Dance Movement Therapy: A Bottom-Up Exploration of Schizophrenia Intervention

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Abstract

The cortico-basal ganglia-thalamic network and the insular network constitute components of sensorimotor-related networks, and alterations in these networks may represent important pathogenic mechanisms underlying schizophrenia. Current mainstream research and clinical interventions have primarily focused on abnormalities in higher-order brain regions of patients, with insufficient attention devoted to the sensorimotor system. Studies on healthy individuals have demonstrated that dance training exerts significant enhancing effects on sensorimotor-related brain networks and facilitates higher-order functions through bottom-up mechanisms. These findings suggest that dance training may constitute a novel intervention approach for schizophrenia and for ameliorating its cognitive functions. The present study proposes to employ multimodal magnetic resonance imaging technology, targeting sensorimotor-related networks in schizophrenia, to elucidate the neural mechanisms of clinical intervention via dance training by analyzing alterations in brain imaging, clinical manifestations, and cognitive behaviors of schizophrenia patients before and after dance training.

Full Text

Dance Therapy: A Bottom-Up Intervention Approach for Schizophrenia

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Abstract
The cortico-basal ganglia-thalamic network and the insular network are sensorimotor-related neural networks, and alterations in these networks may constitute important pathological mechanisms underlying schizophrenia. Current mainstream research and clinical interventions have primarily focused on abnormalities in higher-order brain regions, with insufficient attention devoted to the sensorimotor system. Studies in healthy individuals have demonstrated that dance training produces significant enhancements in sensorimotor-related brain networks and promotes higher-order functions through bottom-up mechanisms. These findings suggest that dance training may represent a novel intervention pathway for schizophrenia and its associated cognitive deficits. Using multimodal magnetic resonance imaging technology and targeting the sensorimotor networks in schizophrenia, this study aims to elucidate the neural mechanisms underlying dance training as a clinical intervention by analyzing changes in brain imaging, clinical symptoms, and cognitive performance before and after dance training in patients with schizophrenia.

Keywords: resting-state brain networks, schizophrenia, dance training, sensorimotor-related brain networks
Classification Code: B845.1

1. Problem Statement

Schizophrenia is a severe mental disorder. According to a 2004 World Health Organization survey, its global prevalence is approximately 4‰ (World Health Organization, 2004), with approximately 7.8 million confirmed cases in China (管丽丽等, 2012). The disease is characterized by high relapse and disability rates, with complete recovery occurring in less than 30% of patients (Harrison et al., 2001; Robinson et al., 2004), imposing substantial burdens on both society and families. While conventional pharmacological treatments effectively control positive symptoms in schizophrenia patients, they show minimal efficacy in restoring cognitive function, necessitating the exploration of innovative therapeutic approaches that can effectively promote cognitive recovery and facilitate patients' return to society (Insel, 2010).

Previous research on cognitive deficits in schizophrenia has concentrated on higher-order functional brain regions, employing a top-down approach to explain cognitive processing impairments. Consequently, clinical interventions have predominantly focused on the effects of pharmacological treatments on higher brain functions (Miyamoto et al., 2005). However, a growing body of research indicates that sensorimotor processing deficits constitute a core feature of schizophrenia, which in turn leads to cognitive impairments through bottom-up mechanisms (Kaufmann et al., 2015). Patients exhibit abnormalities in information processing across multiple sensorimotor modalities, including visual, auditory, tactile, olfactory, and motor systems. These aberrant internal representations subsequently compromise cognitive function and behavioral capacity. Therefore, modifying and improving the internal representations of primary sensorimotor processes and enhancing patients' ability to integrate sensorimotor information may represent a promising new therapeutic avenue for ameliorating cognitive dysfunction in schizophrenia.

Dance training is a complex skill acquisition process that requires efficient processing and integration of various sensorimotor information streams, particularly through the coordination and connection of kinesthetic information with other sensory modalities to link internal perception with the external world, thereby facilitating cognitive generation and modification. Kinesthetic ability is a fundamental and powerful function that enables organisms to adapt to their environment and engage in internal-external information exchange throughout their lifespan. During pre-linguistic developmental stages, cognition relies primarily on sensory and kinesthetic processes, and even as individuals gradually depend on language for learning and communication, sensorimotor abilities remain essential for understanding the external world (Mochizuki-Kawai et al., 2004). This underscores the profound influence of kinesthetic ability on cognitive development. Research has shown that long-term dance training can enhance the neural integration level of the sensorimotor system, improve individual kinesthetic ability, and consequently influence higher-order cognitive functions. The direct impact of dance training on primary sensorimotor abilities and its value in promoting higher-order cognition suggest that it may serve as an effective intervention for schizophrenia.

2.1 Sensorimotor Information Processing Mechanisms and Schizophrenia

Emerging etiological models of schizophrenia and extensive related research indicate that bottom-up sensorimotor processing deficits may constitute a crucial mechanism underlying cognitive impairments. The clinical symptoms of the disease likely reflect a cumulative process of decline and disruption, wherein abnormal processing of perceptual information and disintegration between higher-order and primary processes jointly produce the symptomatology of schizophrenia (Hugdahl, 2009). Dysregulation of the mechanisms for screening, filtering, and inputting sensorimotor information may represent a pathogenic factor for both symptoms and cognitive deficits (Geyer et al., 2001). Patients often experience impaired inhibitory function and inability to filter irrelevant information, resulting in excessive information entering consciousness, which subsequently produces various abnormal perceptual experiences and ultimately affects cognitive function.

