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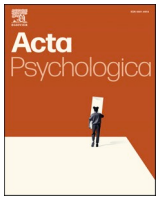

The influence of virtual reality on improving emotional expressiveness in vocal performance

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ABSTRACT

This study aims to evaluate the effectiveness of VR-based training in enhancing the emotional expressiveness of amateur vocalists, with a specific focus on how this improvement may be influenced by the participants' baseline emotional intelligence. The central hypothesis is that the immersive features of virtual reality facilitate vocal emotional development and that a singer's emotional intelligence level significantly moderates this effect. The VR program utilized in the study was specifically designed to enhance participants' emotional expressiveness. The program spanned 12 weeks, consisting of three one-hour sessions per week, and employed high-end equipment, including the Oculus Rift S virtual reality headset, Sennheiser HD 600 headphones, and Alienware Aurora R8 computers equipped with NVIDIA GeForce RTX 2080 graphics processors. The study has a quasi-experimental design, the participants were 109 students from a private music school in Beijing. Emotional intelligence (EI) was measured using the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT). The level of emotional expressiveness was determined through blind expert assessments before and after the 12-week VR program. The results showed a significant improvement in singing expressiveness after the course. There was a strong positive correlation between the EI levels of students and their emotional expressiveness of performance both before and after the intervention. Moreover, the study highlights the importance of a basic EI level in maximizing the benefits derived from immersion and interactive interventions within vocal training. The article continues the global discussion about how psychological differences affect the quality of music education and actualizes the discussion about the role of EI in the training of vocalists.

1. Introduction

In the developing world of music education, the integration of advanced technologies into curricula has been decisive. It opened up new opportunities for improving pedagogical methods and more intensive development of vocal skills (Kaleńska-Rodzaj, 2021; Spreadborough & Anton-Mendez, 2019). Among these technologies, virtual reality (VR) stands out as a promising option, offering an immersive and interactive approach to training (Weiss et al., 2016). This article examines the impact of virtual reality on the emotional expressiveness of solo vocalists. The study delves into how this technology when used in an educational environment, can form a deeper connection between the performer and the emotional range available while singing.

Emotional expressiveness in vocal performance goes beyond the pursuit of technical mastery. It entails the need to evoke a genuine emotional response from the listener by conveying a broad spectrum of emotions (Doganyigit & Islim, 2021; Huang, 2018). The ability to convey a wide range of emotions by voice is an essential indicator of effective vocal performance. This aspect influences the audience's/jury's perception and the level of immersion in the music by the performer (Cayari, 2018). Traditional vocal teaching methods primarily focus on mastering technical skills: pitch, purity of performance, vocal techniques, range, breath control, and others (Huang & Yu, 2022; Jordhus-Lier et al., 2021). However, these methods tend to neglect the intentional development of emotional expressiveness, which can greatly enhance the overall quality of performance, adding authenticity and depth (Meissner & Timmers, 2019).

VR technology has shown tremendous potential in various fields, from medicine to aviation, due to its ability to simulate complex real-world scenarios in a controlled immersive environment (Wang, 2024b; Webb et al., 2024). In the field of vocal education, virtual reality can create personalized settings for performance (Wang, 2024b). This opportunity allows vocalists to train and improve their emotional expressiveness in front of a virtually created audience resembling a real one. It is believed that deep immersion can help overcome stage fright and improve the performer's on-stage behavior. Most importantly,

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performers have the opportunity to experiment with their emotional delivery without the pressure of performing in front of a real audience. Additionally, they can improve their expressiveness through the feedback they receive (Daffern et al., 2019; Jang et al., 2019; Wang, 2024c).

Emotional intelligence (EI) plays a pivotal role in music education, particularly in the development of the ability to convey emotions through vocal performance. EI encompasses the awareness and regulation of one's own emotions, as well as the understanding and interpretation of the emotions of others (Mayer & Salovey, 2007). Research indicates that a high level of EI is closely associated with more expressive vocal performance, as it enables performers to adapt their emotional delivery to the content of a musical piece and the reactions of the audience (Bhatara et al., 2011; Lyons & Schneider, 2005; Resnicow et al., 2004). Furthermore, EI contributes to reducing performance anxiety and enhancing self-confidence, which is particularly crucial in training novice vocalists (Bryant, 2021; Laukka & Elfenbein, 2021).

The hypothesis of this article rests on the idea that the effectiveness of virtual reality (VR) in enhancing the emotional expressiveness of vocal performances is significantly influenced by the individual's emotional intelligence, understood as a capacity that can be developed and refined over time. The latter is defined as the ability to recognize, understand, and manage one's own emotions and those of others (Bryant, 2021). To test this hypothesis, this study investigates the relationship between performers' emotional intelligence (EI) and their ability to enhance emotional expression using virtual reality in music school education. This article aims to provide insight into how VR technology can be utilized to meet the unique needs of performers and enhance their emotional expressiveness during solo vocal performances. Additionally, this research attempts to broaden the discourse on the integration of VR technologies into music education. The findings are expected to offer new empirical evidence on how to use immersion technologies and address the issue of increasing emotional expressiveness among amateur singers.

The relevance of this study is driven by the insufficient exploration of issues related to the development of emotional expressiveness in vocalists. Despite the advances of VR technology in other fields, including medicine and education, its potential in music training remains largely underexplored (Bissonnette et al., 2015; Daffern et al., 2019). Given the importance of emotional expressiveness as a key component of artistic performance, the need to develop effective methodologies becomes evident. Moreover, an important aspect of this research is the examination of the role of emotional intelligence (EI) as a predictor of success in training that incorporates VR. Previous studies have confirmed the influence of EI on the ability to convey emotions (Bryant, 2021; Resnicow et al., 2004). However, the lack of data on the relationship between EI and VR technologies in the context of vocal training represents a significant gap in the scientific literature. This article addresses this gap, underscoring its relevance and scholarly value.

