RESEARCH ARTICLE

Enhancement of music therapy effects based on virtual reality and big data analysis

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Mental health problems are becoming more common among college students. Meanwhile, traditional music therapy has shown problems. The therapeutic outcomes can vary a lot from person to person, and the therapy does not allow people to fully immerse themselves in it. The development of virtual reality (VR) technology and big data analysis has created new opportunities to improve the intervention effects of music therapy. This study explored how VR-based music therapy could improve the mental health of college students, while combined with big data analysis to understand how music features were linked to improvements in mental health. A comparative experiment was designed based on the psychological evaluation system of college students with 500 typical psychological cases. A total of 100 college students were recruited and assigned to an experimental group receiving music therapy based on VR or a control group receiving traditional music therapy for six weeks. The participants went through initial psychological assessment, intervention implementation, and re-reassessment. Multidimensional data were collected for curative effect evaluation. The results showed that the improvement of scores of anxiety and depression in the VR group were significantly higher than those in the control group. The anxiety index of the VR and control groups dropped by 22.8 and 12.5 points on average, while the depression index decreased by 19.8 and 11.3 points in the VR and control groups, respectively. The emotional improvement rate of the VR group was 40%, while the control group only reached 22% ($P < 0.05$). 48% of the VR group showed "very satisfied", which was higher than the 22% in the control group. It was found that the light music and natural sound effects were the most helpful in reducing anxiety. These findings indicated that VR-based music therapy offered clear advantages in college student mental health intervention and provided data support and a technical framework for the development of precision and intelligent mental health services.

Keywords: big data analysis; music therapy; mental health; virtual reality.

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Introduction

In recent years, with the accelerating pace of social development and the mounting pressure regarding academics and employment, mental health issues among college students have become increasingly prominent [1, 2]. Psychological disorders such as anxiety, depression, and excessive stress are highly prevalent in this population and have become major factors impairing learning efficiency, quality of life, and long-term development [3, 4]. Traditional psychological interventions including individual counseling, group guidance, and pharmacotherapy can be effective to a certain degree. But they are not easy to access, and they don't give personalized support, which means that their overall intervention outcomes are

limited [5, 6]. So, it is needed to find more efficient, immersive, and individualized methods to improve mental health support [7, 8].

As a non-pharmacological intervention, music therapy has attracted more and more attention in the field of mental health education because it can positively affect the psychological state *via* melody, rhythm, and emotional resonance [9-11]. Liu *et al*. showed that music therapy made college students' emotional states feel much better and helped them learn more about regulating their mental health [12]. Hu *et al*. also showed that music intervention could help college students with academic stress and sleep problems [13]. But most previous studies used traditional music playback methods and did not include environmental design and immersive experiences. The results of the intervention were very different for each person and did not last very long. In recent years, virtual reality (VR) technology has started to be used in mental health research and has shown some clear benefits. Hoşgelen *et al*. pointed out that the immersive and interactive nature of VR made psychological intervention go beyond isolated language or auditory stimuli and enhanced the intervention effect *via* multi-sensory experience [14]. Spytska used VR to treat anxiety, phobias, and attention disorders [15]. To markedly enhance the immersion and emotional adjustment in music therapy, Impellizzeri and Maggio further proposed that music and VR environments should be combined. Meanwhile, using big data analysis (BDA) led to a new research direction into mental health [16]. Other scientists emphasized that collecting and analyzing large-scale psychological assessment data could find out common features of group psychological states and patterns of individual differences, which could help to furnish theoretical support and develop personalized interventions [17, 18]. Existing studies have shown that music therapy, big data technology, or VR each has its own value in psychological treatment. However, combining these three approaches together still has many limitations. The combination of VR and music therapy does not have a clear set of rules or enough proof that it works. BDA hasn't been used much in music therapy yet, and it still needs more research to see how well personalized recommendation mechanisms work. Most current research is at the stage of small-sample laboratory experiments or algorithm-level validation. The lack of research based on real-world, large-scale psychological databases also limits how widely these intervention outcomes can be applied in real life [19–21].