(1) Sensorimotor Information Processing Deficits

Pathological Mechanisms of the Cortico-Basal Ganglia-Thalamic Network in Schizophrenia

Human and animal studies have demonstrated that the cortical (frontal)-basal ganglia-thalamic network is heavily involved in the gating of sensorimotor information—that is, the processing and filtering of incoming sensorimotor information to provide a foundation for higher-order information processing (Hazlett et al., 2001). Within this circuit, the thalamus serves as an integration hub, receiving sensorimotor information and transmitting it to the cerebral cortex, while also receiving cerebellar input and relaying it to the basal ganglia. The basal ganglia subsequently return information to the premotor cortex for action planning, with thalamic afferent and efferent fibers connecting the cortex, basal ganglia, and thalamus into a unified neural circuit (梅锦荣, 2011; Zikopoulos & Barbas, 2007). Additionally, the thalamus contains the primary dopamine receptors, with most thalamic nuclei receiving dopaminergic innervation and projecting to the prefrontal cortex (Rieck et al., 2004). Schizophrenia patients exhibit abnormalities in this circuit, preventing the integration of sensorimotor and cognitive processing and generating clinical symptoms (Kumari et al., 2003). For instance, studies have found reduced function in the sensorimotor cortex and supplementary motor area (Schroder et al., 1995), as well as structural and functional alterations in the basal ganglia (Heckers, 1997). A meta-analysis by Konick and Friedman (2001) examining nearly 500 schizophrenia patients across various studies found that the vast majority reported reduced thalamic volume. Positive symptoms such as auditory and visual hallucinations have also been associated with decreased function in thalamic nuclei (Noda et al., 1993). Further research has revealed gliosis within the cortico-basal ganglia-thalamic network in schizophrenia, leading to reduced information transmission efficiency (Heckers, 1997), with patients' decreased activation in this network significantly correlating with poorer performance on prepulse inhibition (PPI) tasks (Hazlett et al., 2008).

Pathological Mechanisms of the Insular Network in Schizophrenia

The salience network participates in the filtering and processing of human sensorimotor information. The insula, a critical node in this network, processes and integrates internal and external sensorimotor information, assigns salience to relevant information, and is closely associated with attentional selection (Craig, 2009). Initially, somatosensory signals from the body interior and sensorimotor signals from the external environment undergo primary processing in the posterior insula, forming proprioceptive representations that maintain internal homeostasis (Craig, 2009). Subsequently, the posterior insula transmits sensorimotor information to the anterior insula, which integrates signals from the amygdala, anterior cingulate cortex, ventral striatum, and ventral prefrontal cortex (emotional, cognitive, and motivational signals) to further represent the sensorimotor signals from the posterior insula (Tian & Zalesky, 2018). The insular network functions as an advanced filter for sensorimotor information, assigning different salience and significance to processed information based on integration with emotional, motivational, and cognitive networks. This enables selective attention to motivationally relevant or survival-significant stimuli, facilitates the distinction between self and others through information integration and salience assignment, and generates subjective cognitive and perceptual experiences such as the sense of "self" (Uddin, 2015). Consequently, through salience-based filtering of internal and external sensorimotor information, individuals can selectively process self-relevant stimuli and form self-concepts.

One hypothesis of schizophrenia posits that the disorder results from the brain' s inability to selectively highlight self-relevant sensorimotor stimuli, leading to a failure in distinguishing "self" from "non-self" information and resulting in hallucinations, delusions, and impaired insight (Wylie & Tregellas, 2010). This abnormal salience processing also affects the switching and regulation between the central executive network and default mode network, further causing attention and working memory deficits (Menon & Uddin, 2010). Related studies have consistently identified structural and functional abnormalities in the insula of schizophrenia patients, revealing pathological mechanisms such as: difficulty in recognizing emotional facial expressions (particularly negative emotions) due to abnormal connectivity between the insula and amygdala, prefrontal cortex, and anterior cingulate (Leppanen et al., 2008); impaired discrimination of emotional prosody (Bozikas et al., 2006); abnormal pain perception (Singh et al., 2006); hallucination-related feelings of immersion (Modinos et al., 2009); and associations with clinical indicators (Shepherd et al., 2012), all resulting from insufficient processing of thalamic and sensory cortex information in the posterior insula and impaired connectivity between the anterior insula and limbic system and frontal lobes.

(2) Brain Plasticity in Schizophrenia Patients

Recent research indicates that schizophrenia is a series of neurodevelopmental disorders resulting from alterations in multiple brain circuits (Insel, 2010). As neuroplastic changes occur at synapses, the coordinated regulation of neural circuits becomes altered, synchronization abnormalities emerge, and both functional and structural connectivity within the brain change, producing psychiatric symptoms (Uhlhaas & Singer, 2010). This raises the question: does the schizophrenic brain retain the capacity for plastic changes, and can it undergo plastic modifications in response to specific therapeutic interventions, thereby providing possibilities for symptom improvement? Several studies have yielded promising results. Pajonk et al. (2010) conducted aerobic exercise training with schizophrenia patients and found significant increases in hippocampal gray matter volume alongside improved cognitive function. Eack et al. (2010) used cognitive training to halt progressive gray matter volume reduction in schizophrenia patients. Our research group has demonstrated that music intervention effectively enhanced insular function in schizophrenia patients, with significant alleviation of clinical symptoms (He et al., 2017). These studies suggest that the brains of schizophrenia patients retain neuroplastic potential and can undergo positive plastic changes through training and intervention, leading to improved cognitive function and clinical symptoms.