1.1. Literature review

Emotional expressiveness in solo and group singing goes beyond the technical performance of musical notes. This concept implies a subtle and multifaceted process of conveying the emotional state and idea of the composition (Bissonnette et al., 2015; Daşdöğen, 2023; Guo, 2023). Musical psychology research has shown that the emotional expressiveness of a performer determines their skill, influences the level of engagement of the audience, and impacts the satisfaction of both the performer and the audience with the performance (Gao, 2022; Han, 2022; Hao & Zhang, 2022). These studies indicate the relevance of developing psychological and pedagogical approaches aimed at developing the vocalist's ability to express a wide range of emotions through vocal performance.

As for virtual reality, its use in educational institutions entails the trend toward the formation of an interactive educational environment. The advantage of VR is its capability of creating environments that are as close to reality as possible. VR environments allow for practicing and improving skills with the possibility of receiving feedback (Dibben, 2016; Guo, 2023). The literature on this issue shows that VR can effectively reduce performance anxiety and form a positive attitude toward singing. In addition, VR facilitates the rehearsal process due to high interactivity and the opportunity to try singing in different conditions (Bian, 2016; Li, 2017). VR's ability to provide instant, customizable, and flexible feedback offers an updated approach to teaching and learning. This approach makes the learning experience more personalized and engaging (Condon, 2015, 2018; Lin, 2023; Picado et al., 2022; Wang et al., 2024).

Earlier research has explored the potential of virtual reality (VR) in various aspects of music education, with promising findings. VR has been successfully applied to reduce performance anxiety, improve technical skills, and create immersive environments for rehearsals and practice sessions. For instance, studies have demonstrated that VR can simulate performance scenarios, allowing musicians to practice in front of virtual audiences, which helps reduce stage fright and build confidence (Bissonnette et al., 2015; Daffern et al., 2019). The interactive nature of VR also enables immediate feedback on performance, enhancing technical precision and engagement (Gao, 2022; Li, 2017).

In vocal training, VR has been shown to support singers in developing expressiveness by providing opportunities to experiment with emotional delivery in a controlled and pressure-free environment (Doganyigit & Islim, 2021; Lin, 2023). By offering real-time visual and auditory feedback, VR systems can help vocalists refine their ability to convey emotions, adjust dynamics, and improve overall stage presence (Dibben, 2016; Wang, 2024a). These studies highlight VR's capacity to integrate music education's cognitive, technical, and emotional dimensions, creating a holistic training experience.

The integration of virtual reality (VR) into music education necessitates the retraining of educators. This requirement arises from mastering new technologies that transform traditional teaching methods. Effective utilization of VR demands technical preparation, including equipment setup, management, and troubleshooting (Lin, 2023; Wang et al., 2024). Furthermore, while traditional methods focus on direct interaction with students in physical spaces, VR necessitates a reconfiguration of instructional approaches. Educators must develop the skills to effectively leverage immersive environments to enhance student engagement, provide feedback through virtual interfaces, and design curricula incorporating VR technologies (Daffern et al., 2019; Doganyigit & Islim, 2021).

The integration of VR into music education has its challenges. Technological limitations, high monetary investments, monotonous and uniform teaching methods, and insufficient quality of feedback are some of the issues that have been discussed in relation to increasing the emotional and technical aspects of solo performances. Additionally, there is a need for pedagogical adaptation and retraining for teachers (Akkermans et al., 2018; Lin, 2023; Picado et al., 2022) On the other hand, there remains a certain consensus that virtual reality technology can update and improve the approach to music education, especially regarding the changing needs of modern students (Dai, 2024).

The first level of emotional intelligence (EI) pertains to the perception of emotions, which involves the ability to recognize one's emotional states and those of others. This is achieved through analyzing nonverbal cues, such as facial expressions, tone of voice, and gestures. Individuals with a high level of emotional perception can detect even subtle emotional changes, enabling them to adapt more effectively to interpersonal situations (Mayer & Salovey, 2007).

The next level of EI is the ability to use emotions to support cognitive activities and decision-making processes. Emotions can enhance focus, boost motivation, and foster creative approaches to problem-solving. For instance, positive emotions may facilitate innovative thinking, while mild anxiety can help concentrate on complex tasks (Bryant, 2021).

Understanding emotions represents an even more advanced level of

EI. It encompasses the ability to analyze emotional states, recognize how emotions evolve over time, and anticipate their outcomes. Individuals with well-developed emotional understanding can distinguish complex emotional states, such as mixed feelings or envy, and incorporate these insights into their behavior.

The highest level of EI is emotional regulation, which involves managing one's emotional states and influencing the emotions of others. This level requires maturity and stress management skills, which are particularly crucial in challenging or conflict-laden situations (Mayer & Salovey, 2007). For example, an individual with high EI can remain composed in stressful environments while supporting and inspiring others, fostering a positive atmosphere (Bhatara et al., 2011).

The study of the relationship between the effectiveness of virtual reality (VR) and levels of emotional intelligence (EI) is crucial for optimizing educational approaches and technologies. VR offers opportunities to create personalized learning environments, and understanding the role of EI enables the adaptation of these environments to meet the emotional and cognitive needs of individual learners. A high level of EI is associated with better feedback reception, emotional regulation, and adaptability, which can significantly enhance the effectiveness of VR-based training (Bryant, 2021; Mayer & Salovey, 2007). Conversely, learners with lower EI may require more structured support and additional tools to fully benefit from the potential of VR (Daffern et al., 2019; Picado et al., 2022).

