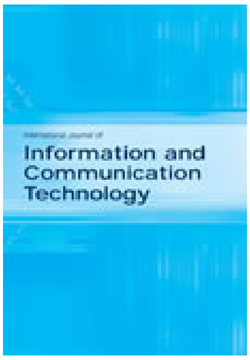

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Interactive study of AI-music experiences in virtual reality on psychological comfort

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Abstract: The goal of this study is to find out if putting artificial intelligence (AI) and virtual reality (VR) together can make people enjoy music and things more. It was made so that the music changes based on what people say. AR and AI were mixed to make a tool that can change how people listen to music. VR is used in this study to look at how AI-made music that changes can affect people's health and happiness. VR and music have been shown to help people who are worried or stressed in the past. In real life, though, where people need to change, not many studies look at how these things work together. It made people feel less at ease when they were in quiet places (M = 5.8) but more at ease when AI-made songs played (M = 7.2). Their heart rates went down and their heart rate variability (HRV) went up when they did the different activity.

Keywords: artificial intelligence; AI; virtual reality; VR; AI-generated music; psychological comfort; stress reduction; music therapy.

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1 Introduction

Virtual reality (VR) and artificial intelligence (AI) together represent a significant step forward in teaching and playing music, as they make the experience livelier, engaging, and personalised for each individual (Westermeier et al., 2023). VR lets people connect with music scenes that change, play in virtual places, and collaborate from afar. This is possible with the help of AI, particularly training models like LSTMs and recurrent neural networks (RNNs). These models enable people to adjust their actions based on what others do in real-time. This created fun and functional spaces for learning and playing music. Although AI and VR have made significant advancements on their own, they are not often combined to provide people with personalised music experiences in real-time. At the time, most of the methods were focused on either VR games or AI-generated music. There are no contacts that can be changed at any time. Kids cannot always do anything when they have music lessons every week. Because of this, it is hard for them to join in and make the lessons their own. Because there are VR options, you can circumvent this issue. With these, you can practice in a real-life setting and receive help immediately. With the help of AI, these methods can also adapt based on the player's skill level. This makes people smarter and helps them learn faster.

In real-time, AI can collaborate with artists, adjust the speed, and create new sounds that fit their style (Khalloufi et al., 2024). VR offers artists new ways to showcase their skills, such as virtual shows featuring three-dimensional images that move in sync. AI and VR collaborate to make music more engaging and meaningful for people. When you tell stories and play the old way, this fills in the holes. These ideas aren't often put together in a way that changes constantly based on what people do and how they learn. A lot of research has been conducted on VR for band practice, MR for learning an instrument, and AI for music creation, but few have explored all three simultaneously. A new study reveals that VR and AR are two emerging technologies being increasingly utilised in music and art events. How people learn to play music, enjoy it, and play, it will change a lot (Zhao and Cheng, 2025). One study examined the use of VR technology for virtual music events. It was amazing how quickly the field has grown since then. Most of the survey focused on multimedia devices and methods for measuring user experience. Mind health is another name for this. Mental health can be influenced by factors such as stress and mood. Why is this important? Because many different things can cause people to get sick. We need to find better ways to manage stress and negative emotions.

A new study found that not long ago, being angry may make the brain swell up, which can help tumours and cancer grow. People need to take care of their mental health right away. The world is becoming more stressed, and 40% of people have at least one mental illness that makes their lives complicated. The point of the study is to find out if music and (made-up) online settings can help people gain health. People used to feel better when they played computer games or listened to music. Still, it is not clear what health benefits VR and music might have when used together (Byrns et al., 2020). It is called 'music therapy' when a trained professional from a well-known music therapy school uses music to help a person reach their therapeutic goals in a way that has been proven effective in the real world. You might also refer to it as 'music therapy'. The people in this study were told to use the responsive music treatment model to listen to recorded music and respond to it. A trained music therapist did not put together the study's songs (Song et al., 2021). Rules used in other music therapy study projects were also used to help choose this music. Low tones, a steady beat, a calm mood, voice lines that are easy to follow, and minimal changes in volume are all things it needs.

This was done to ensure the sound level was approximately the same as in music therapy. Many different parts of the brain can be affected by music. It can cause the chemicals that make us feel good to be released faster, such as when we're at a concert. Additionally, numerous small studies have examined the impact of music on individuals, particularly those facing terminal illness, in helping them cope with stress. Music can help lower your blood pressure, anxiety, and arousal (Alexanian et al., 2022). Folk music has always been a big part of life. Everyone can understand a specific language. Language enables people to share their thoughts and communicate with one another (Liu et al., 2021). This is because, for many, music is an integral part of their lives and a means of expressing who they are, whether they're listening, writing, or playing. These days, AI is being used to enhance music quality, as it is already improving. The primary goal initially was to address issues with how music data was stored and how sounds (notes) were generated. In the past few years, there has been an increase in trouble. As your primary job, you can now make longer pieces of music or sort music into different groups. In recent years, the importance of being able to find or offer music has also increased.

The rise in popularity may be attributed to the success of various music-streaming services (Jiang et al., 2020). This is because AI is continually improving in all areas. What people can do is get better, and sometimes it is even better. It is also challenging to create objective tools for measuring progress, which makes it more difficult to compare various AI models. This often happens to many people when they are creating songs. There are still problems that have not been resolved, and new ones are emerging, even though AI is improving at singing. Long, moving pieces of music that sound as if real people are hard for even musicians to make (Mycka and Mańdziuk, 2025). This is still a trouble spot.

The following is how this paper is put together: 2 has the literature review on the study of AI-music events that can be interacted with. 3 talks about the methods, which are mostly about VR and psychological ease. It ends with a statement, which is found in Section 5.

1.1 Contribution of this study

This study adds an important new way to use AI and VR together to make places with music that make people feel better. This study is different because it looks at both VR and AI at the same time. It mixes actual VR scenes with music made by AI that changes in real-time based on the subjects' mental and physical states. Technology makes music treatment easier to get to, which is how it does this. AI-driven customisation and virtual settings could be used together in the future to improve the mental health of users and make their experiences better. Systems should be made because this study shows how useful they are through full reviews that include body data, self-reports, and behavioural observations. music made by AI in VR not only calms people down, but it also makes them more interested, present, and happy than music that stays the same or no music at all. way music is taught, used for healing, and just fun has changed a lot because of this method from different areas.

2 Literature review

2.1 Virtual reality's impact on mental health

Even Although VR is still pretty new, more and more people are interested in it as a way to get healthier. A study of the medical literature on VR was done in 2017. It was found to be safe for people to use most of the time happy (Bird et al., 2021) say we need to do more study to find out if virtual tools can be used in therapy that works. There are two key ways that VR can help people calm down and deal with stress. Also, putting people in the VR world is a good way to teach them how to manage their feelings. It is also possible to make 'generic environments' for people who don't do much. Putting them in a VR world is another way to teach them how to manage their feelings. The main goal of this study is to find the first way that music can make VA medicine work better. It has been looked into a lot how VR can help people with PTSD deal with worry. It works between 66% and 90% of the time, according to tests. Tech lets them see and hear things that aren't really there. Try to remember something over and over again, and a few other bad things can happen. This fixes a lots of them. been shown to help people who are shy in public or who want to get healthier (Chirico et al., 2020). Study says that VR might help people calm down while they are getting their blood drawn. those who didn't. also less stressed and tired.

