

# ***Research on Immersive Virtual Reality Music Therapy in Interaction Mechanisms Psychological Effects and Cross-Domain Applications***

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**Abstract.** With the increasing prevalence of mental health disorders such as depression and anxiety, exploring innovative and interdisciplinary interventions has become a pressing public health need. Music therapy has long been recognized as an effective method for emotion regulation, and the rapid development of virtual reality (VR) technology has revitalized it. This study integrates interaction theory, presence theory, and flow theory to construct a theoretical framework of "interaction mechanism-immersive experience-psychological effects." Drawing on theoretical analysis and research from the medical, educational, and cultural and social fields, this study explores how the interaction mechanisms in VR environments enhance the therapeutic potential of music. Results indicate that immersive VR music therapy can enhance emotion regulation, reduce anxiety and depression, and improve individual-level self-efficacy. VR music therapy also has important implications in educational settings and at the cultural and social levels. While these results are encouraging, they remain limited, including reliance on small-scale pilot studies and insufficient validation of long-term effects. Future research should prioritize large-scale longitudinal studies.

**Keywords:** VR music therapy, immersive experience, interaction mechanism, psychological effects, cross-domain applications

## **1. Introduction**

With the deepening of globalization and digitalization, mental health issues have gradually become an important issue in the field of public health. According to statistics from the World Health Organization, more than 1 billion people worldwide suffer from mental health problems such as depression and anxiety, among which depression is one of the most common mental disorders. This not only affects the mental health of individuals, but also places a heavy burden on society and the medical system [1]. In this context, exploring the combination of emerging technologies and music therapy has become a common focus of academia and industry. As an interdisciplinary intervention method, music therapy has long been widely used to alleviate anxiety, depression and stress management in daily life and work. A large number of studies have shown that music can regulate an individual's emotional state and improve physical and mental health through its unique rhythm,

melody and emotional color [2]. At the same time, the rapid development of virtual reality (VR) technology has provided new development opportunities for music therapy. VR is highly immersive and interactive, and can create a multi-sensory experience beyond the real environment, allowing individuals to participate more deeply and feel the healing effect of music in an immersive situation. The application scenarios of VR-based music therapy are constantly expanding, and have gone beyond the traditional clinical rehabilitation field and extended to education, corporate training, public health and other fields. However, current research primarily focuses on the advantages of VR technology in providing immersive experiences and short-term emotional relief. However, there is a lack of systematic exploration of how musical elements in VR environments influence individual emotional regulation and psychological experience through rhythm, melody, and interactive mechanisms. Therefore, this article aims to explore the relationship between the interactive mechanisms and psychological effects of immersive VR music therapy through theoretical analysis and practical application. Furthermore, this article will analyze the potential value of immersive VR music therapy in promoting emotional well-being and cognitive regulation.

## 2. Theoretical framework

The effectiveness of immersive VR music therapy can be systematically explained through the theoretical framework of "interaction mechanism - immersive experience - psychological effects (figure 1)." This framework demonstrates how VR music therapy functions through three interconnected dimensions. The interaction mechanism allows users to actively engage with music via gestures, motion feedback, and co-creation, which shapes their sense of participation. These interactions strengthen the immersive experience, fostering presence, multisensory engagement, and flow states. Ultimately, these immersive processes lead to psychological effects, including emotional regulation, enhanced attention, self-efficacy, and overall mental well-being. Building on this chain of influence, the present study constructs its analytical model around three theoretical pillars: Interactivity Theory, Presence Theory, and Flow Theory, which together provide a robust foundation for explaining the mechanisms and outcomes of VR music therapy.

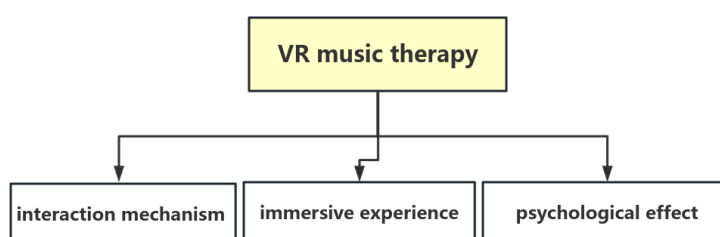


Figure 1. The theoretical framework of VR music therapy

First, the interaction mechanism theory provides a basis for understanding the participation mode in VR music therapy. Rafaeli was the first to systematically propose the concept of "interactivity" in the field of communication studies, defining it as the degree to which subsequent information depends on previous information during the information exchange process [3]. In other words, the information exchange in the interaction process is context-related and responsive, and the feedback of the participants will directly affect the generation and meaning construction of subsequent information. In VR music therapy, the interaction mechanism is reflected in the diverse interactions between users and the virtual music environment, such as playing virtual instruments through

gestures, changing the rhythm of music with body movements, or participating in a virtual ensemble. These interaction methods determine the individual's initiative and sense of control in the healing scene, thereby enhancing their participation and laying the foundation for positive emotional transformation.

