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Addressing Schizophrenia Symptoms: Non-Pharmacological Strategies Using Binaural Beats

Katharina Merry Apriliani Angkawidjaja
Department of Psychiatry, Medical Faculty, University of Surabaya, Surabaya-Indonesia.
Orcid ID: https://orcid.org/0000-0001-5459-3022

ABSTRACT: Schizophrenia is a severe psychiatric disorder that has long posed a significant challenge in treatment and recovery. The condition manifests through a complex array of symptoms, including positive, negative, cognitive, affective, and aggressive domains. Furthermore, common comorbidities such as anxiety, depression with suicide idea, sleep disturbance, and cognitive decline frequently exacerbate the illness severity in schizophrenia patients.

Recently, Binaural Beats (BB) therapy has emerged as a promising non-pharmacological adjunctive treatment for various conditions, including anxiety reduction, sleep improvement, and cognitive enhancement. The introduction of BB therapy offers a novel, non-invasive approach that provides new hope for individuals suffering from schizophrenia, potentially leading to improved cognitive function, decreased anxiety, and enhanced sleep quality. This approach might become new non-pharmacological strategi for clinicians for providing more comprehensive treatment in schizophrenia patients.

KEYWORDS: binaural beats, non-pharmacology therapy, schizophrenia, schizophrenia treatment

SCHIZOPHRENIA

DEFINITION SCHIZOPHRENIA

Schizophrenia is a chronic brain disorder characterized by a significant impairment in the way reality is perceived, and changes in behavior, thinking, and emotional expression. It is a complex mental illness that often involves psychosis, manifesting as a mix of symptoms including hallucinations (sensory experiences that are not real, commonly hearing voices), delusions (fixed, false beliefs held despite evidence to the contrary), disorganized thinking (often observed as jumbled or incoherent speech), and negative symptoms (such as reduced emotional expression, lack of motivation, and social withdrawal).

Schizophrenia is a chronic neuropsychiatric disorder characterized by cognitive, emotional, and behavioral dysfunction that severely impacts daily life. In several decades, Schizophrenia has been one of challenging disorders for clinicians because of prolonged morbidity and bad daily dysfunction. Data from the USA suggests that at least 1% of the general population is affected by schizophrenia. Various studies and literature cite a multitude of risk factors, including genetics, and both perinatal and environmental complications. Individuals with schizophrenia are also at high risk for developing comorbid psychiatric disorders such as bipolar disorder, substance use disorder, and engaging in criminality**.** (Ruijia Xiao, 2024; B. J. et al Sadock, 2017)

CLINICAL SYMPTOMS SCHIZOPHRENIA

Schizophrenia is severe mental disorders, generally defined by loss of the sense of reality (psychosis) and the inability to distinguish between reality and internal experiences/hallucinations, leading to significant functional impairment. The clinical presentation of schizophrenia is classically described across three major symptom clusters: positive, negative, and cognitive symptoms (Ruijia Xiao, 2024). Some literature further includes affective and aggressive symptoms as prominent features of the disorder (B. J. Sadock, 2015; Stahl, 2014; Stahl & Dunitz, 2013)

- **Positive Symptoms** typically include delusions, hallucinations, and disorganized speech and behavior (though disorganized speech often overlaps with negative symptoms in some classifications, such as alogia). This feature sometimes lead schizophrenia patients to be more aggressive.
- **Negative Symptoms** are characterized by absence of normal functions, including restricted emotional expression (flat affect), avolition (decreased motivation), and anhedonia (inability to feel pleasure). Flat affect is often considered patognomonic feature in schizophrenia patients.
- **Cognitive Symptoms** involve pervasive cognitive deficits across multiple domains, such as working memory, attention, concentration, and motor function. Furthermore, sensory disturbances often significantly impair a patient's ability to differentiate reality from non-reality (DSM-V, 2013; Ruijia Xiao, 2024)

Affective symptoms commonly manifest as depressive affect, sometimes described as 'vital melancholy' or mental pain, often accompanied by obsessive thoughts and suicidal ideation Depression is a frequently observed comorbidity in schizophrenia patients. Clinicians must make early detection and management due to the life-threatening potential posed by concurrent depressive and schizophrenic conditions. Also, the **aggressive symptoms** often leads schizophrenia patient to criminality (Rahim, 2016; B. J. Sadock, 2015; SV & O., 2022)

ETIOLOGY AND PATHOPHYSIOLOGY SCHIZOPHRENIA

Schizophrenia has long been linked to disturbances in molecular biology and neurotransmitter function in the brain. For decades, there has been known that pathophysiology of schizophrenia based on neurotransmitter imbalance such as dopamine, also serotonin and norepinephrine (Stahl, 2014).