2.2 Music and sound-enhanced virtual reality

VR has a lot of creative ways to use music, like in live shows. But not a lot of study has been done to figure this out. In the past, animal sounds have helped people in virtual places. People love these places with music. Past, animal sounds have helped people in virtual places. A lots of studies have shown that music can make VR workouts more fun. Kids learned more from therapy than what was going on in their real lives. Kids and people with autism should not use VR or listen to music (Alexanian, 2021). VR and music have been shown to help people remember things and calm down when they are scared of things like heights. One of the few studies that did this was one that looked at how MT and VR affected people with cancer while they were getting treatment, especially how they felt. The main point of the study was to find out how helping people with cancer by letting them make music in VR. This study will look at people who are not in therapy to find out what kinds of information (audio and/or video) and settings (VR or 2D) help them feel better. We can learn more about music therapy and the web from this.

2.3 Music as a therapeutic modulator of stress and anxiety

It says in that worry is a complicated and useful emotion made up of parts that work together in the body, the mind, and the behaviour (Thoma et al., 2013). What it is most known for is making people feel stressed, worried, and afraid about the likelihood of bad things happening or unfavourable results. When emotional or physical stressors throw off the balance of an organism, anxiety can sometimes occur at the same time. Stress reactions begin to appear as soon as the organism is exposed to the factors that cause stress. The stress system is primarily concerned with returning to a state of balance. The hypothalamic-pituitary-adrenal axis and the sympathetic nerve system are under its control, so it can do this. These people have too much stress and their basic processes don't work right when they have an anxiety disorder. Besides that, research has shown that the brain circuits involved in stress and anxiety may overlap and interact in ways that make the anxiety responses to short- term stress stronger (Meyerbröker and Emmelkamp, 2010). This is what they do because stressful events can exacerbate worry. You should feel stressed and worried when bad things might happen, but they only last for a short time. Long-lasting responses to fear and worry, on the other hand, can be nasty for your health.

Because of this, the body's balance can get off, which can make the mind and body sick. Many Studies have shown that music can change the way a person thinks, feels, and moves. These changes can make you feel less worried and stressed (Pan et al., 2012). In fact, people have used music to calm down and manage stress in various settings, including hospitals, doctors' offices, and workplaces. It can also be challenging to understand the meaning of these studies because the locations and songs used in the experiments are not always the same (Seinfeld et al., 2016a).

In order to make learning more engaging and efficient, this research (Lu, 2025) highlights the ways in which adaptive learning is facilitated by real-time feedback. In addition, the study presents research findings that validate the efficacy of ML algorithms in assessing a range of musical styles and students' proficiency levels. Based on the findings, machine learning (ML)-based devices can upend conventional wisdom about music education and creativity while giving contemporary music programs a more welcoming and inclusive foundation. Using data analytics, ML, and AI, this article (Peng, 2025) lays forth a technique for decision-making in music instruction. Through analytics of students' talents, preferences, and evolution, CI systems that are run by AI offer individual lessons, better ways to practice, and quick suggestions. A close look at current CI methods in music education was done to see how well they work for teaching skills, getting students involved, and making programs. To make sure that students get training that fits their skills and goals, a new way of making decisions is also suggested. This makes learning paths more unique to each person.

Two case studies, Bach rewired and Beethoven 360°, showcased distinct applications of AI, real-time rendering, and biofeedback systems, and served as testing grounds for a modular architecture. The adaptable performance aspects were discovered through sensor-based audience input, and deep learning models were employed to link the musical structure to visual output. With a system delay of less than 25 ms, the results demonstrated an average increase in audience immersion from 5.4% to 6.8%. According to Li (2025), computational multimedia systems have the potential to enhance classical concert experiences by introducing innovative approaches to expressiveness, structural clarity, and interactive design, all while preserving the authentic repertory.

2.4 Application in intelligent electronic musical instruments

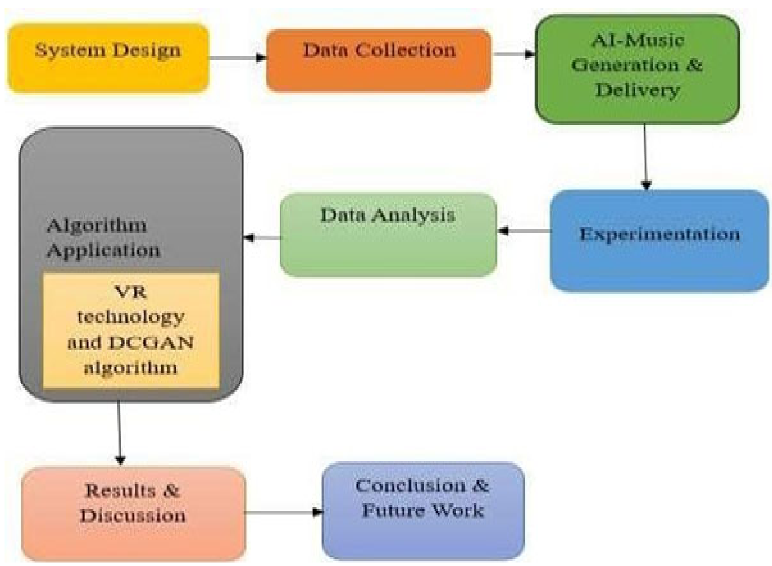
In the past few years, AI has kept getting better. This cool electric guitar can store a lot of different sounds and mix them in useful ways. This has helped computer-made musical instruments become better, more like people, and more skilled by letting them write new songs. You can save a lot of different sounds and mix them in useful ways. Depending on which way the movement is going, different tones can be played (Graili et al., 2021). This it is something that many old tools have. New and different man-made instruments are slowly being added to music lessons to help students learn how to play them. They are important because of this. New computer tools have made it possible to teach music in a new way. One person can now play in more ways than ever. Putting together great sounds from different places can help them come up with new ideas (Hsieh et al., 2020). AI Experts say that making music on a computer, taking music lessons online, and using a Wifi network all work well with each other. This means it is simple for kids to learn music. The kids could also find out more. Most of the time, people talk about how fast science and technology change things these days. things these days. AI is getting better all the time, even though it has issues. As computers get better, it is also more important to be able to play electronic music online and work on projects together over Wifi.

A method for creating music was developed as part of a project to gain a deeper understanding of AI. This could make it easier for people to collaborate over Wifi and teach electronic music online. Intelligent algorithms, Wifi networks, and PC sensor networks are all being explored. This lets us create a brand-new type of innovative artificial singing instrument (Yu et al., 2023).

3 Methodology

The study workflow is depicted in Figure 1, which begins with system design and data collection, followed by AI music creation, VR algorithm application, and experimentation. Results and discussion are informed by data analysis, which leads to the conclusion and subsequent work.

