrenia; BPRS = Brief Psychiatric Rating Scale; SFS = Social Functioning Scale total score; RSAS = Chapman Revised Social Anhedonia Scale total score.

Table 2. Summary of social functioning in the SZ group.

	No. of items	Scale Range	*M* (*SD*)
Social Engagement/Withdrawal	5	0-15	10.800 (2.217)
Interpersonal Behavior	9	0-9	5.840 (1.266)
Pro-social Activities	23	0-69	18.440 (10.689)
Recreation	15	0-45	19.720 (6.955)
Independence-Competence	13	0-39	28.520 (5.402)
Independence-Performance	13	0-39	35.800 (3.202)
Employment/Occupation	1	0-10	4.680 (3.338)

Note. Table summarizes subscales scores from the Social Functioning Scale (SFS) (Birchwood et al., 1990) for descriptive purposes.

Table 3. Mean hit rates, reaction times, and ERP amplitudes by group.

	SZ		HC	
	Neutral *M* (*SD*)	Reward *M* (*SD*)	Neutral *M* (*SD*)	Reward *M* (*SD*)
Hit Rates				
Money	.490 (.130)	.663 (.048)	.495 (.114)	.661 (.045)
Social	.536 (.111)	.632 (.062)	.504 (.091)	.656 (.053)
Reaction Time				
Money	313.214 (78.901)	282.150 (72.718)	274.010 (48.836)	240.347 (36.708)
Social	321.132 (94.502)	303.732 (83.957)	270.734 (43.894)	247.864 (36.768)
Reward Anticipation (SPN)				
Money	-1.360 (2.719)	-.792 (2.211)	-.5175 (3.482)	-1.901 (2.239)
Social	-.277 (3.973)	-.557 (2.021)	.095 (5.681)	-1.829 (2.789)
Reward Sensitivity*				
Money (P2)	--	1.608 (3.512)	--	2.530 (3.202)
Social (RewP)	--	2.007 (2.251)	--	.228 (3.354)

Note. Money = Monetary Incentive Delay task; Smiles = Social Incentive Delay task; SPN = Stimulus Preceding Negativity; RewP = Reward Positivity. *Measurements were calculated from the gain minus no gain difference wave.

Table 4. HC correlations: incentive delay task behavior and ERP amplitudes.

	1	2	3	4	5	6
Money						
1. Reaction Time	--					
2. SPN	-.457*	--				
3. P2	.109	-.120	--			
Social						
4. Reaction Time	.944**	-.516*	.136	--		
5. SPN	-.416^	.485*	-.466*	-.485*	--	
6. RewP	-.163	.116	-.144	-.139	-.069	--

Note. ** p < .01; * p < .05; ^ p < .10; Money = Monetary Incentive Delay task; Smiles = Social Incentive Delay task; SPN = Stimulus Preceding Negativity; P2 = positivity at 200 ms; RewP = Reward Positivity.

Table 5. SZ correlations: incentive delay task behavior and ERP amplitudes.

	1	2	3	4	5	6
Money						
1. Reaction Time	--					
2. SPN	.082	--				
3. P2	.239	-.382^	--			
Social						
4. Reaction Time	.934**	.000	.235	--		
5. SPN	.153	.713**	-.291	.057	--	
6. RewP	-.135	-.126	.044	-.096	-.385^	--

Note. ** p < .01; * p < .05; ^ p < .10; Money = Monetary Incentive Delay task; Smiles = Social Incentive Delay task; SPN = Stimulus Preceding Negativity; P2 = positivity at 200 ms; RewP = Reward Positivity.

Table 6. Intercorrelations with clinical symptoms, social functioning, social cognition and social reward processing in the SZ group.

	1	2	3	4	5	6	7	8	9	10	11	12
1. CAINS MAP	--											
2. CAINS EXP	.398*	--										
3. BPRS Positive	-.085	-.327	--									
4. CDSS	-.240	-.292	.138	--								
5. SFS Total	-.497*	-.275	-.189	.398*	--							
6. TASIT EET	-.178	.085	-.128	.289	.261	--						
7. TASIT SI-M	.048	.124	.173	.217	-.054	.386^	--					
8. TASIT SI-E	.047	.325	-.029	.288	.040	.385^	.738**	--				
9. RSAS	.294	-.094	.092	-.013	-.276	-.097	.087	-.062	--			
10. ABS	.197	-.059	.163	.215	-.233	-.063	.057	-.045	.871**	--		
11. RewP (social)	-.027	-.257	.033	.202	-.133	.044	.199	.004	.228	.061	--	
12. SPN (social)	.487*	.066	.330	-.192	-.312	-.094	-.158	-.319	.248	.291	-.385^	--

Note. ** p < .01; * p < .05; ^ p < .10; CAINS = Clinical Assessment Interview for Negative Symptoms; MAP = Motivation and Pleasure; EXP = Expression; BPRS Positive = Brief Psychiatric Rating Scale positive symptoms subscale; CDSS = Calgary Depression Scale for Schizophrenia; SFS Total = Social Functioning Scale full scale; TASIT = The Awareness of Social Inference Test; EET = Emotion Evaluation Test; SI-M = Social Inference-Minimal; SI-E = Social Inference-Enriched; Social Withdrawal/Engagement ; RSAS = Revised Social Anhedonia Scale; ABS = Asocial Beliefs Scale; RewP = reward positivity; SPN = stimulus preceding negativity.

Table 7. Summary of social cognitive performance by group.

	SZ (n = 25)	HC (n = 22)	Statistic	p
Emotion Perception				
TASIT EET (% correct)				
Positive Emotions	82.333 (11.863)	87.500 (5.605)	t(35.136) = 1.945	.060^
Negative Emotions	84.750 (12.247)	90.057 (6.297)	t(36.791) = 1.900	.065^
Total	83.714 (9.676)	88.961 (4.396)	t(34.416) = 2.440	.020*
Theory of Mind				
TASIT SI-M (% correct)				
Sincere	93.200 (8.646)	86.364 (15.674)	t(31.759) = -1.817	.079^
Simple Sarcasm	70.400 (26.375)	95.000 (6.726)	t(27.506) = 4.500	.000**
Paradoxical Sarcasm	76.600 (21.199)	94.091 (10.075)	t(35.248) = 3.680	.001**
Total	80.067 (13.714)	91.182 (7.575)	t(38.270) = 3.692	.001**
TASIT SI-E (% correct)				
Lies	81.125 (8.581)	87.500 (11.492)	t(38.543) = 2.131	.040*
Sarcasm	73.875 (17.858)	87.784 (9.042)	t(36.482) = 3.427	.002**
Total	77.500 (11.021)	87.642 (6.377)	t(39.245) = 3.916	.000**

Note. ** p < .01; * p < .05; ^ p < .10; TASIT = The Awareness of Social Inference Test; EET= Emotion Evaluation Test; SI-M = Social Inference-Minimal; SI-E = Social Inference-Enriched. Levene's test for equality of variances was violated for each of these tests, so t statistics are reported with equal variances not assumed.

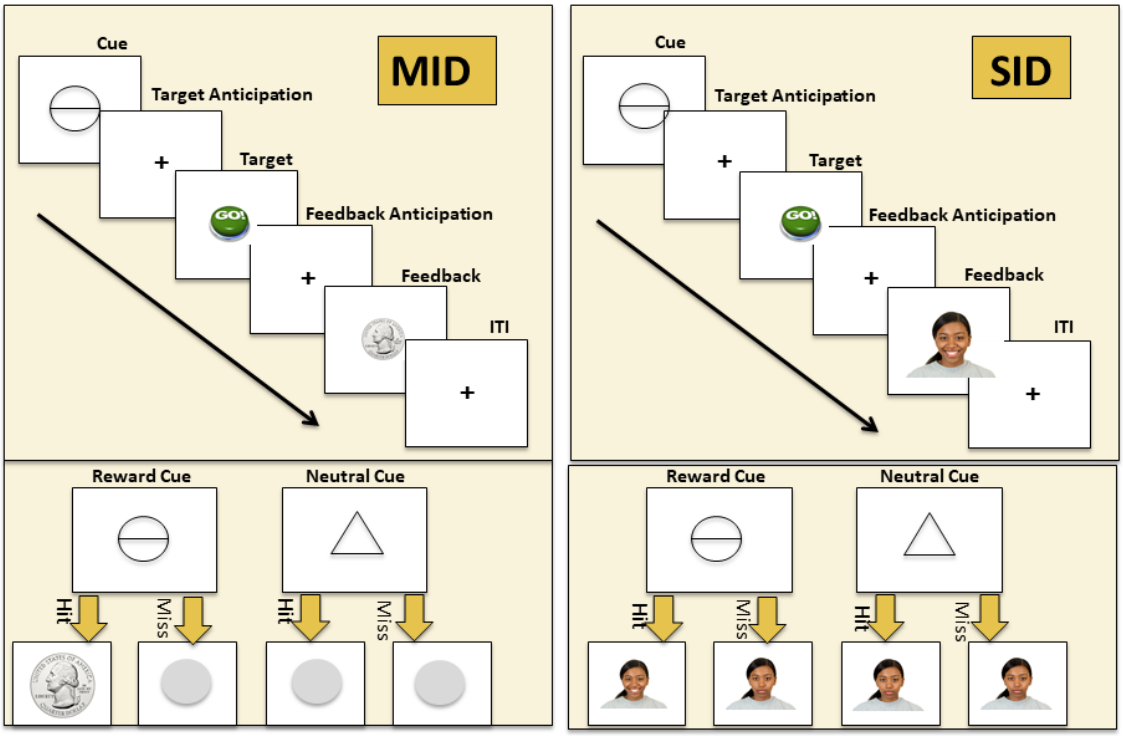

Figure 1. Schematic of the monetary and social incentive delay tasks.

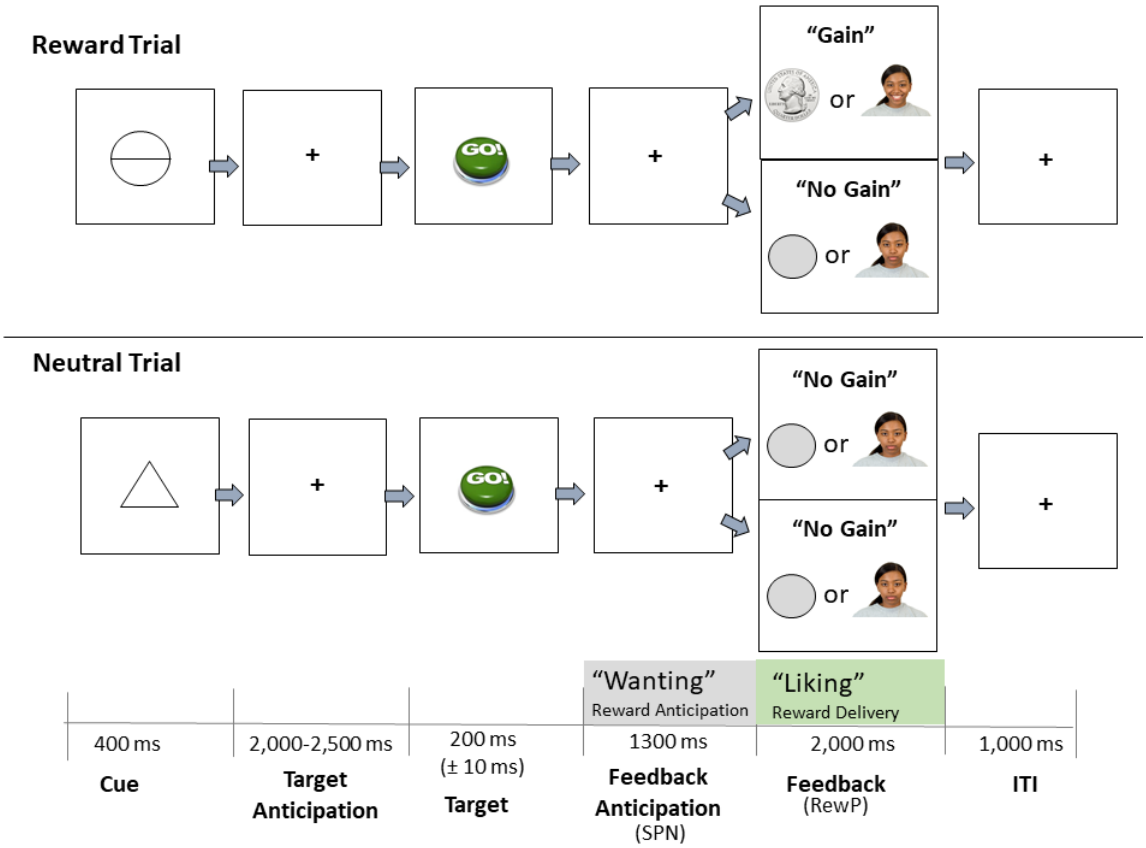

Figure 2. Trial sequence and timing of the incentive delay task.

