Music-elicited EEG Activity and Emotional Responses are Altered in Schizophrenia

Rondell Burge and Aimee Siebert
Bethel College
300 East 27th Street
North Newton, KS 67117 USA

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ABSTRACT

Studies of patients with schizophrenia using facial affect recognition and voice discrimination tasks have identified emotional dysfunction as a prominent clinical feature. In the present study we examine whether emotion processing in patients is also impaired in a less explicitly social context -- continuous self-report of emotions during music using a two-dimensional (pleasantness X activation) emotion space. Electroencephalographic (EEG) activity was also recorded during this task since previous studies using EEG measures have found underlying cortical processes related to emotion. Twelve patients with schizophrenia and eleven controls listened to five 25-second songs. These songs included J.S. Bach's *Invention #13 in A minor* (BWV 784) (designated the original piece), and four computer-generated pieces of which two were designed to be similar to the original, and two were designed to be different. While no significant effects were found in the activation dimension of the self-report measures, the pattern of pleasantness ratings was significantly less differentiated among songs in the patient group than in controls. EEG asymmetry indices at frontal and central electrodes provided evidence of greater hemispheric activation asymmetry (with higher activation on the left) in controls than in patients, a difference that was significant at the central electrodes (C3 and C4). These findings indicate that individuals with schizophrenia interpret emotion-eliciting music differently than do controls, even in a relatively non-social setting, possibly because of less differentiated hemispheric representations.

I. INTRODUCTION

Patients with schizophrenia suffer from a wide variety of cognitive, social and emotional impairments that distinguish the illness from other illnesses. They include positive symptoms, e.g., hallucinations, delusions, and disorganized or catatonic behavior (odd movements or postures) and negative symptoms, e.g., flat affect (blunted emotional responses), social withdrawal, and depressive symptom [1]. In particular, negative symptoms can be instrumental in determining the severity and course of the illness [2].

Recent research has focused on this impairment of emotion processing in schizophrenia for a better understanding of this fundamental dysfunction, generating evidence that includes neurological correlates. Lindenmayer [3] suggests that

serotonin neurotransmitter abnormalities (known to be found in individuals with schizophrenia) may be associated with symptoms of emotion dysfunction in schizophrenia. Furthermore, a study using positron emission topography (PET) by Paradiso et al. [4], found that in response to pleasant and unpleasant visual stimuli, patients with schizophrenia did not activate the emotion-regulatory region of the amygdala nor did they show activation in areas of the prefrontal cortex that are normally associated with identifying pleasant stimuli. These studies show that neurological systems related to emotion are, indeed, dysfunctional in individuals diagnosed with schizophrenia.

Difficulties in emotion processing can be especially devastating in developing and sustaining social relationships. In a study exploring social interactions, it was

found that patients with schizophrenia were significantly less expressive than controls during a social role-play [5]. Also known as flat affect, this lack of expressive dialogue can disrupt a social interaction, and it has been shown to uniquely predict dysfunction in emotion processing in schizophrenia [6]. Another feature of schizophrenia related to affective dysfunction is social withdrawal. This feature may be attributed to the individual's inability to socially relate to others, either as a result of the feeling of alienation derived from the illness or as a direct result of symptomatology. In the same study by Aghevli et al. [5], patients showed significantly fewer outward displays of emotion compared to controls even though they had similar self-reports of emotional experience. This study suggests emotional processing is especially salient for successful social interaction and that these processes are dysfunctional in schizophrenia. This emotional component provides a valid stimulus for exploring such deficits, and various studies have utilized socially-related stimuli to do so [7-10].

However, there have been critiques of using only socially-explicit stimuli in these emotion studies. One argument against the extension of these findings to the greater population of individuals with schizophrenia is that not all persons with the illness suffer from negative symptoms (of which the socially-related flat affect is emphasized in research). So what about individuals with mainly positive symptomatology? Matsumoto et al. [10] explored this possibility in a sample of 15 patients with prominent positive symptoms and found with comparable tasks that the same emotion processing deficits were present in patients suffering from predominantly positive symptoms. In addition, Sloboda and Juslin [11], in their critique of using socially expressive behavior (e.g. facial expressions, vocalizations, and body postures) to elicit emotion, argue that this form of evidence is problematic because emotions are not always accompanied by such behaviors. Thus, one cannot completely differentiate emotion-based social interaction deficits (e.g. "What emotion is he presenting by his facial expressions?") from less socially explicit emotion processing deficits (e.g. "How do I feel in response to losing my job?") using these methods.