Figure 1 AI-music and virtual reality study process flowchart (see online version for colours)



3.1 System design

The system architecture for interactive research on AI-music experiences in VR was constructed through an integrated approach that combines psychological monitoring, immersive VR environments, and AI-based music creation (Wei et al., 2025). The architecture consisted of three modules: a feedback module that enabled real-time tracking of user responses, a VR interface that displayed soothing landscapes and interactive elements timed to the music, and an AI music generator trained on ambient and therapeutic music datasets to create adaptive soundscapes. As the participants' emotional and physical states, as well as their VR activity patterns, were tracked by biometric sensors, including HRV and galvanic skin reactivity, the music was dynamically altered. To optimise psychological comfort, the AI system modified musical elements based on continuous feedback during users' 20–30 minute VR encounters. Assessments were conducted both before and after the sessions to determine the efficacy of the intervention. Standardised anxiety and comfort measures from the intervention were used in these evaluations. The effectiveness of AI-music interactions in promoting relaxation and lowering stress was then assessed through the analysis of quantitative physiological data and qualitative feedback.

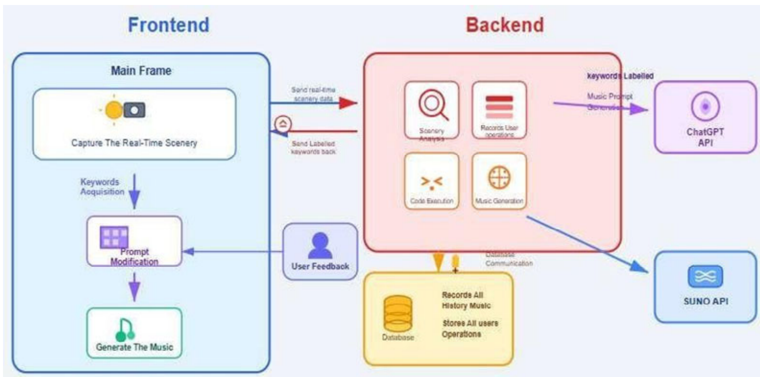
Figure 2 Key elements of CAT (see online version for colours)

The CAT system makes music that is just right for each person based on how stressed they are and where they are. A graphic language model is used to do this. It is mostly made up of three parts: the music player, the place where people can type, and the AI message panel (Figure 2). How each part works will be shown in the pieces that follow, which will all have to do with real-life interactions between people. This is a unique instrument for making music. It takes live video scenes and turns them into separate songs using AI. Figure 3 shows that the plan is broken up into three levels that all work together. There are links to outside APIs on this level. The front end is easy to use, and the back end has a strong processing engine. The server gets this picture right away and looks at the scene, up close. The weather, biology, and social issues that are important to this study can be found in these parts. First, the screen is used to take a picture of what's going on around the person. In this study, parts are used to find important environmental, social, and biological factors. The server sees this picture right away and takes a close look at what it shows. found some biological, social, and environmental factors that were very important to this study.

- User input section: once users choose a subject, they can use a scale to change the level of worry and add keywords that describe the subject, such as 'water' or 'piano.' These controls let users show what they want and make the ending music songs their own. The layout was made to make adding data easier in a way that is easy for anyone to use and find their way around.

- Music player: based on the clues, words, and stress level given, the Sunos application programming interface (API) is used to make two songs. When the person is done, they can press the 'generate' button to make these songs. You can play, stop, or delete songs from this folder with the sound player. Every song is kept in a folder called 'my album' play, stop, or delete songs from this folder with the sound player.

Figure 3 Workflow for the system (see online version for colours)

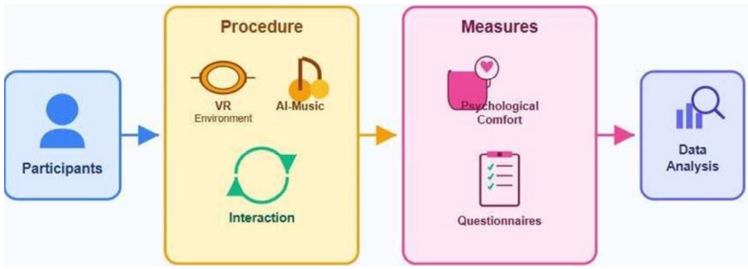


3.2 Data collection

Each participant in the study received three VR lessons at three different locations. It was a repeated-measures experiment. They had both music that could be played and music that had already been written but couldn't be played. Sixty people between the ages of 18 and 45 were selected to participate in the study. Their eyes and ears were examined to ensure they were healthy in every way. Both were fine, and neither their balance nor their hearing was off. People in this group joined after seeing ads around town and at colleges. A real-time generative music system was paired with high-end VR glasses that incorporated headphones. The user could adjust sound settings based on their movement and system usage. The level and speed of songs that were already written were altered so that they could be used as sets (Seinfeld et al., 2016b). We continuously monitored your heart rate and observed how your skin responded to the galvanic current at all times. After that, the body data and the VR events could be brought together. Participants in the study completed official forms with Likert scores to assess their psychological comfort, mood (using the PANAS), presence, simulator sickness, and music experience. During the six- to eight-minute sessions, the settings were changed so that the order did not mean as much.

To ensure that everyone was on the same page, the time of each data stream had to be recorded. In the pre-processing step, physiological signs were filtered, behavioural logs were compiled, and actions taken at the start of the experiment were modified. This method provided a comprehensive picture of mental health by combining information from various sources, including physiological, behavioural, and social factors. The work process is illustrated in Figure 4. People who want to participate first talk with others while listening to songs created by AI in a VR setting. Polls are then used to find out how calm people are. Everything is carefully looked over once it is all put together.

Figure 4 Methodology flowchart for the psychological comfort study using VR and AI-music (see online version for colours)



3.2.1 Multimodal data fusion and synchronisation

It was possible to combine information about behaviour and the body using a method called sense fusion. A weighted average was used for feature-level merging. Given the strength of their links with psychological comfort scores, heart rate, HRV, and GSR were each given a weight of 0.4, 0.3, and 0.3. Behavioural factors from VR contact logs (like eye tracking, moving patterns, and the number of times people engaged) were added. One feature graphic was made this way. Because each sensor had a different sample rate, it was very important to change the timing lag. The GSR sensors worked at 64 Hz, and the heart rate and HRV monitors worked at 128 Hz. At 90 Hz, which was the same rate as the headset's update rate, VR behavioural logs were kept. As part of a way for matching based on timestamps, linear interpolation was used to change all the waves to a common 64 Hz baseline. Another study found that there was an average delay of 45–80 ms between the start of a body reaction and the start of an activity. A moving window method with 100 ms delay zones was used to fix this. To downsample signals and keep the time the same across all modes, cubic spline interpolation was used to upsample lower-frequency signals and moving average filtering (window size = 5 samples) was used to upsample signals. This way, as little information as possible was lost.