Understanding this relationship also contributes to the development of emotional and social skills, such as expressiveness and empathy, which are essential in various educational and professional contexts. Furthermore, examining these factors assists VR developers and educators in designing inclusive and effective programs, ensuring equal opportunities for all participants (Lin, 2023; Wang et al., 2024).

The importance of EI for music education in terms of the development of emotional expressiveness has been empirically studied before. However, these findings must be updated and extended to include different groups of musicians with diverse backgrounds and experiences (Lyons & Schneider, 2005; Resnicow et al., 2004; Scherer et al., 2017). Another challenge is the lack of research on evaluating the effectiveness of VR in relation to the level of emotional intelligence of a vocalist and the connection between these two factors (Han, 2022). Thus, the relationship between EI and VR in the context of vocal training is an underresearched area. Studies in this field could provide valuable insights into how the emotional and cognitive profiles of individual students influence their level of emotional expressiveness in singing. Thus, this study fills a noticeable gap in research by examining how the basic emotional intelligence of amateur vocalists affects their learning in a VR program designed to enhance their ability to express emotions through music.

The assessment of emotional intelligence (EI) is a critical component of studies exploring the relationship between emotional expressiveness and psychological factors. One of the most widely used tools for measuring EI is the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT). This instrument is based on the Mayer and Salovey model of emotional intelligence (Mayer & Salovey, 2007). It objectively evaluates EI's core components: emotion perception, understanding, utilization, and regulation.

The MSCEIT consists of eight tasks distributed across four primary domains of EI, allowing for a comprehensive assessment of participants' ability to perceive and interpret emotions. One of the key advantages of MSCEIT is its objectivity; the test results are derived from the completion of standardized tasks rather than self-reports, which are susceptible to subjective biases such as social desirability or individual interpretation of questions (Li et al., 2020). This feature makes MSCEIT a reliable tool for research requiring precision and reproducibility of data.

Previous studies utilizing the MSCEIT have demonstrated its effectiveness in examining the impact of EI across various domains. For instance, Resnicow et al. (2004) identified that a high level of EI facilitates better interpretation of the emotional content of music and enhances the quality of musical performances. Additionally, Bhatara et al. (2011) showed that participants with higher EI are more adept at recognizing emotional nuances in musical compositions, reflecting their ability to engage more deeply with the emotional context of performance. These findings underscore the significance of EI as a critical factor in music education and other fields involving emotional processes.

1.2. Problem statement

The use of VR in music education contributes to improvements in the vocal abilities of both children and adults (Daşdöğen, 2023). On the other hand, the influence of individual psychological traits, particularly EI, on the effectiveness of such technologies remains an insufficiently studied issue (Bryant, 2021).

The study of the relationship between emotional expressiveness and levels of emotional intelligence (EI) is critical as it addresses fundamental aspects of how individuals interpret, manage, and convey emotions. This is particularly significant in music education, where emotional depth profoundly impacts performance quality. Emotional expressiveness is not merely a technical skill; it reflects a performer's ability to connect with the audience and convey genuine emotions, forming the foundation for creating a lasting impression (Bhatara et al., 2011; Bryant, 2021).

The goal of this study is to examine the relationship between the basic level of emotional intelligence and the ability of non-professional adult vocalists to improve their emotional expressiveness by participating in a VR program. This information can shed light on whether the level of EI affects the effectiveness of immersion interventions for solo singers. To achieve this goal, it is necessary to solve several research tasks:

1. Measure the basic EI level of participants using reliable psychological tools that exclude self-reporting.
2. Develop and implement a VR training program aimed at developing emotional expressiveness.
3. Evaluate the changes in the emotional expressiveness of the participants before and after they completed the VR training program.
4. Analyze the relationship between the initial EI level and the improvement of emotional expressiveness; determine to what extent EI affects the effectiveness of a short VR-based exercise.

By addressing these challenges, the study aims to fill a gap in current empirical research and contribute to optimizing the use of VR to improve vocal learning. The findings are expected to contribute to a better understanding of the personalized use of technology in art education. In addition, the study can shed light on the impact of psychological variables on vocal performance.

2. Methods and materials

This study used the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT). The MSCEIT is a comprehensive tool for evaluating emotional intelligence across a wide range of emotional and social competencies. This test is based on the emotional intelligence model proposed by Mayer and Salovey (2007). The methodological tool consists of 141 questions divided into eight tasks. Scores are distributed on a scale of 60 to 160, with higher scores indicating a greater ability to process emotional stimuli and use them effectively in daily life (Ma et al., 2010). This test has been adopted in various countries, including China (Li et al., 2020). The tool was chosen for this study because it does not include self-reporting elements, which can be influenced by subjective perception and social desirability. The MSCEIT offers an assessment based on the results.

The assessment of emotional expressiveness in vocal performance assumed the participation of a panel of expert judges. The panel included five expert judges who brought diverse perspectives,

mitigating individual bias. The judges evaluated the performances based on predetermined criteria, among which they paid attention to emotional authenticity, emotional range, and the ability to convey appropriate emotions through singing. The selected experts were vocal teachers, music educators, and music psychologists with more than 5 years of experience in the field of the music jury. The involvement of judges with different experiences ensured a comprehensive assessment of performance, covering technical, emotional, and pedagogical aspects.