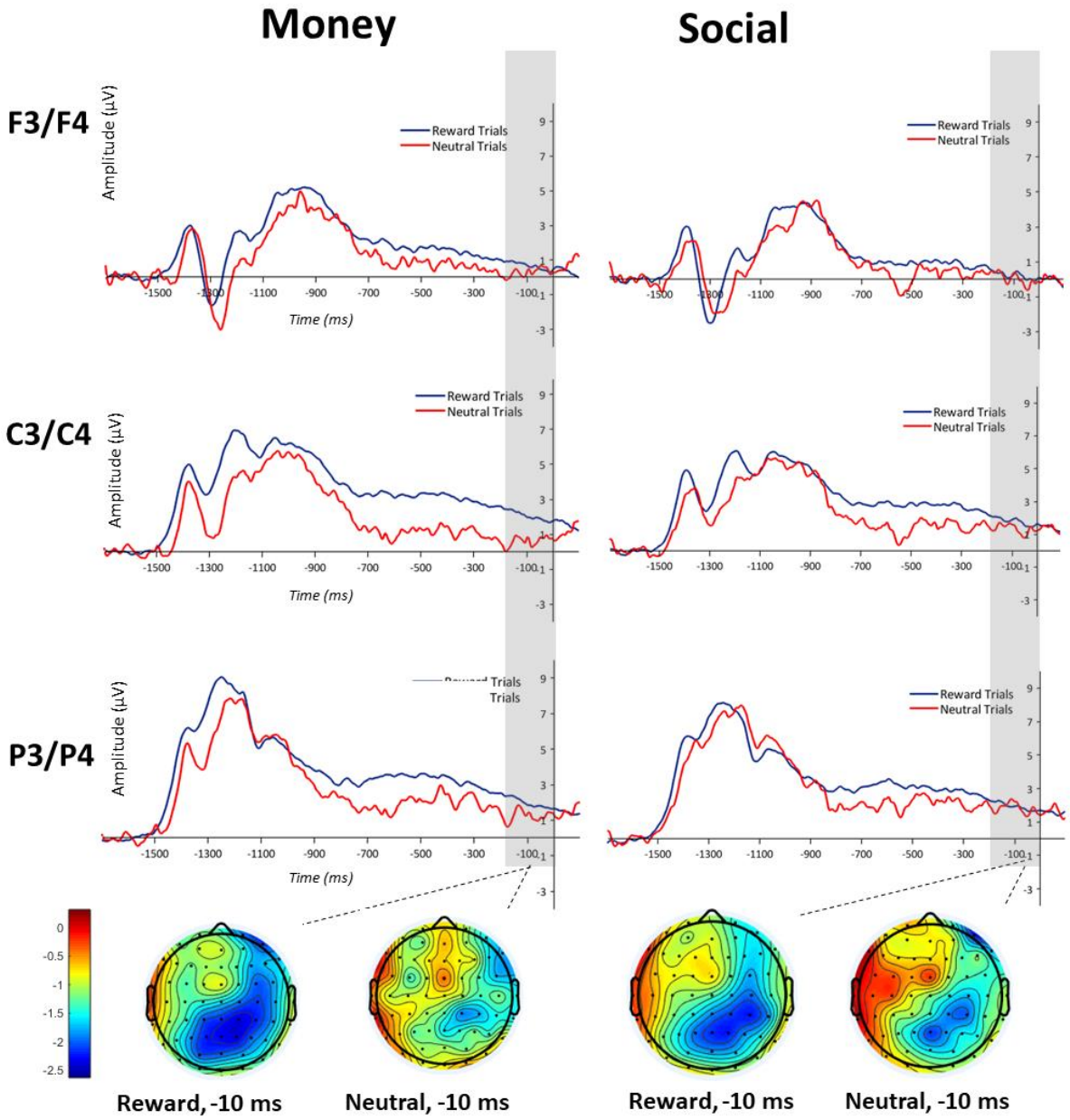

Figure 3. Grand-average waveforms during the reward anticipation phase. Waveforms are time-locked to the feedback and baseline corrected to -1700 to -1500 ms pre-feedback (200 ms before the target). Plots are shown for midline electrode sites (F3/F4, C3/C4, and P3/P4). Of note, the SPN is a negative waveform; therefore, more negative values reflect larger amplitudes. The gray bar indicates the time window for statistical analysis.

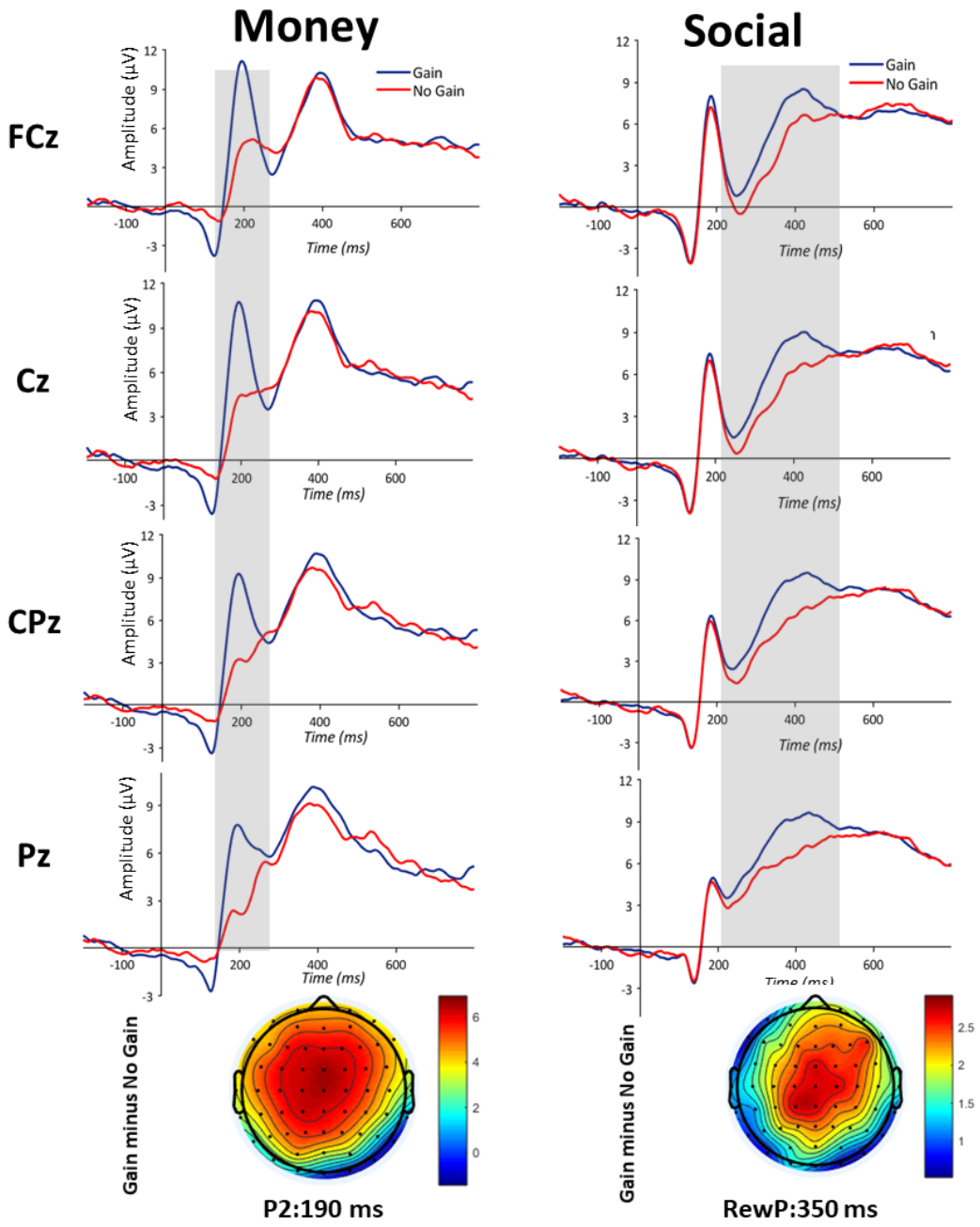

Figure 4. Grand-average waveforms during the reward feedback phase. Waveforms are time-locked to reward feedback and baseline corrected to 200 ms before stimulus onset. Plots are shown for the midline electrodes (FCz, Cz, CPz, Pz). These waveforms are presented for comparison with traditional plots depicting activity across midline electrodes. For example, we do not see the expected larger Gain minus No-Gain difference at FCz in the money condition, although there is a weak effect in Pz. Instead, we see a robust P2 at 190 ms. In the social condition, there is a positivity that peaks at approximately 350 ms that reflects the RewP. The gray bar indicates the time window for statistical analysis.