3.2.2 Experimental controls and randomisation

- Counterbalancing: a Latin square design was used to randomly assign condition sequences to participants in order to reduce order effects. Participants were equally divided among all six possible orders for the three experimental conditions (AI-generated music, static pre-recorded music, and no music). To reduce carryover effects, a 5-minute washout interval with neutral visual stimuli was used in between trials.
- Blinding protocol: participants were told they would encounter 'different audio settings' without any explicit labels designating AI-generated, pre-recorded, or quiet circumstances; they were single-blinded to condition types. To lessen interpretation bias, data analysis was carried out by independent researchers who were not aware of condition assignments, even though the experimenter in charge of condition presentation was not blinded.
- Statistical robustness: Bonferroni adjustment was used to apply multiple comparison adjustments (adjusted $\alpha = 0.0083$ for six pairwise comparisons). Cohen's d for t-tests

(small: 0.2, medium: 0.5, large: 0.8) and partial eta-squared (η^2) for ANOVA analyses were used to determine effect sizes. When compared to the no-music control, the AI-music condition displayed significant effect sizes (Cohen's d = 1.24, 95% CI [0.89, 1.59]). For each of the major outcomes, 95% CIs were presented. A sufficient sample size of 60 was validated by power analysis to identify medium-to-large effects (power = 0.85, $\alpha = 0.05$).

3.3 AI-music generation and delivery

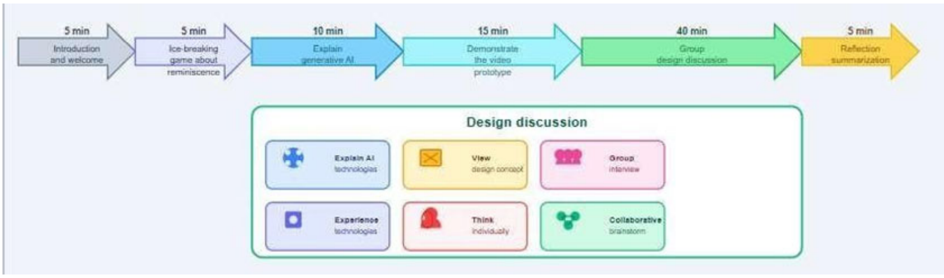
Scientists investigated the impact of music generated by AI on people's mental health in VR by using participants who were similar to one another. Thirty-six healthy individuals between the ages of 18 and 55 participated in the study (Jin et al., 2024). The rules were put in a different order for each person. The participants observed different scenes in VR while listening to various types of music. AI could pick the sound, leave it the same, or not play it at all. ML was used to create songs that adapted to the current context and people's emotions. The quiet music, on the other hand, consisted of pre-selected recordings of natural sounds. At the start, there were only sounds from the surroundings. A visual analog comfort measure and the STAI were used to ask participants in the study to rate their own comfort and mental health. There were also tests of presence and subjective music satisfaction that were conducted in conjunction with these results. Heart rates, HRV, and galvanic skin responses of the people were closely watched and recorded while they were in VR. With short breaks in between, each VR task was given to the people one after the other. This was done after a short period of adjustment and calibration.

To determine how the sound sets affected people's feelings, linear mixed-effects models were used to analyse the data. The player could choose the type of scene, the order of the effects, and how the characters were different. We also compared AI-adaptive music to cases with static music or no music at all after the fact. That was fun! AI can generate questions and words that help you remember things. These computer-made pieces could help older people remember things and feel them more deeply. Additionally, creative AI can be used to create images that evoke memories associated with the music, connecting people to specific memories. This provides a more lively and engaging way to remember. We aim to develop creative AI that can assist older people in remembering songs as part of this project. The two design meetings we set up and ran had these primary goals:

- Also, it would be interesting to know how older people feel about AI that can remember songs creatively.
- To find out what issues and design challenges come up when you use creative AI to help older people remember where they put their music.

The classes were a way to gather feedback from people who had tried out the prototypes. It was made with the user in mind. Intelligent AI could also be used to help people remember songs. The whole study plan and method are shown in Workshops I and II. First, you have to make something, then watch how people use it. Figure 5 illustrates the main plan for the study and outlines the approach to be taken. When we plan and create things, a method called iterative design helps us understand how older people feel and utilise their ideas. Ten adults attended both of the lessons we planned. There were interview sources and study tools that were not in English. To make them work with this piece, we translated them into English.

Figure 5 Workshop II tasks include presenting and testing digital prototypes and group design discussions (see online version for colours)



People in social work also helped spread the word about our study. Table 1 presents basic information about the participants. To gather this information, participants who wanted to take part were asked to fill out a form ahead of time, which included a few questions, two songs that could evoke memories, and a brief account of the memories the songs triggered. We were able to better plan the material of the prototypes with the help of hearing the songs and memories.

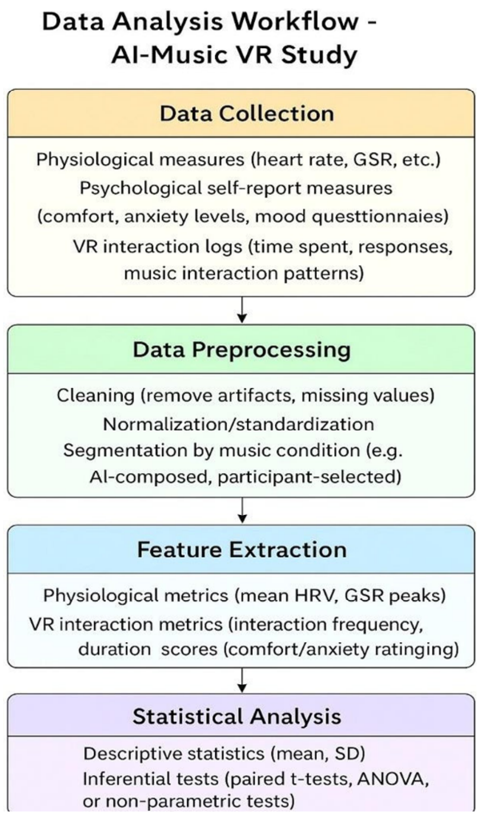
Table 1 Design workshop participants for generative AI music memory tools

ID	*Age range (years)*	*Gender*	*Background in education*	*Frequency of music listening*	*Willingness to hear music that brings back fond memories*	*Joined a workshop*
P1	55–65	Female	Middle School	Several times weekly	Sometimes	1&2
P2	55–65	Female	Bachelor	Frequently during the day	Sometimes	1&2
P3	> 65	Male	Bachelor	Rarely	Sometimes	1
P4	55–65	Male	Middle School	Frequently during the day	Frequently	1&2
P5	55–65	Female	Master	Several times weekly	Sometimes	1&2

3.4 Data analysis

The information was used in a study that looked at how music events created by AI in VR affected the mental health of the people who attended. The person and the body were both used to measure HRV, galvanic skin reaction (GSR), and eye tracking (Varela, 2024). The state-trait anxiety inventory (STAI) and the positive and negative affect schedule (PANAS) could be used to get psychological data. Anyone could fill out the forms. To begin, simple information was used to quickly show the users' ages, genders, levels of comfort, and how involved they were with the VR experience. So that the level of stress before and after the action could be compared, this was done. Paired t-tests and repeated measures ANOVA were used to do it. You could use effect numbers to figure out how big the changes were. Pearson's correlation and multiple regression analysis were used to find links between how people felt and how their bodies responded. They were also used to guess how comfort would change depending on the music decisions made by AI and the amount of time spent in VR. A mixed merging method was used to show trends in both health and mental data.

