Virtual Reality in Music Education: A Qualitative User Study of HarmosphereVR

Weronika Stachurska[1,†], Aleksandra Witoszek-Kubicka[2,†] and Magdalena Igras-Cybulska[1,*,†]

[1]AGH University of Krakow, Krakow, Poland
[2]Cracow University of Economics, Krakow, Poland

Abstract

Harmony is considered one of the most challenging and rigorous subjects in music education. This study focuses on the qualitative evaluation of HarmosphereVR, a virtual reality (VR) prototype designed to support the self-learning of harmony through immersive interactive exercises. The methodology included usability testing, reaction cards, and in-depth interviews to collect comprehensive feedback on the application's effectiveness and user experience. The evaluation engaged six participants (four male and two female participants); half had previously participated in an exploratory interview to identify challenges and needs in learning harmony at music schools before the application was designed, while the rest of the participants were not acquainted with the project. The findings suggest that VR can serve as an auxiliary tool in music education, providing an engaging and effective platform for mastering complex theoretical concepts.

Keywords

Virtual Reality, Music Education, Harmony, User-centered Design, Qualitative Evaluation, Reaction cards

1. Introduction

Music theory has consistently been a core element of traditional music education. Despite recent debates concerning its significance and role within the educational framework, evidence suggests that music theory continues to be a vital area of study. It is essential, however, to customize teaching approaches and materials to align with student necessities [1]. A primary issue from the perspective of students is the failure to effectively integrate music theory content with other related disciplines, resulting in gaps in understanding its wider relevance. Ignoring the diverse dimensions such as cultural, physical, psychological, and metaphorical aspects has made it challenging for learners to link music theory to their extensive musical experiences. The predominant reliance on keyboards, divergent perceptions of theory study among various instrumental groups, and the scarcity of content on non-traditional music genres and traditions are identified as significant challenges [2]. Also, educators recognize the urgency in finding supportive measures for music theory instruction. The shift towards remote education propelled by the COVID-19 pandemic has prompted educators to incorporate new technologies and

RealXR: Prototyping and Developing Real-World Applications for Extended Reality, June 4, 2024, Arenzano (Genoa), Italy
*Corresponding author.
weronasta@student.agh.edu.pl (W. Stachurska); witoszea@uek.agh.edu.pl (A. Witoszek-Kubicka); magda.igras@gmail.com (M. Igras-Cybulska)
0000-0001-5304-3379 (A. Witoszek-Kubicka); 0000-0001-5621-7901 (M. Igras-Cybulska)

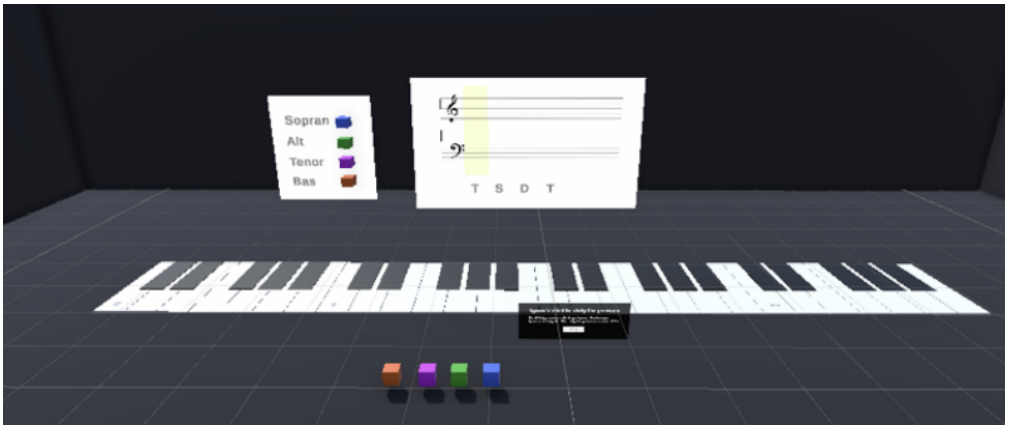

Figure 1: HarmosphereVR - scene before excercise.

methodologies in music education. There exists a strong inclination to persist in the use of these innovative tools to enhance the quality of learning experiences [3]. The application of technology in supporting classroom instruction and its integration into students' independent study facilitates essential music discussions outside of traditional settings and contributes to creating a more captivating learning atmosphere [4].

