Psychophysiological Processing of Emotional and Self-Referential Information in Schizophrenia

by

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Abstract

People with schizophrenia have problems with social functioning, and it may be related to deficits in processing social information. This study investigated how people with schizophrenia process eye gaze, a form of self-referential social information, and whether it is related to paranoia symptoms in schizophrenia. Twenty-one participants with schizophrenia and 26 healthy controls were shown facial stimuli that differed on three dimensions: eye gaze direction, head orientation, and emotion. The participants chose whether they thought the person was looking at them or away from them. Their accuracy, response time, and event-related potentials (ERPs) were recorded. Although participants with schizophrenia did not differ from controls in accuracy, they had a longer reaction time compared to controls. N170 amplitudes in schizophrenia participants were comparable to controls', but were affected by eye gaze direction and facial emotion in an opposite direction than in controls. Patients had an overall reduction in the P300 amplitude compared to controls, and they failed to show enlarged P300 to fearful faces relative to neutral faces as controls did. However, these processes were not significantly correlated with paranoia symptoms. These findings suggest that schizophrenia is characterized by abnormal modulation by emotion and gaze direction in facial structure encoding and reduced mental resources for memory update for salient information when they process self-referential and emotional social information. Limitations of this study and directions for future research were discussed.

Psychophysiological Processing of Emotional and Self-Referential Information in Schizophrenia

Schizophrenia can cause people with the disorder to be severely affected in their everyday lives. For example, people with schizophrenia can have trouble interpreting abstract social signals, such as other people's facial expressions and intentions (Corrigan & Green, 1993). This difficulty in social cognition can affect social and occupational functioning (Addington, Saeedi, & Addington, 2006). Paranoia is a major symptom of schizophrenia in which people mistakenly believe that people are directing their intentions toward them even if they are not, including thoughts such as "They are staring at me" or "They are out to get me". These paranoid thoughts are related to self-referential processing because they are misinterpretations of information directed at the self. It has been shown that people with schizophrenia exhibit abnormal patterns of brain activity during theory of mind- related tasks (Park et al., 2011); however, instead of investigating general theory of mind, investigating self-directed social information processing can provide more evidence into the symptom of paranoia. Understanding the neurocognitive functions related to self-referential information processing can offer insight into the social difficulties in schizophrenia and may inform treatment options. Below I will review research in gaze processing in schizophrenia and two other factors, emotion and head orientation, that potentially influence gaze processing in schizophrenia.

Eye Gaze Processing in Schizophrenia

Eye contact is generally maintained throughout a social interaction by both parties and it is independent of other social cues (Kleinke, 1986). People spend more time looking at internal facial features, especially eyes, than at other facial features. Eye gaze during interactions between people can show several crucial social signals, including attention, synchronization and social control (see Itier & Batty, 2009 for review). Because eye gaze is crucial to social interactions and is used in interpreting others' intentions and goals, eye gaze is a good example of self-referential signals.

A study by Choi et al. (2010) explored the nature of eye gaze in patients with schizophrenia during emotional social situations. This study used a virtual reality system to place patients and controls in virtual social situations that were either positive or negative. The participant's gaze was detected and measured during the interaction. The patients with schizophrenia had reduced eye gaze directed at the virtual person with whom they were interacting compared to controls, particularly in negative social situations, suggesting differences in receiving social input, especially in negative situations.

In addition to differences in directing their own eye gaze, several studies propose a tendency for patients to think people are looking at them even if they are not. Rosse, Kendrick, Wyatt, and Isaac (1994) suggested that people with schizophrenia were more likely than controls to perceive a face looking at them even when it was looking away from them. A study by Hooker and Park (2005) supports these findings. Patients with schizophrenia and controls were briefly shown a face and were instructed to decide if the person was looking at them. They were also presented with a geometric control task in which they were shown a black box inside a rectangle and they needed to determine if the box was in the center of the rectangle. The people with schizophrenia judged that the person was looking at them significantly more than controls even when the gaze was actually averted; however they had no differences from controls in the geometric control task. Therefore, the authors concluded that the patients with schizophrenia had a direct gaze bias which is not solely due to general perceptual difficulties.

However, some studies conflicted with these results and found that people with schizophrenia do not have deficits in gaze processing. When patients with schizophrenia and controls chose whether gaze was directed to the right or the left, no impairment in schizophrenia was found (Franck et al., 1998). Another study investigated both deciding between left or right gaze and whether or not the face is looking at you. The study found that people with schizophrenia did not have a difference from controls in distinguishing the correct gaze direction (Franck et al., 2002). If this is the case, delusions may be a result of higher level processing rather than eye gaze. This is supported by a study which found that although people with schizophrenia had no differences from controls in determining the eye gaze of a face, they had different brain activation patterns in the frontal and temporal regions than controls (Kohler et al., 2008). The different brain activation may suggest higher level processing involved in the schizophrenia symptoms. Because of the methodological variations in these studies, further study is needed to clarify whether gaze processing is impaired and what role it plays in schizophrenia.

Emotional Processing in Schizophrenia

Abnormal emotional processing has been widely reported in schizophrenia. The negative symptoms of schizophrenia have been a focus of emotion research in schizophrenia due to their broad effects to diminish emotional experience. For example, patients with schizophrenia reported more negative reactions to both positive and neutral stimuli compared to controls (see Cohen, Minor, & Najolia, 2010 for review). Another difference in schizophrenia from controls is disruptions in sustained attentional processing of emotional stimuli. While individuals with schizophrenia did not differ from controls in the initial sensory processing of positive stimuli, they had trouble sustaining the pleasurable feelings (Horan, Wynn, Kring, Simons, & Green, 2010). This may affect social interactions, because positive interactions with others may be forgotten or not fully processed.

People with schizophrenia have also shown impairment in emotional recognition (Kee, Horan, Wynn, Mintz, & Green, 2006; Kohler, Walker, Martin, Healey, & Moberg, 2010). A recent event-related potential (ERP) study showed that the P3a component during an identity recognition task of emotional faces was also lower for schizophrenic patients than controls, implying difficulty focusing on emotional cues and attending on emotional recognition (Ramos-Loyo, Gonzalez-Garrido, Sanchez-Loyo, Medina, & Basar-Eroglu, 2009). Difficulty in emotional processing in schizophrenia may be due to problems with early facial recognition. Patients with schizophrenia have been shown to have impairments in early facial recognition and encoding as suggested by reduced P1 (sensory stage) and N170 (perceptual stage) amplitudes (Caharel et al., 2007). Turetsky et al. (2007) examined how this deficit in early facial encoding affects emotional processing. In their study of 16 participants with schizophrenia and 16 controls, the participants were shown pictures of faces with different emotions (e.g., very sad, somewhat sad, neutral, somewhat happy, or very happy) that were briefly presented for 100 ms, and they were asked to identify the emotions. The behavioral results showed that participants with schizophrenia were less accurate than controls in recognizing emotions. The ERP showed that the participants with schizophrenia showed deficits in early facial processing, quantified by the reduced amplitude of the N170 component, which represents early structural encoding of faces. This suggests that the difficulties in schizophrenia with emotional recognition may be attributed to problems with initial processing of faces. Another study also showed an N170 deficit in schizophrenia, supporting that the impaired emotional processing abilities in people with schizophrenia is related to impairment in early visual recognition. Bediou et al. (2007) asked 10 healthy controls and 10 patients with schizophrenia to identify the emotions of faces displayed to them. The results showed that the early processing component, N170, of the facial structure encoding was lower in people with schizophrenia compared to controls during the emotional recognition task. They suggested that this difference may explain the disruption in the later processes of emotional recognition.

People with schizophrenia have been shown to have difficulty with processing early facial and emotional components, but few studies have examined this in relation to specific symptoms in the disorder. A study by Herrmann, Reif, Jabs, Jacob and Fallgatter (2006) showed that participants with schizophrenia with paranoid symptoms have over-activation of the brain as measured with ERP (P300 and P400) to neutral faces in comparison to participants with schizophrenia without paranoid symptoms. The paranoid subgroup showed higher activation than the non-paranoid subgroup during the neutral facial expressions, which may be interpreted as the tendency for schizophrenia patients high in paranoid symptoms to misread neutral situations as salient. This study provided preliminary evidence for the relationship between emotion processing and specific schizophrenia symptoms, and further investigation is warranted to confirm this relationship.