In summary, deficits in sensorimotor system information processing may constitute an important cause of clinical symptoms and cognitive dysfunction in schizophrenia. Specifically, the cortico-basal ganglia-thalamic network and the insular network may be the primary networks responsible for these processing deficits. Therefore, targeting and improving these networks in schizophrenia patients holds promise for alleviating clinical symptoms and cognitive dysfunction. However, current mainstream research and clinical interventions continue to focus on abnormalities in higher-order brain regions, with insufficient attention to the study and intervention of primary sensorimotor systems. Research has demonstrated that schizophrenia patients' brains retain plasticity and can be modified through external stimulation and training. Consequently, this study proposes that improving sensorimotor-related networks in schizophrenia patients may enhance overall brain function and ultimately help patients improve relevant cognitive functions.

2.2 Potential Therapeutic Value of Dance Training

Dance training is a highly complex sensorimotor process that differs from both daily activities and general sports. Numerous studies have shown that both systematic long-term dance training and intermittent amateur dance practice can lead to significant improvements and changes in explicit behavioral capacities. Professional dancers exhibit superior body posture control (Rein et al., 2011), while short-term training can produce better balance (Ricotti & Ravaschio, 2011), enhanced body movement coordination (Golomer et al., 2009), superior spatial and rhythmic perception (Stevens et al., 2011), and more pronounced spatial imagination (Golomer et al., 2008). These behavioral changes involve the brain's control of body spatial position, synchronization of dance movements with musical rhythm, and expression of movement emotions. During this process, dancers' brains must repeatedly integrate multiple sensory, cognitive, and motor feedback signals, continuously strengthening their sensorimotor-related brain networks. Extensive research has demonstrated that dance training exerts significant plastic effects on the brain, primarily concentrated in sensorimotor-related networks, which subsequently influence higher brain functions by enhancing the integration level of the sensorimotor system.

(1) Effects of Dance Training on the Cortico-Basal Ganglia-Thalamic Network

The plastic effects of dance training are closely associated with the cortico-basal ganglia-thalamic network. This network is responsible for processing and integrating various sensorimotor information streams, facilitating fluent movement execution and generating goal-directed behaviors, while also participating in the regulation of motivation and emotion-driven actions (Haber & Calzavara, 2009). Long-term dance training can activate broader regions within this network (Brown et al., 2006), enhance sensorimotor cortex responses to familiar actions (Calvo-Merino et al., 2005), promote the formation of new response patterns in sensorimotor networks (Ono et al., 2014), and effectively increase thalamo-cortical functional connectivity, enabling more efficient bottom-up prefrontal regulation (Burzynska et al., 2017). Emotionally expressive movements in dance can exert greater influence on sensorimotor networks (Cruz-Garza et al., 2014). Our previous research has also found that dance training enhances functional connectivity in the cortico-basal ganglia network (Li et al., 2015). Beyond functional enhancements, dance training induces structural changes within this network, including reduced gray and white matter volumes in multiple regions (Hanggi et al., 2010) and altered sensorimotor white matter fiber tracts that connect to more extensive sensorimotor cortical areas with longer-range connectivity (Giacosa et al., 2016). Other studies have identified dance-training-specific increases in local gray matter volume within this network, such as in the superior temporal gyrus related to auditory-motor integration (Karpati et al., 2017) and the region of sensorimotor cortex representing the foot (Jessica et al., 2016). These changes in the cortico-basal ganglia circuits of healthy dancers are associated with explicit kinesthetic abilities, reflecting higher-level sensorimotor information processing. Based on existing evidence of brain plasticity from dance training in healthy populations and the potential for change in schizophrenia patients' brains, we hypothesize that dance training may produce similar effects on the cortico-basal ganglia-thalamic network in schizophrenia patients, thereby ameliorating their sensorimotor information processing deficits and serving as an effective therapeutic intervention.

(2) Effects of Dance Training on the Insular Network

Related studies have found that dance training activates insular-related networks (Zabicki et al., 2016). Long-term dance training enhances the function of the insular network with the insula as its hub node, promoting the level of sensorimotor information screening and processing, and further influencing higher brain functions through transfer effects. For example, dancers with long-term training demonstrate better working memory (Cortese & Rossi-Arnaud, 2010) and creativity (Fink et al., 2009). Our research has yielded similar findings: dancers show enhanced functional connectivity between the insula and the whole brain, enabling more efficient salience selection of sensorimotor information. In particular, dance training alters the functional connectivity patterns of the posterior insula, enhancing its capacity to integrate sensory information. These enhanced insular network functions further influence higher brain functions, with individuals exhibiting greater empathic ability (Gujing et al., 2019). Based on these findings, we infer that implementing dance training for schizophrenia patients may also affect and improve the function of their advanced sensorimotor information processing system (the insular network), thereby influencing higher brain functions.