Before the start of the study, all judges received instructions on evaluation criteria to standardize assessments throughout the group. During this session, the experts were introduced to the scoring system and the existing criteria for evaluating emotional expressiveness. The criteria covered emotional authenticity (how sincerely the performer conveys emotions), emotional range (the variety of emotions that the performer can express), and the correspondence between the vocal material and the emotion conveyed by the performer.

The rating system was set on a scale from 1 to 10 for each criterion. The scores from 5 judges for each criterion were averaged to obtain a final score. The total score of the participants was calculated by summing the average scores according to all criteria. This approach provided a comprehensive assessment of the emotional expressiveness of the performers. The maximum total score was 30 points. To ensure the transparency of the experiment, performances were anonymous, and the judges did not discuss their decisions on scores with each other.

The VR program developed for this study focused on increasing the emotional expressiveness of solo vocalists through immersive modeling of the environment and interactive feedback mechanisms. A central feature of the program was real-time visual and auditory feedback, which tracked and analyzed the performers' emotional expressiveness. At the end of the session, participants received a report on their performance. An extensive library of interactive scripts and songs implemented within this system allowed the participants to practice singing in different musical genres and conveying various emotions. In addition, the program included interactive modules dedicated to the peculiarities of breathing and relaxation. These modules were designed to eliminate performance anxiety. The program was 12 weeks, with three sessions per week lasting approximately 1 h each.

The vocalists used the Oculus Rift S VR headset, known for its high-resolution display and immersive spatial sound. The built-in tracking system made it possible to accurately track the movements and facial expressions of participants accurately, increasing the realism of the virtual environment and the accuracy of the feedback provided. To provide the high-quality audio output needed for vocal training, Sennheiser HD 600 headphones were utilized. The classes took place on high-performance Alienware Aurora R8 computers equipped with NVIDIA GeForce RTX 2080 graphics cards, capable of rendering complex virtual environments with real-time and lag-free feedback.

2.1. Research design

The study used a quasi-experimental design. Before starting the experiment, the participants had 1 week to complete MSCEIT, which took 40 to 60 min. The experimental period lasted 12 weeks, during which the participants underwent a series of VR training sessions aimed at improving their emotional expressiveness. To assess the impact of VR training on the emotional expressiveness of the participants, EI was evaluated before and after the intervention.

To ensure uniformity in assessing emotional expressiveness, all participants performed the same set of songs. A standardized list allowed the researchers to control differences in song complexity and emotional range, ensuring that any observed differences in performance were mainly due to the effects of VR training. The participants performed the selected pieces of music twice: once before the start of VR training and once after. These performances were recorded in a controlled environment to ensure uniformity of sound quality and minimize external variables that could affect the performance or its evaluation. In order to avoid bias, the identities of the participants were anonymous, and the judges did not know whether they evaluated the performances before or after the training. Each judge listened to the recordings independently through high-quality audio systems provided by the music school that participated in the study. After evaluating all the performances, the judges' scores were summed up and averaged for each participant. This approach ensured that the final scores represented consensus among the judges, reducing the impact of individual differences in scores. The average length of each performance was about 3 min.

The program was based on using advanced tracking technologies integrated into the Oculus Rift S virtual reality headset and high-performance computing systems. This setup enabled instantaneous and accurate feedback on key parameters related to emotional expressiveness. Visual feedback was provided through an emotion recognition system that analyzed participants' facial expressions using motion sensors embedded in the headset. The system evaluated the alignment between the intended emotional expression and facial movements. Participants could see a scale in their peripheral vision displaying the intensity and authenticity of their expressed emotions. For instance, if the facial expression did not align with the intended emotion, the system offered recommendations such as “broaden your smile to convey joy” or “relax your brows to reduce tension.”

Auditory feedback was delivered via built-in acoustic sensors that analyzed vocal tone, pitch variations, and dynamics. Participants received real-time prompts through headphones to adjust their emotional delivery. For example, if the performance lacked depth, the system generated a suggestion to “add vibrato to create warmth.”

After each performance segment, the program displayed textual recommendations, providing advice such as “increase vocal intensity during climactic moments” or “work on emotional transitions between phrases.” Additionally, adaptive scenarios were employed, dynamically adjusting based on previously provided feedback to encourage participants' gradual improvement.

To minimize system latency, high-performance processors (e.g., NVIDIA GeForce RTX 2080) and optimized motion and sound processing algorithms were utilized. This ensured instantaneous feedback without disrupting the training flow.

2.2. Participants

The study involved students from a private vocal music school in Beijing, China. The participants were 109 people aged 18 to 28 years old who had studied for at least 1 year and had experience of performing. Before being included in the study, potential participants were tested to confirm the absence of health conditions such as epilepsy or mental disorders. This process included an assessment of the general state of health to ensure that there were no medical contraindications for using the headset. All volunteers expressed a desire to improve their emotional expressiveness during solo singing in a VR environment.

2.3. Ethical issues

The study was conducted in accordance with the principles of the Helsinki Declaration and was approved by the Ethics Committee. Each participant was informed about the objectives of the study, the nature of the VR intervention, and the duration of the experimental period. The informed consent form contained a point stating that participation was completely voluntary and participants could withdraw from the study at any time without any sanctions. To ensure the confidentiality of the participants, personal information and other data were only available to the research group. The presentation of the research results excluded the identification of individuals. Before the start of the experimental period, the participants received instructions on how to safely use the equipment. Technical support was available at any time. There was no risk to the mental or physical health of participants, as all immersion sessions were carefully monitored and controlled. In case of any technical issues,

the participants could seek assistance from the support team.