Figure 6 The data analysis pipeline for an AI-Music VR study comprises five steps: physiological and psychological data collection, pre-processing, feature extraction, statistical analysis, and result interpretation (see online version for colours)



Heat maps and call logs are two types of data that you can look at. The changes we made were correct, and we used a significance level of $p < 0.05$ for all of our data. Python and SPSS were also used for each project. Figure 6 shows one way to look at how music made by AI might change how VR games are played. This is being done to get different kinds of data for this study. To do this, they keep track of things like mood, fear, and comfort, as well as heart rate, GSR, EEG, and VR trade logs. The data needs to be cleaned up and set up before it can be used for the body, social, and relationship measures. After that, the most important parts are found. It is interesting how different types of music can make you feel and move differently. There are a number of statistics tests that can be used to look for patterns in these effects and to check how well music made by AI works in VR. The most important thing is to make songs that can be played in VR.

3.4.1 Model configuration and training parameters

- Dataset: therapeutic soundscapes with frequencies ranging from 20 Hz to 8 kHz were among the 15,000 ambient music samples used to train the DCGAN model from the FreeSound and MusicNet datasets. At a sampling rate of 22.05 kHz, audio segments were pre-processed into 128 × 128 Mel-spectrograms with a hop length of 512 samples.
- Training configuration: the generator network was made up of four transposed convolutional layers with kernel size 4 × 4 stride 2 and filter sizes [512, 256, 128, 64]. In the discriminator, four convolutional layers with corresponding sizes were employed. The Adam optimiser was used for training, with a learning rate of 0.0002 for both networks ($\beta_1 = 0.5$, $\beta_2 = 0.999$). With a batch size of 64, the model was trained for 200 epochs, taking about 18 hours on an NVIDIA RTX 3080 GPU. With discriminator loss stabilising at 0.22 and generator loss stabilising at 0.28, loss convergence was attained by epoch 150.
- Real-time integration: Mel-spectrograms produced by the trained DCGAN generator are transformed into audio waveforms via Griffin-Lim reconstruction. Through a parameter mapping layer that converts physiological inputs (normalised HR, HRV, and GSR) into DCGAN latent space modifications, musical features (tempo, pitch, and timbre) are adjusted in real-time. The 40–60 ms pipeline in which this procedure takes place keeps up with the 60–90 FPS VR scene rendering. During adaptive transitions, the batch normalisation layers maintain consistent timbral quality by stabilising feature extraction across audio frames.

3.5 VR technology and DCGAN algorithm

Several key prerequisites must be in place before VR can be utilised (Han et al., 2025). Some of these parts take pictures, watch space, and interact with things in real-time. Moving sensors and screens that sit on top of the head are used by VR systems to track the location and movement of users. After that, this data is updated immediately in the imaginary world. This is what VR stands for: VR. You can hear, see, and touch this tool simultaneously for a whole three-dimensional experience. DCGANs require two neural networks that are trained to compete with each other to produce high-quality images. The generator and the discriminator are the names for these two. The brain is trained by both neural networks working together. There are jobs where people need to be able to distinguish between real and fake pictures. People who work as producers must create images that appear realistic enough to deceive those who review the files. Standard models differ from this adversarial method. This method makes it easier for the creator to find complex visual structures and traits. The generator is the first thing used to create a picture. A noise vector is put into this part. A CNN with more than one layer allows the person who made it to take this data and produce something that looks good.

This is the proper way to write the generator, which can be found in equation (1):

$$(z) = \left(BN\left(W_{g3}.\sigma\left(BN\left(W_{g2}.\sigma\left(\left(W_{g1}.z + b_{g1}\right)\right) + b_{g2}\right)\right) + b_{g3}\right)\right) \quad (1)$$

According to equation (1), the weights are denoted by and the layers that comprise the system are denoted by and.

The first function is for activation, and the second is for batch normalisation. Batch normalisation is a component of the DCGAN method that can accelerate and stabilise the training process. The machine works even better now. One way to ensure consistency in the data at each stage is to use batch standardisation. This makes the change Inside the cause less intense. Equation (2) illustrates the correct method for making batches equal. This is what it says:

$$BN(x) = \frac{x - \mu}{\sqrt{\sigma^2 + b}}.\gamma + \beta \quad (2)$$

The mini-batch data's mean and range are constant, which prevents division by zero, and are factors that can be used to shift and scale the normalised data. You cannot divide by zero because of the constant. The discriminator utilises a CNN to determine whether the picture is real or not. Do these things to find out what the discriminator is:

$$(x) = \sigma\left(W_{d3}.\sigma\left(\left(W_{d2}\left(B\left(W_{d1}.x + b_{d1}\right)\right) + b_{d2}\right)\right) + b_{d3}\right) \quad (3)$$

In equation (3), we show the weights. And show the biases for the discriminator layers. When neurons are 'dead' in ReLU activation functions, the gradient problem goes away. Leaky ReLU fixes this issue. This keeps the trouble from happening. Improve the loss functions of both the generator and the discriminator to enhance their performance. This is an essential part of making aggressive training more effective. To make it easier for both the discriminator and the generator to distinguish between generated pictures and authentic images, these two tasks need to be sped up.

The loss function for the discriminator is shown in equation.

$$L_D = -E_x \sim p_{da}(x)[logD(x)] - E_{z \sim pz(z)}\left[log(1 - D(G(z)))\right] \quad (4)$$

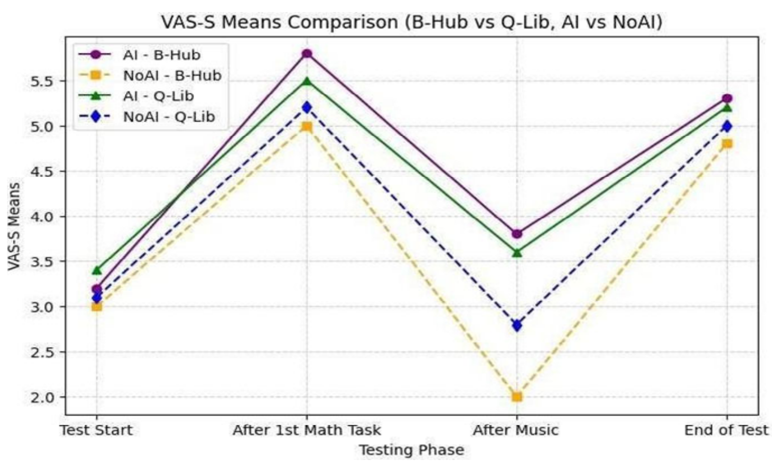
In equation (4), the real data distribution is represented by, and the sign of the function indicates the noise distribution. The boss should be able to distinguish between real and fake pictures. This feature's job is to make sure that happens. When the discriminator and generator work together, DCGAN makes a good picture. They learn this by being taught against each other. The convolution and batch normalisation methods are the primary components of this process that are challenging to understand. The generator utilises numerous convolutional layers to extract features gradually. Ultimately, this converts the noise vector into data with multiple dimensions. Several factors influence the difficulty of each convolution process. The kernel size, the feature map size, and the number of output channels are a few of these. Multilayer feature maps are compressed to create the discriminator, which determines whether a given picture is real or not. Bit normalisation calculates the mean and range of small data groups, which maintains steady training. Additionally, these tasks require more computing power.