In summary, dance training is an efficient multidimensional sensorimotor stimulation method that can specifically induce widespread structural and functional changes in the cortico-basal ganglia-thalamic network and the insular network, subsequently affecting trainees' higher cognitive functions. Given that schizophrenia patients exhibit extensive pathological alterations in these two sensorimotor-related networks, dance training may potentially improve these networks in patients, thereby enhancing their sensorimotor information processing and integration capabilities and providing a novel therapeutic approach for schizophrenia.

3. Research Framework

This study focuses on the sensorimotor-related brain networks in schizophrenia (the cortico-basal ganglia-thalamic network and the insular network). Based on the plastic effects of dance training on these networks in healthy individuals, we propose to administer dance training to schizophrenia patients to enhance their sensorimotor information processing level and thereby improve cognitive function and control clinical symptoms. Using resting-state fMRI, high-resolution structural MRI (sMRI), and diffusion tensor imaging (DTI), combined with clinical symptom assessment and cognitive function evaluation, this study will conduct a comprehensive analysis of the associations between sensorimotor-related brain networks and clinical-psychological data in schizophrenia, mapping the dynamic changes in brain functional and structural networks before and after dance training (see Figure 1 [Figure 1: see original paper]).

Figure 1. Schematic diagram of the research framework investigating the effects of dance training on sensorimotor-related brain networks in schizophrenia

3.1 Study 1: Acquisition of Multimodal Data from Schizophrenia Patients

In addition to basic demographic information (gender, age, marital status, education level, medication status, age at onset, illness duration) and brain imaging data, this study will assess patients' clinical symptoms using the Positive and Negative Syndrome Scale (PANSS) administered by psychiatrists before and after dance training intervention. For cognitive function evaluation, we will employ the MATRICS Consensus Cognitive Battery (MCCB), a comprehensive assessment tool for cognitive impairment initiated by the U.S. National Institute of Mental Health and the Food and Drug Administration (FDA). The MCCB is suitable for evaluating cognitive abilities in patients with psychiatric disorders and has become the standardized measurement tool for assessing cognitive treatment efficacy in schizophrenia, featuring high test-retest reliability, minimal practice effects, strong correlation with patient functioning, and excellent practicality and tolerability (Marder & Fenton, 2004). Introduced to China in 2008, the Chinese version of the MCCB has established a domestic normative database and comprises nine subtests representing seven cognitive domains: processing speed, attention/vigilance, working memory, verbal learning, visual learning, reasoning and problem-solving, and social cognition.

To evaluate the effectiveness of dance training, we will invite professional dance instructors to assess four behavioral indicators—musical rhythm sense, balance, movement coordination, and movement completion—before and after the intervention, based on the design rationale and actual implementation of the dance program. According to composite evaluation scores, participants will be classified as training-qualified or unqualified, with data from qualified individuals included in the analysis. All acquired data will be integrated into the brain imaging data analysis to achieve comprehensive multimodal analysis.

3.2 Study 2: Development of a Dance Training Protocol for Schizophrenia Patients

Research indicates that the brains of schizophrenia patients retain plasticity, and various forms of intervention can induce plastic changes. For instance, six months of aerobic exercise (cycling) enhanced white matter fiber integrity in schizophrenia patients (Svatkova et al., 2015), and three months of Tai Chi training (three sessions per week) significantly improved psychophysiological indicators (Ho et al., 2016). Meta-analyses have further shown that yoga training, aerobic exercise, and other physical activities for schizophrenia patients typically last 8–12 weeks with training frequencies of 2–4 sessions per week, with most studies reporting corresponding changes in cognitive function (Firth et al., 2017). Although these modalities share certain similarities with dance training in terms of physical movement and sensorimotor training, direct evidence regarding dance training and brain plasticity in schizophrenia is lacking. Based on these related studies, we have established the training duration and frequency for the current study.

Considering the severity of symptoms in schizophrenia patients and practical hospital constraints, participants in this study will undergo 12 weeks of dance training, with two sessions per week, each lasting approximately one hour. Each session will consist of three phases: warm-up (approximately 15 minutes), movement learning and practice (approximately 30 minutes), and integration phase (approximately 15 minutes). During classes, the focus will be on movement observation and imitation, emphasizing individual mastery of dance movements and body awareness. Training will be conducted on an individual basis without arranging interpersonal dance interactions or social engagement among participants, thereby minimizing potential confounding effects of social interaction during training.

The training program comprises three stages. The **initial stage** (Weeks 1–3) focuses on fundamental dance movement perception, positioning, coordination, and rhythm abilities, training participants to acquire basic dance movements such as breathing exercises, body position awareness, rhythmic footwork, and flexibility training. The **consolidation stage** (Weeks 4–9) builds upon the previous stage by increasing movement complexity (combinatorial and variable movements) while ensuring participants can successfully perform them. During this stage, participants will learn basic movement units (each unit comprising two eight-counts), mastering a total of 6–8 dance movement units. The **integration stage** (Weeks 10–12) focuses on refining movement accuracy and coordination, requiring participants to integrate and memorize the complete dance sequence, enabling them to independently perform the entire learned routine to the best of their ability. Additionally, beyond the twice-weekly training sessions, the intervention group will be scheduled for one to two 30-minute individual dance machine training sessions per week. The professional dance training will be conducted jointly by a university dance instructor and a registered psychotherapist with dance movement therapy training background.