Head Orientation

Head orientation is another important variable in interpreting people's intentions. In daily life, eye gaze direction is not the only variable involved in social interactions. Head orientation is also used to determine people's intentions. When changing the direction of sight to visually explore the environment, head orientation and eye gaze often change together due to saccadic eye movements (Freedman, 2008). Because they often move together to view the environment, it is reasonable to assume the influence of head orientation on perception of gaze direction. In a study by Ricciardelli and Driver (2008), pictures of faces were shown with the directions of eye gaze and head orientation either congruent or incongruent. Pictures of just eyes were also shown without information of the head orientation. The participants were instructed to determine in which direction the person was looking. Participants had faster reaction times for congruent trials than incongruent trials, but only when the whole face was shown, suggesting head orientation significantly affected how participants processed gaze direction. This was further supported in a later study (Todorovic, 2009). Therefore, it is important to consider head orientation when investigating eye gaze processing.

The Present Study

ERPs, or event-related brain potentials, are electrical signals generated by the brain time-locked to a stimulus. The amplitudes and time course of the ERP can provide information about the amount and timing of mental resources used to process the stimulus or associated mental activities. Because facial recognition and encoding are rapid cognitive processes that occur on the order of milliseconds, ERP is a good method to tap into these processes with its excellent temporal resolution (Wynn, Lee, Horan, & Green, 2008). Different ERP components have been shown to be related to different aspects of information processing. The present study focuses on the N170 and P300 components, a negative-going wave peaking around 170 milliseconds after stimulus onset and a positive-going wave peaking around 300 milliseconds after stimulus onset, respectively. These two components were selected based on their relevance to facial information processing.

The N170 and P300 components have been widely studied to determine what neural processes they represent. The N170 component is thought to relate to early stages of facial structural encoding, a cognitive process that is required in, for example, detecting and identifying faces (Eimer, 2000). N170 is significantly more negative when human faces are presented than the ERP elicited when non-human face stimuli are presented, such as animal faces, hands, ears and furniture, suggesting that N170 is specific to human face encoding. The N170 component is also more negative when inverted faces are displayed compared to right-side-up faces, which suggests that this component reflects mechanisms involved in facial processing such as facial configuration (Bentin, Allison, Puce, Perez, & McCarthy, 1996). The idea that the N170 component is related to facial processing has been challenged by some who say that it may be related to several perceptual and conceptual factors besides the human face (Thierry, Martin, Downing, & Pegna, 2007), but experts in the field still generally agree on its face-specific nature (Rossion & Jacques, 2008). The P300 component has been studied in relation to mental resources for memory update and salience. The P300 is shown to increase in amplitude for novel and unexpected stimuli (see Hajcak, MacNamara, & Olvet, 2010 for review). The P300 component has also been related to emotional contexts. The P300 has been shown to increase more after viewing emotional faces compared to neutral faces, suggesting emotional stimuli may be naturally perceived as salient due to their significance in motivating actions (Hajcak, MacNamara, & Olvet, 2010). In this study, the P300 component was used as a measure of salience of the stimulus to the participant. The P300 responses would give insight into how salient self-referential and emotional information is to participants.

Research Aims and Hypotheses

This study aims to investigate several research questions:

1. Is gaze processing impaired in patients with schizophrenia and schizoaffective disorder?
2. Is paranoia correlated to psychophysiology during gaze processing in schizophrenia/ schizoaffective disorder?

We used both behavioral and psychophysiological data to investigate these questions.

It was hypothesized that:

1. Patients with schizophrenia/ schizoaffective disorder would have lower accuracy and longer reaction time on the gaze discrimination task compared to controls.
2. Patients with schizophrenia/ schizoaffective disorder would have reduced N170 amplitudes compared to controls, suggesting a deficit in facial structural encoding.
3. Patients with schizophrenia/ schizoaffective disorder would have overall reduced P300 amplitudes compared to controls, suggesting reduced mental resources for processing social information. Patients with schizophrenia would also have larger P300 amplitudes in response to fearful faces compared to neutral faces, and this difference would be larger than that in controls.
4. Severity of paranoia would be correlated with ERP amplitudes.

Method

This study is based on a part of the dissertation research of Ivy Tso (*unpublished data*).

Participants

This study investigated two groups of participants: individuals with schizophrenia or schizoaffective disorder (SCZ) and healthy controls (HC). The SCZ participants met the DSM-IV (American Psychiatric Association, 1994) criteria for schizophrenia or schizoaffective disorder. The HC group was used as a comparison to the SCZ group. Participants who were unable to give informed consent, have other Axis I disorders, a history of closed head injury, a history of seizures or current seizures or a history of alcohol or substance abuse or dependence in the past six months were excluded. All participants were tested for vision using a Snelling chart and they had at least 20/30 vision. The healthy control participants do not have any history of mental illness nor do they have any first-degree relatives with a history of psychosis or bipolar disorder.

The participants were recruited from local health centers and the community through flyers and online advertisements. The healthy controls were demographically matched to the SCZ participants in age, sex, and parental education. Our sample included participants between the ages of 18 and 60; the upper limit of age was to reduce the possible confounding effect of aging on ERP data. We recruited individuals of both sexes and from all racial and ethnic backgrounds.

All participants were compensated with $15 per hour in the form of a gift card to a local grocery store or cash. They gave written consent to participate in the study after receiving a detailed description of the study. The participants were initially screened in a brief phone interview to determine basic eligibility, and then during the first session a graduate student trained in clinical psychology confirmed clinical diagnoses using the Structural Clinical Interview for DSM-IV (SCID-I; First et al., 1995).

Assessment

The participants were assessed using a variety of measures in order to confirm their clinical diagnosis and cognitive functioning. A trained graduate student in clinical psychology assessed the SCZ participants for positive schizophrenia symptoms, including paranoid delusions, with the Scale for Assessment of Positive Symptoms (SAPS; Andreasen, 1984).

Gaze Discrimination Task

The gaze discrimination task involved brief displays of faces with the eye gaze looking toward you or away from you, with the head orientation central or averted, and fearful or neutral emotion. See Appendix A for an example of these eight experimental conditions. Before the task began, the participant was instructed to press either the shift or control key with their right or left hand if they think the picture is looking at him or her and the other key with the opposite hand if they think the picture is looking away from him or her. The keys and hands used were counterbalanced among participants. There was a fixation cross in the middle of the screen for 500 milliseconds, a display of a face for 100 ms, and then a blank screen for 2000 ms which gave the participant time to respond. There was then a 1000 ms delay before the next trial. See Appendix B for an example of the paradigm. There were 64 trials for each of the eight experimental conditions for a total of 512 trials. The trials were divided into four blocks with a brief break in between each block. The ERP response was measured throughout the task.

EEG Recording and Processing

Participants' EEG signals were recorded using a Lycra cap with 32 electrodes positioned according to the International 10-20 system, a standardized method of placing the electrodes around the scalp. The EEG was referenced to the FCz electrode during data collection. The electrodes' impedances were kept below 5 kΩ by applying mildly abrasive gel and conductive gel. The EEG signals were amplified using a 32 channel amplifier. The signal was digitally sampled at 5000 Hz.

Vision Analyzer software was used to analyze the EEG data after collection. The signal was re-sampled at 250 Hz off-line. The EEG was re-referenced to the average of the mastoids ((TP9 + TP10)/2) using Vision Analyzer software. The data was segmented into 1.2 second epochs, with 200 ms baseline and 1000 ms post-stimulus. A 0.01-Hz high pass filter and a 30-Hz low-pass filter were applied. Eye blinks were corrected using the Gratton, Coles, & Donchin (1983) regression algorithm semi-automatically. A baseline correction was applied to individual trials. Data greater or less than 80 µV were automatically rejected. All trials were then manually inspected to remove additional artifacts. Trials were then averaged by experimental condition. The mean amplitude of the ERP components was used in statistical analysis. The N170 and P300

ERP components were isolated through PCA, inspection of the waveforms and a literature review. The N170 (130-210ms) was isolated at the P7 and P8 electrode sites and the P300 (220-420ms) was isolated at the Pz electrode site.