Schizophrenia is understood to be a disorder arising from a complex interplay between genetic and environmental factors, resulting in a multifactorial etiology. Strong evidence suggests a significant hereditary component, supported by twin and family studies that identify numerous polygenic risk variants rather than a single causative gene. Environmental contributors acting as triggers or contributing factors include prenatal and perinatal complications (e.g., maternal infections, nutritional deficits, or birth hypoxia), as well as severe psychosocial stressors during critical developmental periods, especially adolescence and early adulthood.(B. J. et al Sadock, 2017)(Owen et al., 2016)

The pathophysiology is linked to widespread neurobiological alterations in the brain. The most established models involve the dysregulation of neurotransmitter systems, predominantly the dopamine pathways (the dopamine hypothesis). Excess dopamine activity in the mesolimbic pathway is thought to cause positive symptoms (like hallucinations and delusions), while reduced dopamine activity in the mesocortical pathway is associated with negative and cognitive symptoms. Furthermore, the dysregulation of the glutamate system (via NMDA receptors) and GABA are also considered critically important. Structurally, brain imaging studies frequently reveal reduced gray matter volume (particularly in the prefrontal and temporal cortices) and ventricular enlargement, reflecting abnormal neuronal connectivity. These deficits underpin the disturbed neural circuits and synaptic connectivity that drive impaired information processing and executive function.(Mccutcheon et al., 2019; Owen et al., 2016)

However, environmental factors such as life stress and various traumas (e.g., sexual trauma, childhood trauma) are known to contribute significantly to the onset of the disorder. Other research has established a correlation with inflammation and infection, particularly in patients with a family history of schizophrenia or a history of infectious diseases during childhood. Several pathogens, including *Toxoplasma gondii*, herpesviruses, *Chlamydophila*, and others, have been implicated as potential causative factors in schizophrenia (Ruijia Xiao, 2024; B. J. et al Sadock, 2017)

BINAURAL BEATS

DEFINITION BINAURAL BEATS

Definition of Binaural beats are a psychoacoustic phenomenon, an auditory illusion, that occurs when two pure-tone sine waves of slightly different frequencies are presented separately to each ear, typically using stereo headphones. The central auditory pathway, specifically the brainstem, processes these differing signals and creates the perception of a third, rhythmic tone, or "beat," which is not actually present in the external environment. The perceived frequency of this beat is mathematically equal to the difference between the two tones presented. Proponents claim that this phenomenon can induce a form of brainwave entrainment (or frequency-following response), where the brain's electrical activity synchronizes with the frequency of the beat.(Ruth Maria Ingendoh et al., 2023)

Binaural beats refer to an auditory perceptual phenomenon that occurs when two pure tones of slightly different frequencies are presented separately to each ear. This process results in the perception of a single, illusory tone with a frequency equal to the average of the two input tones, alongside an amplitude modulation that fluctuates at the difference frequency. For example, when a 400 Hz tone and a 410 Hz tone are delivered to the left and right ears, respectively, the listener perceives a single 405 Hz tone with an amplitude that cyclically varies (beats) at 10 Hz. This perceptual integration of information presented separately to both ears is known as binaural integration and the difference 10 Hz beats is claimed to encourage the Alpha brainwave state, associated with relaxation (Garcia et al., 2018; Ruth Maria Ingendoh et al., 2023).

Binaural beats can be perceived within the frequency range of approximately 1-30 Hz, a range that coincides precisely with the main human Electro Encephalo Graphy (EEG) frequencies. The core of its application involved the brainwave entrainment hypothesis, which suggests that external stimulation at a specific frequency causes the brain's electrocortical activity to oscillate at the same frequency. This entrainment is hypothesized to mediate the effects of binaural beat stimulation on cognitive and affective functions (Maria et al., 2023).

Indeed, binaural beats elicit measurable physiological responses in the brain, including subcortical responses (Frequency Following Response) and cortical entrainment (Auditory Steady-State Response). Uniquely, they can generate cross-frequency coupling patterns, demonstrating that binaural beats are not inert; they actively interact with auditory pathways and brain activity.

