Music therapy and its impact on anxiety and mental well-being of Chinese students: An experimental comparison of traditional and VR approaches

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A B S T R A C T

The incorporation of advanced technologies into music therapy can potentially benefit many therapeutic approaches. This study aims to examine the effectiveness of music therapy, conventional and VR-enhanced, in improving graduate students' mental well-being and reducing their anxiety level. The study involved 270 fourth-year undergraduate students from three universities in China. Using the Chinese versions of the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS) and the Test Anxiety Scale (TAS), the study found that the control group experienced the worsening of mental well-being and higher anxiety when compared to baseline, with the mean differences of 2.62 and 2.60 points, respectively. The conventional music therapy group exhibited an improvement in mental well-being of 3.81 points, whereas their anxiety level decreased by 3.53 points. The effects of the intervention were even more pronounced in the VR-MT group, with an increase in the WEMWBS score of 7.48 points and a decrease in the anxiety score of 6.36 points. The results provided strong evidence of significant differences between the three conditions ($p < 0.001$). This study provides empirical evidence that VR-enhanced music therapy is a more effective method for reducing anxiety and improving mental health than the conventional approach.

1. Introduction

Music therapy is a widely used approach to introduce changes and improve the emotional, physical, social and cognitive well-being of individuals (Sharma, 2022). Over the past decades, interest in music therapy has increased, supported by modern technologies that create new opportunities in music psychology and therapeutic approaches, increasing their significance and effectiveness (Knott & Block, 2020; Li et al., 2021; Quigley & MacDonald, 2024). Historical analysis illustrates that music has been used as a powerful tool to manage and express emotions appropriately and influence the mind (Morgan & Marroquín, 2024). In the modern world, individuals may experience stress, anxiety, apathy, and depression, especially young individuals and students experiencing pressure from their inner self and society. In this way, music therapy is the method to overcome these unfavourable psychological states (Hwang, 2023; Scrine, 2021). Thus, technological innovations, such as virtual reality, expand the traditional approach of music therapy, making it adaptable to the unique needs of each individual (Bellinger et al., 2023; Chirico et al., 2020; Estrella-Juarez et al., 2023). Traditional methods of music therapy are listening to music, live

performance, and active participation in music sessions (Barnish & Barran, 2020).

Nonetheless, the methods mentioned above can go hand in hand with new interactive tools, such as virtual reality, to create immersive musical environments. These approaches aim to ensure deep immersion of individuals into music therapy and the assessment of the expected consequences (Bauer et al., 2023). Students experience stress and anxiety as a result of high expectations, an intensive academic curriculum, social pressure, and personal psychological problems that can significantly worsen their mental health conditions (Asif et al., 2020). Previous research reveals that music therapy can reduce anxiety and improve emotional well-being (Lu et al., 2021; Situmorang, 2021). Music exercises, listening to relaxing music, and special practices help students cope with emotional stress and achieve inner balance (Liu & Li, 2023). Similar to the approach described above, the present research suggests that the integration of technologies in music therapy develops new perspectives for research in music psychology and related fields of knowledge (Rodgers-Melnick et al., 2024).

In this context, music therapy is understood as a structured intervention based on the use of musical activities—listening, performing,

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improvising, and creating music—to support psycho-emotional well-being and regulate anxiety. Although music therapy is traditionally applied in clinical practice for individuals with mental or neurological disorders, it is here considered a tool for psychological support for university students. The scientific and practical significance of the present research is to collect empirical data on the effectiveness of conventional music therapy based on modern technologies aimed to improve well-being and reduce anxiety among students. The results are important for psychologists and psychotherapists working with young individuals. The proposed approaches are also important for the development of new mental health support programmes in educational institutions. At the same time, the collected data can be the core base for further scientific research of music psychology and therapeutic practices introduced by music psychotherapists. The proposed strategies' implementation can lead to the development of a favorable learning environment that reduces students' anxiety and improves their well-being. The key areas of the research application are education, psychotherapy, and other fields of scientific research related to the spheres discussed above.