Statistical Analysis

The data for this study were analyzed using a 2 (gaze: at you or away) x 2 (head orientation: central or averted) x 2 (emotion: fearful or neutral) x 2 (laterality: P7 or P8) x 2 (group: SCZ or HC) mixed analysis of variance (ANOVA) for the N170 component and a 2 (gaze: at you or away) x 2 (head orientation: central or averted) x 2 (emotion: fearful or neutral) x 2 (group: SCZ or HC) mixed ANOVA for the P300 component. The behavioral data (response time and accuracy) were analyzed using a 2 (gaze direction) x 2 (head orientation) x 2 (emotion) x 2 (group) mixed ANOVA. The mean amplitudes of N170 and P300 for all conditions were tested for Pearson correlations with a sum of SAPS items 8, 14 and 16 (items related to paranoid delusions).

Results

Twenty-one participants with schizophrenia and 26 healthy controls participated in this study. Non-significant independent samples t-tests and chi-square test suggested that the two groups were demographically matched in age, sex and parental education. Table 1 details the results of the demographic comparisons.

See Figures 1 through 3 for examples of the waveforms from N170 at P7 and P8 sites and P300 at Pz site, respectively.

Behavioral Results

Due to the loss of behavioral data of one control participant, behavioral data of 21 patients and 25 controls were analyzed.

Accuracy. Table 2 summarizes the results of the mixed ANOVA analysis for accuracy. Contrary to our prediction, the results did not indicate a main effect for group, indicating that there was no statistically significant difference in accuracy between patients and controls. However, there was a significant gaze effect, with all participants having significantly greater accuracy for gaze directed away than gaze at them. There was also a head orientation effect with significantly higher accuracy for the central head orientation than the averted head orientation. There was an emotion effect such that participants had a significantly higher accuracy for neutral faces compared to fearful faces.

The ANOVA also showed a complex Gaze x Head x Emotion interaction. Further analysis revealed that the lower accuracy for fearful compared to neutral faces with direct eye gaze in the averted head orientation drives this interaction (see Figure 4). No by-group interactions were found to be significant.

Reaction Time (RT). The mixed ANOVA for reaction time is summarized in Table 3. In support of our hypothesis, there was a main effect for group: overall, SCZ patients had significantly longer RT than controls. There was also a head effect, where RT for averted head orientation was significantly longer than central. The other variables, gaze and emotion, did not have significant effects.

Analysis further revealed several significant interaction effects. There was a significant interaction between eye gaze and head orientation. A plot of this interaction showed that when the gaze was directed at you, RT was significantly longer in the averted head condition compared to the central head condition, while when the gaze was away from you there was no significant difference in reaction time between the averted and central head orientations (see Figure 5). There was also a significant interaction between head orientation and group. Plotting this interaction revealed that patients with schizophrenia had a significantly longer reaction time for the averted head orientation compared to the central head orientation while controls did not show a significant difference in reaction time between averted and central head orientation (see Figure 6).

ERP Results

N170. The results of the mixed ANOVA for the amplitude of the N170 component are summarized in Table 4. Contrary to our prediction, there was no significant main effect for group differences in the amplitude of the N170 component. The ANOVA revealed a significant head effect, as averted heads elicited a larger N170 amplitude than central heads. There was also a significant effect for the laterality of the N170 component, with the right hemisphere (P8 electrode) showing a more negative N170 component than the left (P7 electrode). No significant emotion and gaze effects were found.

The ANOVA also yielded a significant interaction between gaze, emotion and group. A plot of this interaction shows that in the neutral emotion condition, the SCZ group has a larger N170 amplitude for at you gaze compared to away, while in the fearful emotion condition they had a smaller N170 amplitude for the at you gaze compared to away (see Figure 7). Control participants had an opposite result, where they showed a smaller N170 amplitude for at you gaze compared to away in the neutral condition and a larger N170 amplitude for at you gaze compared to away in the fearful emotion condition.

P300. A summary of the mixed ANOVA for the amplitude of the P300 component is in Table 5. Consistent with our hypothesis, there was a highly significant main effect for group, showing that patients had a significantly smaller P300 amplitude than healthy controls. There was also a trend-level gaze effect, with gaze at you eliciting a more positive P300 amplitude than gaze away. The emotion effect was marginally significant: fearful faces had a significantly more positive P300 component than neutral faces.

A test for interactions revealed a marginally significant interaction between emotion and group. A plot of this interaction showed that patients with schizophrenia did not have as much of a difference in the amplitude of the P300 component whether the face was neutral or fearful, but controls had a higher P300 amplitude when the face was fearful compared to neutral (see Figure 8).

Correlations with Paranoid Symptoms

The mean amplitudes of N170 and P300 for all conditions were tested for Pearson correlations with a sum of SAPS items 8, 14 and 16 (items related to paranoid delusions). A higher score is indicative of higher paranoia. Contrary to our hypothesis, no significant correlations were found. See Table 6 for a summary of the correlation results.

Discussion

The present study examined how people with schizophrenia process emotional and self-referential information. We examined both psychophysiological and behavioral data to see how patients and controls processed the social cues of eye gaze, head orientation and emotional expression while determining if the face is looking at them or away from them. Participants with schizophrenia did not differ from controls in accuracy, but they had a longer reaction time compared to controls. N170 amplitudes in schizophrenia participants were not different overall from controls', but were affected by eye gaze direction and facial emotion in an opposite direction than in controls. Patients had an overall reduction in the P300 amplitude compared to controls, and they did not have an enlarged P300 amplitude to fearful relative to neutral faces as controls did. These processes were not significantly correlated with paranoia symptoms.

While the patients with schizophrenia do not show a difference from controls in accurately determining the gaze direction of the face, the longer reaction time they took and the psychophysiological results for N170 and P300 suggested that people with schizophrenia process social information differently than controls, consistent with the idea that people with schizophrenia have difficulty processing social signals (Corrigan & Green, 1993). Our results also support that ERPs can provide more information about the psychological mechanisms behind social information processing that cannot be revealed with only behavioral measures. Specifically, the ERP results offer further insight into how people with schizophrenia encode facial information. Although there was no difference for the overall N170 amplitude between patients and controls, people with schizophrenia have the opposite pattern from controls for the emotion and eye gaze effect on N170 amplitude. Therefore, facial structural encoding in schizophrenia is abnormally modulated by emotion and eye gaze. Previous studies found a smaller N170 amplitude in patients compared to controls during tasks with facial stimuli (Caharel et al. 2007; Bediou et al. 2007); however the present study suggests that emotion and eye gaze play a role in this difference between patients and controls. This could account for problems in social functioning, because these differences in encoding may cause people with schizophrenia to interpret social signals inappropriately. Also, the smaller P300 amplitude in people with schizophrenia compared to controls suggests that people with schizophrenia have reduced mental resources for memory update than healthy individuals. This may explain why people with schizophrenia have trouble processing social information. If people with schizophrenia do not see other people’s expressions as salient, this could cause deficits in social interactions. People with schizophrenia did not have a difference in their P300 amplitude depending on whether the emotion was neutral or fearful, while controls had a greater P300 amplitude for fearful compared to neutral faces. This may be explained by a finding from a meta-analysis by Cohen, Minor and Najolia (2010) that patients with schizophrenia experience more negative emotions when viewing neutral (and positive) stimuli. In the present study, the people with schizophrenia may have viewed the neutral faces as negatively as the fearful faces. Viewing neutral emotions as negative may lead to misinterpreting how someone is feeling, which could contribute to problems in processing social signals.