2.4. Data analysis

The IBM SPSS Statistics (Version 23) software was used to analyze the data. Initially, the researchers checked for missing values and outliers to ensure that all data was entered and formatted correctly. Paired selective *t*-tests were conducted to assess changes in emotional expressiveness after VR training. The comparison of the participants' scores for emotional expressiveness before and after the intervention revealed differences related to the training program. Pearson's correlation coefficient allowed for studying the relationship between baseline emotional intelligence and improved emotional expressiveness.

3. Results

Table 1 provides an overview of the results from a study on the impact of VR training on increasing the emotional expressiveness of vocal performance among students of a private vocal school in Beijing. The study measured the participants' levels of emotional intelligence, as well as their ability to express emotions when singing both before and after undergoing a series of virtual reality training sessions. These sessions were designed to immerse participants in a diverse performance environment by providing them with real-time feedback aimed at improving their emotional expressiveness.

The average MSCEIT score among the participants was 110.61 out of 160 possible, with a standard deviation 29.262. This result indicates a moderately high baseline level of emotional intelligence in the group. Thus, the participants had a sufficient level of ability to perceive, use, understand, and manage emotions.

Before starting VR-based training, the average score of the participants for emotional expressiveness, according to experts, was 17.71 out of a maximum of 30 points, with a standard deviation of 4.682. These indicators reflect a wide range of initial skills in expressing emotions through vocals. Some participants showed a higher natural tendency toward emotional expressiveness than others.

After the VR training, there was a noticeable improvement: the average score for emotional expressiveness after the experiment increased to 19.62 out of 30, with a standard deviation of 4.690. This increase highlights the positive impact of the VR training program on participants' ability to convey emotions aloud. Therefore, VR technology has the potential as a tool to enhance the emotional expressiveness of vocal performance.

Table 2 presents the results of a statistical study aimed at quantifying the improvement of vocal emotional expressiveness among vocal students after a virtual reality (VR) training program. A paired selective *t*-test allowed the researchers to compare expert assessments of the participant's ability to convey emotions through their vocal performances before and after the training.

The average difference in points indicating improvement after training was −1.916 points. This negative value represents an increase in post-experiment scores compared to pre-experiment scores. The results suggest that participants could convey emotions more effectively in their vocal performances after undergoing VR training.

The standard deviation of the differences between the paired scores was 0.862, which highlights the variability in the participants' improvement indicators after training. Despite this variability, the root mean square error of the average difference was 0.083. This result is an accurate estimate of the sample distribution of the average difference.

The 95 % confidence interval was within the range from −2.080 to −1.753. This fact indicates that the true average difference in improvement was within this interval and statistically significant, starting from zero. The interval was not equal to zero, confirming the conclusion that VR training had a measurable positive effect on the emotional expressiveness of vocal performance.

The t-statistics of −23.219 with 108 degrees of freedom once again confirmed the reliability of the observed improvement. The *p*-value was 0.000, which is significantly lower than the usual 0.05 threshold. Consequently, the results are statistically significant. This fact implies that the observed improvements in vocal emotional expressiveness associated with VR training are unlikely to be the result of chance.

The analysis of the paired sample *t*-test provided convincing statistical evidence to conclude that virtual reality training significantly increases the emotional expressiveness of vocal performance. The data clearly affirms the effectiveness of VR as a vocal training tool. Thus, the inclusion of VR in vocal training programs offers a reasonable way to improve emotional expression in singing, which is an important component of an engaging and impressive performance.

Pearson's correlation analysis shows a very significant and strong relationship between participants' levels of emotional intelligence (EI), measured by MSCEIT scores, and their ability to express emotions during vocal performance before and after completing the virtual reality (VR) training program. Correlation coefficients indicate a stable positive relationship. The results emphasize the relationship of EI with vocal emotional expressiveness in the context of VR-based learning (Table 3).

The Pearson correlation coefficient of 0.907 between MSCEIT scores and Pre-Experiment Emotional Expressiveness Scores means a very strong positive correlation. This suggests that individuals with higher levels of emotional intelligence tend to be rated higher by experts regarding their emotional expressiveness. The relationship between these two variables is statistically significant, with a *p*-value of 0.000, indicating that the probability of this strong correlation being due to random variation is less than 0.1 %.

Similarly, the correlation between MSCEIT scores and Post-Experiment Emotional Expressiveness Scores is also strong and positive, with a coefficient of 0.890. This again highlights the important role of EI, not only at the initial stage but also in determining how much participants can improve their emotional expressiveness after VR-based learning. The statistical significance of the correlation with a *p*-value of 0.000 confirms the unlikely role of randomness in this relationship.

The strongest correlation observed in the analysis is the correlation between Pre-Experiment and Post-Experiment Emotional Expressiveness Scores with a Pearson coefficient of 0.983. This extremely high correlation demonstrates that participants who initially scored higher on emotional expressiveness also tended to show greater improvements after learning VR. Given the *p*-value of 0.000, this result reflects consistent progress in improving emotional expressiveness among participants, proving the effectiveness of the VR training program.

These correlations, significant at 0.01 (two-sided), illustrate the internal relationship between EI and vocal emotional expressiveness. Additionally, the correlations confirm the powerful influence of VR training on enhancing this expressiveness in vocal performers. These data strongly support the assumption that emotional intelligence is an important factor in vocal education. Virtual reality can be an effective tool for developing emotional expressiveness, a key aspect of vocal performance.

Table 1
Impact of virtual reality training on emotional expressiveness in vocal performance: a quantitative overview.

	MSCEIT scores	Pre-experiment emotional expressiveness scores	Post-experiment emotional expressiveness scores
Mean	110.61	17.71	19.62
N	109	109	109
Standard deviation	29.262	4.682	4.690

4. Discussion

The observed increase in emotional expressiveness of the voice after VR-based training echoes the results of previous research. Other studies

Table 2
Statistical analysis of improvements in vocal emotional expressiveness post-VR training.