1.1. Literature review

Music therapy, as a part of music psychology, implies the use of music and its elements to improve human health conditions (Bressan & Sironi, 2023). The scientists single out *the active forms* of music such as singing, playing musical instruments, and music making, and *the receptive forms* such as listening to musical compositions, their perception and emotional responses (Hakvoort & Tönjes, 2023). The key to music therapy is to use musical elements to help individuals express emotions, reduce anxiety, relieve stress, and improve mood and well-being (Liao et al., 2023). Music therapy was introduced by scientists and practitioners and became popular in the 21st century. Music therapy is based on the principle of treatment used in therapeutic practice and its ability to evoke emotional responses (Brancatisano et al., 2020; Hakvoort & Tönjes, 2023). For instance, music affects the physiological state of individuals by reducing the stress hormone cortisol (Hasanah & Haikal, 2022). Also, music can stabilise the heart rate (Mojtabavi et al., 2020). Music therapy has been shown to be effective in improving cognitive functions (Zhang, 2020), strengthening interpersonal connections, and promoting the development of social skills (Blanky-Voronov & Gilboa, 2022). It comes in many different forms (De Witte et al., 2022). The theory of music synesthesia explains how music can be linked to certain images and feelings, causing synesthetic responses (Hu, 2020). The theory of neuroplasticity states that music causes changes in the brain and stimulates its functions, promoting the improvement of cognitive function and emotional well-being (Kaczmarek, 2020).

In addition to traditional methods of music therapy, alternative approaches have emerged in recent years that significantly expand the therapeutic potential of music. Neurological music therapy (NMT) is one such approach that uses rhythm and melody to stimulate specific areas of the brain, promoting the restoration of cognitive and motor functions in patients with neurological disorders and post-stroke conditions (Gu et al., 2024). Unlike classical music therapy, which primarily focuses on the emotional state of the patient, NMT is based on neuroplasticity and the mechanisms of the central nervous system (Wei & Qiao, 2024). Group music therapy is a method in which patients are encouraged to engage in collaborative musical interaction for therapeutic purposes (Feng et al., 2024). These sessions improve social skills, aid in the treatment of depression and anxiety disorders, and foster a sense of community and emotional support (Sun et al., 2021). Music-meditative therapy combines elements of musical stimulation and mindfulness practices, enabling patients to achieve a state of deep relaxation. This approach is used to reduce stress levels, improve sleep quality, and treat psychosomatic disorders (Bogatyrenko, 2024). With the development of technology, new approaches have emerged, such as interactive music therapy using biofeedback, which allows patients to control the sound

environment based on physiological parameters, such as heart rate (Sudha et al., 2025).

With the advent of technology, we can expand the reach of music therapy (Giordano et al., 2020). Virtual reality (VR) can provide patients complete immersion in a musical environment (Brungardt et al., 2021; Lin et al., 2020). This approach requires individuals to use VR headsets that create exposure environments that meet the goals of the therapy. The integration of VR into the practice of therapeutic treatment requires the development of VR-based scenarios by music therapists. The programme should combine different visuals and pieces of music adapted for specific therapeutic needs (Tamplin et al., 2020). These scenarios can be designed in a way that fulfills the unique needs of an individual, such as cognitive stimulation, stress reduction, or mood improvement (Kaimal et al., 2020). With the help of VR headsets, people not only distract themselves from stress-inducing factors and focus on positive sensory experiences but also engage with music and its visual elements (Best et al., 2022). In some VR scenarios, individuals can participate directly in the musical process, for example, through music writing or by playing virtual instruments (Van Kerrebroeck et al., 2021). This may be particularly beneficial to people with special emotional or psychological needs who suffer from stress overload, high anxiety, and impaired interpersonal connections (Lu et al., 2021; Pedersen et al., 2022; Situmorang, 2021). Music therapy can be improved through the addition of VR elements that allow creation of adaptive, personalized environments (Byrns et al., 2020).