Contrary to our hypothesis, the ERP amplitudes were not found to be related to measures of paranoia. This is inconsistent with previous literature (Herrmann, Reif, Jabs, Jacob, & Fallgatter, 2006) and this discrepancy may be due to our participant limitations. All the participants with schizophrenia were in treatment at the time of the study, so most paranoid symptoms were attenuated by medications. This may reduce the chance to find significant correlations because of the narrow range of paranoid symptoms. This may be further investigated in the future by recruiting participants with a wider range of paranoid symptoms or non-medicated patients.

The congruency between head orientation and eye gaze also affected eye gaze perception. Across participants, it took longer to decide whether the person was looking at them or away from them for incongruent head-eye trials (i.e., central head with looking away eyes, and averted head with looking at you eyes) compared to congruent ones. This effect was especially pronounced for the averted head orientation, suggesting that it is especially challenging to decide when the head is averted but the eye gaze is directed at you. The lower accuracy rate for the averted head- at you eye gaze condition also shows this difficulty. This resonates with a previous research finding that having one variable directed at you and the other away can be challenging to resolve (Ricciardelli & Driver, 2008; Todorovic, 2009). Also, patients with schizophrenia took longer to decide when the head was averted compared to the central head orientation, while controls were not as affected by head orientation. This suggests that although unconventional ways of presentation of information (in this case, averted head) requires more processing time for everybody, it poses particularly more challenge for patients with schizophrenia. This could help explain some of the difficulties people with schizophrenia have in social interactions compared to controls. There are often confusing social signals, such as people with averted head orientation, in everyday life and these signals may cause people with schizophrenia to have trouble processing these situations. Cognitive training focusing on processing incongruent or confusing social signals such as eye gaze or body language may help people with schizophrenia overcome this difficulty.

Several findings are consistent with the current literature, supporting the validity of the paradigm. We found significant head orientation effect (averted heads require more resources for structural processing compared to centrally oriented heads) and laterality effect (facial structural encoding is lateralized to the right hemisphere) in N170, consistent with findings from current literature (Horan, Wynn, Kring, Simons, & Green, 2010; Bentin, Allison, Puce, Perez, & McCarthy, 1996; Todorovic, 2009). There were also significant gaze effect (gaze directed at you is more salient than gaze directed away) and emotion effect (fearful faces are more salient than neutral faces) in P300, as were found in previous research (Horan, Wynn, Kring, Simons, & Green, 2010; Itier & Batty, 2009).

Gaze direction, head orientation and emotion were all found to play a role in gaze perception in this study. As expected, gaze direction, head orientation and emotion affected how accurate the participants were when responding. All participants were found to be more accurate when the gaze was looking away from them compared to at them. They also had higher accuracy for centrally oriented heads compared to averted heads. Finally, participants had higher accuracy for neutral faces compared to fearful faces. These differences support the idea that the social cues of eye gaze, emotion and head orientation affect people's ability to judge whether or not the person is looking at them. Furthermore, the gaze, head orientation or emotion effect on accuracy and N170 differed depending on the other two variables, suggesting that these three factors influence gaze processing in a complex way which may be reflecting the nature of social interactions. During a social interaction, each of these three variables is present. Therefore, it is important to consider all these factors when investigating social information processing. Failing to consider gaze, head orientation and emotion would be leaving out information on how people determine whether or not people are looking at them. As far as we are aware, there have been no studies studying all three variables together, so this finding highlights the importance of including these three variables when studying facial encoding processes.

In summary, the present study found that although people with schizophrenia do not have differences from controls in accurately deciding whether a face is looking at them or away from them, it takes the patients longer to reach this decision. The patients also have different patterns of facial structural encoding based on gaze direction and emotion compared to controls even though they do not have an overall facial encoding deficit compared to controls. People with schizophrenia also have overall reduced mental resources for memory update compared to controls and their mental resources for memory update are not affected by emotion as much as in controls. These findings show how differences in processing social cues in schizophrenia compared to how controls process social cues may explain why people with schizophrenia have trouble in social situations.

This study has several limitations. The small sample size may not have enough power to detect group differences or symptom correlates. Also, using medicated patients means that it is difficult to conclude whether the results are based on their illness or the effects of the medication. Because all the patients were in treatment during the study, the study cannot be generalized to people who are not in treatment. Most of the patients in this study have chronic schizophrenia, so the results from this study may only be generalized to chronically ill patients but not people who are in the early course of schizophrenia.

This study makes several noteworthy contributions. It fills a gap in the literature by studying emotion, eye gaze and head orientation together as opposed to studying one variable at a time, which resulted in finding many complex interactions between these variables that would not be apparent if studied only one or two of these variables. This study also looks at both N170 and P300 ERP amplitudes in relation to these three variables and paranoid symptoms. Previous work usually focuses on one of these variables instead of investigating how they play a role on each other. Future studies should consider all three variables together and their relationships with specific symptoms when studying social information processing.

In the future several modifications may be helpful to address research questions that remain to be answered. People with schizophrenia with a wider range of paranoid symptoms may be recruited for a more representative sample. This would allow more power for correlational analysis linking paranoia to ERP amplitudes. Controlling for medications or including non-medicated participants could reduce the uncertainty about the effects of medication on the results, although it is very difficult to recruit non-medicated patients given the federal and institutional regulations. Including patients who were recently diagnosed with schizophrenia could allow the study to be generalized across the time course of the illness, not just those who are chronically ill. Recruiting a larger sample, ideally from different geographical locations, would also allow the results to be more generalized to all people with schizophrenia. Turetsky et al. (2007) also investigated how people with schizophrenia process happy emotions, so expanding the study to include positively valenced emotions could investigate if people with schizophrenia process negatively valenced emotional information the same way as positively valenced emotional information.

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Table 1

Demographic Characteristics of Participants

	Schiz	Control	*p*
Average age	41.52 ± 13.4	41.42 ± 13.7	0.980
Sex	16 male, 5 female	17 male, 9 female	0.421
Average parental education	14.62 ± 3.4	15.04 ± 3.0	0.658
Average SAPS score	4	N/A	N/A
Average SANS score	4.95	N/A	N/A

Table 2

Results of Four-Way Mixed ANOVA on Accuracy

	F (1, 44)	*p*
Gaze	22.12	0.000
Gaze*Group	1.42	0.240
Head	224.55	0.000
Head*Group	2.79	0.102
Emotion	9.36	0.004
Emotion*Group	0.01	0.919
Gaze*Head	116.65	0.000
Gaze*Head*Group	3.10	0.085
Gaze*Emotion	6.66	0.013
Gaze*Emotion*Group	0.19	0.662
Head*Emotion	25.22	0.000
Head*Emotion*Group	0.00	0.999
Gaze*Head*Emotion	6.46	0.015
Gaze*Head*Emotion*Group	1.48	0.230
Group	0.76	0.389

Table 3

Results of Four-Way Mixed ANOVA on Reaction Time

	F (1, 44)	*p*
Gaze	1.83	0.183
Gaze*Group	0.01	0.937
Head	40.70	0.000
Head*Group	3.38	0.073
Emotion	0.15	0.703
Emotion*Group	0.78	0.382
Gaze*Head	108.67	0.000
Gaze*Head*Group	0.00	0.993
Gaze*Emotion	1.13	0.293
Gaze*Emotion*Group	0.39	0.537
Head*Emotion	0.54	0.468
Head*Emotion*Group	0.16	0.692
Gaze*Head*Emotion	0.04	0.840
Gaze*Head*Emotion*Group	1.60	0.212
Group	11.20	0.002

Table 4

Results of Five-Way Mixed ANOVA on N170 Amplitude

	F (1, 45)	*p*
Gaze	0.00	0.999
Gaze*Group	0.22	0.638
Emotion	0.00	0.990
Emotion*Group	0.00	0.951
Head	4.33	0.043
Head*Group	1.06	0.310
Laterality	4.65	.037
Laterality*Group	.34	.563
Gaze*Emotion	1.27	.265
Gaze*Emotion*Group	8.13	.007
Gaze*Head	1.92	.173
Gaze*Head*Group	.50	.482
Emotion*Head	.25	.621
Emotion*Head*Group	.92	.343
Gaze*Emotion*Head	3.75	.059
Gaze*Emotion*Head*Group	1.46	.233
Gaze*Laterality	.02	.898
Gaze*Laterality*Group	.81	.373
Emotion*Laterality	1.95	.169
Emotion*Laterality*Group	.31	.584