One possible solution to better study pure emotion deficits in schizophrenia is to use a stimulus that is relatively less social. Music is one such stimulus that has been identified as an alternative emotion-eliciting agent, reliable across participants with varying musical experience [12-14]. Cesarec & Nielzen [15], in their study on emotional experience of music by psychiatric patients, argued that music constitutes an emotional communication of more or less pure form. Furthermore, music has been described as abstract in that it does not refer directly to specific events in the world [16]. Past studies of the neurological effects of listening to music have provided evidence for the value of electroencephalography (EEG) in measuring responses to musical stimuli [17]. When paired with degree of musical training, a significant difference between functional interdependencies was found in listening to music compared to those found during a resting state, especially in and near the midline cortical areas, with frontal and mid-line regions being most involved [17]. These findings provide evidence that music is an effective and valid stimulus for exploring deficits in cortical representation of emotion, and that EEG analyses are an appropriate methodology for exploring these issues. Similarly, EEG studies are also an effective way to find underlying cortical processes related to emotion processing and have a history of use in the exploration of brain processes in schizophrenia [16, 18-21]. Findings most relevant to the current study are those showing a pattern of asymmetrical frontal EEG activity in relation to emotional valence. In general, individuals exhibited greater relative activation in the left frontal lobe in response to positive emotion and greater relative activation in the right frontal lobe in response to negative emotion [18]. In studies involving patients with schizophrenia, a significant finding is the tendency toward "diffuse hyper-activation" or a less differentiated alpha band activation between brain regions during music perception. The alpha frequency band (8-13 Hz) represents a resting state in brain areas and can be used to determine the arousal level in response to a specific stimulus when analyzed. Paradiso et al. [4] suggest that "diffuse hyperactivation" is a presentation of overall dysfunctional connectivity and

reflects a failure in neural systems used to support emotional attribution. Methodologies utilizing EEG can be used to help define dysfunction through music-elicited frontal lobe representation and to explore emotion-processing deficits in schizophrenia more extensively.

It is evident that studying emotion-processing deficits in schizophrenia is vital to exploration of the course of the illness. Furthermore, it is pertinent to explore these deficits outside of explicitly social stimuli and by so doing, further delineate social interaction dysfunction from emotional processing deficits. The present study pursued this approach by measuring both continuously self-reported emotional responses and EEG activity during musical stimuli in patient and control participants. In an effort to extend the findings of impairments in facial expression identification and voice discrimination tasks [7-9], the present study examined whether self-reported responses are significantly different for a population of schizophrenia patients than for controls. More specifically, the responses were expected to be less differentiated in the patient group. This prediction is in accordance with the tendency for patients to remain somewhat emotionally neutral when presented with a stimulus. Although less differentiated, it was also predicted that these responses would be relatively more positive than those of controls, as was found by Nielzén and Cesarec [15]. It was predicted that impaired emotional processing in the patient group would also be revealed in different frontal lobe continuous EEG activity, perhaps in the form of diffuse hyperactivation (no clear difference between left and right frontal activation) as found by Guthrie et al. [21].

II. METHODS AND MATERIALS

a. Participants

The participants were patients with a diagnosis of schizophrenia ($n = 8$) or schizoaffective disorder ($n = 4$; total patient sample, males = 5, females = 7; mean age = 42.90, education = 3.72 years) and age-matched controls (males = 5, females = 6; mean age = 37.4, education = 5.5 years). All gave written informed consent after

procedures had been clearly described to them. Furthermore, each patient participant was given five dollars as an incentive to participate. All participants indicated that they were right-handed. The study was approved by the Bethel College Institutional Review Board (KS), as well as the Prairie View Psychiatric Hospital Institutional Review Board.

Patients were recruited from various community mental health organizations in central Kansas (Breakthrough Club of Wichita and Caring Place of Newton) and from the inpatient and outpatient services of Prairie View Psychiatric Hospital of Newton. Patients' respective licensed social workers confirmed that the patients' diagnoses met DSM-IV criteria for schizophrenia or schizoaffective disorder. All patients disclosed that they were currently taking medications for their mental illness and that they had taken them the day of the experimental session. One patient's data were excluded because it appeared that his level of cognitive functioning may have impaired his performance on the task.