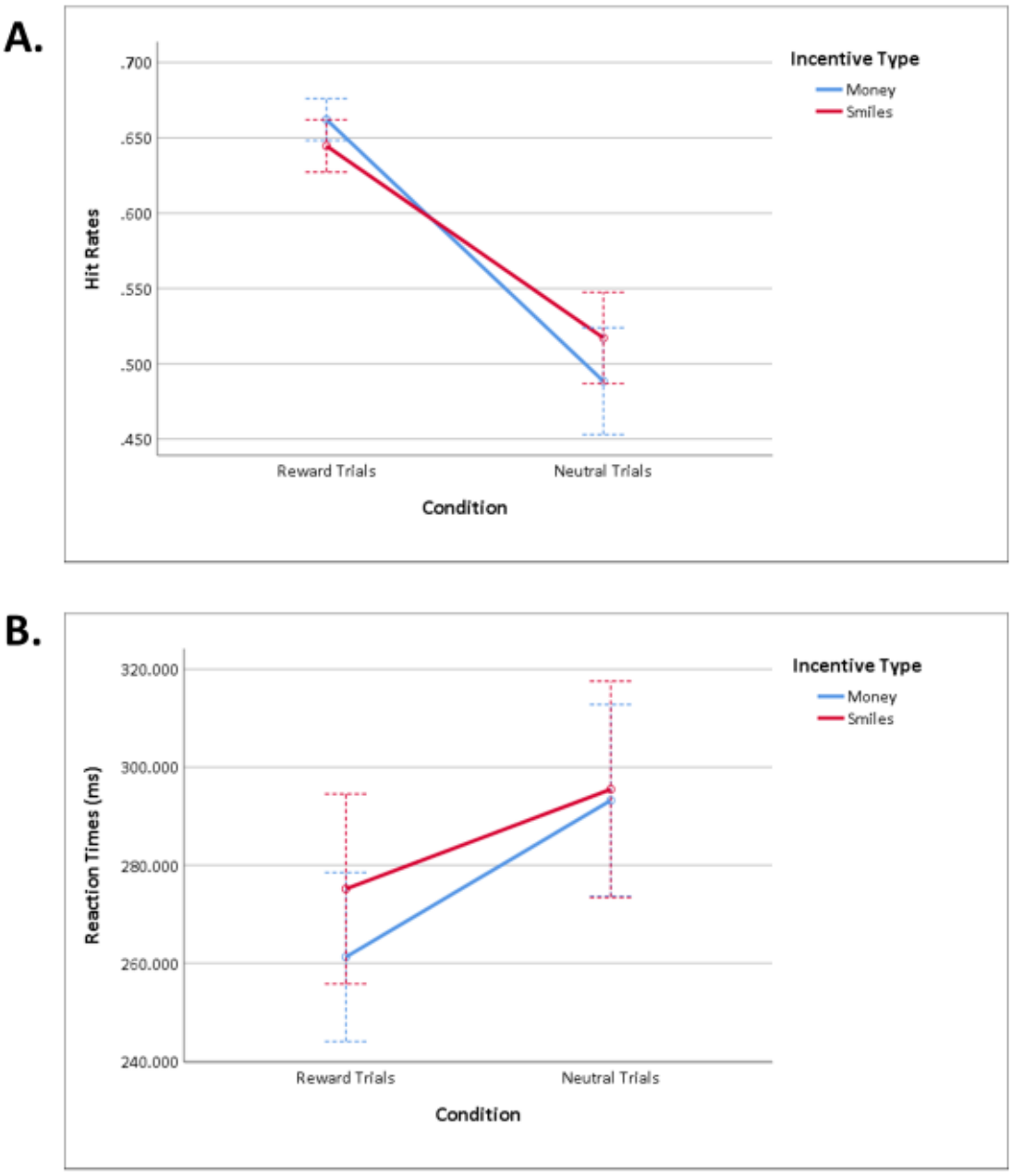

Figure 5. Behavioral data from the incentive delay tasks. Line graphs depict significant Condition X Incentive Type interaction effects for (A) hit rates, and (B) reaction times collapsed across the full sample. Error bars reflect +/- 2 Standard Errors from their respective means.

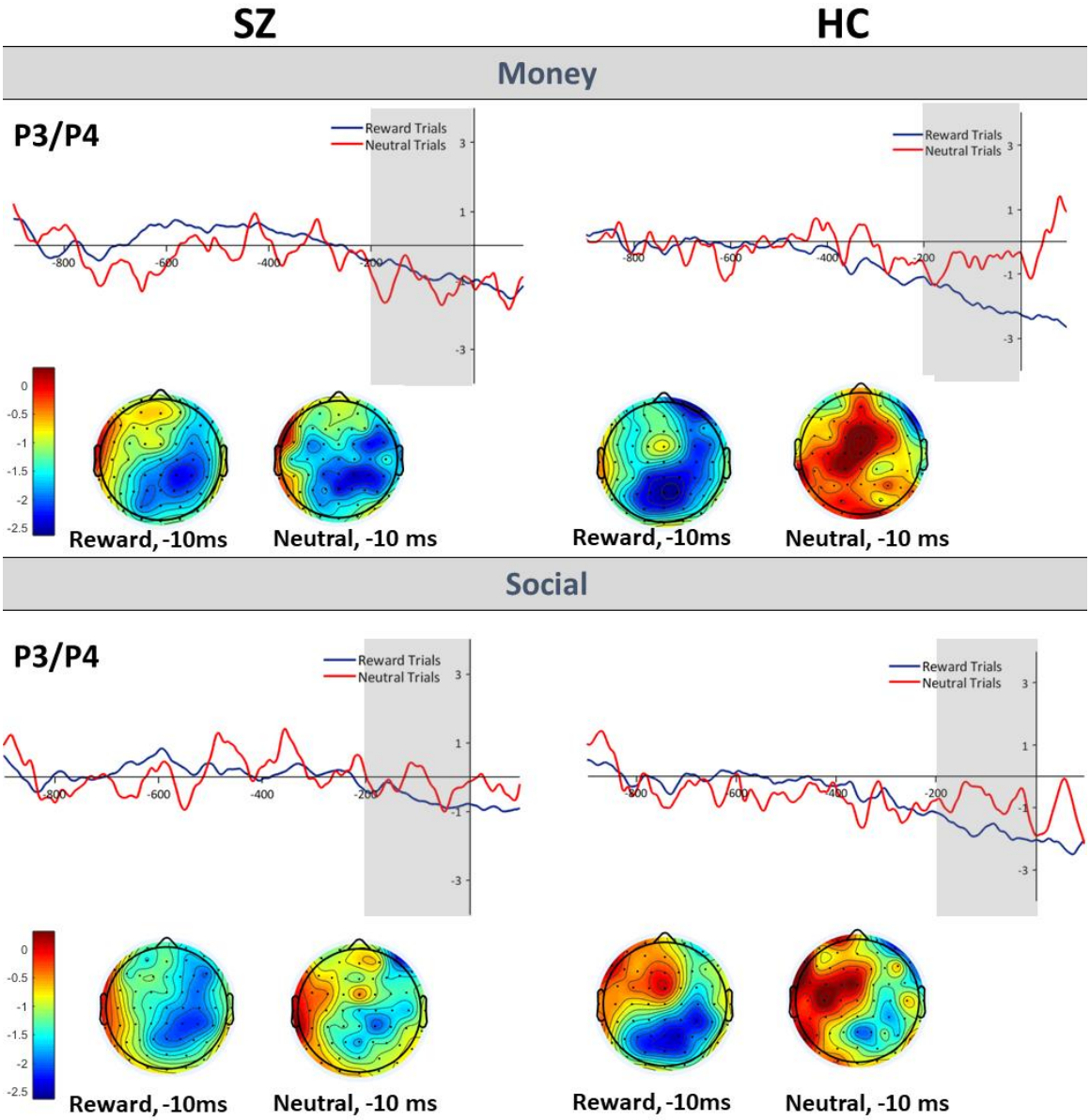

Figure 6. Reward anticipation waveforms. SPN waveforms and scalp distributions from the money (top) and social (bottom) tasks are shown for the SZ (right) and HC (left) groups. Plots are baseline corrected to -900 to -700 before feedback onset, after brain activity associated with the target. The shaded region of the waveforms shows the segment from -200 ms to 0 ms where the mean activity was scored at electrodes P3/P4.

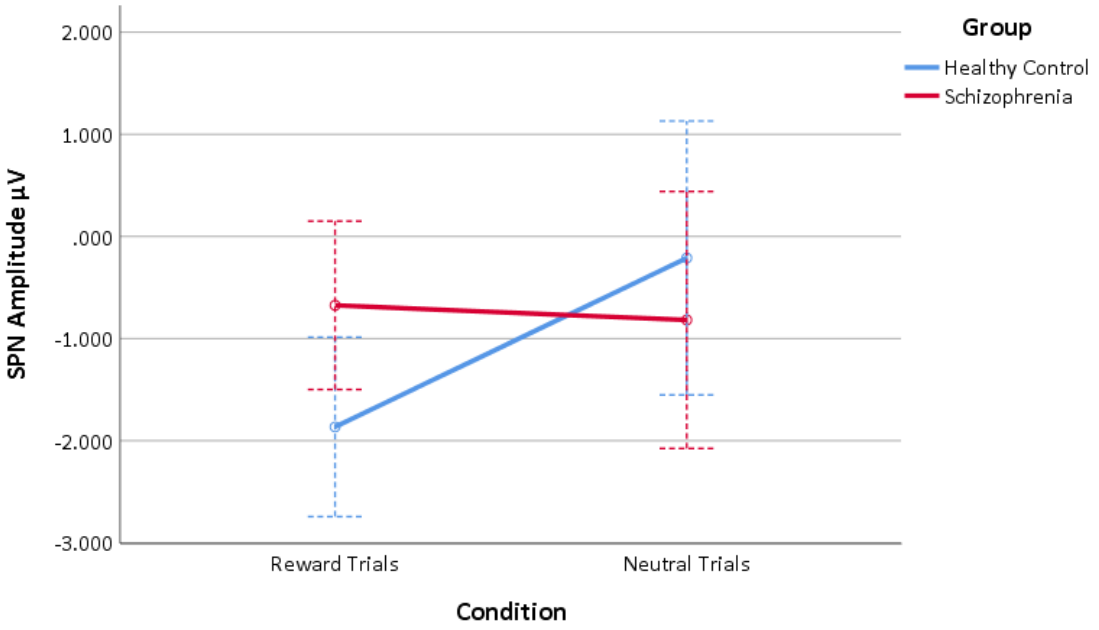

Figure 7. SPN amplitudes by condition and by group. Values reflect estimated marginal means of SPN amplitudes. Of note, the SPN is a negative waveform; therefore, more negative values reflect larger amplitudes. There is a significant Group X Condition interaction effect, showing that HC participants showed significantly more anticipation of reward feedback than neutral feedback, whereas the SZ participants showed similar anticipation regardless of whether there was a potential to win a reward. Error bars reflect +/- 2 Standard Errors from their respective means.