Gaze*Emotion*Laterality	.08	.780
Gaze*Emotion*Laterality*Group	.63	.432
Head*Laterality	1.09	.303
Head*Laterality*Group	.05	.832
Gaze*Head*Laterality	1.41	.242
Gaze*Head*Laterality*Group	1.23	.274
Emotion*Head*Laterality	.02	.885
Emotion*Head*Laterality*Group	1.00	.322
Gaze*Emotion*Head*Laterality	.73	.399
Gaze*Emotion*Head*Laterality*Group	.07	.792
Group	.00	.984

Table 5

Results of Four-Way Mixed ANOVA on P300 Amplitude

	F (1, 45)	*p*
Gaze	3.49	.068
Gaze*Group	.63	.432
Emotion	3.92	.054
Emotion*Group	3.63	.063
Head	1.24	.271
Head*Group	.00	.960
Gaze*Emotion	1.76	.192
Gaze*Emotion*Group	.02	.877
Gaze*Head	.11	.742
Gaze*Head*Group	1.06	.308
Emotion*Head	.55	.464
Emotion*Head*Group	.53	.472
Gaze*Emotion*Head	.03	.864
Gaze*Emotion*Head*Group	.70	.408
Group	9.94	.003

Table 6

Pearson Product- Correlation Matrix of SAPS Scores to N170 and P300 Mean Amplitudes for All Experimental Conditions

	SAPS Sum of Items 8, 14 and 16	
	Pearson Correlation	*p*
S1.N170.P7	.198	.403
S2.N170.P7	.088	.712
S3.N170.P7	.177	.455
S4.N170.P7	.278	.235
S5.N170.P7	.060	.803
S6.N170.P7	.104	.664
S7.N170.P7	.029	.902
S8.N170.P7	.005	.985
S1.N170.P8	.271	.247
S2.N170.P8	.357	.123
S3.N170.P8	.319	.171
S4.N170.P8	.347	.134
S5.N170.P8	.290	.215
S6.N170.P8	.364	.114
S7.N170.P8	.332	.153
S8.N170.P8	.324	.164
S1.P300.Pz	.252	.284
S2.P300.Pz	.191	.421

S3.P300.Pz	.167	.482
S4.P300.Pz	.194	.413
S5.P300.Pz	.287	.221
S6.P300.Pz	.198	.402
S7.P300.Pz	.155	.515
S8.P300.Pz	.058	.808

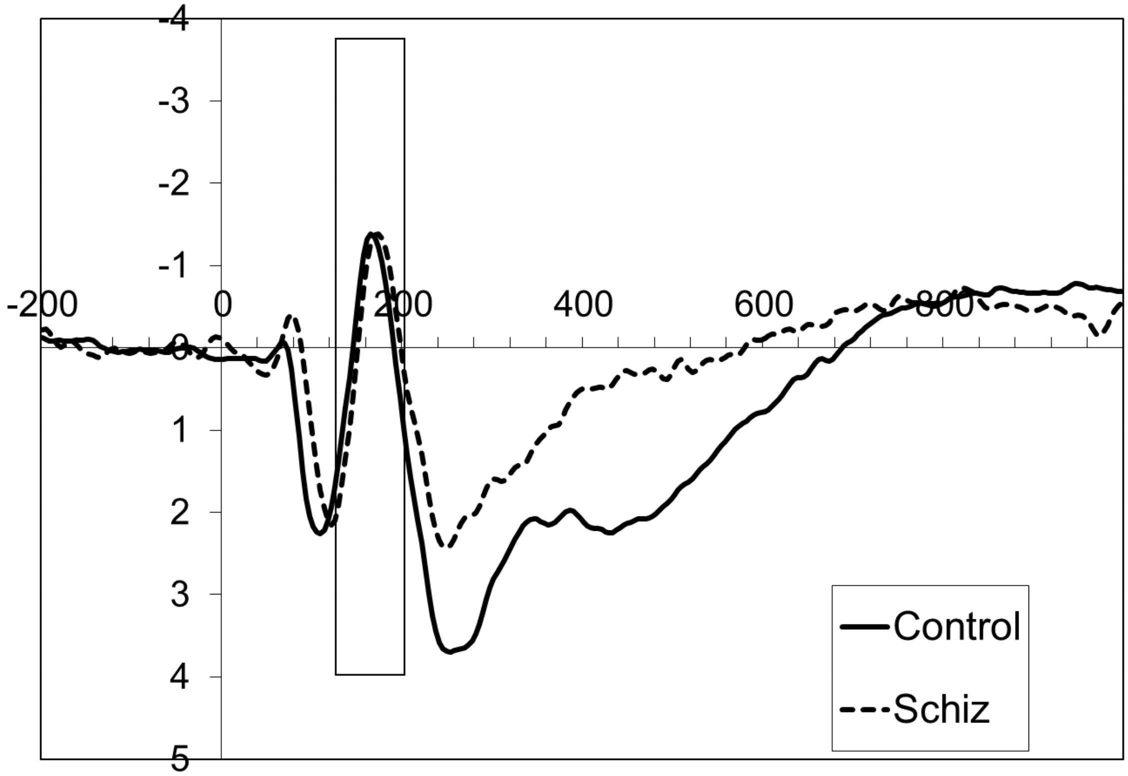


Figure 1. The grand average N170 waveform from the P7 electrode site by group.

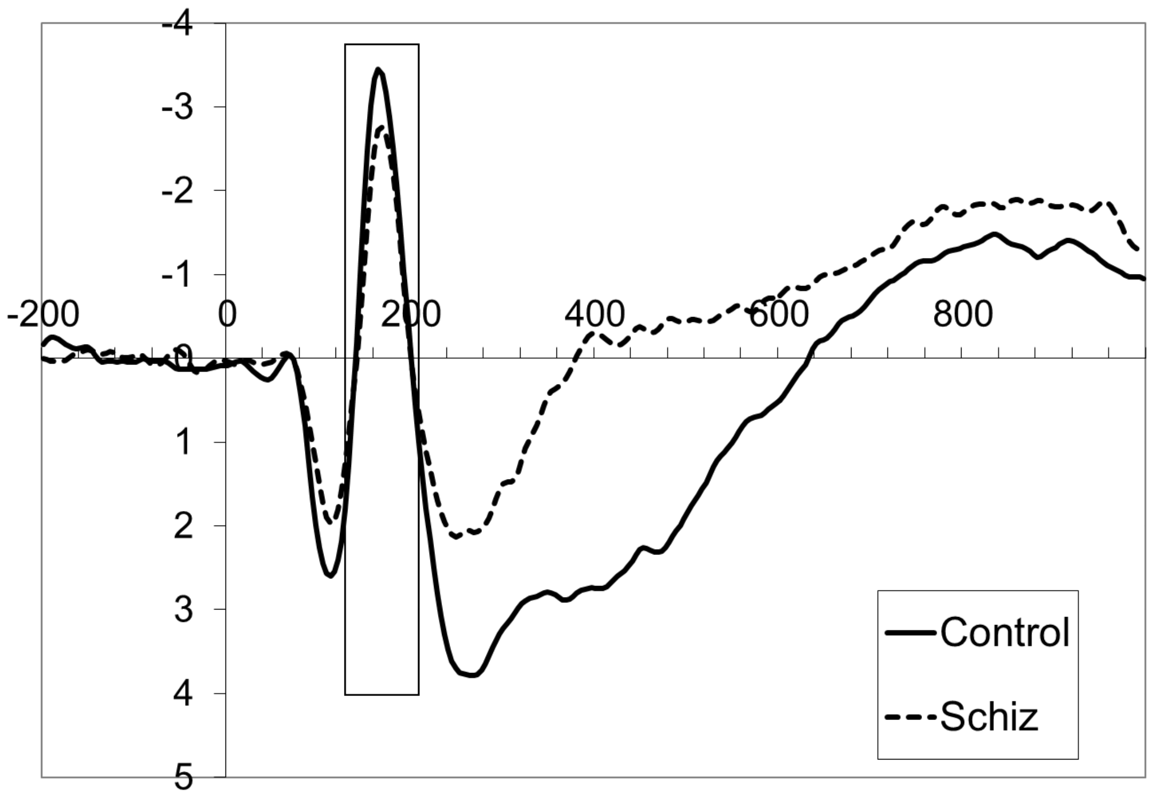


Figure 2. The grand average N170 waveform from the P8 electrode site by group.