Control participants were solicited mainly by word of mouth from the community and the Bethel College student body. None of the controls were currently diagnosed with any category of Axis I psychiatric illness.

b. Data Acquisition

Electrophysiological signals were recorded using the ActiveTwo Data Acquisition System (BioSemi, Amsterdam, Netherlands), powered by a DC battery pack via active Ag/AgCl electrodes [22]. EEG data were recorded from 16 electrode locations (International 10-20 System, 256 Hz sampling rate) using a nylon electrode cap, referenced to two electrodes placed on the mastoid bones behind each ear (attached by adhesive disks). Two additional electrodes were placed above and to the left of the left eye (measuring electro-ocular signals) to control for interference from eye movements and blinks. Electro conductance gel was used at all electrode sites to increase signal strength. The above data were transferred via fiber-optic cable to a laptop computer in a neighboring room. This computer recorded and saved the signals with the use of LabVIEW-based ActiVIEW

software (BioSemi, Amsterdam, Netherlands).

The continuous self-report emotion ratings were also recorded via a LabVIEW virtual instrument (National Instruments, Austin, TX) using the Windows platform on a Mac Mini computer. This virtual instrument (VI) included a two-dimensional circumplex with various affect description words (e.g. happy, sad, lethargic, nervous etc.) located around a circle that is divided into four quadrants [23], around which participants could move an 'x' to indicate their current emotional state. The use and location of the words were determined by their activation and relative valence (emotional quality) and served as cues for the participant to accurately negotiate self-report responses within this circle. Activation is represented by the vertical axis and valence by the horizontal axis, with opposite emotions being positioned across from one another. The recording of a continuous rating that combines categorical (emotional components) and dimensional (level of activity) approaches has been suggested to be the most effective in measuring the most bits of information regarding a listener's response [24]. These second-by-second recorded data were then saved for later analysis.

Along with the continuously self-reported emotion ratings, current emotional state and music preference for each piece were recorded using the same LabVIEW VI following each song. The Self Assessment Manikin (SAM) was used to measure current emotional state [25]. The scale has been shown to have strong reliability coefficients for valence and activation (Cronbach's alpha, range = 0.83 - 0.93) [26] and it has been effectively used in music research [27]. The music preference rating was recorded by using a simple 9-point Likert scale. In both of these measures, the participants were asked to use a slider on the computer screen to indicate their responses.

c. Music Listening Session

The study consisted of a 30-40 minute session for each participant. These sessions were held in the Bethel College psychology laboratory and in another similarly controlled environment at the Break Through Club of Wichita, KS. Before each

session, the participant received an overview of the procedures to ensure the voluntary nature of the study. After this we asked them to rate how their day had been going (via the SAM rating scale) and then proceeded to attach all electrodes and sensors. Within each of these sessions the subjects listened to a practice excerpt and then to five songs, presented in a different random order for each participant. Four of the five songs were computer-generated to be either similar or dissimilar to the fifth [28], which was J.S. Bach's *Invention #13 in A minor* (BWV 784) and is hereafter referred to as the original song. Standardized instructions were read before a separate practice excerpt and before the experimental session. Questions ensuring comprehension of the task were asked after the practice excerpt and any confusion was subsequently clarified. Each of the five music 'events' consisted of a one-minute baseline, one of the five randomly-ordered 30-second pieces of music and a rating section in which they were asked to rate their current emotion state (via SAM) and to what degree they liked the piece (via a 9-point Likert scale), in that order.

While participants listened to the five songs, self-reported emotion ratings were gathered via the two-dimensional emotion circumplex mentioned earlier. Participants used a computer mouse to move a small X around the circumplex that was displayed on the computer screen; they could move the X as often as they chose during the music. Each participant had the opportunity to practice this task before the session. Before proceeding with the experimental session, the experimenter ensured that the participant had mastered this task. Throughout the five songs, EEG data were also continuously recorded. After the completion of the experiment, a short debriefing sheet was filled out and any concerns were addressed.

d. Preprocessing of Rating Data

The psychological ratings for the five songs were placed in a consistent order for all participants using spreadsheet software. Pleasantness and activation ratings recorded during the music were averaged across time for each song. These manipulations resulted in five sets of ratings

Figure 1. Means and standard errors of emotion pleasantness ratings during the music for patient and control groups for the five songs.

for each group – mean pleasantness ratings during the music, mean activation ratings during the music, liking ratings, pleasantness mood ratings after the music, and activation mood ratings after the music.

e. EEG Preprocessing and Analysis

EEG data were recorded for each participant in BioSemi data format (BDF) and then analyzed using EEGLAB through the MATLAB platform. A notch filter was applied to the data to remove 60 Hz noise. The EEG data were referenced to the mastoid electrodes before being sliced into time epochs for separate analysis of each individual song (with five seconds of baseline recording). Within the individual song analysis, the three seconds immediately preceding song onset were excluded to remove possible effects of an aural signal that was used to warn participants of the song's imminent start. The song and the remaining two seconds of baseline were subjected to independent components analysis to aid in removal of eye movement artifacts in the EEG data.