Mental well-being is a multifaceted construct that encompasses emotional, cognitive, and social health, which contribute to an individual's adaptation to stressors and enhance quality of life (Marsh et al., 2020). According to Carol Ryff's model of psychological well-being, its key components include autonomy, self-acceptance, personal growth, positive relationships with others, environmental mastery, and purpose in life (Mahmoudi et al., 2022). In the academic environment, the level of mental well-being plays a crucial role, as it affects students' ability to cope with academic demands, maintain motivation, and manage stress (Yangdon et al., 2021). Some researchers suggest that high levels of well-being can strengthen interpersonal relationships and improve one's coping abilities (Morales-Rodríguez et al., 2020; Shuo et al., 2022). One of the most common factors negatively impacting mental well-being is anxiety (Glas, 2020). According to Beck's cognitive-behavioral theory of anxiety, it is formed as a result of automatic negative thoughts and irrational beliefs about potential threats (Al-Habies et al., 2024). In the academic environment, anxiety often manifests as exam anxiety, social anxiety, and chronic stress, which can impair cognitive functions and reduce concentration (Mofatteh, 2021). Physiologically, anxiety is associated with elevated cortisol levels, increased heart rate, and changes in the functioning of the prefrontal cortex, as confirmed by neurophysiological studies (Locatelli et al., 2022). Music therapy has long been regarded as an effective tool for regulating anxiety and improving mental well-being (Liao et al., 2023). According to the affective emotion regulation theory (Elfenbein, 2023), music helps reduce anxiety by activating the dopamine system and inhibiting the amygdala, leading to a reduction in physiological stress manifestations (De Witte et al., 2022). Music therapy influences the psycho-emotional state through several mechanisms: biological (stabilization of heart rate and reduction in cortisol levels), cognitive (distraction from negative thoughts), emotional (expression of suppressed emotions), and social (improvement of communication skills and formation of support within a group) (Hasanah & Haikal, 2022; Zhang, 2020). Integrating new technologies, such as virtual reality (VR), into music therapy expands its therapeutic potential. VR enables deeper engagement of the patient in the therapeutic process through multisensory stimulation, which enhances emotional responses and reduces anxiety more effectively than traditional methods (Giordano et al., 2020). Studies have shown that VR-enhanced music therapy is particularly effective in reducing anxiety in patients with autism spectrum disorders (Bauer et al., 2023; Chirico et al., 2020). It has been proven

that the virtual environment allows patients to focus on positive sensory experiences and distract from stressors, thereby promoting deeper relaxation (Best et al., 2022).

This study is grounded in the theoretical foundations outlined above and offers an empirical examination of the effectiveness of VR-enhanced music therapy within an academic context. Unlike most previous studies, which have examined the impact of VR and music therapy separately, this research explores their interaction and combined effect on anxiety levels and mental well-being among students. The novelty of this study lies in its focus on the academic environment, where high levels of anxiety represent a critical issue that affects academic performance and overall quality of life. Existing studies confirm the effectiveness of music therapy, primarily in clinical populations, but its impact on anxiety in students remains underexplored. Despite technological advancements, the role of VR-enhanced music therapy in reducing anxiety and improving mental well-being has not been adequately investigated. Most studies are correlational in nature and do not employ experimental designs, which complicates the establishment of causal relationships. This research addresses this gap by providing an experimental comparison of traditional and VR-enhanced music therapy among university students. The findings will help determine whether VR integration is a more effective tool for managing anxiety in the academic setting. The novelty of the study lies in the integration of VR-enhanced music therapy as a holistic tool capable of not only reducing anxiety but also fostering sustainable emotional regulation mechanisms. Unlike traditional approaches, the VR component creates a deeper level of sensory immersion, which enhances the therapeutic effect and makes the process more adaptable to the individual needs of students. The results obtained may serve as the basis for the development of new psychological support programs in educational institutions, offering strategies for enhancing emotional well-being and reducing stress.

1.2. Problem statement

This study presents a comparative analysis of VR-enhanced music therapy and its conventional equivalent with respect to its effects on graduating students' mental health – that is, the self-reported levels of mental well-being and anxiety. It aims to determine which approach is best when preventing the increase of psychological distress in students. Three hypotheses were formulated in the course of the study:

H-1. Conventional music therapy (C-MT) contributes to the reduction of anxiety and improvement of mental well-being among students. This hypothesis is based on the evidence that music therapy distracts from negative thoughts, enhances social engagement, activates the dopamine system, reduces cortisol levels, and aids in emotional regulation (Blanky-Voronov & Gilboa, 2022; De Witte et al., 2022; Hasanah & Haikal, 2022).