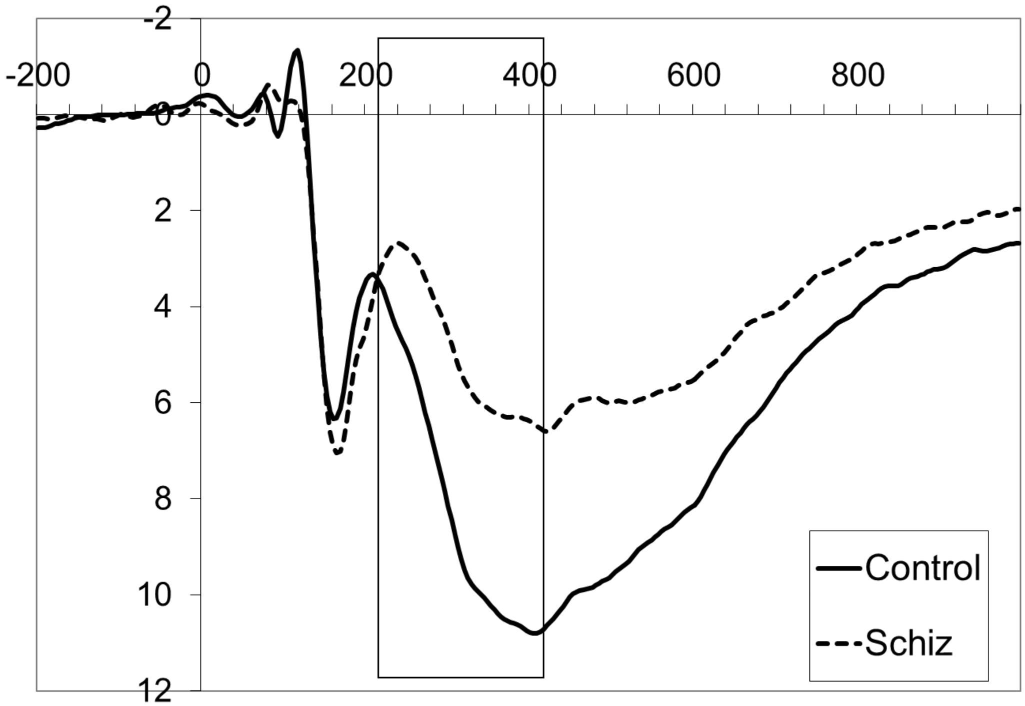


Figure 3. The grand average P300 waveform from the Pz electrode site by group.

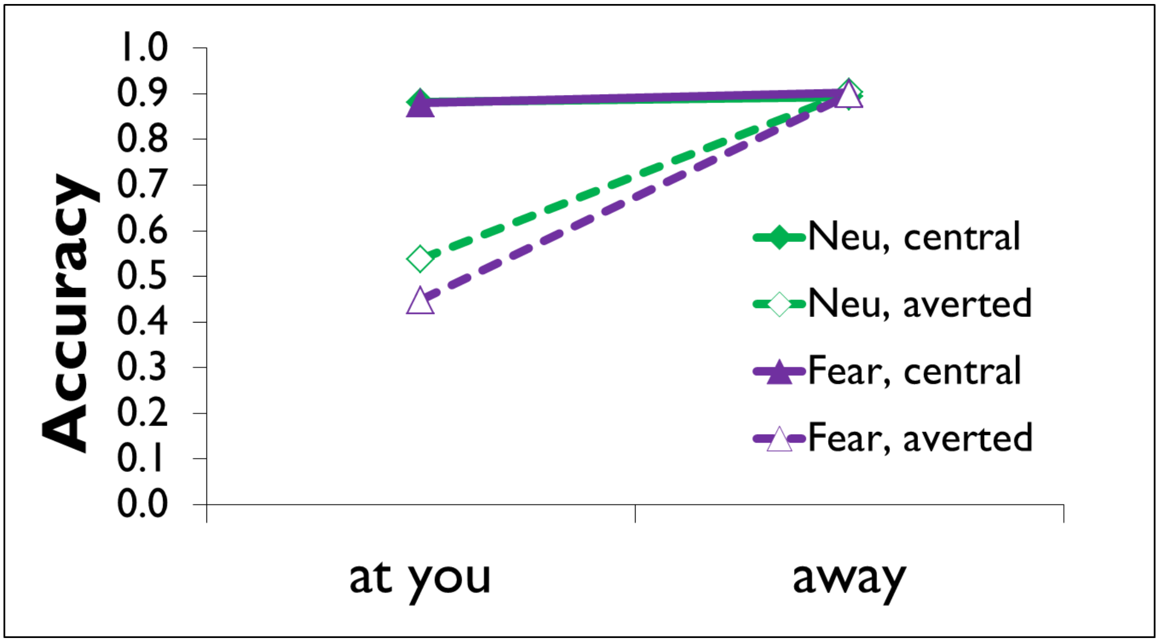


Figure 4. A plot of the gaze x head x emotion interaction revealed that the lower accuracy for fearful compared to neutral faces with direct eye gaze in the averted head orientation drives this interaction.

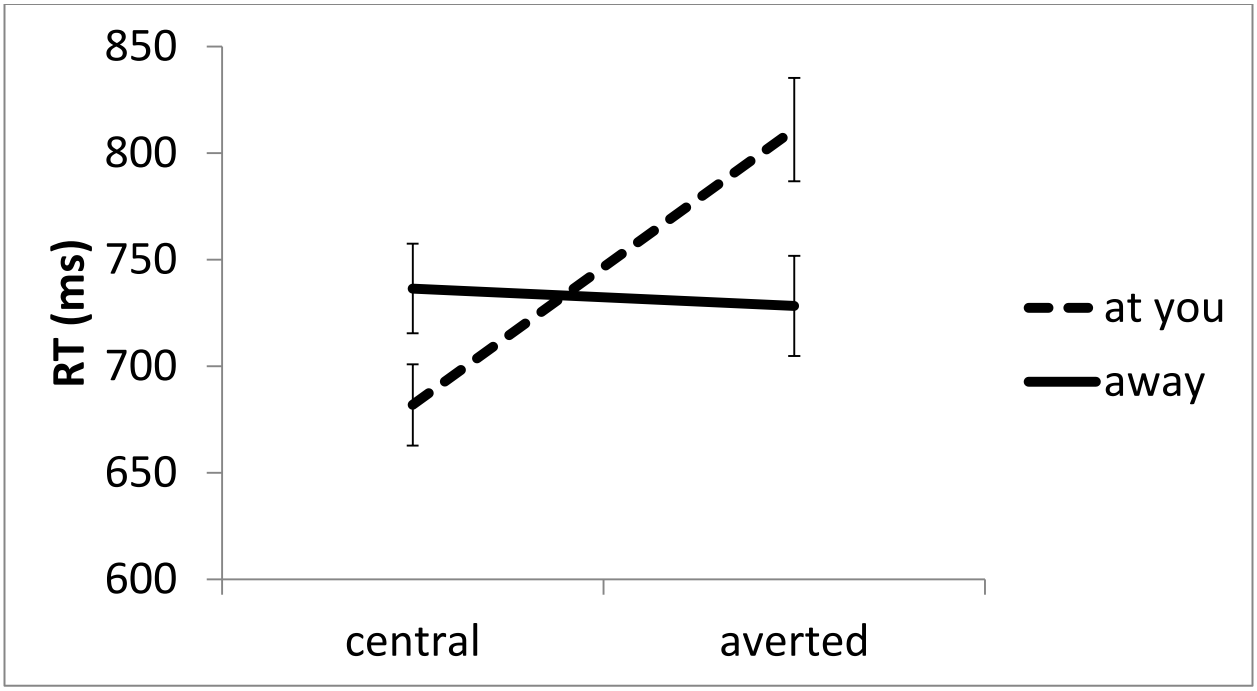


Figure 5. A plot of the interaction between eye gaze and head orientation showed that when the gaze was directed at you, the reaction time was significantly longer in the averted head condition compared to the central head condition, while when the gaze was away from you there was no significant difference in reaction time between the averted and central head orientations.