This interaction holds significant implications for fundamental neuroscience research into auditory processing and brain connectivity (Perez et al., 2019)

CLINICAL AND COGNITIVE IMPLICATIONS of BINAURAL BEATS

The clinical and cognitive implications of binaural beats largely stem from the hypothesis of brainwave entrainment, where the brain's oscillatory activity is theorized to synchronize with the frequency of the beat, potentially shifting the listener toward a desired mental state. Cognitively, the most frequently investigated effects include improvements in attention and memory. For example, stimulation using frequencies corresponding to the Theta range (4-8 Hz) is sometimes associated with enhanced creativity and memory encoding, while Beta frequencies (13-30 Hz) are explored for their potential to boost concentration and alertness. Clinically, the use of binaural beats has been extensively studied as a non-pharmacological intervention for managing anxiety and pain. By using beats tuned to the Alpha (8-12 Hz) or Theta range, which are associated with states of relaxation and reduced arousal, some studies suggest a modest but significant reduction in self-reported anxiety levels and perceived acute or chronic pain intensity, although the overall efficacy and reliability of these effects remain subjects of ongoing debate and rigorous scientific inquiry. (Ruth Maria Ingendoh et al., 2023)

Several studies report that binaural beats can influence cognitive function and mental states, suggesting positive implications for improving sleep quality, anxiety, and overall quality of life. Furthermore, this implication has been shown to effectively reduce physiological stress and is utilized as a method for lowering perceived stress levels (M. Lee et al., 2022; Muñoz et al., 2020).

Conversely, other research indicates that binaural beat stimulation did not significantly improve sustained attention, although another research showed improvement in general attention function (Robison et al., 2021).

BINAURAL BEATS TREATMENT AS POTENTIALLY INTERVENTION FOR SCHIZOPHRENIA

MECHANISMS OF ACTION

The effects of both **binaural beat (BB)** and **monaural beat (MB)** stimulation have been reported to enhance attentional processing speed and improve overall cognitive capabilities, potentially benefiting various populations (Engelbregt et al., 2019).

Binaural auditory beats are hypothesized to influence the brain and mental state through several key mechanisms. The perceptual processing of binaural beats involves a distinct series of brain regions (Garcia et al., 2018):

1. Initial Processing: Binaural auditory beats are initially processed in the superior olivary nucleus and the brainstem.
2. Reticular Involvement: Following their origination in these lower brain regions, the processing moves to the reticular formation.
3. Cortical Measurement: The effects of the binaural beats can subsequently be measured in the cerebral cortex as a Frequency Following Response (FFR), typically assessed via electroencephalography (EEG).

The FFR refers to the brain's electrocortical activity tending to synchronize its neuronal activity to the frequency of the externally presented stimulus (entrainment). Evidence suggests that FFR is generated through the phase reset and entrainment (phase-lock) of neural excitation to the binaural beat (Garcia et al., 2018). This process is believed to result in changes in response gain and the strengthening of neural responses, leading to rhythmic fluctuations in neural excitation that align with the stimulus.

Recent research further suggests that binaural beats can modulate functional connectivity between different brain regions, as well as connectivity within cortical networks. In summary, the mechanism involves the initial processing of binaural beats in the lower brain, leading to the synchronization of brain activity (FFR) through neuronal entrainment, and ultimately altering functional connectivity within the brain (Garcia et al., 2018).

EFFECTS OF BINAURAL BEATS

A range of studies reports that exposure to binaural beats causes several psychophysiological changes, such as reduced anxiety, increased hypnotic susceptibility and creativity, and enhancements in attention, vigilance, and memory (Garcia et al., 2018). The duration of exposure significantly impacts cognitive progress, with longer periods generally leading to increased effectiveness and optimal benefits (9). Interestingly, some research suggests that both BB and MB stimuli have a comparable effect on attentional processing speed (Engelbregt et al., 2019).

Meta-analyses and related studies provide strong evidence for the efficacy of binaural beats, indicating several practical in clinical applications across various domains, often more broadly than monaural beats (Basu & Banerjee, 2022; Chaieb et al., 2017; Garcia et al., 2018; H. Lee et al., 2024; Olcucu et al., 2020; Perez et al., 2019):

1. Enhanced Cognitive Function

Binaural beats have been shown to positively influence memory and attention tasks (Garcia et al., 2018).This suggests potential application in educational settings, cognitive training programs, or for individuals seeking to enhance focus and recall abilities.