This study explored how to improve VR-based music therapy for mental health intervention problems among college students and assessed how well different types of music could help people and how they could be used to improve mental health. The study used a psychological assessment system to handle college students' mental health problems with an integrated music therapy module. VR technology was introduced to expand and upgrade the music therapy module, thus forming a music therapy system based on VR. BDA methods were employed to find links between musical features and improvements in people's mental health. The results of this study provided a feasible technical model, experience reference, and practical and scientific support for mental health education and intervention in colleges and universities

Materials and methods

Research platform and system description

This study employed a self-developed psychological assessment system that relied on a comprehensive, large-scale database and was primarily used to monitor and track the mental health status of college students. The database covered lots of mental health problems including anxiety, depression, academic stress, and emotional disorders. A VR-based music therapy system was further developed serving as a key extension and application module of the assessment framework, thereby establishing a closed loop between assessment and intervention. The psychological assessment

system carried out data collection and abnormal screening, while the VR-based music therapy system paid attention to the intervention practice by providing the students marked *via* the screening process with an immersive music therapy experience. The psychological assessment system first tested the psychological state of college students using standard instruments and scales. The results were then stored in the database. The system then automatically identified any abnormal results and flagged them for further attention. Based on these screening outcomes, the system activated the music recommendation module. To make each student have a tailor-made intervention plan, psychological cases were combined with musical attributes *via* large-scale data analysis. Also, the VR-based music therapy system was taken as an interventional tool. To create an immersive music scene, participants received passive music stimulation and got a multi-sensory experience in a virtual environment *via* VR technology, which could help them relax and feel better. This design combined psychological assessment and intervention in a natural way. The system worked in a cycle of assessment – screening – recommendation – intervention – reassessment. The participant's psychological state was first assessed. The results of this assessment were analyzed automatically. Any problems that were identified were noted. When students needed help, the system gave them personalized music recommendations and helped them *via* the therapeutic process in a VR environment. When the therapy was finished, the information and feedback were sent back to the psychological database, which helped improve and optimize the model. Through this closed-loop mechanism, the platform was able to rapidly and effectively provide appropriate psychological interventions for college students. Meanwhile, it continuously optimized its database and recommendation engine, building a self-improving system.

Research subjects and samples

The sample data of this study came from the Psychological Assessment Database of China College Students, independently established by the 2024 university-level scientific and technological innovation team of Hebi Polytechnic (Hebi, Henan, China). The database contained 500 typical psychological cases covering different psychological conditions of anxiety, depression, and stress with 240 males (48%), 260 females (52%), and age range from 18 to 25 with average age of 20.5 ± 1.8 years old. The data was collected between September 2023 and June 2025. All cases were evaluated using the same psychological scales. The database also held basic information about the age and any previous interventions of the participants. The samples were classified according to the types of psychological states to analyze the intervention effects of the VR-based music therapy system in different psychological conditions. The numbers of anxiety, depression, and stress cases were 200, 175, 125 cases accounting for about 40%, 35%, 25%, respectively. The comprehensive characterization of college students' psychological state was realized *via* the statistical processing and organization of database samples. All procedures of this research were approved by the Hebi Vocational Ethics Committee (Hebi, Henan, China).

Experimental design

A total of 100 college students from Hebi Polytechnic (Hebi, Henan, China) during March 2024 to May 2024 were recruited for this study with 48 males (48%), 52 females (52%), aged from 18 to 25 with the mean age of 20.3 ± 1.6 years old. No personally identifiable information was collected. All data was completely anonymous. A test based on preliminary screening using psychological scales was conducted to assess the participants' levels of anxiety, depression, or stress before they were divided into an experimental group and a control group with 50 people in each group. The experimental group received music therapy intervention based on VR, while the control group underwent conventional music therapy with three 30 minutes sessions per week for totally 6 weeks. Before each session, the system performed a brief state assessment to make sure