Second, immersion and presence are key features of VR [4]. Presence emphasizes the feeling of being "inside" the individual in the virtual space, while immersion is closely related to the richness of sensory channels, the immediacy of system response, and the naturalness of interaction. In the VR music therapy process, the melody and rhythm of the music, combined with the visual, auditory and tactile elements in the virtual environment, can significantly enhance the immersive experience, making it easier for users to escape from the stress and anxiety of reality and gain a stronger emotional resonance and psychological stability.

Finally, the flow theory provides important support for explaining the transformation between immersive experience and psychological effects. Csikszentmihalyi proposed that flow is an optimal psychological state of high concentration and pleasure that occurs when an individual's skills and challenges are balanced [5]. As a natural tool for emotional regulation and attention guidance, music is more likely to induce a flow experience in the immersive and interactive environment created by VR technology. This deep involvement can not only immediately relieve negative emotions such as anxiety and depression, but may also improve an individual's sense of self-efficacy and psychological resilience in the long term.

### 3. Cross-domain comparison

As a universal medium for emotional and cognitive regulation, music supported by virtual reality technology is expanding its therapeutic applications beyond psychotherapy into diverse fields such as healthcare, education, and culture.

#### 3.1. Exploring VR music therapy in healthcare

In the field of healthcare, music therapy, as a non-drug intervention method that combines scientific evidence and artistic expression, is gradually receiving widespread attention and application worldwide. Studies have shown that music, with its unique characteristics of melody, rhythm and harmony, can stimulate individuals' positive emotional experiences and show significant results in relieving anxiety, depression symptoms and reducing chronic pain [5]. In pediatric medical environments, music therapy and other music-based interventions have been proven to be not only safe and feasible, but also widely accepted and welcomed by children and families [5]. Through interaction with music, children can effectively divert their attention from physical discomfort and medical stress, thereby promoting the recovery process and improving the overall quality of life.

In this context, the introduction of VR technology provides a more immersive and interactive environment for music therapy, further strengthening the role of music in emotional and cognitive regulation[6]. For example, a single-group pilot study conducted at a US hospital involved hospice patients, guided by a music therapist, creating customized music playlists and immersing themselves in a natural virtual reality environment. Results showed a significant reduction in overall symptom distress (ESAS-r total score) (effect size  $d = 0.68$ ), with moderate improvements in both physical discomfort ( $d = 0.52$ ) and psychological distress ( $d = 0.60$ ). Furthermore, there were small improvements in quality of life (MQOL-r total score) and sense of presence[7]. Importantly, VR music therapy not only improved patients' physical and mental well-being but also fostered deeper and more meaningful communication between doctors and patients. This suggests that the

combination of VR technology and music therapy can not only enhance the effectiveness of traditional psychotherapy interventions but also open up new applications in healthcare, providing more comprehensive physical and mental care for patients.

### **3.2. The application of VR music therapy in learning and mental health support**

In the field of education and cognitive training, music therapy is increasingly recognized as a powerful tool to support children's emotional regulation, cognitive development, and social engagement. Music, with its rhythmic and melodic structure, can stimulate neural pathways related to memory, attention, and executive function, thereby enhancing learning readiness and resilience. This is particularly important for children and adolescents facing challenges such as anxiety, stress, or attention deficit hyperactivity disorder (ADHD), as these disorders are closely related to difficulties in maintaining attention and regulating behavior. Based on Piaget's theory of cognitive development, music therapy in a VR environment provides opportunities for active exploration and experiential learning, which is crucial for children in the preoperational and concrete operational stages [8]. Through hands-on musical interaction, children interact with sounds, rhythms, and symbols in meaningful contexts to construct knowledge, which is consistent with Piaget's view that learning occurs through active manipulation and mental reorganization [8]. In addition, the structured and fun nature of VR music creation can support cognitive processes such as classification, sorting, and problem solving, while also providing a safe environment for emotional expression.

In terms of mental health support, music therapy has been shown to have positive effects on alleviating anxiety, enhancing self-regulation, and improving learning motivation. It is worth noting that the incidence of attention deficit/hyperactivity disorder (ADHD) among children and adolescents has been increasing in recent years. This group often faces challenges in maintaining attention, time perception, executive function, and social interaction. Studies have shown that active music therapy (such as virtual instrument playing and rhythm imitation) can help improve the attention and self-control of children with ADHD, while passive music therapy (such as music listening) has shown positive effects in reducing anxiety and improving reading and arithmetic performance [9]. VR technology has brought new opportunities for the application of music therapy in education and cognitive training. By combining virtual or augmented reality environments with music, educators can create immersive and interactive learning scenarios for students. For example, studies have shown that embedding music therapy strategies into VR games can provide multimodal intervention experiences for students with ADHD: children interact with rhythm and movement in a virtual environment, which not only improves attention and time perception, but also improves impulse control and learning adaptability [10]. Similar VR music games are used in classrooms and rehabilitation training to create a fun and safe learning atmosphere for students, helping them to enter the flow state more easily and enhance their learning engagement and mental health [10]. Compared with traditional music therapy, VR can provide an immersive, multi-sensory learning and experience space, allowing learners to not only passively accept music stimulation as listeners, but also directly influence the rhythm and expression of music through motion capture and interactive operations. Immersive VR music therapy can more effectively stimulate students' participation, improve their concentration, and make it easier for them to enter the flow state during the interaction.