H-2. Virtual reality integrated into music therapy (VR-MT) has a more pronounced positive effect on reducing anxiety and improving mental well-being compared to traditional music therapy. This is explained by the fact that VR technologies create a deeper sensory immersion, fostering better emotional responses and effective distraction from stressors (Bauer et al., 2023; Best et al., 2022; Giordano et al., 2020).

H-3. In the absence of music therapy, students' anxiety levels increase, and their mental well-being decreases. According to Carol Ryff's model of psychological well-being, the lack of emotional regulation tools leads to a reduced ability to cope with stress, which is exacerbated in the academic environment due to high academic workload and social uncertainty (Mahmoudi et al., 2022; Yangdon et al., 2021).

To reach this goal and to test hypotheses, the following steps were taken: (1) A series of mental health surveys were conducted on three groups of students from different Chinese universities to measure their well-being and anxiety levels before and after the therapeutic intervention. The pre-test and post-test variables were then compared to determine if the treatments had a significant effect on student

participants. (2) Afterwards, the groups were compared using one-way ANOVA to determine which treatment condition had the most impact. (3) Finally, Tukey's post-hoc analysis was conducted to evaluate the effects of conventional (C-MT) and VR-enhanced (VR-MT) music therapy.

2. Material and methods

2.1. Study design

The present study aimed to assess the effectiveness of traditional music therapy and music therapy integrated with virtual reality in reducing anxiety and improving the mental well-being of students. The study commenced in September 2023, during which all organizational procedures were carried out, including participant selection, group allocation, and pre-tests. Standardized scales such as the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and the Trait Anxiety Scale (TAS) were utilized to assess the baseline levels of anxiety and mental well-being. Based on the collected data, students from three universities were assigned to three groups, ensuring homogeneity in key demographic and psychological characteristics. The control group continued their standard academic activities without intervention; the first group underwent traditional music therapy (C-MT), and the second group participated in music therapy with virtual reality integration (VR-MT). The intervention lasted seven months, starting in October 2023, and included 50 sessions held twice a week for 60 min. The sessions were conducted in small groups of 10 participants, allowing for a personalized approach for each individual. The music therapy programs were developed by certified music psychotherapists with the required qualifications and at least five years of experience. For the VR intervention, specialists experienced in using virtual reality technologies in therapeutic interventions were engaged. A description of the intervention is provided in Fig. 1.

In the first experimental group, traditional music therapy methods were employed, incorporating both active and receptive techniques. Active techniques included playing musical instruments such as the piano, guitar, drums, and percussion instruments and vocal practices aimed at promoting relaxation and self-expression. Additionally, group improvisation sessions and collaborative music-making were conducted, fostering the development of social skills and reducing anxiety. Receptive techniques involved listening to carefully selected musical compositions, visualizing images in response to the music, and discussing the emotions evoked during the perception of musical works.

The second experimental group received VR-enhanced music therapy based on the integration of music with a virtual environment. Oculus Rift VR headsets, headphones, controllers, and specialized software synchronizing visual and auditory effects were used. This methodology focused on immersiveness—deep sensory engagement in the therapeutic process. Sessions included relaxation exercises in virtual natural or abstract spaces synchronized with music, the use of virtual instruments to create compositions, music games, rhythm exercises, and interactive analysis of musical works. Biological feedback allowed the therapy to be adapted to participants' physiological parameters, such as heart rate, enhancing the relaxation effect and reducing anxiety.

The control group did not receive any musical intervention during the study and continued with their standard educational activities. In early May 2024, after the completion of the music therapy program, all participants, including those in the control group, completed the WEMWBS and TAS scales again, enabling a comparative analysis of changes in anxiety levels and mental well-being.