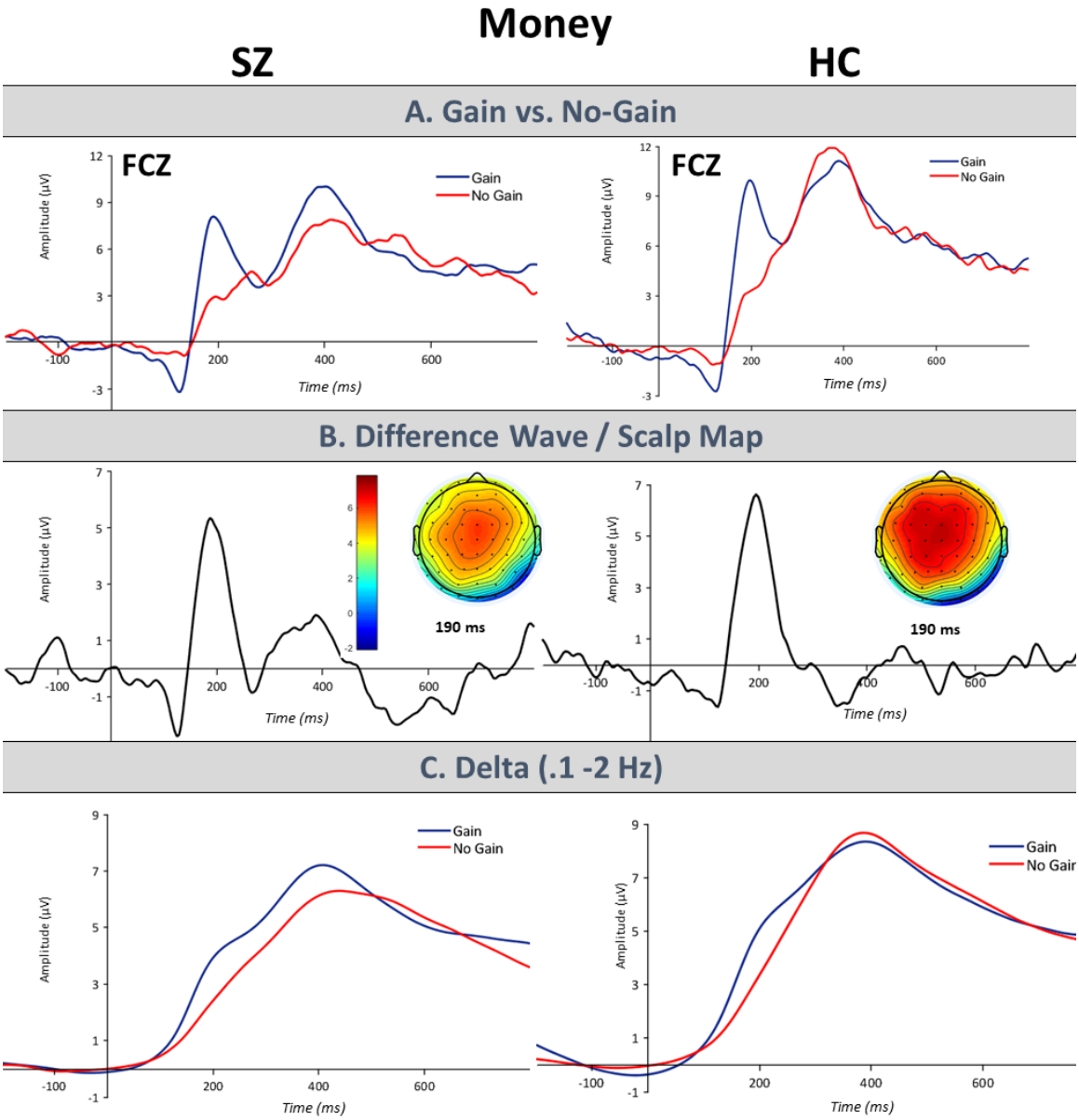

Figure 8. Nonsocial reward feedback waveforms. Plots show (A) ERPs to gain and no gain feedback recorded at channel FCz, (B) the associated difference waves, and (C) delta waveforms for SZ and HC groups.

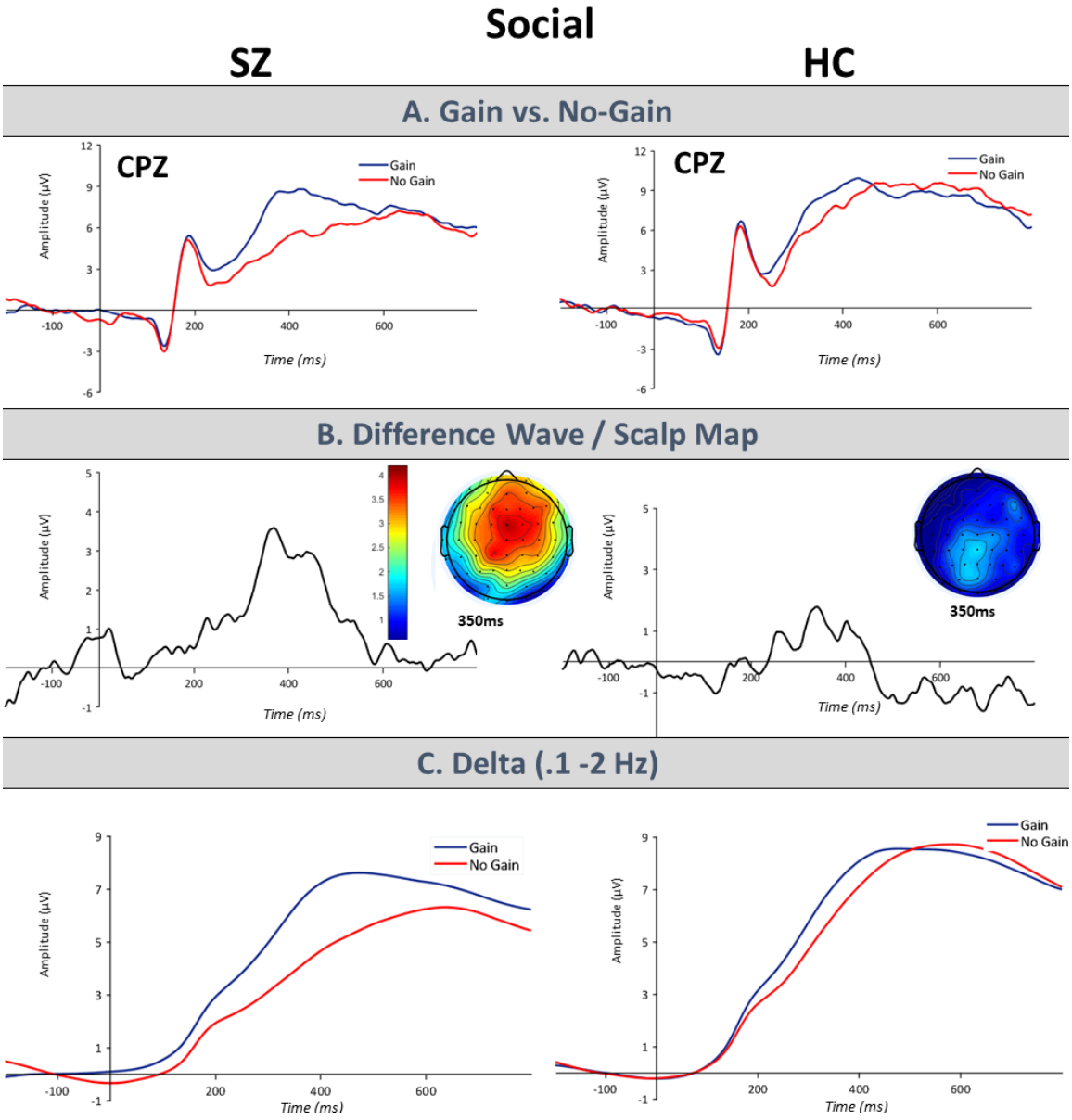

Figure 9. Social reward feedback waveforms. Plots show (A) ERPs to gain and no gain feedback recorded at channel CPz, (B) the associated difference waves, and (C) delta waveforms for SZ and HC groups.

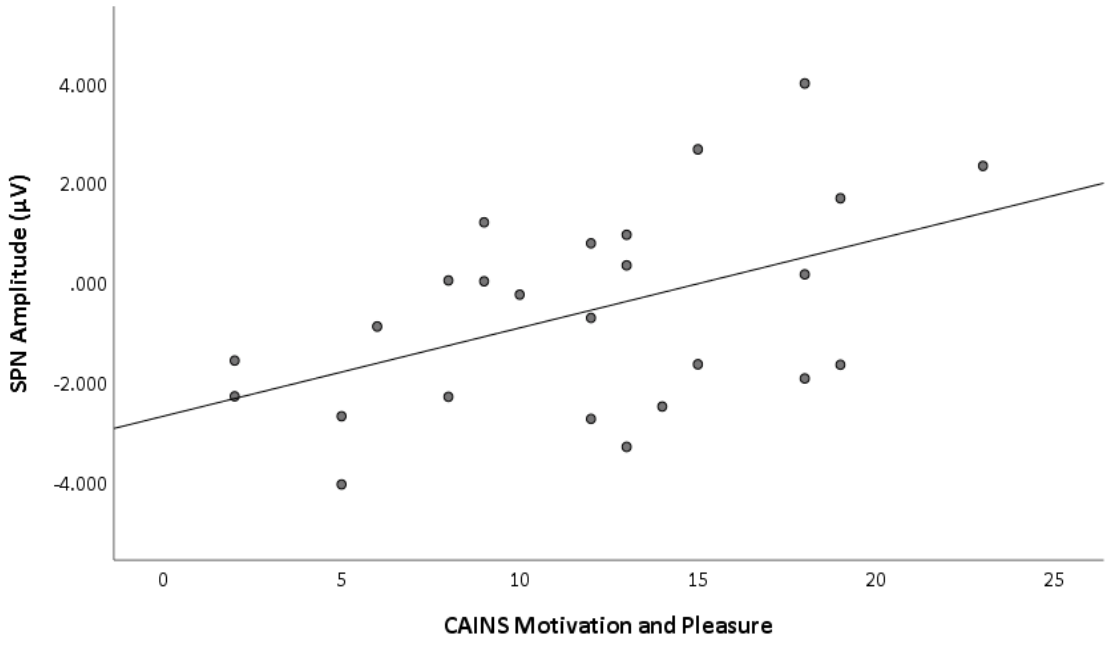

Figure 10. SPN amplitude and motivation and pleasure deficits in the SZ group. More severe motivation and pleasure deficits are significantly correlated with less social reward anticipation.

Appendix A: Clinical Interview for Negative Symptoms (CAINS)

CAINS (v1.0)

ID: _____ DATE: _____ RATER: _____

Overall Introduction: ***In this interview, I'll be asking you some questions about things you have been doing over the past week. In the first section, I'm going to ask you some questions about your family, romantic partners, and friends, including how motivated you have been to spend time with them and how you felt when you were around them.***

I. SOCIAL (MOTIVATION & PLEASURE)

ITEM 1: MOTIVATION FOR CLOSE FAMILY/SPOUSE/PARTNER RELATIONSHIPS

[Note: Romantic relationships can be rated in either Item 1 or Item 2 but NOT both. A spouse/ partner relationship in which the couple is living together should be assessed in Item 1. A dating/romantic relationship in which the couple is not living together should be assessed in Item 2.]

The following questions are about your family. This can include relatives like parents, brothers or sisters and other relatives, as well as your spouse [if married] or live-in partner. Have you been in contact with or visited with any family members in the past week (in person, phone, email)? Any contact with a spouse or partner?

IF CONTACT:

- *Who have you been in contact with? Anybody else?*
- *What things have you done with your family?*
- *IF RELEVANT: What things have you done with your spouse/partner?*
- *How much time did you spend together?*

Behavior

- *What have you done to see or contact your [family/spouse/partner] in the past week?*
- *When you were with your [family/spouse/partner] who decided what you would do?*
- *Who started the conversation? Did you start it? Did your [family/spouse/partner]? Were you involved in the conversation?*
- *Did you ever find that you quickly wanted to end your interactions with your [family/spouse/partner]? Did you want them to last longer?*

Motivation & Interest in Closeness

- *Have you been motivated to be around or in touch with your [family/spouse/partner] in the past week? (Why is that?)*
- *What did you talk about? Can you talk about good and bad times with your [family/spouse/partner]?*
- *How close do you feel to your [family/spouse/partner]? What does being close mean for you?*
- *Were there times in the past week when you just didn't want to be around or in touch with your [family/spouse/partner]?*
- *How important is being part of a family to you?*
- *What about that is important to you? Have you felt this way throughout the past week?*

IF NO FAMILY CONTACT:

[NOTE: This section applies when not part of a close family or if available relatives could be contacted but person has chosen not to interact. If the person is not currently in a relationship with a live-in spouse/partner, interest in romantic relationships is assessed in Item 2.]