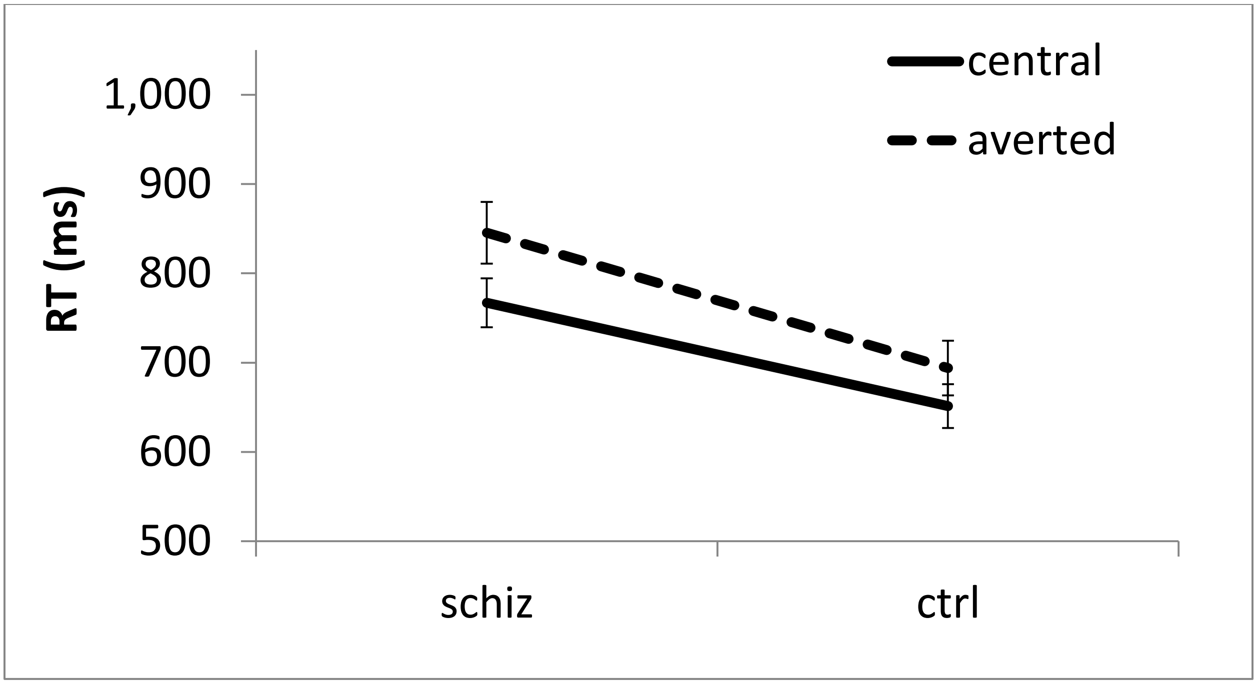
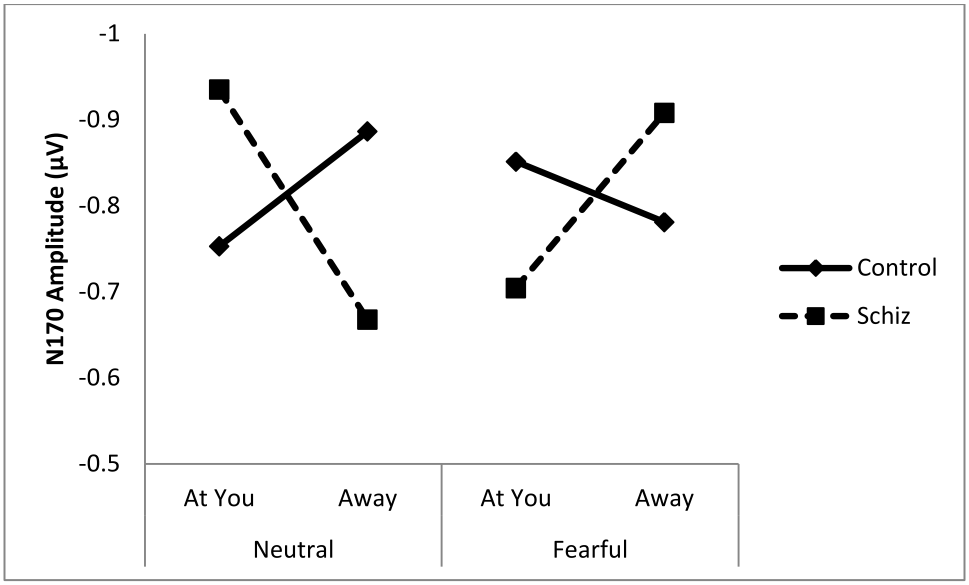


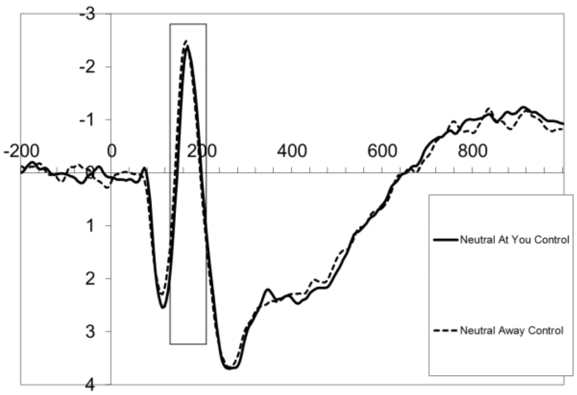
Figure 6. A plot of the interaction between head orientation and group revealed that patients with schizophrenia had a significantly longer reaction time for the averted head orientation compared to the central head orientation while controls did not show a significant difference in reaction time between averted and central head orientation.

A.



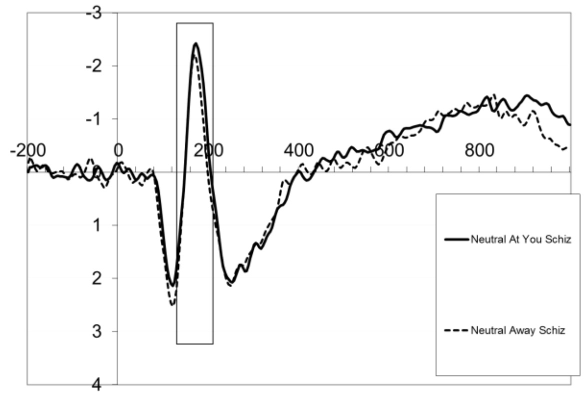
N170 Amplitude (μV)
-1
-0.9
-0.8
-0.7
-0.6
-0.5
At You
Away
At You
Away
Neutral
Fearful
Control
Schiz

B.