2.2. Participants

A total of 270 fourth-year undergraduate students from different universities in China (90 per university) participated in this study, as shown in Table 1. Participants from each university were randomly
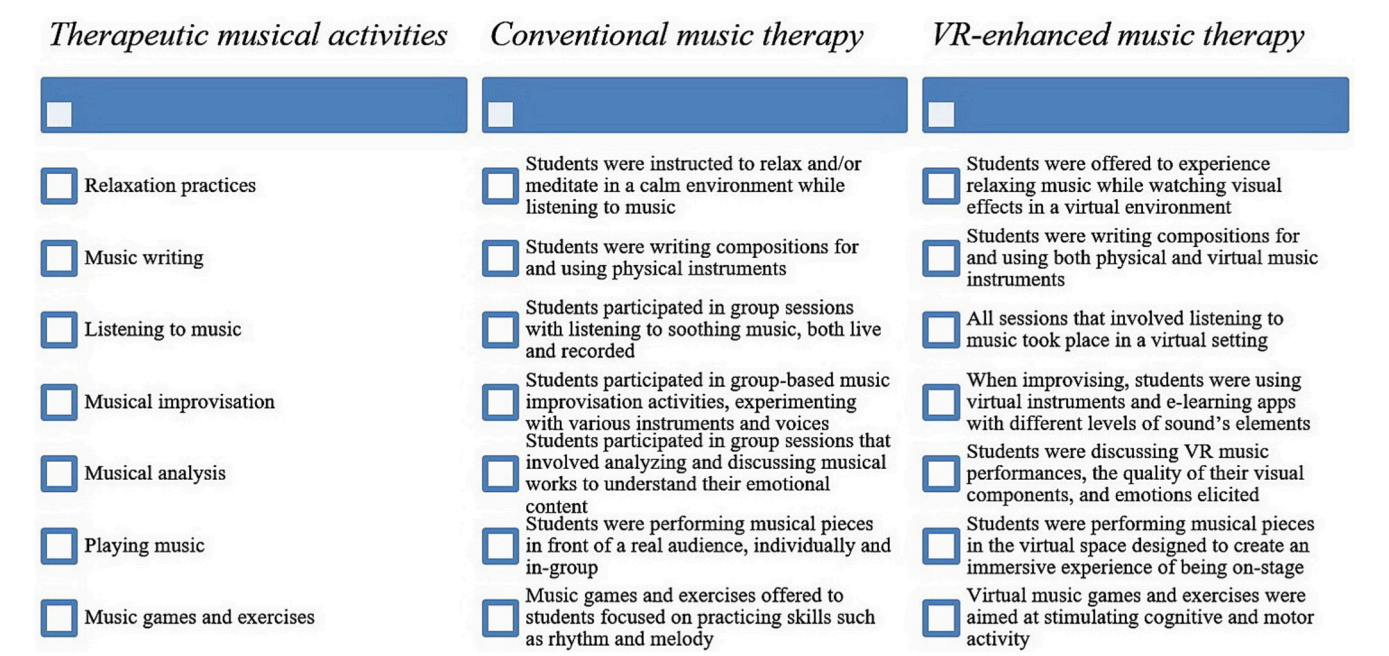
Fig. 1. Therapeutic, conventional, and VR-enhanced musical activities.

Table 1
Data on student participants.

	Number of participants
University	
[BLINDED] Conservatory of Music	90
[BLINDED] Conservatory of Music	90
[BLINDED] Normal University	90
Sex	
Males	96
Females	174
Age	
22 years	189
23 years	81
Assignment	
Control	90
Conventional music therapy	90
VR-enhanced music therapy	90

assigned to one of three conditions: conventional music therapy, VR-enhanced music therapy, and no music therapy (control group). The pre-test scores on the WEMWBS and TAS show that all groups were homogeneous before the intervention.

Participants were recruited through university announcements and voluntary registration on the university's website. Inclusion criteria required that students be enrolled in a specific academic year, have no diagnosed mental disorders, and be willing to complete the full course of the study. All participants provided informed consent at the outset of the project.

2.3. Instruments

To measure students' well-being, we used the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS), which has been previously validated and adapted for use in China (Fung, 2019). It consists of 14 positively worded statements that assess different aspects of mental well-being. The responses are organized on a 5-point Likert scale, with 1 being 'Never' and 5 being 'Always'. The total score ranges from 14 to 70,

with higher scores indicating higher levels of mental well-being. The Cronbach's alpha is 0.903.