3.3 Study 3: Integrated Analysis of Dance Training Effects on Schizophrenia Patients

This study will include three groups: schizophrenia dance intervention group, schizophrenia control group, and healthy control group. Multimodal brain imaging data, behavioral-psychological data, and clinical data will be collected from all three groups at baseline. Post-intervention data will be collected from both schizophrenia groups (see Figure 2 [Figure 2: see original paper]).

Figure 2. Experimental design investigating the effects of dance training on sensorimotor-related brain networks in schizophrenia

Data Analysis Components:
First, we will analyze the pathological characteristics of sensorimotor-related brain networks in schizophrenia. At baseline, we will construct brain network (functional and structural) maps of schizophrenia by analyzing patients' fMRI, sMRI, and DTI data. Through group comparisons, we will further characterize the pathological features of sensorimotor-related brain networks (cortico-basal ganglia-thalamic network and insular network) in schizophrenia.

Second, we will analyze the effects of dance training on brain regions within the sensorimotor-related networks. By comparing pre- and post-training fMRI, sMRI, and DTI data from schizophrenia patients, we will investigate the plastic effects of dance training on brain regions within these networks and identify the core brain regions through which dance training exerts its effects.

Third, we will examine the impact of dance training on functional and structural connectivity within sensorimotor-related networks. By comparing pre- and post-training fMRI and DTI data, we will investigate the effects of dance training on the sensorimotor-related networks (cortico-basal ganglia-thalamic network and insular network) in schizophrenia. We will also explore the associations between these networks and other major brain networks, examining the effects of dance training on whole-brain network structure and function at both the inter-regional and inter-network levels to reveal the neural network mechanisms underlying dance training effects.

Finally, we will conduct integrated analysis of dance training intervention in schizophrenia. By integrating all pre- and post-intervention brain imaging metrics with clinical and cognitive measures, and correlating these changes with clinical and cognitive indicators, we will investigate the relationships between sensorimotor-related brain networks and other brain networks in schizophrenia, thereby further characterizing the associations between brain network changes and clinical-cognitive assessments.

Overall Data Analysis Strategy:
We will use one-way ANOVA (1$×3)*forbaselinestatisticalcomparisonstoidentifyabnormalfunctionalbrainne* *andpost−interventiondatafromthetwoschizophreniagroups*, *wewillemploytwo− wayANOVA*(2×$2) to investigate the plastic effects of dance training on functional brain networks. Finally, combining results from both ANOVA analyses, we will identify the mechanisms through which dance training ameliorates abnormal brain regions and modulates non-abnormal regions in schizophrenia patients.

Specific Analytical Methods:
First, this study will employ data-driven analytical approaches. In addition to using mainstream analysis tools DARTEL and FSL to obtain structural characteristics of gray matter regions and white matter structural network features, we will utilize two data-driven methods: Independent Component Analysis (ICA) and Functional Connectivity Density (FCD). FCD will be used to characterize the significant effects of dance training on local brain region functional features, based on which regions of interest (seed points) will be selected. Functional Connectivity (FC) analysis will then be used to characterize changes in functional networks. Simultaneously, ICA will be employed to investigate the plastic effects of dance training on intra- and inter-network functional connectivity in schizophrenia.

Second, this study will also conduct hypothesis-driven brain functional network analysis. Based on the aforementioned literature and our research hypotheses, we will select three functional subregions of the insula (posterior insula [PI], ventral anterior insula [vAI], dorsal anterior insula [dAI]), precentral gyrus, postcentral gyrus, visual V1/V2 areas, subregions of the basal ganglia, and bilateral thalamus as seed points. FC will then be calculated to determine connectivity among these seed points and their connectivity with the whole brain.

Finally, based on statistical results from repeated-measures ANOVA, we will use Pearson correlation analysis to conduct covariate analysis between imaging data and clinical-cognitive data before and after dance training in schizophrenia patients, thereby obtaining integrated analysis results regarding the effects of dance training on schizophrenia.

4.1 Novel Research Perspective and Theoretical Framework

Various hypotheses and theories regarding the etiology of schizophrenia persist. The dominant hypothesis focuses on higher-order brain functions, positing that the pathogenic mechanism of schizophrenia lies in the disruption of higher-order functional brain regions that top-down affect brain functions at all levels, forming the basis for drug and treatment design. However, clinical practice has revealed suboptimal treatment outcomes in some patients and slow recovery of cognitive and social functions. The human brain is a dynamically connected complex network system, and the pathogenic mechanisms of schizophrenia require consideration of primary functional regions in addition to higher-order brain areas. Based on previous research on the influence of primary sensorimotor brain functions on higher-order functions, we hypothesize that deficient filtering and processing of primary sensorimotor information may also be a contributing factor to schizophrenia. Therefore, enhancing sensorimotor-related brain networks in schizophrenia patients may influence higher-order brain networks and improve higher cognitive functions. To this end, this study adopts a bottom-up information processing approach, utilizing dance training as an intervention for schizophrenia. By integrating brain imaging, clinical, and psychological-behavioral information, we will comprehensively analyze the specific effects of dance training on sensorimotor-related brain networks in schizophrenia patients and elucidate the underlying neural mechanisms. This novel perspective may reveal the neural mechanisms of bottom-up information processing and interaction in schizophrenia patients, holding significant implications for etiological theories of schizophrenia.