that the participants were in a good state for music therapy by using self-rating anxiety scale (SAS) (https://cmee.csu.edu.cn/xsgz/info/1042/1268.htm) and self-rating depression scale (SDS) (https://cmee.csu.edu.cn/xsgz/info/1042/1267.htm). The evaluation process was carried out in a quiet room. Each participant completed the two scales on their own following standardized instructions. SAS included 20 items with 4-point scale to evaluate the frequency and severity of anxiety symptoms with 1 for none or very little time, 2 for some time, 3 for a considerable amount of the time, and 4 for most or all the time. SDS also contained 20 items with the same 4-point rating system to assess the frequency and intensity of depressive symptoms. The response options were defined as A for none of the time, B for some time, C for a considerable amount of the time, and D for most or all the time. Participants were classified as "anxiety type" when the standardized SAS score obtained by multiplying 1.25 with raw score reached or exceeded 50 or as "depression type" when the standardized SDS score obtained by multiplying 1.25 with raw score reached or exceeded 53. When both SAS ≥ 50 and SDS ≥ 53 were met simultaneously, participants were classified as "stress type", which meant that anxiety and depression could happen at the same time and often cause by high levels of stress. The Chinese versions of these scales were reliable and validated in previous studies involving Chinese college students with Cronbach's alpha coefficients for SAS and SDS as 0.86 and 0.88, respectively. The study also used a subjective emotional experience questionnaire to understand participant's short-term emotional fluctuations and subjective feelings. This questionnaire used a 5-point scale with 1 for very negative and 5 for very positive. It covered four aspects including relaxation level, sense of immersion, pleasure level, and music preference to make sure that the immediate psychological effects could be recorded when VR scenes and music were mixed. Resting heart rate and heart rate changes during the intervention were also collected *via* heart rate monitoring equipment and were used as objective indices of psychological stress level and degree of relaxation. The psychological assessment system automatically collected and stored all assessment data and created individual psychological profiles, which made it easy to compare different intervention effects and to find new information. During the intervention, the participants in experimental group received the immersive music therapy provided by the music therapy system based on VR. The scene content included natural environments, meditation spaces, and virtual art landscapes. Each of them was combined with personalized music recommendation plans. The control group received conventional music therapy and played the same type of music *via* a standard audio player without virtual environments or interactive experiences. During the whole intervention process, the system synchronously recorded the user's operational behavior data, subjective feedback, and music preference. After the intervention, all participants completed the same psychological assessment again to compare the differences before and after the intervention. BDA methods were used to explore the links between musical features and psychological improvement. Meanwhile, the system recorded operational logs about the treatment and the participant's reactions, which provided a lot of information for the analysis of the treatment's effect.

Data analysis

This study used a multi-level data analysis framework that integrated traditional statistical analysis and BDA. All analyses were conducted using Python (version 3.9) (Python Software Foundation, Beaverton, OR, USA) and its associated libraries including scikit-learn (version 1.0.2), pandas (version 1.4.0), and statsmodels (version 0.13.5). Analysis of variance was applied to compare differences in key psychological indicators between experimental and control groups before and after the intervention. Regression analysis was used to understand the relationship between intervention-related factors such as intervention duration and degree of immersive experience and the extent of psychological improvement. k-means clustering

was carried out using scikit-learn library (version 1.0.2) (https://scikit-learn.org) to categorize student psychological states and identify latent groups with distinct psychological characteristics. The optimal number of clusters was determined using the elbow method based on the within-cluster sum of squares with the value of k being set to 3. In addition, TextBlob library (version 0.17.1) (https://textblob.readthedocs.io) was used for sentiment analysis to analyze the emotional tendency of subjective questionnaires and text feedback of system logs. Each text response was assigned a polarity score ranging from -1 (strongly negative) to +1 (strongly positive). These scores were aggregated to calculate the average emotional tendency of each participant. Association rule mining was carried out using the Apriori algorithm implemented in the mlxtend library (version 0.21.0) (http://rasbt.github.io/mlxtend) to explore the potential associations between music therapy schemes and psychological improvement outcomes. The minimum support and confidence thresholds were set to 0.3 and 0.6, respectively. The resulting rules were written as {music features} → {psychological improvement outcomes}. Support and confidence were used to evaluate the strength of each association. Four main indicators of anxiety index, emotional improvement rate, depression index, and user satisfaction were employed to assess efficacy. The anxiety and depression indices came from standard psychological scales. The results of psychological tests and questionnaires were used to calculate the emotional improvement rate, which were given to people before and after the intervention. Users were asked to give feedback in a questionnaire after they had used the service. These indicators showed the effects of the VR-based music therapy system in different ways.

Results and discussion

Comparison of overall therapeutic effects between VR-based and conventional music therapy

To compare the differences between the experimental and control groups, three core indicators of improvement in anxiety index, reduction in depression index, and emotional improvement rate were examined. The results showed that the experimental group was obviously superior to the control group in all three key indicators with the anxiety improved by 35%, more than 15% of the control group. The results indicated that the immersive VR environment could reduce anxiety very well. The same pattern was observed at depression reduction. The experimental group had a bigger improvement of 14% than that in the control group. In terms of emotional improvement, the experimental group almost doubled the progress compared to the control group (Figure 1). These findings demonstrated that VR-based music therapy was better than conventional music therapy, and immersive technology could get around the problems of the conventional ways of stimulating senses and shaping environments. Through multi-channel sensory input including vision, auditory, and interaction, the VR scene made participants immerse themselves in the atmosphere of music creation and blocked external interference faster, thus amplifying the effect of psychotherapy. These results also gave data-driven verification for the effectiveness and necessity of music therapy based on VR as a new intervention method.