Anxiety checks were performed using the Test Anxiety Scale (TAS) (Jiang, 2023; Xu et al., 2021). It comprises 37 items arranged into three subscales: emotionality (physiological reactions related to stress), worry (negative thoughts and fear of failure), and interference (anxiety-induced distraction from the task). All item scores are summed to create a total anxiety score, with higher scores indicating higher anxiety. The Cronbach's alpha is 0.894.

2.4. Data analysis

The analysis of data was performed in SPSS 25. To assess within-group changes (pre- and post-intervention), a *t*-test was used to determine whether participants had significant differences in anxiety levels and mental well-being scores after the musical therapy intervention. However, as the study involved three groups (control group, traditional music therapy, and VR-enhanced music therapy), a one-way analysis of variance (ANOVA) was employed to analyze differences between the groups. Following the identification of a significant effect through ANOVA, a post hoc Tukey test was conducted to determine which specific groups were statistically different from one another. To adjust for multiple comparisons, the Holm-Bonferroni method was applied to control the significance level and prevent Type I errors.

2.5. Ethical issues

The intervention protocol was validated and approved by the Ethics Committees of the participating universities under Protocol No. 456–1, dated 21/01/2023. The study was conducted in China; however, the authors are affiliated with a Ukrainian university, ensuring compliance with the ethical requirements of both countries. The issue of data security and its transfer between countries was carefully considered, and participants' personal data were anonymized at the data collection stage, eliminating the possibility of identifying specific students. Data management was conducted following international standards for the protection of personal data. Anonymized data were used and transmitted solely in aggregated form through secure university servers for analysis. All students singed a written consent to participate in the study and did so voluntarily. Although none of them declared their intolerance to the

use of VR, students were told they could withdraw their participation at any time without negative consequences.

3. Results

When the pre-test and post-test scores of mental well-being and test anxiety were compared (Table 2), the result revealed that students in the control group became more anxious over time, which reflected in their well-being. In contrast, their peers in the experimental groups demonstrated improvements. Specifically, the mean anxiety score on the TAS for the control group had increased by 2.60 points at the post-test, causing a decrease in mental well-being of around 2.62 points on the WEMWBS. The C-MT and VR-MT groups exhibited within-group reductions in anxiety of 3.53 and 6.36 points, whereas their well-being improved by 3.81 and 7.48 points, respectively.

Changes observed within the control group were statistically significant, as evidenced by the results of the paired t-test (Table 3). The prospect of taking final exams and graduating into the unknown was the likely reason behind these negative changes. The improvements seen among students exposed to some kind of music therapy were also significant ($p < 0.001$) and can be ascribed to participation in musical activities.

One-way ANOVA revealed that there were no statistically significant differences in pre-test scores among the groups ($p = 0.332$ for WEMWBS; $p = 0.840$ for TAS). However, the post-test had statistically significant differences ($p = 0.000$). The results of the one-way ANOVA are depicted in Table 4.

The Tukey's post-hoc test revealed that participating in therapeutic musical activities, whether in VR or outside of the virtual space, helps to prevent the worsening of mental well-being in graduating students. The control group's score of the WEMWBS was significantly lower than that found in the C-MT and VR-MT groups, with the mean differences being -6.522 and -9.533 points (p < 0.001; Table 5), respectively.

At the same time, improvement in the C-MT group's mental well-being lagged behind the improvement in the VR-MT group's mental well-being, and this difference was significant (-3.011, p < 0.001).

Table 2

Descriptive statistics of the pre-test and post-test WEMWBS and TAS scores among the three groups.