- *Has your family tried to contact you or visit you in the last week?*
- *Has anything kept you or held you back from being in contact with your family?*
- *Do you wish you were closer to your family? OR Do you wish you were part of a close family?*
- *Did you miss interacting with your family in the past week?*
- *Is having a relationship with your family important to you? What about having a relationship is important to you?*
- *Have you preferred to spend your time alone rather than with your family?*

Item 1 – Motivation for Close Family/Spouse/Partner Relationships

0 = No impairment: VERY INTERESTED in and highly values close family bonds as one of the most important parts of life. Strongly desires and is highly motivated to be in contact with family. Regularly initiates and persists in interactions with family and actively engages in these interactions; good and bad times are openly discussed. Well within normal limits.

1 = Mild deficit: GENERALLY INTERESTED in and values close family bonds though response suggests some minor or questionable reduction. Generally desires and is motivated to maintain contact with family. Has a close relationship with family member(s) in which good and bad times can be discussed. Mild deficit in initiating and persisting in regular interactions with family – generally actively engaged when interactions occur.

2 = Moderate deficit: SOMEWHAT INTERESTED in family relationships and considers them somewhat important. May occasionally miss close connections with family but is only somewhat motivated to seek out interaction with family. Notable deficit in initiating and persistently engaging in interactions; discussion of good and bad times is limited. Interactions with family members may occur but are largely superficial and participation is best characterized as "going through the motions"; interactions are more likely initiated by family with mostly passive involvement of the person.

3 = Moderately severe deficit: LITTLE INTEREST in family relationships (could "take it or leave it") and does not describe family bonds as important. Describes hardly any motivation and minimal effort to have close family relationships. Rarely has discussion of good and bad times with family members. Contact and engagement with family is superficial and passive with almost all initiation and efforts to engage coming from others.

4 = Severe deficit: NO INTEREST in family relationships and does not consider them at all important. Prefers to be alone and is not at all motivated to be with family. If person does see family, it is done so grudgingly, passively and with no interest.

ITEM 2: MOTIVATION FOR CLOSE FRIENDSHIPS & ROMANTIC RELATIONSHIPS

Let's talk about friends (and dating or romantic relationships) now. By friends, I mean people who you know and spend time with, anyone you consider a friend, or people you can rely on and count on. Have you had any contact with friends in the last week (in person, phone, email)? IF RELEVANT: have you been in contact with a romantic partner or dating in the last week?

IF CONTACT:

- *In the past week, what have you done with your [friends/partner/dates]?*
- *Tell me about what you did [or what you talked about] during that [visit, activity, conversation]?*
- *How much time did you spend together with [friends/partners/dates]?*

Behavior

- What steps did you take to see or contact your [friends/partner/dates] in the past week?
- When you were with your [friends/partner/dates], who decided what you would do?
- When you spoke with your [friends/partner/dates], who started the conversation? Did you?
- Did you ever find that you quickly wanted to end your interaction with your [friends/partner/dates]? Did you want them to last longer?

Motivation & Interest in Closeness

- *Have you been motivated to be around your friends* (partner/dates) *in the past week? Why is that?*
- *Can you talk about both good times and bad times?*
- *Were there times in the past week when you just didn't feel like being around your friends* (partner/dates)*?*
- *How important is having friendships* (partner/dates) *to you? What about that is important to you?*
- *How close do you feel to your friends* (partner/dates)*? What does being close mean for you?*

IF NO FRIENDS/ROMANTIC CONTACT:

- *Are you interested in having friends or dating?*
- *Is having friendships [or being in a romantic relationship] important to you? If Yes, what about [specify friendships/romantic partner] is important?*
- *Did you miss these types of relationships in the past week?*
- *Would you like to have friends [or a romantic partner] with whom you could talk about good and bad times?*
- *(If any indication of interest) Have you taken any steps to meet someone who might be a friend (or romantic partner)?*
- *Has anything kept you or held you back from being in contact with your friends?*
- *Would you prefer to have friendships [or a romantic relationship] or would you prefer to be alone?*

Item 2 – Motivation for Close Friendships & Romantic Relationships

0 = No impairment: VERY INTERESTED in and highly values friend/romantic relationships as one of the most important parts of life. Strongly desires and is very motivated to engage in friendships. Regularly initiates and persists in interactions with friends/partner and actively engages in these interactions; good and bad times are openly discussed. Well within normal limits.

1 = Mild deficit: GENERALLY INTERESTED in and values friend/romantic relationships though response suggests some minor or questionable reduction. Generally desires and is motivated to engage in friendships. Has friendships/relationship in which good and bad times can be discussed though this may be less consistent. Mild deficit in initiating or persistently engaging during interactions with friends/partner. If no friends/relationship, misses friend/romantic relationships, is motivated to have friends/relationship, and makes efforts to seek out friends/relationship.

2 = Moderate deficit: SOMEWHAT INTERESTED in friend/romantic relationships and considers them somewhat important. May occasionally miss close connections with friends/partner and is somewhat motivated to have friends/partner. Notable deficit in initiating and persistently engaging in interactions; discussion of good and bad times is limited. Interactions with friends/romantic partner may occur but are largely superficial and participation is best characterized as "going through the motions"; interactions are initiated by others with mostly passive involvement of the person. If no friend/romantic relationships, is only somewhat motivated to have friends/partner and rarely if ever seeks out friends/partner.

3 = Moderately severe deficit: LITTLE INTEREST in friend/romantic relationships (could "take it or leave it") and does not describe friends/partner as important. Describes hardly any motivation to have friendships, and would just as soon be alone. Contact and engagement with others is superficial and passive with almost all initiation and efforts to engage coming from others.

4 = Severe deficit: NO INTEREST in friend/romantic relationships and does not consider them at all important. Prefers to be alone and is not at all motivated to have friends/partner.

ITEM 3: FREQUENCY OF PLEASURABLE SOCIAL ACTIVITIES – *PAST* WEEK

[NOTE: Ratings are based on **NUMBER OF DAYS IN THE WEEK** that pleasurable activity with other people is experienced. When there are reports of several different activities occurring, clarify if these happened on same or different days.]

Now, I want to talk to you about how you felt during the times you spent with or were in contact with others during the past week. You can include times with any of the people we have talked about so far or anyone else. Did you have any enjoyable interactions with other people, such as:

- *Family* (PAUSE)
- *Romantic or dating partners* (PAUSE)
- *Friends* (PAUSE)
- *Any other enjoyable social interactions or time spent with people*? (PAUSE)
- *IF NEEDED: Ask about people brought up in other sections* ***that were described as enjoyable interactions***

Sun	Mon	Tue	Wed	Thu	Fri	Sat

IF YES:

- *What about that was enjoyable?*
- *How many days did you enjoy/get pleasure from these interactions [time spent with xx person(s)] (for each)?*
- [If many (i.e., 5 or 6) days mentioned or if not clear which days of week interactions were enjoyed] *Were there any days that you did not have enjoyable interactions with other people?*

Item 3 – Frequency of Pleasurable Social Activities – Past Week

0 = No impairment: Pleasure experienced daily.
1 = Mild deficit: Pleasure experienced 5-6 days.
2 = Moderate deficit: Pleasure experienced 3-4 days.
3 = Moderately severe deficit: Pleasure experienced 1-2 days.
4 = Severe deficit: No pleasure reported

ITEM 4: FREQUENCY OF EXPECTED PLEASURABLE SOCIAL ACTIVITIES – *NEXT* WEEK

[NOTE: Ratings are based on total **NUMBER OF EXPECTED PLEASURABLE ACTIVITIES**, regardless of days on which they are expected to occur].

Now I would like you to think ahead to NEXT week (next 7 days), thinking about whom you will spend time with. You can include people you have already talked about or anyone else. What do you think you will enjoy doing in the NEXT week with other people?

FOR EACH ANSWER PROVIDED:

- *What about it do you expect to enjoy?*
- *How often do you think you will enjoy this in the next week?*

FOLLOW UP

- *Are there other experiences with people you think you will enjoy in the next week?*

ITEM 4 – Frequency of Expected Pleasurable Social Activities – Next week

0 = No impairment: Expecting MANY (7 or more) pleasurable experiences.
1 = Mild deficit: Expecting enjoyment from SEVERAL (5-6) pleasurable experiences.
2 = Moderate deficit: Expecting enjoyment from a FEW (3-4) pleasurable experiences.
3 = Moderately severe deficit: Expecting a COUPLE (1-2) pleasurable experiences.
4 = Severe deficit: Expecting NO pleasurable experiences.

II. WORK & SCHOOL (MOTIVATION & PLEASURE)

ITEM 5: MOTIVATION FOR WORK & SCHOOL ACTIVITIES

Now I am going to ask you some questions about work and school, including how motivated you have been for work or school activities and how you felt while doing these things over the past week. Have you been working or going to school over the past week? Any volunteer work? Are you in a work-related treatment program?

IF IN A RELEVANT ROLE:

- *Tell me about what you do in your [insert role here]*
- *How much time has this involved over the past week?*

Behavior

- *Have you been able to complete tasks at [insert role here]?*
- *In the past week has anyone raised any concerns with your [insert role here] performance?*
- *Have you missed any days in the past week? Why?*
- *Does someone need to remind you about [insert role here]? Why is that?*
- *Were there things you meant to do or were supposed to do but just never got around to doing them? Why?*

Motivation

- *How do you feel about [insert role here]?*
- *Have you been motivated to do your [insert role here]?*
- *What motivates you to do your [insert role here]?*
- *Were there times during the past week when you just didn't feel like [insert role here]?*
- *How important is your [insert role here] to you? What about it is important?*

IF NO CURRENT ROLE:

- *Is there a reason why you are not currently (work/school/volunteer)?*
- *Has anything held you back from looking for (work/school/volunteer)?*
- *How do you feel about working or going to school or volunteering?*
- *Have you felt much interest in work/school/volunteer? {Tell me more}*
- *Is working important to you? What about working/going to school/volunteering is important?*
- *Do you miss work/school/volunteer?*
- *Have you tried to take any steps to start working/going to school/volunteering? What steps have you taken? How often have you looked into work/school/volunteer?*

ITEM 5 – Motivation for Work & School Activities

0 = No impairment: Person is VERY MOTIVATED to seek out work or school, or new opportunities in work or school; initiates and persists in work, school, or job-seeking on a regular basis. Well within normal limits.

1 = Mild deficit: Person is GENERALLY MOTIVATED to seek out work or school or new opportunities in work or school; a mild deficit in initiating and persisting; may report instances of initiating, but with moderate persistence.

2= Moderate deficit: Person is SOMEWHAT MOTIVATED to seek out work or school or new opportunities in work or school; notable deficit in initiating; may have initiated activities, but needed reminders on multiple occasions, and/or not initiated any new activities, and/or not persisted for very long.

3 = Moderately severe deficit: Person is only SLIGHTLY MOTIVATED to seek out work or school or new opportunities in work or school; significant deficit in initiating; may have needed constant reminders, and/or initiated a few activities; did not persist for very long.

4 = Severe deficit: Person is NOT AT ALL MOTIVATED to seek out work / school; nearly total lack of initiation and persistence in work, school, or job seeking.

ITEM 6: FREQUENCY OF EXPECTED PLEASURABLE WORK & SCHOOL ACTIVITIES - *NEXT* WEEK
[NOTE: Ratings are based on total **NUMBER OF EXPECTED PLEASURABLE ACTIVITIES,** regardless of days on which they are expected to occur].