Further eye movement artifacts were removed by a pass-band filter with a lower-edge at 2 Hz. Filtering artifacts occasionally appeared at the end of the song data after this filter and were subsequently removed. The natural log of power in the alpha frequency band (8-13 Hz) was extracted for each electrode from the artifact-free data. Power in the alpha band is assumed to be inversely related to brain activation and was used to summarize relative activity from right and left leads for further statistical analysis [29].

f. Statistical Analysis

For analysis of the EEG data, the antilog of the data was found for the channel spectra. Then the average across the alpha band was obtained for each electrode, and the natural log was taken of these averages. The asymmetry between left and right hemispheres was measured by finding the differences between the averages for left and right frontal pole (fp2 and fp1), frontal (f4 and f3), central (c4 and c3), occipital (o2 and o1), parietal (p4 and p3), and temporal

Figure 2. Means and standard errors of liking ratings of the five songs for patient and control groups.

(t8 and t7) electrodes for each song. Movement artifacts and/or poor electrode contact with the scalp resulted in exclusion of the data for one control participant at frontal sites and for one patient participant at central and parietal sites.

III. RESULTS

a. Self-Report Measures

i. Continuous Emotion Ratings

The two dimensions of averaged continuous self-reported emotion ratings, activation and pleasantness, were analyzed using a repeated-measures ANOVA with one between-subjects (patient versus control group) and one within-subjects (song) variable. No significant effects of group or song and no interaction between the two variables were found for the activation dimension. However, there was a significant main effect of song ($F(4,84) = 5.597$, $p = 0.001$) for pleasantness ratings. The pattern of pleasantness ratings for both the patient and control groups can be seen

in Figure 1. There is a visibly different pattern of pleasantness ratings across songs, in general a less differentiated one, in patients with schizophrenia. This interaction proved to be significant ($F(4,84) = 3.148$, $p = 0.025$) and is in accordance with our initial hypothesis. However, the main effect of participant group was not significant for pleasantness ratings ($p > 0.4$).

ii. Liking Ratings

In addition to emotion ratings, participants were also asked to rate how much they liked each song after listening to it. As seen in Figure 2, the pattern of liking ratings was very similar for both the patient and control groups. However, it can be seen that for all but the original song, the patient group found the songs to be somewhat more attractive, with the biggest divergence between groups found in the two songs that are most different from the original. This main effect of group approached significance in a repeated-measures ANOVA ($F(1,21) = 2.980$, $p = 0.099$). There was also a significant main effect of song on liking ratings ($F(4, 84) = 11.864$, $p < 0.001$)

Figure 3. Means and standard errors of mood ratings after the five songs for patient and control groups in the pleasantness dimension.

but no significant interaction between group and song ($p > 0.15$).

iii. Post-Listening Mood Ratings

The activation and pleasantness mood ratings that the participants made after each song using the Self Assessment Manikin were also analyzed with a repeated-measures ANOVA. As with the activation ratings made during the music, the post-listening activation ratings did not vary significantly between groups or across songs, and there was no interaction between these factors. However, there was a significant difference in pleasantness mood ratings among songs ($F(4,84) = 5.267$, $p = 0.002$). The difference between groups and the interaction between the two factors were not significant ($p > 0.5$). Thus, the songs affected the participants' moods in the pleasantness dimension differently, and this effect was similar for both the patient and control groups (see Figure 3).

b. EEG Asymmetry Indices

Asymmetry measures were analyzed for each brain region using repeated-measures ANOVAs like those described for the psychological ratings. The patterns of asymmetry at frontal electrodes (F4 – F3) across songs can be seen in Figure 4. Although the differences are not significant, one can see that frontal asymmetry was generally greater in the control group than in the schizophrenia group.