		Paired differences					t	Degrees of freedom	*p*-Value (2-sided)
		Mean	Standard deviation	Root mean square error	95 % confidence interval for the difference				
					Lower	Upper			
Pair 1	Pre-experiment scores – post-experiment scores	−1.916	0.862	0.083	−2.080	−1.753	−23.219	108	0.000

Table 3
Exploring the nexus between emotional intelligence and vocal emotional expressiveness: insights from Pearson correlation analysis.

		MSCEIT scores	Pre-experiment emotional expressiveness scores	Post-experiment emotional expressiveness scores
MSCEIT scores	Pearson's correlation coefficient	1	0.907**	0.890**
	Sig. (2-sided)		0.000	0.000
	N	109	109	109
Pre-experiment emotional expressiveness scores	Pearson's correlation coefficient	0.907**	1	0.983**
	Sig. (2-sided)	0.000		0.000
	N	109	109	109
Post-experiment emotional expressiveness scores	Pearson's correlation coefficient	0.890**	0.983**	1
	Sig. (2-sided)	0.000	0.000	
	N	109	109	109

** The correlation is significant at 0.01 (2-sided).

also show that immersion technologies can significantly affect the development of expressive skills in singers (Bian, 2016; Li, 2017; Lin, 2023; Picado et al., 2022). The integration of real-time feedback in a virtual reality environment that simulated live performances might have improved the participants' levels of emotional expressiveness. This thesis is consistent with studies that emphasize the effectiveness of immediate feedback in acquiring and improving skills (Bissonnette et al., 2015; Daşdöğen, 2023; Guo, 2023; Han, 2022; Hao & Zhang, 2022).

A significant correlation between MSCEIT scores and expressiveness scores before and after the experiment confirms the results of earlier studies. Other researchers have also found that a higher level of emotional intelligence assumes greater sensitivity and control over the expression of emotions in solo or group singing (Bhatara et al., 2011; Lyons & Schneider, 2005; Olteţeanu, 2010; Resnicow et al., 2004). The results of the study expand this discourse by empirically demonstrating the direct influence of EI on the ability to improve emotional expressiveness through targeted immersion training. The findings emphasize the importance of EI for musicians, as reported in previous studies (Bryant, 2021; Dai, 2024; Laukka & Elfenbein, 2021; Yang et al., 2021).

The obtained data also substantiate the continuity of the development of emotional expressiveness in singers. Learning through the VR program can benefit all students. However, those who initially have a higher level of expressiveness can be more successful than those who lack control over their emotions. This conclusion expands the range of knowledge about the importance of individual differences in learning outcomes. It is necessary to develop and implement personalized educational programs with elements of psychological training. These programs can help singers of different ages to express and manage emotions, thereby improving their vocal skills, the artistic value of their performance, or even their confidence (Bhatara et al., 2011; Shpyrka et al., 2021; Wang, 2024b).

Within the broader context of existing knowledge, the research contributes to a deeper understanding of how virtual reality can enhance emotional expressiveness. By demonstrating a direct correlation between EI and the effectiveness of VR training, the study confirms the thesis that the psychological traits of singers can influence the quality of improvements provided by interactive educational environments (Hao & Zhang, 2022; Weiss et al., 2016). These findings are relevant within the framework of the digitalization of public and private education in China and other countries.

4.1. Limitations

The use of a specific VR platform and a predefined set of songs may limit the possibility of generalizing the results. The virtual reality training program was designed with the Oculus Rift S hardware and individual software configurations, which may not cover all available virtual reality technologies. Another limitation is the composition of the study participants, which consisted of people with different levels of vocal training and emotional intelligence. While this diversity provides a wide range of participants, it also introduces some variability in the effects of VR learning. Differences in basic vocal skills, musical experience, and emotional intelligence could impact the participant's perception of the training program, potentially affecting the results of the study.

Recognizing these limitations is crucial for contextualizing research findings in the broader context of music education. In future research, it is necessary to address these limitations, possibly through the use of longitudinal design, a wider range of VR technologies, as well as control groups. These measures can strengthen the evidence base in terms of increasing emotional expressiveness when singing.

5. Conclusions

This study explored the use of virtual reality (VR) to enhance the emotional expressiveness of vocal performance. The results revealed that participants demonstrated a marked improvement in their ability to express emotions through singing after the VR training.

The findings have practical and scientific significance, providing new empirical evidence that EI is essential in training singers and musicians. Another important discovery is the fact that VR has the potential to increase emotional expressiveness, rather than just assisting with practicing some techniques or improving the technical aspects of performance. The obtained data indicate a shift in the educational paradigm

toward a wider introduction of immersion technologies. Moreover, the definition of EI as a factor determining the success of technological interventions makes it necessary to consider the psychological profiles of students. It is crucial to develop highly specialized programs with the involvement of professional psychologists who can teach students to understand better and show emotions.

Future research should explore how other psychological parameters such as self-esteem, subjective well-being, anxiety, depression, character, and others affect emotional expressiveness and whether these parameters impact the success of VR training programs. Another possible research direction is a longer-term study examining the effectiveness of VR in improving emotional expressiveness in comparison with the usual educational environment. In this context, it is also important to analyze the influence of situational factors (such as experience, age, gender, and others) on the effectiveness of immersive learning.

CRediT authorship contribution statement

Meitian Zhao: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Informed consent

Informed consent was signed by participants.

Consent for publication

Not applicable.