Now I would like you to think ahead to NEXT week (next 7 days); thinking about work/volunteer/school.

IF HAS A RELEVANT ROLE:
- *What do you think you will enjoy doing in the NEXT week at work/volunteer/school, etc.*

IF NO RELEVANT ROLE:
- *Do you think you will enjoy anything related to seeking paid or volunteer work, or school?*

FOR EACH ANSWER PROVIDED:
- *What about it do you expect to enjoy?*
- *How often do you think you will enjoy this in the next week?*

FOLLOW UP:
- *Are there other work/school experiences you think you will enjoy in the next week?*

ITEM 6 – Frequency of Expected Pleasurable Work & School Activities – *Next* Week

0 = No impairment: Expecting MANY (7 or more) pleasurable experiences.
1 = Mild deficit: Expecting enjoyment from SEVERAL (5-6) pleasurable experiences.
2 = Moderate deficit: Expecting enjoyment from a FEW (3-4) pleasurable experiences.
3 = Moderately severe deficit: Expecting a COUPLE (1-2) pleasurable experiences.
4 = Severe deficit: Expecting NO pleasurable experiences.

III. RECREATION (MOTIVATION & PLEASURE)

ITEM 7: MOTIVATION FOR RECREATIONAL ACTIVITIES

In the next section, I am going to ask you some questions about what you do in your free time – any hobbies or recreational activities. I will ask about your motivation and feelings about the things that you have done in your free time over the past week.

- *What have you done in your free time in the past week?*
- *Have you participated in any hobbies or leisure activities such as sports or games, going to church, TV, music, reading, internet, walking or other such activities during the past week?*

IF YES:
Behavior
- *Tell me about (activity). How much time has this involved over the past week? Did you want to do (activity) more than that? Did it last longer than you had hoped? Why did it only last for (xx)?*
- *Did anything get in the way of doing these activities over the past week? What was that?*
- *Who initiated these activities? Did someone need to remind you to participate in these activities?*

Motivation

- *How has your motivation or drive to get involved in these activities been over the past week?*
- *Did you ever feel like you just weren't very interested in these activities?*
- *Are these types of activities important to you? Why? Have you been interested in these activities?*
- *Did you ever feel that you would just as soon do nothing instead of getting involved in these types of activities?*

IF NO:

- *Is there a reason why you haven't gotten involved in any hobbies or recreational activities in the past week?*
- *Have you wanted to or were you motivated to do something with your free time in the past week?*
- *Did anything ever get in the way of doing these types of activities over the past week? What was that?*

ITEM 7 – Motivation for Recreational Activities

0 = No impairment: Person is VERY MOTIVATED to seek out hobbies and recreational activities; initiates and persists in hobbies and recreational activities on a regular basis, well within normal limits.
1 = Mild deficit: Person is GENERALLY MOTIVATED to seek out hobbies and recreational activities; a mild deficit in initiating and persisting; may report initiating hobbies, but with moderate persistence.
2 = Moderate deficit: Person is SOMEWHAT MOTIVATED to seek out hobbies and recreational activities; notable deficit in initiating; may have initiated some activities and/or not persisted for very long. Others were somewhat more likely to initiate hobbies or activities.
3 = Moderately severe deficit: Person is only SLIGHTLY MOTIVATED to seek out hobbies and recreational activities; significant deficit in initiating and persisting; may have initiated a few activities and not persisted for very long. Others were much more likely to initiate hobbies or prompt initiation.
4 = Severe deficit: Person is NOT AT ALL MOTIVATED to seek out hobbies and recreational activities; nearly total lack of initiation and persistence in hobbies or recreational activities.

ITEM 8: FREQUENCY OF PLEASURABLE RECREATIONAL ACTIVITIES – *PAST* WEEK

[NOTE: Rating is based on both **VARIETY** of pleasurable activities and **DAILY FREQUENCY** that these are experienced. When there are reports of several different activities occurring, need to clarify if these happened on same or different days.]

Did you have any enjoyable (pleasurable) experience from things you did in your free time last week? You can include any of the activities we've talked about so far or any other leisure activities in the past week, including TV, sports or games, going to church, music, reading, internet, walking or other such activities?

- *What about [insert activity here] was enjoyable?*
- *How many days did you enjoy/get pleasure from these experiences?*
- *IF NEEDED: Ask about activities brought up in other sections* ***that were described as enjoyable***

FOLLOW UP:

Any other enjoyable experiences from things you do in your free time or your hobbies?

Activity	Sun	Mon	Tue	Wed	Thu	Fri	Sat

ITEM 8 – Frequency of Pleasurable Recreational Activities - Past Week

0 = No impairment: At least A FEW (3) different types of pleasurable experiences, experienced daily.
1 = Mild deficit: At least A FEW (3) different types of pleasurable experiences, experienced more days than not.
2 = Moderate deficit: 1 or 2 different types of pleasurable experiences, experienced more days than not.
3 = Moderately severe deficit: 1 type of pleasurable experience, experienced on just a few days.
4 = Severe deficit: No pleasurable experiences.

ITEM 9: FREQUENCY OF EXPECTED PLEASURABLE RECREATIONAL ACTIVITIES – *NEXT* WEEK
[NOTE: Ratings are based on total **NUMBER OF EXPECTED PLEASURABLE ACTIVITIES**, regardless of days on which they are expected to occur]

Now I would like you to think ahead to NEXT week (next 7 days), thinking about your free time/hobbies/ recreation. You can include any of the activities you have already talked about or anything else. What do you think you will enjoy doing in the NEXT WEEK in your recreational/free time?

FOR EACH ANSWER PROVIDED:
- *What about it do you expect to enjoy?*
- *How often do you think you will enjoy [activity] in the next week?*

FOLLOW UP:
- *Are there other things you do in your free time like hobbies or recreational activities that you think you will enjoy in the next week?*

ITEM 9 – Frequency of Expected Pleasurable Recreational Activities – Next Week

0 = No impairment: Expecting MANY (7 or more) pleasurable experiences.
1 = Mild deficit: Expecting enjoyment from SEVERAL (5-6) pleasurable experiences.
2 = Moderate deficit: Expecting enjoyment from a FEW (3-4) pleasurable experiences.
3 = Moderately severe deficit: Expecting a COUPLE (1-2) pleasurable experiences.
4 = Severe deficit: Expecting NO pleasurable experiences.

IV. EXPRESSION

ITEM 10: FACIAL EXPRESSION
When making the facial expression rating, consider facial movements across all parts of the face, including in the eyes (e.g., raised brows when surprised), mouth (smiling or grimacing), and mid-face (e.g., wrinkled nose when disgusted).

ITEM 10 - Facial Expression

0 = No impairment: WITHIN NORMAL LIMITS; frequent expressions throughout the interview.
1 = Mild deficit: MILD DECREASE in the frequency of facial expressions, with limited facial expressions during a few parts of the interview.
2 = Moderate deficit: NOTABLE DECREASE in the frequency of facial expressions, with diminished facial expressions during several parts of the interview.
3 = Moderately severe deficit: SIGNIFICANT LACK of facial expressions, with only a few changes in facial expression throughout most of the interview.
4 = Severe deficit: NEARLY TOTAL LACK of facial expressions throughout the interview.

ITEM 11: VOCAL EXPRESSION

This item refers to prosodic features of the voice. This item reflects changes in tone during the course of speech. Speech rate, amount, or content of speech is not assessed.

Item 11 - Vocal Expression

0 = No impairment: WITHIN NORMAL LIMITS. Normal variation in vocal intonation across interview. Speech is expressive and animated.
1 = Mild deficit: MILD DECREASE in vocal intonation. Variation in intonation occurs with a limited intonation during a few parts of the interview.
2 = Moderate deficit: NOTABLE DECREASE in vocal intonation. Diminished intonation during several parts of the interview. Much of speech is lacking variability in intonation but prosodic changes occur in several parts of the interview.
3 = Moderately severe deficit: SIGNIFICANT LACK of vocal intonation with only a few changes in intonation throughout most of the interview. Most of speech is flat and lacking variability, only isolated instance of prosodic change.
4 = Severe deficit: NEARLY TOTAL LACK OF change in vocal intonation with characteristic flat or monotone speech throughout the interview.

ITEM 12: EXPRESSIVE GESTURES

Expressive gestures are used to emphasize what is communicated verbally through gestures made with the hands, head (nodding), shoulders (shrugging), and trunk (leaning forward, leaning back).

ITEM - 12 Expressive Gestures

0 = No impairment: WITHIN NORMAL LIMITS; uses frequent gestures throughout the interview.
1 = Mild deficit: MILD DECREASE in the frequency of expressive gestures, with limited gestures in a few parts of the interview.
2= Moderate deficit: NOTABLE DECREASE in the frequency of expressive gestures, with lack of gestures during several parts of the interview.
3 = Moderately severe deficit: SIGNIFICANT LACK of expressive gestures, with only a few gestures throughout most of the interview.
4 = Severe deficit: NEARLY TOTAL LACK of expressive gestures.

ITEM 13: QUANTITY OF SPEECH

This item refers to the quantity of words spoken. Other speech abnormalities, such as disorganization, neologisms, or psychotic content are not rated here. For instance, a disorganized person may produce a large quantity of speech and have a low (normal) score on this item.

ITEM - 13 Quantity of speech

0 = No impairment: NORMAL AMOUNT of speech throughout the interview. Replies provide sufficient information with frequent spontaneous elaboration.
1 = Mild deficit: MILD DECREASE in the quantity of speech, with brief responses during a few parts of the interview.
2= Moderate deficit: NOTABLE DECREASE in speech output, with brief responses during several parts of the interview.
3 = Moderately severe deficit: SIGNIFICANT LACK of speech, with very brief answers (only several words) in responses throughout most of the interview.
4 = Severe deficit: All or nearly all replies are one or two words throughout the entire interview.

Appendix B: Brief Psychiatric Rating Scale (BPRS)

Anchors: 1 = Not present; 2 = Very mild; 3 = Mild; 4 = Moderate; 5 = Moderate/Severe; 6 = Severe; 7 = Very severe

1. SOMATIC CONCERN: **1 2 3 4 5 6 7**

Degree of concern over present bodily health. Rate the degree to which physical health is perceived as a problem by the patient, whether complaints have a realistic basis or not.

2. ANXIETY: **1 2 3 4 5 6 7**

Worry, fear, or over-concern for present or future. Rate solely on the basis of verbal report of patient's own subjective experiences. Do not infer anxiety from physical signs or from neurotic defense mechanisms.

3. EMOTIONAL WITHDRAWAL: **1 2 3 4 5 6 7**

Deficiency in relating to the interviewer and to the interview situation. Rate only the degree to which the patient gives the impression of failing to be in emotional contact with other
people in the interview situation.

4. CONCEPTUAL DISORGANIZATION: **1 2 3 4 5 6 7**

Degree to which the thought processes are confused, disconnected or disorganized. Rate on the basis of integration of the verbal products of the patient; do not rate on the basis of patient's subjective impression of his own level of functioning.

5. GUILT FEELINGS: **1 2 3 4 5 6 7**

Over-concern or remorse for past behavior. Rate on the basis of the patient's subjective experiences of guilt as evidenced by verbal report with appropriate affect; do not infer guilt feelings from depression, anxiety or neurotic defenses.