		WEMWBS pre-test	WEMWBS post-test	TAS pre-test	TAS post-test
Control	Mean	40.09	37.47	23.82	26.42
	N	90	90	90	90
	Standard deviation	3.129	1.743	2.775	1.070
	Standard error of the mean	0.330	0.184	0.292	0.113
	Variance	9.790	3.038	7.698	1.146
	Kurtosis	−1.249	−1.413	−1.328	−1.243
	Skewness	−0.116	0.044	0.066	0.038
Conventional MT	Mean	40.18	43.99	24.06	20.53
	N	90	90	90	90
	Standard deviation	3.238	1.434	2.559	1.781
	Standard error of the mean	0.341	0.151	0.270	0.188
	Variance	10.485	2.056	6.547	3.173
	Kurtosis	−1.216	−1.322	−1.265	−1.379
	Skewness	−0.041	−0.004	0.007	0.017
VR-MT	Mean	39.52	47.00	23.93	17.57
	N	90	90	90	90
	Standard deviation	3.251	1.972	2.626	1.729
	Standard error of the mean	0.343	0.208	0.277	0.182
	Variance	10.567	3.888	6.894	2.990
	Kurtosis	−1.238	−1.149	−1.245	−1.275
	Skewness	0.233	−0.216	−0.006	−0.062

Comparing mean anxiety scores revealed that the control group had more severe anxiety than the C-MT group and the VR-MT group, with the mean differences being 5.889 and 8.856 points (p < 0.001), respectively. Results also show that immersive therapy was more effective than the conventional format, with the mean difference being 2.967 (p < 0.001).

4. Discussion

The results of the study confirm both the statistical and clinical significance of music therapy in reducing anxiety and improving students' mental well-being. Statistical analysis revealed significant differences between the groups (p < 0.001), supporting the effectiveness of both traditional and VR-enhanced therapies. The clinical significance lies in the actual improvement in students' emotional states, which is expected to contribute to their academic success and social adaptation. The most pronounced effect was observed in the VR-enhanced music therapy group, highlighting the potential of VR as an innovative tool for psychological support. The findings underscore the need for integrating music therapy into prevention programs. The latest study in this field presents similar conclusions, indicating that music therapy is extremely effective in promoting self-expression among autistic people (Quigley & MacDonald, 2024). These findings emphasize the importance of integrating therapeutic music interventions into the university curriculum and using technology to improve their effectiveness. According to some researchers, the therapeutic strategy must be adaptive to effectively reduce anxiety (Morgan & Marroquín, 2024), and technology can help in achieving this effect. One example of such intervention is a three-level framework for VR-MT (Knott & Block, 2020).

Combining music therapy with VR can be useful in contexts other than university education. Some examples include childbirth (Estrella-Juarez et al., 2023), preparation for on-stage performance (Bellinger et al., 2023), cancer treatment (Chirico et al., 2020), inclusive education (Bauer et al., 2023), and palliative care (Brungardt et al., 2021). Note that the current work is not the first attempt to leverage VR as an instrument to reduce stress and anxiety in people taking music therapy sessions. Specifically, some researchers have offered a Virtual Reality system with this goal in mind (Lin et al., 2020), whereas others examined the therapeutic benefits of publicly available VR content (Best et al., 2022). Finally, a study discussing the integration of VR and an EEG-based intelligent agent in music therapy for patients with Alzheimer's disease reported that this approach improved the emotional state of participants and their cognitive performance (Byrns et al., 2020).

4.1. Limitations

This research project focuses on the short-term effects of music therapy, whereas the long-term effects are ignored. In addition, music therapy programmes can be reinforced with other types of digital technology, which may have a different effect on mental health, but the present study focused a single option. Another limitation of this study is that it only involved students from universities in China, which reduces generalizability to other cultural contexts. Despite efforts to minimize the influence of a single factor, one of the limitations of the study is the composition of the sample, which includes students from two specialized music universities and one multidisciplinary university. This may affect the generalizability of the results, as the level of musical familiarity among some participants may have been higher than the average level among students from other educational institutions. Finally, the study draws data from self-report measures only.

5. Conclusion

The present findings show that music therapy has a significant positive impact on the mental well-being and anxiety levels of graduate

Table 3
Paired t-test results for mental well-being (WEMWBS) and anxiety (TAS) levels across the three comparison groups.