Ethics approval

The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The research was approved by the local ethics committee of Taiyuan Normal University (Protocol No. 6121 of 13.06.2023).

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Declaration of competing interest

The research has no conflict of interest.

Data availability

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

References

Akkermans, J., Schapiro, R., Müllensiefen, D., Jakubowski, K., Shanahan, D., Baker, D., Busch, V., Lothwesen, K., Elvers, P., Fischinger, T., Schlemmer, K., & Frieler, K. (2018). Decoding emotions in expressive music performances: A multi-lab replication and extension study. *Cognition and Emotion, 33*(6), 1099–1118. https://doi.org/10.1080/02699931.2018.1541312

Bhatara, A., Tirovolas, A. K., Duan, L. M., Levy, B., & Levitin, D. J. (2011). Perception of emotional expression in musical performance. *Journal of Experimental Psychology: Human Perception and Performance, 37*(3), 921–934. https://doi.org/10.1037/a0021922

Bian, H. X. (2016). Application of virtual reality in music teaching system. *International Journal of Emerging Technologies in Learning, 11*(11), 21–25. https://doi.org/10.3991/ijet.v11i11.6247

Bissonnette, J., Dubé, F., Provencher, M. D., & Moreno Sala, M. T. (2015). Virtual reality exposure training for musicians: Its effect on performance anxiety and quality. *Medical Problems of Performing Artists, 30*(3), 169–177. https://doi.org/10.21091/mppa.2015.3032

Bryant, G. A. (2021). The evolution of human vocal emotion. *Emotion Review, 13*(1), 25–33. https://doi.org/10.1177/1754073920930791

Cayari, C. (2018). Connecting music education and virtual performance practices from YouTube. *Music Education Research, 20*(3), 360–376. https://doi.org/10.1080/14613808.2017.1383374

Condon, S. (2015). *Creating a musically expressive performance: A study of vocalists' use of emotions in performance preparation* (Master's thesis). University of Jyväskylä. https://doi.org/10.13140/RG.2.1.4702.1526.

Condon, S. (2018). Preparing an emotionally expressive vocal performance. *European Journal of Philosophy in Arts Education, 3*(1), 81–120. https://www.researchgate.net/publication/329403409_Preparing_an_emotionally_expressive_vocal_performance_of_classical_music.

Daffern, H., Camlin, D. A., Egermann, H., Gully, A. J., Kearney, G., Neale, C., & Rees-Jones, J. (2019). Exploring the potential of virtual reality technology to investigate the health and well being benefits of group singing. *International Journal of Performance Arts and Digital Media, 15*(1), 1–22. https://doi.org/10.1080/14794713.2018.1558807

Dai, Y. (2024). Integration of vocal technique and artistic expression in vocal art performances. *Frontiers in Art Research, 6*(2), 7–11. https://doi.org/10.25236/FAR.2024.060202

Daşdöğen, Ü. (2023). *The influence of virtual reality on voice perception and production.* University of Delaware. https://udspace.udel.edu/handle/19716/32737.

Dibben, N. (2016). Vocal performance and the projection of emotional authenticity. In D. B. Scott (Ed.), *The Ashgate research companion to popular musicology* (pp. 317–333). Routledge. https://doi.org/10.4324/9781315613451-22.

Doganyigit, S., & Islim, O. F. (2021). Virtual reality in vocal training: A case study. *Music Education Research, 23*(3), 391–401. https://doi.org/10.1080/14613808.2021.1879035

Gao, P. (2022). System design of vocal music teaching platform based on virtual reality technology. In J. C. Hung, N. Y. Yen, & J. W. Chang (Eds.), *International conference on frontier computing* (pp. 587–594). Springer Nature. https://doi.org/10.1007/978-981-99-1428-9_72.

Guo, S. (2023). Interactive multimedia vocal music teaching system based on virtual reality technology. *Applied Mathematics and Nonlinear Sciences, 9*(1), 1–20. https://doi.org/10.2478/amns.2023.2.00338

Han, X. (2022). Design of vocal music education system based on VR technology. *Procedia Computer Science, 208*, 5–11. https://doi.org/10.1016/j.procs.2022.10.002

Hao, H., & Zhang, T. (2022). Computer-aided simulation and simulation of virtual vocal performance teaching platform. *Computer-Aided Design and Applications, 19*(S7), 34–43. https://doi.org/10.14733/cadaps.2022.S7.34-43

Huang, L. (2018). Issues on multimodal corpus of Chinese speech acts: A case in multimodal pragmatics. *Digital Scholarship in the Humanities, 33*(2), 316–326. https://doi.org/10.1093/llc/fqx040

Huang, W. L., & Yu, H. (2022). Social support in university music students' coping with performance anxiety: People, strategies and performance situations. *Music Education Research, 24*(1), 124–135. https://doi.org/10.1080/14613808.2022.2028752

Jang, H. J., Lee, J. Y., Kwak, J., Lee, D., Park, J. H., Lee, B., & Noh, Y. Y. (2019). Progress of display performances: AR, VR, QLED, OLED, and TFT. *Journal of Information Display, 20*(1), 1–8. https://doi.org/10.1080/15980316.2019.1572662

Jordhus-Lier, A., Nielsen, S. G., & Karlsen, S. (2021). What is on offer within Norwegian extracurricular schools of music and performing arts? Findings from a national survey. *Music Education Research, 23*(1), 62–76. https://doi.org/10.1080/14613808.2020.1866518

Kaleńska-Rodzaj, J. (2021). Music performance anxiety and pre-performance emotions in the light of psychology of emotion and emotion regulation. *Psychology of Music, 49*(6), 1758–1774. https://doi.org/10.1177/0305735620961154