6.TENSION: **1 2 3 4 5 6 7**

Physical and motor manifestations of tension, "nervousness," and heightened activation level. Tension should be rated solely on the basis of physical signs and motor behavior and not on the basis of subjective experiences of tension reported by the patient.

7.MANNERISMS AND POSTURING: **1 2 3 4 5 6 7**

Unusual and unnatural motor behavior, the type of motor behavior which causes certain mental individuals with schizophrenia to stand out in a crowd of normal people. Rate only abnormality of movements; do not rate simple heightened motor activity here. Do not rate movements of Tardive Dyskinesia.

8. GRANDIOSITY: **1 2 3 4 5 6 7**

Exaggerated self-opinion, conviction of unusual ability or powers. Rate only on the basis of patient's statements about himself or self-in-relation-to-others, not on the basis of his demeanor in the interview situation.

9. DEPRESSIVE MOOD: **1 2 3 4 5 6 7**

Despondency in mood, sadness. Rate only degree of despondency; do not rate on the basis of inferences concerning depression based upon general retardation and somatic complaints.

10. HOSTILITY: **1 2 3 4 5 6 7**

Animosity, contempt, belligerence, disdain for other people outside the interview situation. Rate solely on the basis of the verbal report of feelings and actions of the patient toward others; do not infer hostility from neurotic defenses, anxiety nor somatic complaints. (Rate attitude toward interviewer under "uncooperativeness.")

11. SUSPICIOUSNESS: **1 2 3 4 5 6 7**

Belief (delusional or otherwise) that others have now, or have had in the past, malicious or discriminatory intent toward the patient. On the basis of verbal report, rate only those suspicions which are currently held whether they concern past or present circumstances.

12. HALLUCINATORY BEHAVIOR: **1 2 3 4 5 6 7**

Perceptions without normal external stimulus correspondence. Rate only those experiences which are reported to have occurred within the last week and which are described as distinctly different from the thought and imagery processes of normal people.

13. MOTOR RETARDATION: **1 2 3 4 5 6 7**

Reduction in energy level evidenced in slowed movements. Rate on the basis of observed behavior of the patient only; do not rate on basis of patient's subjective impression of own energy level.

14. UNCOOPERATIVENESS: **1 2 3 4 5 6 7**

Evidence of resistance, unfriendliness, resentment, and lack of readiness to cooperate with the interviewer. Rate only on the basis of the patient's attitude and responses to the interviewer and the interview situation; do not rate on basis of reported resentment or uncooperativeness outside the interview situation.

15. UNUSUAL THOUGHT CONTENT: **1 2 3 4 5 6 7**

Unusual, odd, strange, or bizarre thought content. Rate here the degree of unusualness, not the degree of disorganization of thought processes.

16. BLUNTED AFFECT: **1 2 3 4 5 6 7**
Reduced emotional tone, apparent lack of normal feeling or involvement.

17. EXCITEMENT: **1 2 3 4 5 6 7**
Heightened emotional tone, agitation, increased reactivity.

18. DISORIENTATION: **1 2 3 4 5 6 7**
Confusion or lack of proper association for person, place or time.

19. POVERTY OF SPEECH: **1 2 3 4 5 6 7**
Conversation and answers to questions are either vague or meaningless, or tend to be brief, concrete, and unelaborated.

20. INAPPROPRIATE AFFECT: **1 2 3 4 5 6 7**
Affect expressed is inappropriate or incongruous.

Appendix C: Calgary Depression Scale for Schizophrenia

Interviewer: Ask the first question as written. Use the following probes of qualifiers at your discretion. Time frame refers to last 2 weeks unless stipulated. The last item, # 9, is based on observations of the entire interview.

1. **<u>Depressed Mood</u>**: How would you describe your mood over the past 2 weeks? Do you keep reasonably cheerful or have you been very depressed or low spirited recently. In the last 2 weeks, how often have you *(own words)* every day? All day?
0 = Absent (No depressed mood.)
1 = Mild (Expresses some sadness or discouragement on questioning.)
2 = Moderate (Distinct depressed mood persisting up to half the time over the past 2 weeks; present daily.)
3 = Severe (Markedly depressed mood persisting daily over half the time interfering with normal motor and
social functioning.)

2. **<u>Hopelessness</u>**: How do you see the future for yourself? Can you see any future, or has life seemed quite hopeless? Have you given up or does there still seem some reason for trying?
0 = Absent (No hopelessness.)
1 = Mild (Has at times felt hopeless over the last week but still has some degree of hope in the future.)
2 = Moderate (Persistent, moderate sense of hopelessness over the last week. Can be persuaded to acknowledge possibility of things being better.)
3 = Severe (Persisting and distressing sense of hopeless.)

3. **<u>Self-Depreciation</u>**: What is your opinion of yourself compared to other people? Do you feel better or not as good or about the same as most? Do you feel inferior or even worthless?
0 = Absent (No self-depreciation.)
1 = Mild (Some inferiority; not amounting to feeling of worthlessness.)
2 = Moderate (Subject feels worthless, but less than 50% of the time.)
3 = Severe (Subject feels worthless, more than 50% of the time. May be challenged to acknowledge otherwise.)

4. **<u>Guilty Ideas of Reference</u>**: Do you have the feeling that you are being blamed for something or even wrongly accused? What about? (Do not include justifiable blame or accusation; exclude delusions of guilt)
0 = Absent (No guilty ideas of reference.)
1 = Mild (Subject feels blamed but not accused less than 50% of the time.)
2 = Moderate (Persisting sense of being blamed, and/or occasional sense of being accused.)
3 = Severe (Persistent sense of being accused. When challenged acknowledges that it is ***not*** so.)

5. **<u>Pathological Guilt</u>**: Do you tend to blame yourself for little things you may have done in the past? Do you think that you deserve to be so concerned about this?
0 = Absent (No pathological guilt.)
1 = Mild (Subject sometimes feels over guilty about minor peccadillo, but less than 50% of the time.)
2 = Moderate (Subject usually feels (over 50% of the time) guilty about past actions, the significance of which he/she exaggerates.)
3 = Severe (Subject usually feels he/she is to blame for everything that has gone wrong, even when not his/her fault.)

6. **<u>Morning Depression</u>**: When have you felt depressed over the last 2 weeks; have you noticed the depression being worse at any particular time of day?
0 = Absent (No depression.)
1 = Mild (Depression present but no diurnal variation.)
2 = Moderate (Depression spontaneously mentioned to be worse in the morning.)
3 = Severe (Depression markedly worse in the morning, with impaired functioning which improves in afternoon.)

7. **<u>Early Wakening</u>:** Do you wake earlier in the morning than is normal for you? How many times a week does this happen?
0 = Absent (No early wakening.)
1 = Mild (Occasionally wakes (up to twice weekly) one hour or more before normal time to wake or alarm time.)
2 = Moderate (Often wakes early (up to 5 times weekly) one hour or more before normal time to wake or alarm time)
3 = Severe (Daily wakes one hour or more before normal time to wake or alarm time)

8. **<u>Suicide</u>**: Have you felt that life isn't worth living? Did you ever feel like ending it all? What did you think that you might do? Did you actually try?
0 = Absent (No suicidal ideation (behavior).)
1 = Mild (Frequent thoughts of being better off dead, or occasional thoughts of suicide.)
2 = Moderate (Deliberately considered suicide with a plan, but made no attempt.)
3 = Suicidal attempt apparently designed to end in death (i.e. accidental discovery or inefficient means.)

Based on interviewer's observations during entire interview:

9. **<u>Observed Depression</u>**: The question "Do you feel like crying?" Used at appropriate points in the interview, this may elicit information useful to this observation.
0 = Absent
1 = Mild (Subject appears sad and mournful even during parts of the interview involving affectively neutral discussion.)
2 = Moderate (Subject appears sad and mournful throughout the interview, with gloomy monotonous voice and is tearful or close to tears at times.)
3 = Severe (Subject chokes on distressing topics, frequently sighs deeply and cries openly, or is persistently in a state of frozen misery.)

Appendix D: Social Functioning Scale

Section 1: Social Engagement/Withdrawal

1. What time do you get up each day (between 0 and 3)?
(Use the boxes below to determine your score, if boxes scores are different, then use the highest score)

Average weekday: **3** = Before 9 am **2** = 9 – 11 am **1** = 11 am – 1pm **0** = After 1 pm
Average weekend: **3** = Before 9 am **2** = 9 – 11 am **1** = 11 am – 1pm **0** = After 1 pm

2. Hours spent alone

3 = 0 - 3 Very little time spent alone
2 = >3 - 6 Some of the time
1 = >6 - 9 Quite a lot of the time
0 = >9 - 1 2 A great deal of the time

0 = >1 2 Practically all of the time

3. How often will you start a conversation at home/board and care?

0 almost never (< 1x/wk)	1 rarely (At least 1x/wk but not daily)	2 sometimes (Daily)	3 often (>3x/day)

4. **How often will you leave the house (for any reason)?**

0 almost never (< 1x/wk)	1 rarely (At least 2x/mo)	2 sometimes (1x/wk but not daily)	3 often (Daily)

5. **How do you react to the presence of strangers?**

0 avoid them	1 feel nervous	2 accept them	3 like them

____ Total for Social Engagement/Withdrawn (0-15)

Section 2: Interpersonal Communication/Relationships

1. **How many friends do you have at the moment (people whom you see regularly, talk with, do activities with, etc.)?**

0 none	1 one friend	2 two friends	3 three or more friends

2. **Do you have someone you find it easy to discuss feelings/difficulties? Yes (3) No (0)**

3. **How often have you confided in them?**

0 almost never	1 rarely	2 sometimes	3 often

4. **Do other people discuss their problems with you?**

0 almost never	1 rarely	2 sometimes	3 often

5. **Do you have a partner (please circle one)? Yes** (3) **No** (0) or **Married** (3)

6. **Have you had arguments with friends, relatives or neighbors recently?**

0 many major	1 cont. minor or 1 major	2 1 or 2 minor	3 none

7. **How often are you able to have a conversation with someone?**

0 almost never	1 rarely	2 sometimes	3 often

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

0 very difficult	1 quite difficult	2 average	3 quite easy or very easy

9. **Do you feel uneasy with groups of people?**

0 often	1 sometimes	2 rarely	3 almost never

10. **Do you prefer to spend time on your own?**

0 often	1 sometimes	2 rarely	3 almost never

____ **Total for Interpersonal Communication/Relationships (0-9)**

Section 3: Prosocial Activities (Please circle the most appropriate response)

Over the past three months, how often have you participated in any of the following?

	Never (0)	**Rarely (1x/3 mos.)**	**Sometimes (>1x/3mos.)**	**Often (>1x/mo.)**
1. Going to the movies	0	1	2	3
2. Going to theatre/concert	0	1	2	3
3. Watching indoor sports	0	1	2	3
4. Watching outdoor sports				
5. Visiting art gallery/museum	0	1	2	3
6. Visiting an exhibition/fair	0	1	2	3
7. Visiting places of interest	0	1	2	3
8. Meeting, talk, etc.	0	1	2	3
9. Evening class	0	1	2	3
10. Visiting relatives	0	1	2	3
11. Being visited by relatives	0	1	2	3
12. Visiting friend/s	0	1	2	3
13. Being visited by friend/s	0	1	2	3
14. Going to parties	0	1	2	3
15. Attending formal occasions	0	1	2	3
16. Going to a dance club (e.g. disco)	0	1	2	3
17. Nightclub / social club	0	1	2	3
18. Playing an indoor sport	0	1	2	3
19. Playing an outdoor sport	0	1	2	3
20. Participating club/society (e.g. gardening club)	0	1	2	3
21. Going to pub / bar	0	1	2	3
22. Eating out in restaurants	0	1	2	3
23. Participating in Church/temple activity	0	1	2	3

____ **Total for Interpersonal Prosocial Activities (0-69)**

Section 4: Recreation (Please circle the most appropriate response)

Over the past three months, how often have you done any of the following for fun?