	Paired differences					t	df.	Sig. (two-tailed)
	Mean	Std. deviation	Std. error mean	95 % confidence interval				
				Lower	Upper			
Control								
WEMWBS (well-being)	2.622	3.683	0.388	1.851	3.394	6.755	89	0.000
TAS (anxiety)	−2.600	3.122	0.329	−3.254	−1.946	−7.900	89	0.000
C-MT								
WEMWBS (well-being)	−3.811	3.886	0.410	−4.625	−2.997	−9.305	89	0.000
TAS (anxiety)	3.522	3.033	0.320	2.887	4.157	11.019	89	0.000
VR-MT								
WEMWBS (well-being)	−7.478	3.834	0.404	−8.281	−6.675	−18.50	89	0.000
TAS (anxiety)	6.367	2.939	0.310	5.751	6.982	20.54	89	0.000

Table 4
Analysis of variance in mental health across the three comparison groups (one-way ANOVA findings).

		Sum of squares	df	Mean Square	F	Sig.
WEMWBS pre-test (well-being)	Between groups	22.763	2	11.381	1.107	0.332
	Within groups	2744.900	267	10.281		
	Total	2767.663	269			
WEMWBS post-test (well-being)	Between groups	4274.719	2	2137.359	713.889	0.000
	Within groups	799.389	267	2.994		
	Total	5074.107	269			
TAS pre-test (anxiety)	Between groups	2.452	2	1.226	0.174	0.840
	Within groups	1881.478	267	7.047		
	Total	1883.930	269			
TAS post-test (anxiety)	Between groups	3657.030	2	1828.515	750.572	0.000
	Within groups	650.456	267	2.436		
	Total	4307.485	269			

being while achieving a reduction in test anxiety, with within-group differences of 7.48 and 6.36 points, respectively. The differences in WEMWBS and TAS scores between groups were statistically significant as determined by one-way ANOVA ($p < 0.001$). The Tukey's post-hoc test showed that reinforcing the music therapy programme with the VR technology results in greater results. This study provides evidence of the effectiveness of integrating technology, such as VR, into traditional music therapy. Future research can explore novel approaches to music therapy. The results of the current study can be used to design effective music therapy programmes for university students, schoolchildren, elderly people, and other segments of the population.

CRediT authorship contribution statement

Gengchen Liu: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jiandan Hu:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration. **Ilona Kostikova:** Funding acquisition, Project administration, Supervision, Validation.

Informed consent

All students singed a written consent to participate in the study and did so voluntarily after being ensured that all the information they provide would remain anonymous and confidential.

Ethics approval

The research was conducted ethically in accordance with the World

students. In this study, students who did not participate in the music experienced a worsening of mental well-being and higher stress over time, with the WEMWBS score dropping 2.62 points and the TAS score gaining 2.60 points. In contrast, the C-MT group scored 3.81 points higher on the WEMWBS and 3.53 points lower on the TAS. Similarly, participants in the VR-MT group showed an increase in mental well-

Table 5
Tukey's post-hoc test findings.

Dependent Variables	(I) Group	(J) Group	Mean difference (IJ)	Std. error	Sig.	99 % Confidence Interval	
						Lower	Upper
WEMWBS (well-being)	Control	C-MT**	−6.522*	0.258	0.000	−7.28	−5.76
		VR-MT	−9.533*	0.258	0.000	−10.29	−8.78
	C-MT	Control	6.522*	0.258	0.000	5.76	7.28
		VR-MT	−3.011*	0.258	0.000	−3.77	−2.25
	VR-MT	Control	9.533*	0.258	0.000	8.78	10.29
		C-MT	3.011*	0.258	0.000	2.25	3.77
TAS (anxiety)	Control	C-MT	5.889*	0.233	0.000	5.21	6.57
		VR-MT	8.856*	0.233	0.000	8.17	9.54
	C-MT	Control	−5.889*	0.233	0.000	−6.57	−5.21
		VR-MT	2.967*	0.233	0.000	2.28	3.65
	VR-MT	Control	−8.856*	0.233	0.000	−9.54	−8.17
		C-MT	−2.967*	0.233	0.000	−3.65	−2.28

* The mean difference is significant at the 0.01 level.
** Music therapy (MT).

Medical Association Declaration of Helsinki. The intervention protocol was validated and approved by the Ethics Committees of the participating universities (Protocol No. 456–1, dated 21/01/2023).

Funding

Declaration of competing interest

Authors declare that they have no conflict of interest.

Data availability

All data generated or analysed during this study are included in this published article.

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