4.2 Addressing Key Challenges in Schizophrenia Clinical Treatment

As previously mentioned, current schizophrenia treatment remains primarily pharmacological, with mainstream interventions demonstrating clear efficacy in controlling positive symptoms, particularly during the early stages of the illness. However, as the disease course progresses, cognitive decline appears inevitable. A considerable proportion of patients experience severe cognitive deterioration due to prolonged illness duration, ultimately losing the possibility of returning to society. Therefore, effective and precise treatment of schizophrenia requires more diversified and interdisciplinary exploratory research to identify more targeted approaches. This study combines expertise from information science, artistic training, and clinical medicine to investigate schizophrenia from a multidisciplinary perspective. By using dance training to specifically enhance patients' sensorimotor abilities and employing neuroinformatics research methods to verify the mechanisms through which dance training affects sensorimotor brain networks in schizophrenia, we will integrate clinical medical observation and diagnosis to anchor the dance intervention protocol.

4.3 Enrichment of Schizophrenia Treatment Systems

Based on the abnormalities in sensorimotor-related networks in schizophrenia, this study is the first to utilize dance training to influence these networks in patients. This represents an in-depth application of dance therapy in schizophrenia treatment, where the precision and effectiveness of dance training will be critical. Therefore, the project fully comprehends and deeply applies various techniques in dance therapy, thoroughly considers the cognitive characteristics and acceptance levels of schizophrenia patients, and designs an effective training protocol. This protocol will possess strong scientific rigor, specificity, and operability, and is expected to become a promotable and effective approach in the clinical treatment of schizophrenia.

管丽丽，杜立哲，马弘． (2012)． 精神分裂症的疾病负担（综述）． 中国心理卫生杂志， v.26(012),
梅锦荣．(2011)．神经心理学：中国人民大学出版社．

Bozikas, V. P., Kosmidis, M. H., Anezoulaki, D., Giannakou, M., Andreou, C., & Karavatos, A. (2006). Impaired perception of affective prosody in schizophrenia. *The Journal of Neuropsychiatry and Clinical Neurosciences, 18*(1), 81-85.

Brown, S., Martinez, M. J., & Parsons, L. M. (2006). The neural basis of human dance. *Cereb Cortex, 16*(8), 1157-1167.

Burzynska, A. Z., Finc, K., Taylor, B. K., Knecht, A. M., & Kramer, A. F. (2017). The dancing brain: structural and functional signatures of expert dance training. *Frontiers in Human Neuroscience, 11*, 566.

Calvo-Merino, B., Glaser, D. E., Grezes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: an fMRI study with expert dancers. *Cereb Cortex, 15*(8), 1243-1249.

Cortese, A., & Rossi-Arnaud, C. (2010). Working memory for ballet moves and spatial locations in professional ballet dancers. *Applied Cognitive Psychology, 24*(2), 266-286.

Craig, A. D. (2009). How do you feel-now? The anterior insula and human awareness. *Nature Reviews Neuroscience, 10*(1), 59-70.

Cruz-Garza, J. G., Hernandez, Z. R., Nepaul, S., Bradley, K. K., & Contreras-Vidal, J. L. (2014). Neural decoding of expressive human movement from scalp electroencephalography (EEG). *Frontiers in Human Neuroscience, 8*, 188.

Eack, S. M., Hogarty, G. E., Cho, R. Y., Prasad, K. M. R., Greenwald, D. P., Hogarty, S. S., et al. (2010). Neuroprotective effects of cognitive enhancement therapy against gray matter loss in early schizophrenia results from a 2-year randomized controlled trial. *Archives of General Psychiatry, 67*(7), 674-682.

Fink, A., Graif, B., & Neubauer, A. C. (2009). Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. *Neuroimage, 46*(3), 854–862.

Firth, J., Stubbs, B., Rosenbaum, S., Vancampfort, D., Malchow, B., Schuch, F., et al. (2017). Aerobic exercise improves cognitive functioning in people With Schizophrenia: A Systematic Review and Meta-Analysis. *Schizophrenia Bulletin, 43*(3), 546–556.

Geyer, M. A., Krebs-Thomson, K., Braff, D. L., & Swerdlow, N. R. (2001). Pharmacological studies of prepulse inhibition models of sensorimotor gating deficits in schizophrenia: a decade in review. *Psychopharmacology (Berl), 156*(2-3), 117–154.

Giacosa, C., Karpati, F. J., Foster, N. E., Penhune, V. B., & Hyde, K. L. (2016). Dance and music training have different effects on white matter diffusivity in sensorimotor pathways. *Neuroimage, 135*, 273–286.

Golomer, E., Boulliette, A., Mertz, C., & Keller, J. (2008). Effects of mental imagery styles on shoulder and hip rotations during preparation of pirouettes. *Journal of Motor Behavior, 40*(4), 281–290.

Golomer, E., Toussaint, Y., Bouillette, A., & Keller, J. (2009). Spontaneous whole body rotations and classical dance expertise: how shoulder-hip coordination influences supporting leg displacements. *Journal of Electromyography and Kinesiology, 19*(2), 314–321.