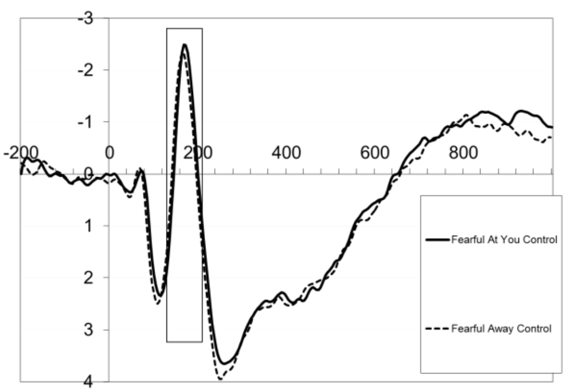
Neutral At You Control
Neutral Away Control

C.



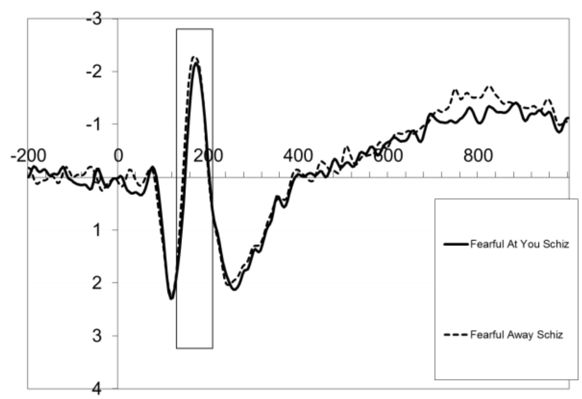
Neutral At You Schiz
Neutral Away Schiz

D.



Fearful At You Control
Fearful Away Control

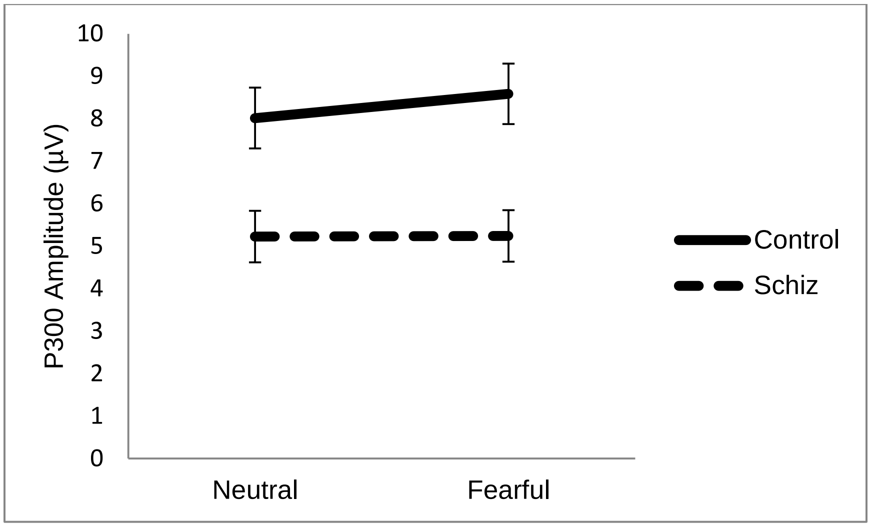
E.



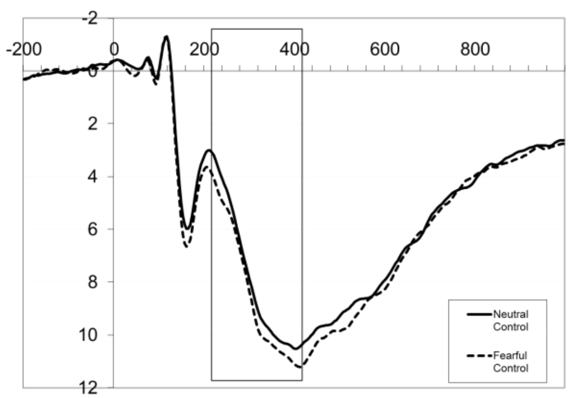
Fearful At You Schiz
Fearful Away Schiz

Figure 7. A. A plot of the interaction between gaze, emotion and group shows that in the neutral emotion condition, the SCZ group has a larger N170 amplitude for at you gaze compared to away, while in the fearful emotion condition they had a smaller N170 amplitude for the at you gaze compared to away. B. N170 for neutral control by gaze direction. C. N170 for neutral schiz by gaze direction. D. N170 for fearful control by gaze direction. E. N170 for fearful schiz by gaze direction.

A.



B.



C.

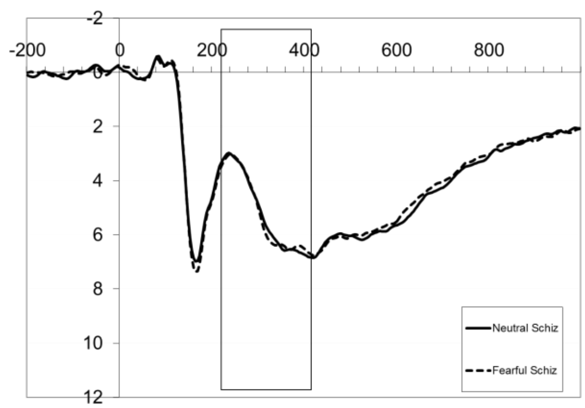
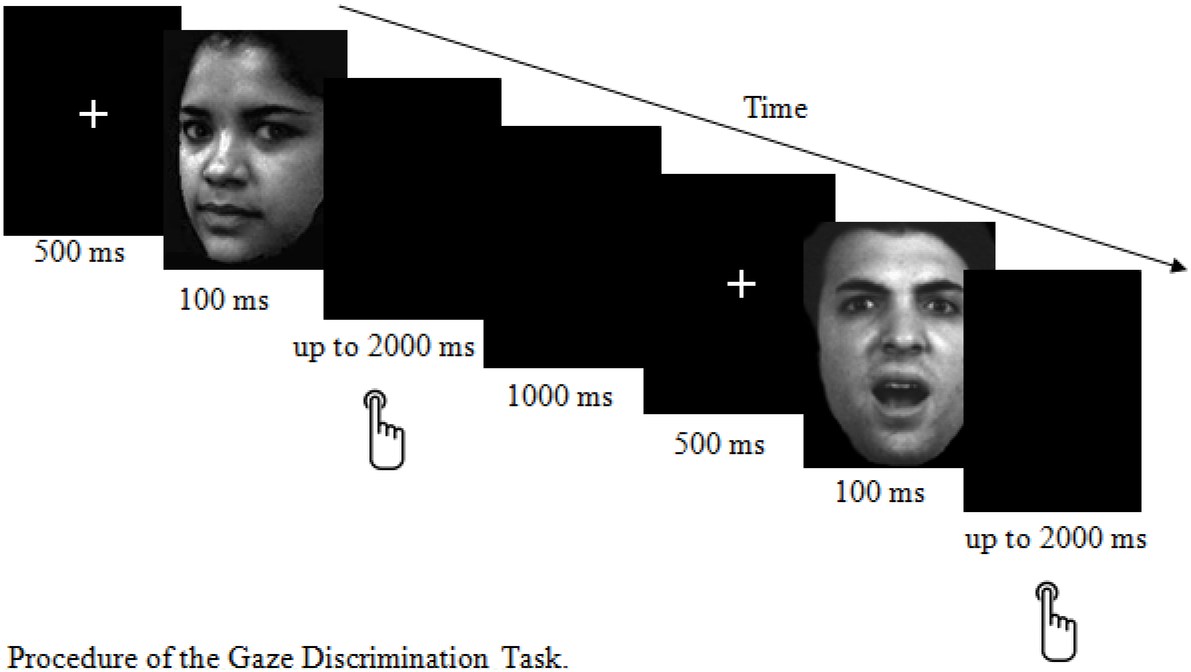


Figure 8. A. A plot of the interaction between emotion and group showed that patients with schizophrenia did not have as much of a difference in the amplitude of the P300 component whether the face was neutral or fearful, but controls had a higher P300 amplitude when the face was fearful compared to neutral. B. P300 for control by emotion. C. P300 for schiz by emotion.

Appendix A

Face stimuli varying in eye gaze direction (at you, away), head orientation (central, averted), and emotion (neutral, fearful).

Appendix B



Procedure of the Gaze Discrimination Task.