At the nearby central electrodes (roughly at the frontal-parietal lobe boundary), an ANOVA showed significant group differences in asymmetry ($F(1,20)=4.991$, $p = 0.037$). Overall, the patient group showed less differentiation between left and right hemispheres when compared to the control group, who showed overall greater left hemispheric activation (see Figure 5). These findings are consistent with the possibility that individuals with schizophrenia have less differentiated

Figure 4. Means and standard errors frontal asymmetry indices across all five songs for patient and control groups

hemispheric representations of music than controls.

The main effects of group and song and the interaction between these two factors were not significant at frontal pole, parietal, and temporal electrodes. At occipital electrodes the main effects were also not significant though there was a significant interaction between the two variables ($F(4, 84) = 2.885$, $p = 0.027$), a rather obscure finding since the stimuli were auditory.

IV. DISCUSSION

The use of the less-explicitly social stimuli, music, has provided a new dimension in the exploration of emotion processing deficits in schizophrenia. The analysis of self-report pleasantness emotion ratings supported the central hypothesis that the schizophrenia group would have a less-differentiated emotional response to the music when compared to the control group. This finding is consistent with previous research that has identified a more neutral

response by individuals with schizophrenia to emotional stimuli [18] and an overall difference in how they identify emotions [7-10].

Results from the analysis of liking ratings support the hypothesis that the schizophrenia group's ratings would be more positive overall, when compared to the control group. This is congruent with research by Nielzén and Cesarec [15], who found that individuals suffering from schizophrenia experienced music as more attractive than did the other participants. Why these individuals rate emotional stimuli as more attractive is not yet clear; however, these results add to the evidence of the presence of differences in emotion processing. It seems that there is a fundamental deficit in how persons with schizophrenia perceive and identify emotion stimuli.

Although there were significant differences in the participants' subsequent moods from song to song, there were no significant differences in this pattern between the two groups. Thus, the differ-

Figure 5. Means and standard errors of central asymmetry indices for all five songs for patient and control groups.

ences in emotional response to the music seemed to be limited to the experience during the presentation of emotional stimuli (as evidenced by less differentiated pleasantness responses) and not to any lasting effects on mood after the pieces were over.

The EEG asymmetry indices were not as congruent with predictions as were the self-report measures. Although the frontal asymmetry indices (at F4 and F3) were not found to be significantly different between the two groups, at slightly more posterior sites (C4 and C3) the group differences were significant. At both pairs of sites there is visual evidence of a greater asymmetry in activation between left and right hemispheres in the control group (higher alpha power on the right, indicating greater activation on the left) than in the patient group. It is possible that the relatively small samples resulted in a Type II error at the frontal sites, i.e. that larger samples would result in significant differences at the frontal electrodes as well. Although not as localized in the frontal regions as

hypothesized, the absence of a clear difference between the hemispheres in emotion-related continuous EEG activity for the patient group is consistent with the previous findings for psychiatric patients [21].

These findings are important on two fronts. These results mirror what has been found in previous emotion research using socially-dependent stimuli [7-9]. The parallel with this previous research offers support for the validity of using music as a stimulus to study emotion and provides the field a less socially-explicit stimulus to explore emotion-processing deficits in schizophrenia somewhat independently of social interaction dysfunction. Not only are individuals with schizophrenia impaired in interpersonal emotional expression but they also show this dysfunction in emotional experience (as measured in our study by emotional ratings and physiological responses). These findings suggest that the difficulty in verbal and nonverbal expression of emotion in schizophrenia is accompanied by deficits in emotional experience. These

findings also add to past research that points to possible biological abnormalities causing such emotion-processing dysfunction [3,4].

The lack of differentiation in self-report emotion ratings and physiological responses across excerpts may also have treatment implications for the clinical symptom of flat affect. Social training techniques that help in social functioning may not help in treating this emotion processing dysfunction directly. Using music to explore the emotion deficits that are found in schizophrenia may be a useful approach to understanding the nature of the symptoms and the subsequent treatment options. Thus, music research methodology provides a unique and important look into how these deficits are manifest in the illness and can be used to develop more specific treatment options for affective symptoms outside of the social domain.

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Matt made the decision to get actively involved with his major both in- and outside the classroom. In addition to working as a teacher's assistant and conducting research with faculty, he's also a member of the physics club and the UNI chapter of the Golden Key National Honor Society.

"What I like about the College of Natural Sciences and UNI is the number of opportunities offered to me as a student, including student research, academic clubs and field trips. I also value the availability of the professors and the fact that they are always willing to help with questions."

Matt

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