Activities for fun	**Never (0)**	**Rarely (≤1x/mo)**	**Sometimes (>1x/mo)**	**Often (≥1x/wk)**
1. Playing musical instruments/singing	0	1	2	3
2. Sewing, knitting	0	1	2	3
3. Gardening, growing plants	0	1	2	3
4. Reading books, magazines, newspaper, etc.	0	1	2	3
5. Watching television	0	1	2	3
6. Listening to musical devices	0	1	2	3
7. Cooking	0	1	2	3
8. Do it yourself activities	0	1	2	3
9. Fixing things (car, bike, household etc.)	0	1	2	3
10. Walking, hiking	0	1	2	3
11. Driving/cycling (for recreation)	0	1	2	3
12. Swimming	0	1	2	3
13. Hobby (e.g. collecting things)	0	1	2	3
14. Shopping	0	1	2	3
15. Artistic activity (painting, crafts, dancing, acting, writing, etc.)	0	1	2	3

____ **Total for Recreation Activities (0-45)**

Section 5: Independence (Performance) (Please circle the most appropriate response)

Over the past month, how often have you done any of the following?

	Never (0)	**Rarely (<1x/wk)**	**Sometimes (1x/wk)**	**Often (>1x/wk)**
1. Buying everyday items from stores	0	1	2	3
2. Washing pots, tidying up, etc.	0	1	2	3
3. Regular washing and bathing	0	1	2	3
4. Washing own clothes	0	1	2	3
5. Looking for a job/working	0	1	2	3
6. Doing the food shopping	0	1	2	3
7. Preparing and cooking a meal	0	1	2	3
8. Leaving the house	0	1	2	3
9. Using buses, trains, car, etc.	0	1	2	3
10. Using money to purchase something	0	1	2	3
11. Budgeting and planning expenses (e.g. do you budget your daily expenses?)	0	1	2	3
12. Shopping for clothes.	0	1	2	3
13. Taking care of personal appearance (brushing teeth, combing hair)	0	1	2	3

____ Total for Independence-Performance (0-39)

Section 6: Independence (Competence) (Please circle the most appropriate response)

Please indicate how able you are at doing or using the following:

	Not Known	**Unable or only with lots of help**	**Needs help or prompting**	**Adequately, no help needed**
1. Public transport	0	1	2	3
2. Handling money correctly	0	1	2	3
3. Budgeting	0	1	2	3
4. Cooking for self	0	1	2	3
5. Weekly shopping	0	1	2	3
6. How to look for a job	0	1	2	3
7. Washing own clothes	0	1	2	3
8. Personal hygiene	0	1	2	3
9. Cleaning, tidying, etc.	0	1	2	3
10. Purchasing from shops	0	1	2	3
11. Leaving the house alone	0	1	2	3
12. Choosing and buying clothes	0	1	2	3
13. Taking care of personal appearance (brushing teeth, combing hair)	0	1	2	3

____ Total for Independence- Competence (0-39)

Section 7: Occupation/Employment

Are you in regular employment? (this includes industrial therapy, rehabilitation, or work retraining) **YES** **NO** (Please circle)

IF YES:

What sort of job? _____

How many hours per week do you work?_____

How long have you had this job?_____

If employed, please assign one of the following scores on the basis of the above information: (Possible scores 7-10)

Score 10 if full time gainful earnings, full time employment, or homemaker *(Note: homemaker = manages most household affairs for self, requiring little assistance and caring for at least one other)*

Score 9 if part time gainful earnings

Score 8 if employed until recently, e.g. in the last 6 mos. and actively pursuing work

Score 7 if industrial therapy, rehabilitation, or volunteer work

____ Total If Employed 7-10

IF NO: **If not employed (do not answer if working),**

When were you last in employment?_____

What sort of job was it?_____

How many hours per week did you work?_____

Are you disabled / receiving disability income? YES NO (please circle)

Do you attend day program? YES NO (please circle)

If unemployed, how do you usually occupy your day?

Morning	
Afternoon	
Evening	

If Unemployed, please circle the following:	**Definitely no**	**Would have great difficulty**	**Would have some difficulty**	**Definitely yes**
Do you think you are capable of some sort of employment?	0	1	2	3
	Almost Never	**Rarely (≤1x/wk)**	**Sometimes (>1x/wk)**	**Often (Daily)**
How often do you make attempts to find a job?	0	1	2	3

____ Total If Unemployed (0-6)

Appendix E: Revised Social Anhedonia Scale

Instructions: Please mark each item true or false. Please do not skip any items. It is important that you answer every item, even if you are not quite certain which is the best answer. An occasional item may refer to experiences that you have had only when taking drugs. Unless you have had the experience at other times (when not under the influence of drugs), mark it as if you have not had that experience.

Some items may sound like others, but all of them are slightly different. Answer each item individually, and don't worry about how you answered a somewhat similar previous item.

Circle the answer that best describes you.

1.	There are things that are more important to me than privacy.	TRUE	FALSE
2.	Sometimes when walking down the sidewalk, I have seen children playing.	TRUE	FALSE
3.	Although I know I should have affection for certain people, I don't really feel it.	TRUE	FALSE
4.	Driving from New York to San Francisco is generally faster than flying between these cities.	TRUE	FALSE
5.	There are few things more tiring than to have a long, personal discussion with someone.	TRUE	FALSE
6.	There have been a number of occasions when people I know have said hello to me.	TRUE	FALSE
7.	People are usually better off if they stay aloof from emotional involvements with most others.	TRUE	FALSE
8.	My relationships with other people never get very intense.	TRUE	FALSE
9.	I find that I often walk with a limp, which is the result of a skydiving accident.	TRUE	FALSE
10.	I have often found it hard to resist talking to a good friend, even when I have other things to do.	TRUE	FALSE
11.	I cannot remember a single occasion when I have ridden on a bus.	TRUE	FALSE
12.	I'm much too independent to really get involved with other people.	TRUE	FALSE
13.	On some occasions I have noticed that some other people are better dressed than myself.	TRUE	FALSE
14.	Although there are things that I enjoy doing by myself, I usually seem to have more fun when I do things with other people.	TRUE	FALSE
15.	Knowing that I have friends who care about me gives me a sense of security.	TRUE	FALSE
16.	I prefer watching television to going out with other people.	TRUE	FALSE
17.	People sometimes think that I am shy when I really just want to be left alone.	TRUE	FALSE
18.	If given the choice, I would much rather be with others than be alone.	TRUE	FALSE
19.	I don't really feel very close to my friends.	TRUE	FALSE
20.	When things are going really good for my close friends, it makes me feel good too.	TRUE	FALSE
21.	People who try to get to know me better usually give up after awhile.	TRUE	FALSE
22.	In many ways, I prefer the company of pets to the company of people.	TRUE	FALSE
23.	I am usually content to just sit alone, thinking and daydreaming.	TRUE	FALSE

24.	I have always enjoyed looking at photographs of friends.	TRUE	FALSE
25.	When someone close to me is depressed, it brings me down also.	TRUE	FALSE
26.	There have been times when I have dialed a telephone number only to find that the line was busy.	TRUE	FALSE
27.	I feel pleased and gratified as I learn more and more about the emotional life of my friends.	TRUE	FALSE
28.	When things are bothering me, I like to talk to other people about it.	TRUE	FALSE
29.	I cannot remember a time when I talked with someone who wore glasses.	TRUE	FALSE
30.	I go at least once every two years to visit either northern Scotland or some part of Scandinavia.	TRUE	FALSE
31.	I find that people too often assume that their daily activities and opinions will be interesting to me.	TRUE	FALSE
32.	When others try to tell me about their problems and hang-ups, I usually listen with interest and attention.	TRUE	FALSE
33.	I like to make long distance phone calls to friends and relatives.	TRUE	FALSE
34.	Making new friends isn't worth the energy it takes.	TRUE	FALSE
35.	People often expect me to spend more time talking with them than I would like.	TRUE	FALSE
36.	It made me sad to see all my high school friends go their separate ways when high school was over.	TRUE	FALSE
37.	I prefer hobbies and leisure activities that do not involve other people.	TRUE	FALSE
38.	I attach very little importance to having close friends.	TRUE	FALSE
39.	I have never combed my hair before going out in the morning.	TRUE	FALSE
40.	At times when I was ill or tired, I have felt like going to bed early.	TRUE	FALSE
41.	Just being with friends can make me feel really good.	TRUE	FALSE
42.	Playing with children is a real chore.	TRUE	FALSE
43.	I could be happy living all alone in a cabin in the woods or mountains.	TRUE	FALSE
44.	I never had really close friends in high school.	TRUE	FALSE
45.	I believe that most light bulbs are powered by electricity.	TRUE	FALSE
46.	When I am alone, I often resent people telephoning me or knocking on my door.	TRUE	FALSE
47.	My emotional responses seem very different from those of other people.	TRUE	FALSE
48.	I sometimes become deeply attached to people I spend a lot of time with.	TRUE	FALSE
49.	Having close friends is not as important as many people say.	TRUE	FALSE
50.	On some mornings, I didn’t get out of bed immediately when I first woke up.	TRUE	FALSE
51.	It's fun to sing with other people.	TRUE	FALSE
52.	When I move to a new city, I feel a strong need to make new friends.	TRUE	FALSE
53.	A car ride is much more enjoyable if someone is with me.	TRUE	FALSE

Appendix F: Evaluation to Sign Consent

PROCEDURE:
Make a subjective judgment regarding item 1 below. Ask the patient questions 2-6. The evaluator may select the language to use in asking the questions in order to help the patient understand them.

ITEMS: **SCORE**

1. Is the patient alert and able to communicate with the examiner? _____
yes = 2 **no = 0**

2. Ask the patient to name at least two (2) potential risks incurred as a result of participating in the study. **0=not able to list potential risks, 1= able to list one risk, 2 =able to list two risks** _____

_____

_____

3. Ask the patient to name at least two (2) things that will be expected of him/her in terms of patient cooperation during the study. **0=not able to list expectations, 1= able to list one expectation, 2=able to list two expectations** _____

_____

_____

4. Ask the patient to explain what he/she would do if he/she decides that they no longer wish to participate in the study. **0=doesn't know, 1=answers but not the most appropriate response, 2=talk to any staff member** _____

_____

_____

5. Ask the patient to explain what he/she would do if he/she is experiencing distress or discomfort. **0=doesn't know, 1=answers but not the most appropriate response, 2=talk to any staff member** _____

_____

_____

6. Ask the patient to explain how medications (or treatments) are assigned during the study. 0=doesn't know, 1=answers but not the most appropriate response, 2=talk to any staff member _____

_____

_____

SIGNATURES:
I hereby certify that the above patient is alert, able to communicate and able to give acceptable answers to items 2,3,4,5 and 6 above.

Total Score _____

_____ __ __/__ __/__ __ __ __
(Evaluator Signature) (Date signed)

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