Gujing, L., Hui, H., Xin, L., Lirong, Z., Yutong, Y., Guofeng, Y., et al. (2019). Increased Insular Connectivity and Enhanced Empathic Ability Associated with Dance/Music Training. *Neural Plasticity, 2019*, 9693109.

Haber, S. N., & Calzavara, R. (2009). The cortico-basal ganglia integrative network: the role of the thalamus. *Brain Research Bulletin, 78*(2–3), 69–74.

Hanggi, J., Koeneke, S., Bezzola, L., & Jancke, L. (2010). Structural neuroplasticity in the sensorimotor network of professional female ballet dancers. *Human Brain Mapping, 31*(8), 1196–1206.

Harrison, G., Hopper, K., Craig, T., Laska, E., Siegel, C., Wanderling, J., et al. (2001). Recovery from psychotic illness: a 15- and 25-year international follow-up study. *the British Journal of Psychiatry, 178*, 506–517.

Hazlett, E. A., Buchsbaum, M. S., Tang, C. Y., Fleischman, M. B., Wei, T. C., Byne, W., et al. (2001). Thalamic activation during an attention-to-prepulse startle modification paradigm: a functional MRI study. *Biological Psychiatry, 50*(4), 281–291.

Hazlett, E. A., Buchsbaum, M. S., Zhang, J., Newmark, R. E., Glanton, C. F., Zelmanova, Y., et al. (2008). Frontal-striatal-thalamic mediodorsal nucleus dysfunction in schizophrenia-spectrum patients during sensorimotor gating. *Neuroimage, 42*(3), 1154–1163.

He, H., Yang, M., Duan, M., Chen, X., Lai, Y., Xia, Y., et al. (2017). Music Intervention Leads to Increased Insular Connectivity and Improved Clinical Symptoms in Schizophrenia. *Frontiers in Neuroscience, 11*, 744.

Heckers, S. (1997). Neuropathology of schizophrenia: cortex, thalamus, basal ganglia, and neurotransmitter-specific projection systems. *Schizophrenia Bulletin, 23*(3), 403–421.

Ho, R. T. H., Fong, T. C. T., Wan, A. H. Y., Au-Yeung, F. S. W., Wong, C. P. K., Ng, W. Y. H., et al. (2016). A randomized controlled trial on the psychophysiological effects of physical exercise and Tai-chi in patients with chronic schizophrenia. *Schizophrenia Research, 171*(1-3), 42–49.

Hugdahl, K. (2009). "Hearing voices" : auditory hallucinations as failure of top-down control of bottom-up perceptual processes. *Scandinavian Journal of Psychology, 50*(6), 553–560.

Insel, T. R. (2010). Rethinking schizophrenia. *Nature, 468*(7321), 187–193.

Jessica, M., Sofie, T. M., & Jürgen, H. (2016). Differences in Cortical Representation and Structural Connectivity of Hands and Feet between Professional Handball Players and Ballet Dancers. *Neural Plasticity, 2016*, 1–17.

Karpati, F. J., Giacosa, C., Foster, N. E., Penhune, V. B., & Hyde, K. L. (2017). Dance and music share gray matter structural correlates. *Brain Research, 1657*, 62–73.

Kaufmann, T., Skatun, K. C., Alnaes, D., Doan, N. T., Duff, E. P., Tonnesen, S., et al. (2015). Disintegration of Sensorimotor Brain Networks in Schizophrenia. *Schizophrenia Bulletin, 41*(6), 1326–1335.

Kay, S. R., Fiszbein, A., & Opler, L. A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin, 13*(2), 261–276.

Konick, L. C., & Friedman, L. (2001). Meta-analysis of thalamic size in schizophrenia. *Biological Psychiatry, 49*(1), 28–38.

Kumari, V., Gray, J. A., Geyer, M. A., ffytche, D., Soni, W., Mitterschiffthaler, M. T., et al. (2003). Neural correlates of tactile prepulse inhibition: a functional MRI study in normal and schizophrenic subjects. *Psychiatry Research, 122*(2), 99–113.

Leppanen, J. M., Niehaus, D. J., Koen, L., Du Toit, E., Schoeman, R., & Emsley, R. (2008). Deficits in facial affect recognition in unaffected siblings of Xhosa schizophrenia patients: evidence for a neurocognitive endophenotype. *Schizophrenia Research, 99*(1–3), 270–275.

Li, G., He, H., Huang, M., Zhang, X., Lu, J., Lai, Y., et al. (2015). Identifying enhanced cortico-basal ganglia loops associated with prolonged dance training. *Scientific Report, 5*, 10271.

Marder, S. R., & Fenton, W. (2004). Measurement and Treatment Research to Improve Cognition in Schizophrenia: NIMH MATRICS initiative to support the development of agents for improving cognition in schizophrenia. *Schizophrenia Research, 72*(1), 5-9.

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: a network model of insula function. *Brain Structure & Function, 214*(5-6), 655-667.

Miyamoto, S., Duncan, G. E., Marx, C. E., & Lieberman, J. A. (2005). Treatments for schizophrenia: a critical review of pharmacology and mechanisms of action of antipsychotic drugs. *Molecular Psychiatry, 10*(1), 79-104.