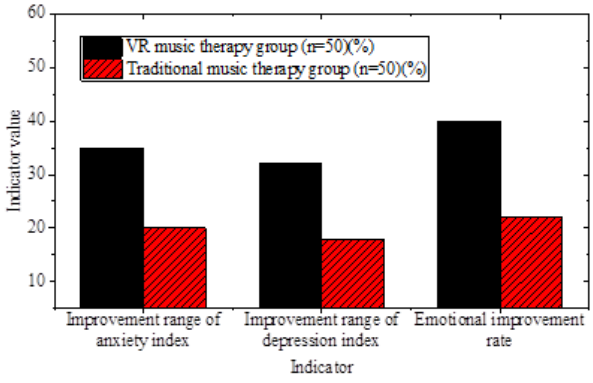

Figure 1. Comparison of therapeutic effects between the two groups.

Variations in anxiety and depression indices

The results showed that experimental group demonstrated big differences on anxiety and depression before and after intervention. After intervention, the experimental group showed much less anxiety than those in the control group with an average reduction of anxiety by 22.8%, which was almost twice the reduction of 12.5% in the control group. The results indicated that VR could be used to help people feel less anxious when it came to regulating their heart rate and reducing tension. There was a similar downward trend in the depression index. The experimental group showed 8.5% more reduction in depression than control group (Figure 2). Conventional music therapy primarily operated through the auditory channel. In contrast, VR-based music therapy helped individuals focus on shifting their attention and experiencing emotions by creating an experience of "total immersion" in a specific emotional atmosphere. The natural landscapes, colors, and environmental sounds in the VR system could help individuals with depression stop thinking in a negative way and start feeling relaxed and positive more quickly.

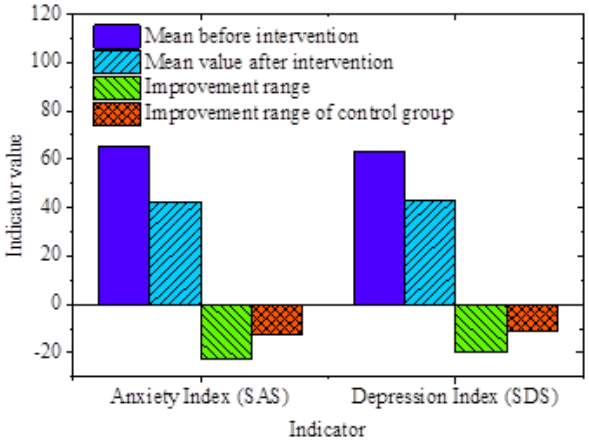

Figure 2. Statistics on changes in anxiety and depression indices.

Comparison of user satisfaction

Therapeutic effects were reflected in both quantitative indicators and subjective experiences. To investigate the satisfaction of two groups with the music therapy process, this study used a questionnaire survey. The results showed that college students liked VR-based music therapy more than conventional music therapy. In the experimental group, 48% of participants selected "very satisfied", which was twice as many as the control group. Notably, 26% of participants in the control group rated their experience as "average". However, only 12% of participants in the experimental group said the same (Figure 3). The study found that the potential reasons for the participant's high satisfaction in the VR group might be because of interactivity and immersion, personalized recommendation mechanism, and novelty and engagement. The interactivity and immersion were generated by the VR system that made the experience better by letting participants see and touch, so they could move beyond passive listening and "enter" the music scene. Personalized recommendation mechanism was that the system provided music programs that were designed to suit everyone's personality to make the positive effects of therapy even stronger. Novelty and engagement included that VR technology made psychological interventions more advanced and interesting, which made participants more likely willing to attend. VR technology demonstrated real advantages compared to conventional methods and should be promoted.

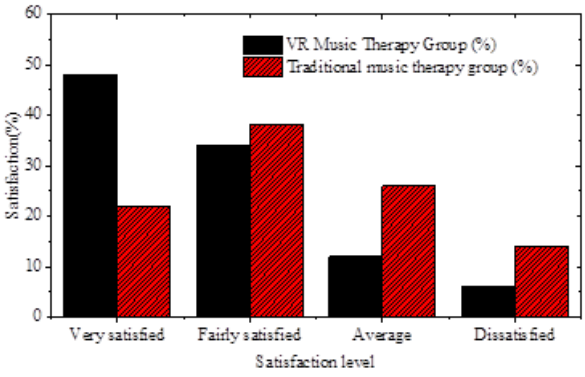

Figure 3. Comparison of user satisfaction.