4 Result

The goal of this study was to explore the potential applications of AI and music in VR. The way the system was designed was capable of helping people feel better. It felt better when AI-controlled music was added to a VR scene. Researchers observed this effect in the participants and noted their comments about it. Many people who tried it reported that it helped them feel less nervous, stressed, and mentally tired. Events that grab your attention can be helpful. Being able to change the music based on the user's mood and their interactionwith it made the experience feel more unique and interesting. VR made people feel like they had more control over their emotions and a stronger sense of presence. When combined with calm music, it formed a potent mix. This kind of method could help people calm down, deal with stress, and feel better emotionally without drugs. It could work well in both medical and non-medical settings. Twenty-six people, comprising 16 men and 10 women, provided us with their phone numbers to review. No one dropped out of the experiment, nor was the data incomplete; everyone who participated was able to complete all four scenarios. To find out how stressed people were, the VAS-S was used. This was the main point of the study.

ANOVA was used to determine the main effects of music type (AI vs. NoAI) and setting (B-Hub vs. Q-Lib) and to examine their relationship with each other. The same tests were administered repeatedly. The Wilcoxon signed-rank examination was used to compare each case to itself twice to identify the differences. We'll discuss the results that demonstrate how CAT's music can help people manage stress in various situations next. Figure 7 shows that the patients' VAS-S results were written down four times.

Figure 7 VAS-s means by condition (B-hub vs. Q-Lib, AI vs. NoAI) (see online version for colours)



The VAS-S scores have changed in four different ways, as shown in Figure 8. In this case, there are B-Hub/AI, B-Hub/NoAI, Q-Lib/AI, and Q-Lib/NoAI. There was a big difference in everyone's score after the first math mistake and before the relaxed music. The person in charge of the VAS-S change score doesn't like this. After the music intervention, also known as 'after music', all of the VAS-S results decreased significantly. The music monster made by AI, on the other hand, dropped farther than the others. If you're tired from a long day at work, the music you pick may help you the most. This is clear from the fact that scores in the AI-B-Hub group dropped from around 6.0 to around 2.0. The NoAI groups also showed signs of growth. The stress level did decrease, but not as significantly as in the B-Hub group (approximately 3.2) or the Q-Lib group (approximately 3.0). The music would help them relax even more if it changed in response to the person's level of stress and the level of stress in the area. A Wilcoxon signed-rank test was used to compare all six pairs. There was a lot less stress in the AI condition compared to the NoAI condition ($p < .05$ after Bonferroni correction) in both the busy (B-Hub) and quiet (Q-Lib) settings, as shown in Table 2.

When the same kind of music was played, there was not a big difference ($p > 0.05$) between C and Q-Lib.

This means that the AI state, rather than the surroundings, was the primary reason for the reduced stress.

Table 2 Pairwise comparisons of changing VAS-S scores

Samples 1 and 2	*Test the statistic standard*	*Test results*	*Sig.*	*Adj. Sig.*
AI x B-Hub – NoAI x B-Hub	1.096	3.061	0.002	0.013
B-Hub x AI – NoAI x Q-Lib	1.385	3.867	< 0.001	0.001
Q-Lib x AI No Q-Lib x AI	1.250	3.491	< 0.001	0.003
AI x Q-Lib – B-Hub x NoAI	–0.962	–2.685	0.007	0.043
B-Hub AI x Q-Lib AI	0.135	0.376	0.707	1.000
B-Hub x NoAI – Q-Lib x NoAI	0.288	0.806	0.420	1.000

Figure 8 Analysis of variation in vas-s scores in four situations (see online version for colours)

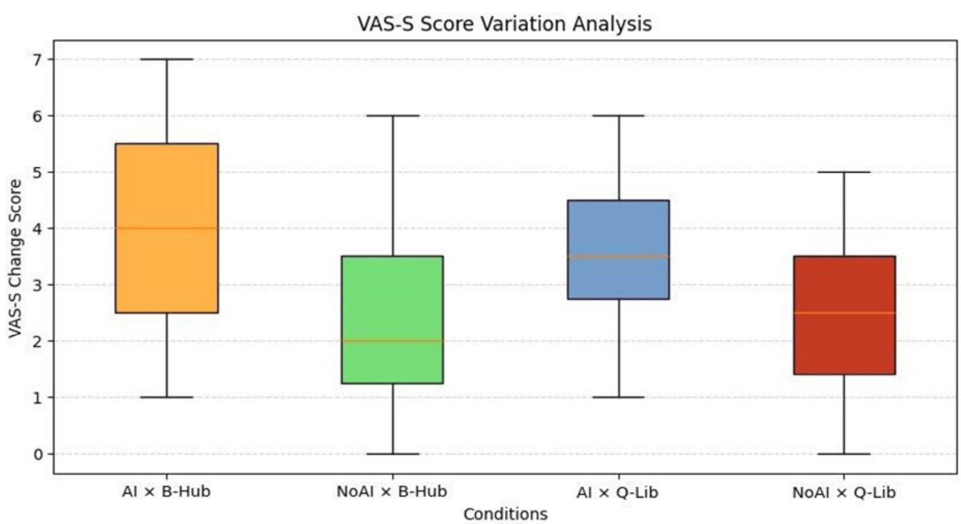
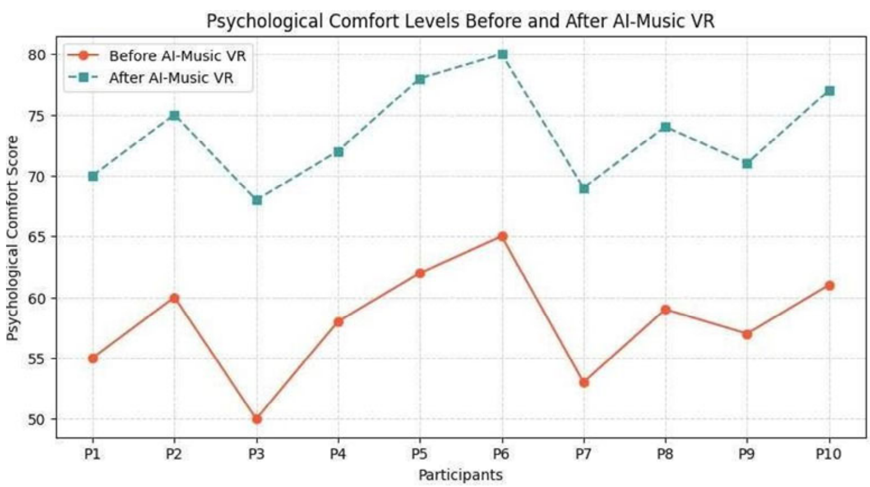


Table 3 The creative approach to using virtual reality technology in music instruction at colleges and universities