Laukka, P., & Elfenbein, H. A. (2021). Cross-cultural emotion recognition and in-group advantage in vocal expression: A meta-analysis. *Emotion Review, 13*(1), 3–11. https://doi.org/10.1177/1754073919897295

Li, H. (2017). Design of multimedia teaching platform for Chinese folk art performance based on virtual reality technology. *International Journal of Emerging Technologies in Learning, 12*(9), 28–40. https://doi.org/10.3991/ijet.v12.i09.7487

Li, Y. M., Li, J., Zou, H., & Wei, S. (2020). Development and validation of the emotion regulation ability test for Chinese youth. *Journal of Pacific Rim Psychology, 14*, Article e7. https://doi.org/10.1017/prp.2019.31

Lin, H. (2023). Optimal design of vocal music teaching platform based on virtual reality technology. In F. Huang (Ed.), *2023 4th International Conference on Artificial Intelligence and Education (ICAIE 2023)* (pp. 394–400). Atlantis Press. https://doi.org/10.2991/978-94-6463-242-2_49.

Lyons, J. B., & Schneider, T. R. (2005). The influence of emotional intelligence on performance. *Personality and Individual Differences, 39*(4), 693–703. https://doi.org/10.1016/j.paid.2005.02.018

Ma, W. F., Tsai, G. E., Chang, J. P. C., & Lane, H. Y. (2010). Reliability and validity of three Chinese-version tasks of Mayer–Salovey–Caruso Emotional Intelligence Test. *Journal of Clinical Nursing, 19*(17–18), 2656–2658. https://doi.org/10.1111/j.1365-2702.2010.03316.x

Mayer, J. D., & Salovey, P. (2007). Mayer-Salovery-Caruso emotional intelligence test. *Multi-Health Systems Incorporated.* https://www.eiconsortium.org/measures/msceit.html.

Meissner, H., & Timmers, R. (2019). Teaching young musicians expressive performance: An experimental study. *Music Education Research, 21*(1), 20–39. https://doi.org/10.1080/14613808.2018.1465031

Olteţeanu, I. (2010). Vocal expression, music performance, and communication of emotions. *Linguistic and Philosophical Investigations, 9*, 311–316. https://philpapers.org/rec/OLTVEM.

Picado, M., Pereira, C., & Castilho, L. C. (2022). Emotional intelligence and self-regulation in the teaching and learning process of music ensemble with singing. In D. Raposo (Ed.), *Meeting of research in music, arts and design* (pp. 712–732). Springer International Publishing. https://doi.org/10.1007/978-3-031-09659-4_50.

Resnicow, J. E., Salovey, P., & Repp, B. H. (2004). Is recognition of emotion in music performance an aspect of emotional intelligence? *Music Perception, 22*(1), 145–158. https://doi.org/10.1525/mp.2004.22.1.145

Scherer, K. R., Sundberg, J., Fantini, B., Trznadel, S., & Eyben, F. (2017). The expression of emotion in the singing voice: Acoustic patterns in vocal performance. *The Journal of the Acoustical Society of America, 142*(4), 1805–1815. https://doi.org/10.1121/1.5002886

Shpyrka, A., Bondarenko, L., Kondratenko, G., & Shpyrka, A. (2021). Emotional expressiveness of the vocalist: A cross-sectional study. *Rast Müzikoloji Dergisi, 9*(2), 2893–2916. https://doi.org/10.12975/rastmd.20219211

Spreadborough, K. L., & Anton-Mendez, I. (2019). It's not what you sing, it's how you sing it: How the emotional valence of vocal timbre influences listeners' emotional perception of words. *Psychology of Music, 47*(3), 407–419. https://doi.org/10.1177/0305735617753996

Wang, S. (2024a). Vocal improvisation using interactive music technology. *Interactive Learning Environments, 32*(1), 245–256. https://doi.org/10.1080/10494820.2022.2084755

Wang, Y. (2024b). The effectiveness of innovative technologies to manage vocal training: The knowledge of breathing physiology and conscious control in singing. *Education and Information Technologies, 29*(6), 7303–7319. https://doi.org/10.1007/s10639-023-12108-6

Wang, Y. (2024c). Vocal creativity: Analyzing students song making processes in blended learning. *Interactive Learning Environments, 32*(5), 2196–2206. https://doi.org/10.1080/10494820.2022.2141267

Wang, Y. M., Chiu, W. C., Lin, H. H., Wang, Y. S., Wang, Y. Y., & Chen, I. F. (2024). Determinants of students' adoption of virtual reality-based learning systems: An individual difference perspective. *Innovations in Education and Teaching International, 61*(1), 143–153. https://doi.org/10.1080/14703297.2022.2098512

Webb, A. L. M., Hibbard, P. B., Dawson, J., van Dam, L. C., Asher, J. M., & Kellgren-Parker, L. J. (2024). Immersive-360° theater: User experience in the virtual auditorium and platform efficacy for current and underserved audiences. *Psychology of Aesthetics, Creativity, and the Arts*. https://doi.org/10.1037/aca0000624 (in press).

Weiss, M. W., Trehub, S. E., Schellenberg, E. G., & Habashi, P. (2016). Pupils dilate for vocal or familiar music. *Journal of Experimental Psychology: Human Perception and Performance, 42*(8), 1061–1065. https://doi.org/10.1037/xhp0000226

Yang, S., Reed, C. N., Chew, E., & Barthet, M. (2021). Examining emotion perception agreement in live music performance. *IEEE Transactions on Affective Computing, 14*(2), 1442–1460. https://doi.org/10.1109/TAFFC.2021.3093787