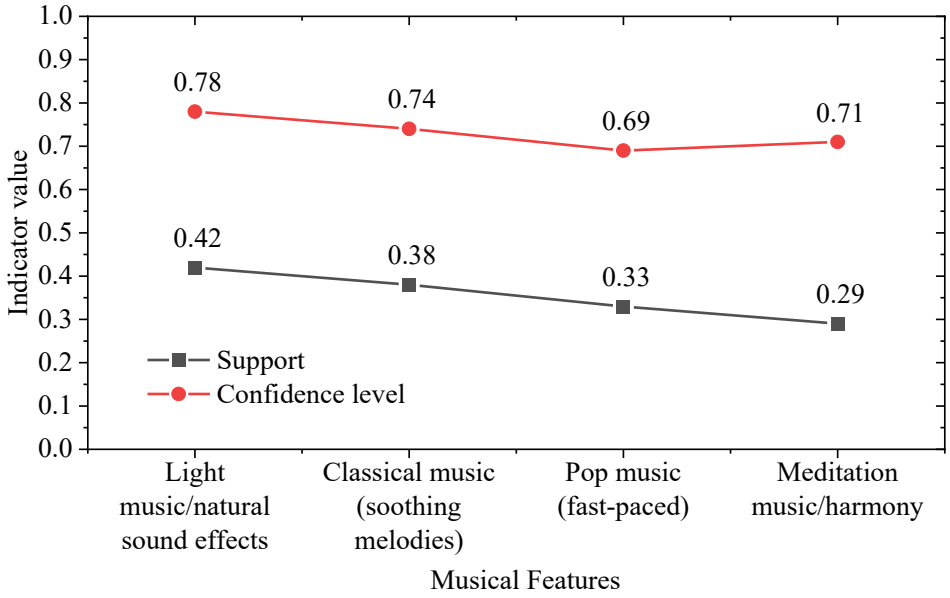

Figure 4. Association rules between psychological improvement and music features.

Association rules between music features and psychological improvement

The database cluster analysis and association rule mining for the possible connection between different music features and psychological improvement demonstrated that there was a systematic relationship between musical features and psychological improvement. Light music and natural sound effects were the best at reducing anxiety symptoms. This effect might be linked to the slow tempo of light music, and the natural auditory elements like birdsong and flowing water made people feel relaxed, which could reduce stress by lowering cortisol levels and heart rate. The results indicated that classical music, particularly pieces with soothing melodies and stable harmonies, helped alleviate symptoms of depression and enable participants to break free from negative thoughts. This finding aligned with other studies on classical music. Pop music with a fast rhythm was better at reducing academic stress and fatigue. However, its effectiveness in alleviating anxiety and depression was not particularly significant, which might be due to its strong sense of rhythm and highly stimulating content. Music like meditation and harmony could help with both anxiety and depression with moderate to large improvements. This type of music was usually described as having low frequencies and a slow rhythm, which made it good for helping people to manage their emotions and for use in psychology (Figure 4). The identified association rules proved that the personalized recommendation mechanism was effective. Various mental health problems needed different music therapy programs. In future study, VR systems might use real-time emotion recognition to change music and immersive scenes to suit each individual, which could achieve more precise and adaptive interventions.

Conclusion

This study demonstrated that music therapy using VR was much better at reducing anxiety and depression in college students than normal music therapy. VR-based therapies not only enhanced emotional experiences but also boosted well-being, demonstrating the critical importance of employing fully immersive, multisensory experiences in psychological interventions. BDA showed that different types of music could improve different aspects of mental health. However, there were still some

problems, which were that all samples in this study came from a single university, so the results might not be representative of the wider situation. The period of intervention was only six weeks, which made it hard to know for sure whether the treatment was effective in the long run. Also, the current VR system mainly relied on visual and auditory channels. It needed to integrate multimodal interaction methods such as tactile feedback or electroencephalogram (EEG) signal monitoring. Future research should include a wider range of universities and regions to make the results more representative and practical. Making the expectation longer and adding a follow-up evaluation process also helps to check the effect of music therapy using VR in the long term.

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