### 3.3. The application of VR music therapy cultural and social applications

At the cultural and social levels, immersive VR music therapy demonstrates unique public value and cultural significance. In practical applications, music-focused virtual therapy formats, such as immersive VR concerts and digital music art exhibitions, are rapidly emerging. In these experiences, audiences wear VR headsets to enter a virtual music and art environment, enabling not only a highly immersive sensory experience but also the opportunity to create and interact with music, achieving a "viewing-participating-co-creation" process. For example, a study evaluated and analyzed audience feedback from immersive music therapy exhibitions. During one live performance, researchers asked 110 audience members to complete a questionnaire, systematically analyzing their responses across dimensions such as "motivation for viewing," "emotional experience," and "performance evaluation." The results showed that individual backgrounds significantly influenced audience motivation and satisfaction, while immersive music therapy exhibitions generally enhanced participants' emotional experience and sense of cultural identity [11]. This case demonstrates that VR music therapy not only meets individual psychological needs but also fosters stronger emotional resonance and community cohesion within public cultural activities.

Furthermore, the application of immersive music therapy in public spaces also demonstrates positive social value. VR music therapy installations can also be installed in libraries, community centers, or public squares, allowing the public to easily access music therapy in their daily lives, alleviating the stress and loneliness associated with city life. These public healing spaces not only enhance individual mental health but also foster communication and build social support networks among community members. Furthermore, immersive music therapy exhibitions and metaverse music experiences provide platforms for communication and co-creation among groups from diverse cultural backgrounds, promoting cross-cultural understanding and social integration.

## 4. Discussion

While immersive VR music therapy shows promising application prospects in various fields, it still faces numerous challenges in its practical development. First, the high hardware cost of VR devices makes them difficult to widely adopt in medical institutions, schools, or public spaces. Furthermore, prolonged use of the devices can cause visual fatigue, dizziness, and physical discomfort, requiring the supervision and guidance of relevant professionals. This makes widespread public adoption even more unlikely. Additionally, significant individual differences exist across age groups in their adaptability to VR effects and musical perception. Therefore, designing VR music therapy content that is universally accessible, personalized, and adaptable to address the experiences and needs of diverse populations remains a key research topic.

Another crucial issue is ethical and privacy concerns. Because the therapy process often relies on physiological monitoring and emotion recognition technology, users' heart rate, EEG, facial expressions, and behavioral data may be continuously recorded and analyzed. Without transparent data management and security mechanisms, this sensitive information could be at risk of misuse or leakage. Also, the intense immersion of VR can weaken users' perception of the boundary between virtual and real life, potentially leading to dependency or a sense of loss after withdrawal in psychologically vulnerable individuals. Especially when targeting children or those with mental health issues, ensuring informed consent, safe use, and appropriate exposure to prevent new psychological risks are urgently needed ethical guidelines. Besides, in virtual performances or public healing spaces, participants' interactive data, expressions, and behaviors may be recorded by the

platform. However, relevant regulations and policies are currently incomplete, posing significant risks to participants.

## 5. Conclusion

In conclusion, this study explored the potential applications of immersive VR music therapy in healthcare, education, and cultural and social fields, highlighting its value as an interdisciplinary intervention. The study found that VR music therapy not only improves emotional regulation and alleviates anxiety and depression symptoms at the individual level, but also promotes cognitive development and learning motivation. Furthermore, this study proposed a theoretical framework of "interaction mechanism-immersive experience-psychological effect." Through applied analysis, this study found that immersive VR environments can amplify the therapeutic effects of music, transforming individuals from passive listeners to active participants, thereby gaining deeper psychological comfort and self-efficacy. At the public level, immersive VR music therapy, through virtual concerts, digital exhibitions, and shared healing spaces, demonstrates its unique significance in promoting cross-cultural communication and enhancing social cohesion.

However, this study also has some limitations. The relevant empirical studies referenced in this study primarily focused on small-scale or pilot projects, lacking systematic validation of long-term effects and large population samples. Future research should conduct large-scale, long-term studies to systematically evaluate the sustained effectiveness and applicability of VR music therapy in diverse populations.

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