- The effect on memory is frequency-dependent: Alpha, Beta, and Gamma frequencies generally exhibit positive effects, whereas Theta frequencies may sometimes inhibit memory function. This implies that specific frequencies should be selected based on the desired cognitive outcome (Garcia et al., 2018).
- One study (Marie et al., 2023) reported that 40 Hz BB improved attention, concentration, and cognitive function, though another study reported conflicting results (Borges et al., 2023).
- Specifically, Beta BB (20 Hz) was found to enhance long-term memory, while Theta waves reportedly impaired long-term memory, reducing word recall potential (Garcia et al., 2017).
- 15 Hz BB was reported to improve verbal working memory by modulating cortical frequency response, enhancing network connectivity, and strengthening regional coupling in brain areas (Beauchene et al., 2017).
- 10 Hz and 4 Hz BB were reported to enhance interhemispheric coherence between auditory cortices, thereby improving verbal communication skills, though they did not affect behavioral or emotional improvement (Hautus et al., 2021; Petrovich, 2018; Solcà et al., 2015).

2. Reduced Anxiety and Pain Perception

Binaural beats have consistently demonstrated effectiveness in reducing anxiety levels (Garcia et al., 2018; Perez et al., 2019). This is beneficial in clinical practice for managing pre-operative anxiety or general anxiety, potentially offering a non-pharmacological intervention.

Binaural beats can also reduce the amount of anesthesia required during surgical procedures and lower pain perception (Garcia et al., 2018). This has significant implications for pain management, potentially reducing reliance on medical and traditional pain medications.

3. Lowered Heart Rate and Optimized Sleep Quality

Other research reports that BB in the Delta frequency range (0–3 Hz) can potentially improve sleep quality, specifically by increasing sleep efficiency about 4.3% and reducing the likelihood of waking up during sleep onset (Garcia et al., 2018). Additionally, BB is reported to modulate the autonomic nervous system by decreasing sympathetic activity and enhancing parasympathetic activity, thereby lowering the heart rate during sleep initiation and throughout sleep (Garcia et al., 2018).

Specifically, binaural beats induce measurable neural responses, including cortical entrainment and unique cross-frequency connectivity patterns (Perez et al., 2019). However, some studies indicate that BB is less robust than monaural beats (MB) in terms of cortical entrainment. Furthermore, evidence regarding how BB specifically affects mood or definitively influences cognitive performance remains inconclusive (Garcia et al., 2018; Perez et al., 2019)

CONCLUSION

POTENTIAL APPLICATIONS AND EFFICACY

Binaural beat (BB) therapy presents a promising alternative and adjunctive therapeutic modality for alleviating various symptoms associated with schizophrenia. Clinical evidence suggests improvements in negative symptoms, general symptoms, and emotional lability in patients with schizophrenia disorder.

Significantly, the strategies in combined use of pharmacological treatment and BB brain stimulation has demonstrated a notable efficacy in improving refractory schizophrenic symptoms, particularly the severe affective symptoms, with associated obsessive ideas and suicidal ideation, also frequently exhibit a poor response to pharmacotherapy alone (SV & O., 2022)

Broadly, BB stimulation is a non-invasive tool with high potential for cognitive enhancement, anxiety reduction, and pain management (Garcia et al., 2018). To maximize its effectiveness, practical application must be carefully calibrated to specific frequencies, adequate exposure duration, and optimal timing relative to the desired therapeutic effect, while considering appropriate masking sounds (Garcia et al., 2018).

BB therapy is a new strategies as adjunctive treatment to provide more comprehensive service for schizophrenia patients.

FUTURE DIRECTIONS

Multiple studies indicate that the integration of non-pharmacological therapies, such as BB brain stimulation, can significantly improve clinical outcomes in schizophrenia, particularly concerning negative, cognitive, and affective (emotional lability) symptoms.

The fundamental advantage of binaural brain stimulation lies in its non-invasive nature, which makes it a more accessible and acceptable treatment option for patients compared to more invasive procedures. Its integration into existing treatment regimens offers a well-tolerated method to boost therapeutic efficacy without imposing a significant additional burden on patients.

This therapeutic approach may lead to the development of more comprehensive, integrated therapeutic protocols in the future. The goal of incorporating non-pharmacological interventions is to achieve superior patient outcomes, potentially allowing for a reduction in the dosage of pharmacological agents used either singly or in psychotropic combinations. Ultimately, this therapy holds practical implications as a vital adjunctive treatment for the comprehensive management of schizophrenia patients.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests in this study.

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