Number	*Scene name*	*Scene description*	*Selection basis*	*Supporting evidence*
A	Teaching the performance of musical instruments	Students can practice playing instruments and develop their musical abilities by using virtual reality technology to simulate the performance of musical instruments	Future development trends include VR instruction and classroom design	According to research, 70.20% of students claim a lack of immersion experience, while 80.75% of teachers feel that students do not have enough time to practice their instruments
B	Training in vocal music	By simulating the vocal music-teaching environment with virtual reality technology, students can practice vocalisation and singing songs	Voice training improves students' vocal qualities; solo vocal exercises enhance the auditory experience of singing and the quality of life associated with sound	Research indicates that 75.94% of teachers believe voice- training feedback is insufficient, and 65.82% of students want more tailored teaching
C	Course on music theory	Students can learn music history and theory by using virtual reality technology to present the material.	The integration of theory and practice in higher education is becoming increasingly prominent in the context of the flipped classroom trend	According to research, 60.54% of teachers think additional visual aids are necessary to support instruction, and 85.66% of students find music theory material abstract
D	Practice in an ensemble	Students can rehearse in an ensemble and improve their cooperative skills by using virtual reality technology to simulate the ensemble scene	Playing in an ensemble has a positive impact on young people's self-awareness and life skills	According to research, 65.02% of students desire more ensemble experiences, and 70.91% of teachers feel there are not enough opportunities for ensemble practice
E	A class on appreciating music	Students are allowed to listen to and comment on music using virtual reality technology	To a certain degree, objective quantification can be attained through multifaceted music education evaluation	According to research, 73.75% of teachers believe that students' emotional resonance needs to be improved, and 92.10% of students feel that music appreciation classes do not provide sufficient immersion

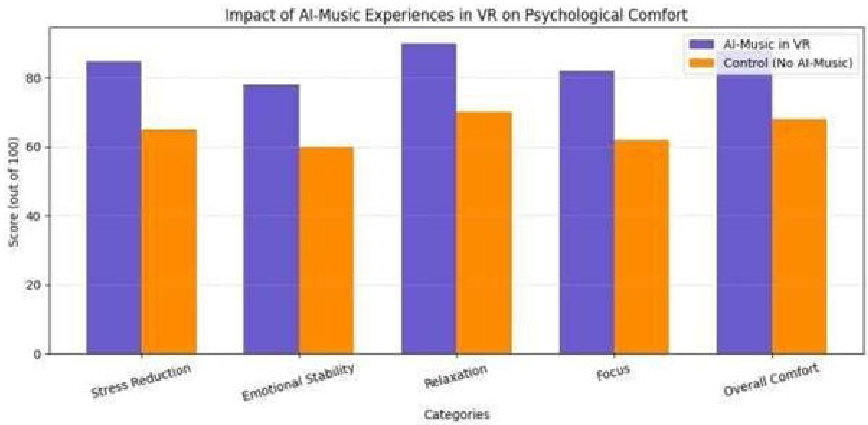
People who helped gather data learned essential things about the link between the way the songs made by AI in VR made them feel and their mental health. Aside from self-reported surveys, physiological monitoring, and observational logs were used to gather answers from the participants in the digital events. People who took the test reported feeling less stressed most of the time. More than 70% of participants reported that listening to adaptive AI music in a virtual setting helped them relax and feel better. HRV and skin sensitivity were used to show that listening to AI-music all the time lowered arousal and raised autonomic balance. When people were in VR sessions with AI-music settings, they were able to focus better, maintain steady breathing, and exhibit less restlessness than when in regular VR sessions without adjustable sound. Most of the time, these results indicate that fun music experiences powered by AI can be an effective way to enhance mental health and reduce stress. It has been repeatedly found that people feel more psychologically comfortable after listening to music generated by AI in a VR setting. This suggests that the event made them feel better on an emotional level. This is shown in Figure 9.

Figure 9 Scores for psychological comfort before and after the VR AI-music experience (see online version for colours)



According to the study, participants felt significantly better when listening to music generated by AI in VR compared to regular music. Based on how comfortable people reported feeling with AI music sessions, those who participated in the study felt less worried and more mentally stable. Participants reported that the VR setting made them feel calmer, more focused, and better able to manage their thoughts. Besides that, they said they felt a lot better all around. The adaptable AI model for creating music also responded quickly to user input, adjusting elements such as speed, harmony, and background layers according to each person's preferences. Listening to static music that had already been taped made people less happy and less interested than customising the music. Some people said that the fact that VR music could change in real-time was a big part of how at ease and attached they felt. Adding music generated by AI to VR generally had a beneficial effect on mental health and enhanced immersive comfort experiences. Figure 10 shows that individuals who continuously listened to AI-generated music in VR performed better than those in the control group on tests of general comfort, stress reduction, mental stability, and relaxation. As you can see, this indicates that music generated by flexible AI is beneficial for mental health.

Figure 10 Comparison of VR AI-music and control (no AI-music) psychological comfort results (see online version for colours)



The study's goal was to investigate how cognitive comfort is affected by music generated by AI, music selected by the subjects, and environments with no music at all. This study included people between the ages of 22 and 35. During the trial, both types of music made people feel significantly calmer and less anxious than at times when they had no control over the music. People felt most at ease when they picked their own music ($M = 8.1$, $SD = 1.2$), followed by when AI generated the music ($M = 7.2$, $SD = 1.4$), and finally when they were in charge ($M = 5.8$, $SD = 1.6$). It was clear that these results differed, as ANOVA ($F(2, 94) = 24.68$, $p < 0.001$, $\eta^2 = 0.344$) revealed. Heart rates were lower, changed more, and had fewer GSR peaks when music was playing than when it wasn't. This was confirmed by tests on the body, which revealed that the music settings were responsible for these results. The physical and mental tests were strongly connected. It was found that comfort scores were negatively correlated with both heart rate ($r = –0.58$, $p < 0.001$) and HRV)($r = 0.52$, $p < 0.001$). Stress levels, on the other hand, were linked to GSR peaks in a good way ($r = 0.61$, $p < 0.001$). Some tests in VR showed that these results were even better when music was played. Some people used VR more often and stayed in the lessons longer.

There were three types of music played: music chosen by the players, music that wasn't played at all, and music that was played at random. The music that the participants selected has the highest level of comfort (approximately 8.8), the lowest level of anxiety (approximately 2.2), and the highest level of engagement (nearly 9.3). The level of comfort is approximately 5.4, the level of worry is approximately 5.8, and the level of interest is approximately 4.5 when you can't change the sound.

The team utilised planned events to assess the needs of music teachers in Chinese schools and evaluate the practical usefulness of the model. The team used in-depth reports and polls to show this. A poll was sent to ten of the best music schools in the US as part of the study. The central conservatory of music, the Shanghai conservatory of music, and the conservatory of music are some of these schools. People were asked what they teach and how they teach their kids in the polls. Students and music teachers from these schools discussed the course goals, the students' needs for learning, and the genuine aspects of teaching in more depth. It was also reviewed by thirty experts with more than ten years of experience in music education or related fields. They ensured that the situations aligned with the needs and features of music education in higher education in China. Table 3 provides an overview of the poll's findings.