Mochizuki-Kawai, H., Kawamura, M., Hasegawa, Y., Mochizuki, S., Oeda, R., Yamanaka, K., et al. (2004). Deficits in long-term retention of learned motor skills in patients with cortical or subcortical degeneration. *Neuropsychologia, 42*(13), 1858-1863.

Modinos, G., Vercammen, A., Mechelli, A., Knegtering, H., McGuire, P. K., & Aleman, A. (2009). Structural covariance in the hallucinating brain: a voxel-based morphometry study. *Journal of Psychiatry & Neuroscience, 34*(6), 465-469.

Namkung, H., Kim, S. H., & Sawa, A. (2017). The Insula: An Underestimated Brain Area in Clinical Neuroscience, Psychiatry, and Neurology. *Trends in Neurosciences, 40*(4), 200-207.

Noda, S., Mizoguchi, M., & Yamamoto, A. (1993). Thalamic experiential hallucinosis. *Journal of Neurology Neurosurgery and Psychiatry, 56*(11), 1224-1226.

Ono, Y., Nomoto, Y., Tanaka, S., Sato, K., Shimada, S., Tachibana, A., et al. (2014). Frontotemporal oxyhemoglobin dynamics predict performance accuracy of dance simulation gameplay: temporal characteristics of top-down and bottom-up cortical activities. *Neuroimage, 85* Pt 1, 461-470.

Pajonk, F. G., Wobrock, T., Gruber, O., Scherk, H., Berner, D., Kaizl, I., et al. (2010). Hippocampal Plasticity in Response to Exercise in Schizophrenia. *Archives of General Psychiatry, 67*(2), 133-143.

Rein, S., Fabian, T., Zwipp, H., Rammelt, S., & Weindel, S. (2011). Postural control and functional ankle stability in professional and amateur dancers. *Clinical Neurophysiology, 122*(8), 1602-1610.

Ricotti, L., & Ravaschio, A. (2011). Break dance significantly increases static balance in 9 years-old soccer players. *Gait & Posture, 33*(3), 462-465.

Rieck, R. W., Ansari, M. S., Whetsell, W. O., Jr., Deutch, A. Y., & Kessler, R. M. (2004). Distribution of dopamine D2-like receptors in the human thalamus: autoradiographic and PET studies. *Neuropsychopharmacology, 29*(2), 362-372.

Robinson, D. G., Woerner, M. G., McMeniman, M., Mendelowitz, A., & Bilder, R. M. (2004). Symptomatic and functional recovery from a first episode of schizophrenia or schizoaffective disorder. *American Journal of Psychiatry, 161*(3), 473–479.

Schroder, J., Wenz, F., Schad, L. R., Baudendistel, K., & Knopp, M. V. (1995). Sensorimotor cortex and supplementary motor area changes in schizophrenia. A study with functional magnetic resonance imaging. *the British Journal of Psychiatry, 167*(2), 197-201.

Shepherd, A. M., Matheson, S. L., Laurens, K. R., Carr, V. J., & Green, M. J. (2012). Systematic Meta-Analysis of Insula Volume in Schizophrenia. *Biological Psychiatry, 72*(9), 775–784.

Singh, M. K., Giles, L. L., & Nasrallah, H. A. (2006). Pain insensitivity in schizophrenia: trait or state marker? *Journal of Psychiatric Practice, 12*(2), 90–102.

Stevens, C. J., Ginsborg, J., & Lester, G. (2011). Backwards and forwards in space and time: Recalling dance movement from long-term memory. *Memory Studies, 4*(2), 234–250.

Svatkova, A., Mandl, R. C. W., Scheewe, T. W., Cahn, W., Kahn, R. S., & Pol, H. E. H. (2015). Physical Exercise Keeps the Brain Connected: Biking Increases White Matter Integrity in Patients With Schizophrenia and Healthy Controls. *Schizophrenia Bulletin, 41*(4), 869–878.

Tian, Y., & Zalesky, A. (2018). Characterizing the functional connectivity diversity of the insula cortex: Subregions, diversity curves and behavior. *Neuroimage, 183*, 716–733.

Uddin, L. Q. (2015). Salience processing and insular cortical function and dysfunction. *Nature Reviews Neuroscience, 16*(1), 55–61.

Uhlhaas, P. J., & Singer, W. (2010). Abnormal neural oscillations and synchrony in schizophrenia. *Nature Reviews Neuroscience, 11*(2), 100–113.

Wylie, K. P., & Tregellas, J. R. (2010). The role of the insula in schizophrenia. *Schizophrenia Research, 123*(2–3), 93–104.

World Health Organization. (2004). *The global burden of disease: 2004 update.* Retrieved October 21, 2020 from http://www.who.int/healthinfo/global_{burden}*{disease}/GBD*{report}*{20*

Zabicki, A., de Haas, B., Zentgraf, K., Stark, R., Munzert, J., & Kruger, B. (2016). Imagined and Executed Actions in the Human Motor System: Testing Neural Similarity Between Execution and Imagery of Actions with a Multivariate Approach. *Cereb Cortex, 26*(4), 1572–1586.

Zikopoulos, B., & Barbas, H. (2007). Circuits for multisensory integration and attentional modulation through the prefrontal cortex and the thalamic reticular nucleus in primates. *Reviews in the Neurosciences, 18*(6), 417–438.