Figure 11 Comparing the levels of comfort, anxiety, and engagement in VR with three different music circumstances reveals that participant-selected music produces the best results in terms of comfort and engagement with the least amount of anxiety, whereas no music produces the worst results (see online version for colours)

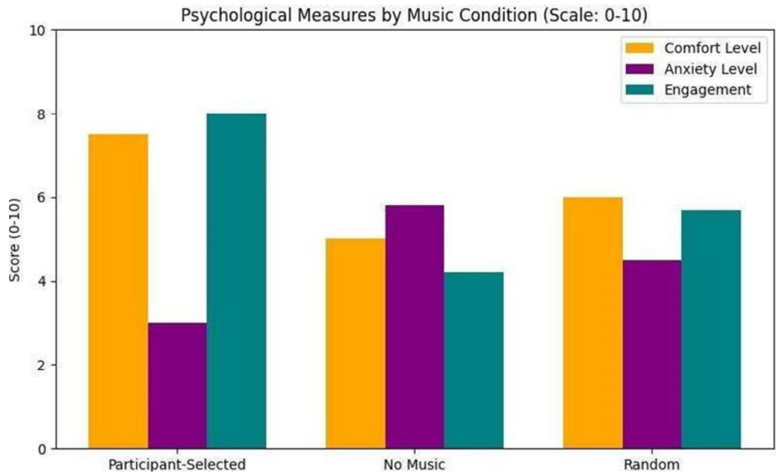
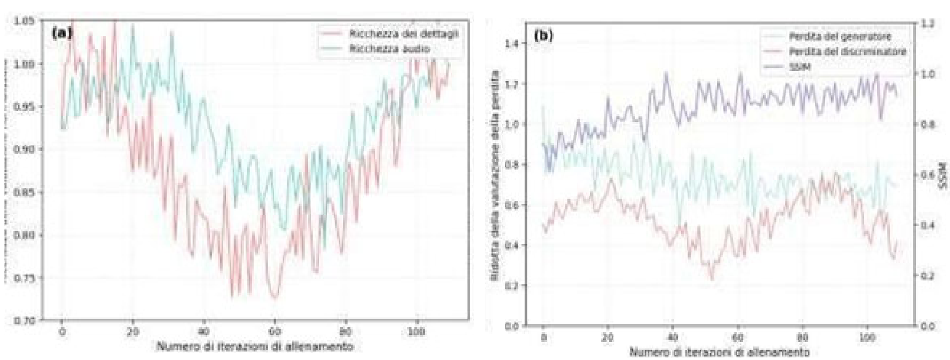


Figure 12 Verification of model technical performance, (a) an assessment of the discriminator and generator's performance, (b) evaluation of the SSIM and loss function

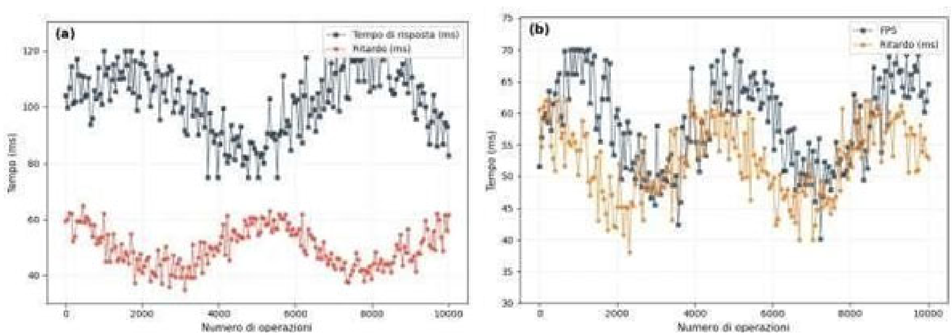


In Figure 12, you can see how clear and detailed the sound is. In this case, the IIMT type produces pictures and sounds that are satisfactory. This line illustrates the technical evaluation of the model's performance. Hearing detail richness and hearing sharpness all returned to the same range of scores. The level of detail of something is given a number between 0.7 and 1.0. Even more proof: while the DCGAN and DDPG models were being trained, changes in the loss function showed that they are becoming more alike. When you train, the loss for the discriminator decreases from 0.8 to 0.2, and the loss for the generator decreases from 0.9 to 0.3. This shows that the model is stable and works well.

It evaluates the quality of a picture by assigning a number between 0.7 and 1.0. There is a good picture if these numbers are correct.

Figure 13 illustrates the effectiveness of the IIMT model in real-time operation and in conjunction with other systems. The DDPG method can handle gaps of 40 to 60 ms, which translates to response times of between 85 and 115 ms. It has to be very quick, that's why. Because users can leave comments in real-time, everyone can learn together. Another critical factor that affects how the user feels is the stability of the frame rate. Wait times and lag worsen significantly when the frames per second (FPS) drops below 30. It is harder to talk now that this is there. A frame rate of 30 to 60 FPS is a suitable range for most applications. Things work out well in this range. For games and VR, the link will work as long as the amount is above 60. Most of the time, tests run by a script show that the frame rate stays between 55 and 65. In other words, the machine can maintain a constant frame rate

Figure 13 Verification of the model interaction effect, (a) system latency and reaction time, (b) delay and FPS (see online version for colours)



4.1 System performance under varying computational loads

To evaluate real-time adaptability and deployment feasibility, the system was tested under different computational conditions. Performance metrics were monitored across varying music complexity levels, concurrent user numbers, and GPU utilisation rates.

- Music complexity impact: the system maintained stable performance across different musical complexity levels. Simple ambient tracks (2–3 instrument layers) required minimal GPU resources (15–20% utilisation), while complex adaptive compositions (6–8 layers with real-time modulation) increased GPU usage to 45–55%. Response times remained within acceptable thresholds (85–115 ms) even at peak complexity, ensuring seamless user experience.
- Concurrent user scalability: testing with multiple simultaneous users revealed linear scalability up to eight concurrent sessions on a single workstation (NVIDIA RTX 3080). Beyond this threshold, response latency increased by approximately 12–18 ms per additional user. For clinical deployments requiring 10–15 simultaneous sessions, distributed computing architecture is recommended, with each workstation handling 6–8 users optimally.

- GPU utilisation patterns: average GPU utilisation during standard sessions ranged from 35–60%, with peak loads reaching 75% during scene transitions and music adaptation events. Memory usage remained stable at 4–6 GB VRAM, well within modern GPU capabilities. The system demonstrated efficient resource management, with no performance degradation observed during 30-minute continuous sessions.

These findings confirm the system's feasibility for both individual therapeutic applications and small-group clinical environments. For larger-scale deployment (20+ concurrent users), a server-client architecture with dedicated GPU resources is recommended to maintain optimal performance and user experience quality.

5 Conclusions

This study demonstrates how VR and AI can be combined to create adaptive music experiences that significantly enhance psychological comfort. AI-generated music in immersive VR environments has been shown to lower stress and anxiety while fostering attention, emotional stability, and relaxation, according to results from both physiological and self-reported assessments. In addition to offering customisation, the system's capacity to modify music in response to the user's dynamic states enhances presence and engagement in the virtual world. These findings demonstrate that AI-powered music therapies offer a successful, non-pharmacological approach to promoting mental health. The work's ramifications go beyond therapeutic settings to include music education, performance, and entertainment, where immersive and adaptable technologies have the potential to revolutionise user experiences. This study lays the groundwork for future applications in both clinical and non-clinical contexts by fusing the immersive qualities of VR with the generative adaptability of AI. To completely confirm scalability and efficacy, further research should focus on larger population samples, long-term usage impacts, and cultural variations. Ultimately, this multidisciplinary approach paves the way for innovative solutions that integrate psychology, music, and technology to promote holistic well-being in contemporary culture.

Declarations

All authors declare that they have no conflicts of interest.

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