Further research corroborates the views held by both students and educators, showing that online educational courses can bolster music education by promoting self-directed study, fostering collaboration, and enriching musical comprehension [5]. Digital tools, including wikis, simulators, and social networks, enable seamless communication between students and educators, increasing the students' learning interest [6]. Exploration into VR tools for music theory education has led to the identification of various platforms targeting different demographics. "Singing-Blocks," aimed at young adults with no musical background, facilitates the learning of basic harmony principles through an interactive game. Its effectiveness, however, remains to be evaluated [7]. "ChordAR," designed for children, incorporates a serious game approach to teaching music theory basics such as chords through engaging activities [8]. An AR handbook targeted at children aged 4 to 12 introduces them to orchestra compositions and instrument characteristics, with usability tests indicating high levels of learner satisfaction, thereby affirming the potential of AR technology in developing educational materials for music education [9].

Beyond the realm of music theory, the application of VR is expanding to encompass practical skills within music education. Notably, VR has been integrated into vocal music education [10] and piano instruction [11], while Augmented Reality (AR) has been explored for conducting training [12] and piano learning as well [13]. There are also commercial VR and AR application for the latest mixed reality devices such as PianoVision [14].

Despite these advancements, there is a notable absence of VR and AR solutions specifically dedicated to harmony studies. The majority of existing tools either cover only elementary topics or resemble traditional textbooks in their interactivity levels, failing to meet the requirements of secondary-level music school students. This gap underscores the necessity for developing

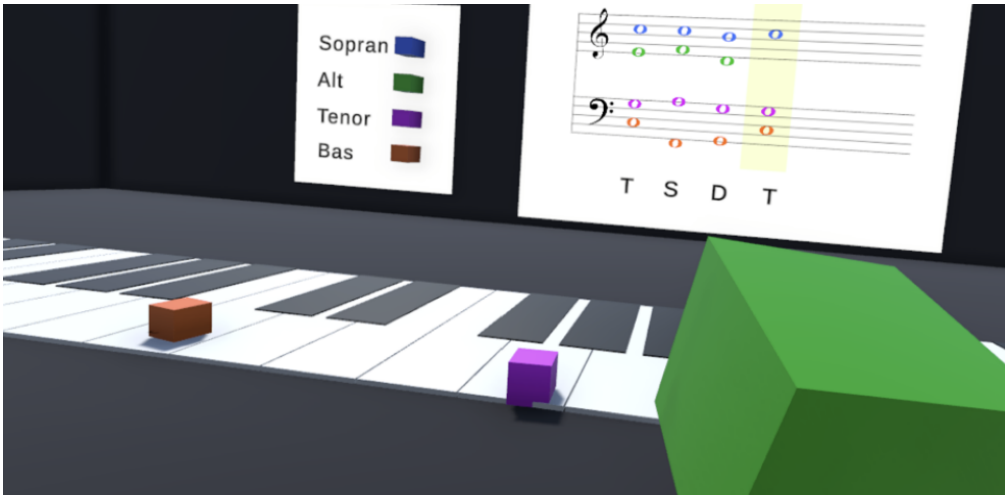

Figure 2: HarmosphereVR - scene during the excercise.

specialized, interactive tools designed to address the sophisticated needs of students pursuing advanced music theory and harmony studies.

In response to the demand for supportive tools in harmony education, we have developed HarmosphereVR - a virtual reality application designed for interactive harmony learning. Our prior publication detailed the investigation into the challenges faced by music students in harmony education, utilizing In-Depth Interviews (IDI), and outlined the design and development process of the VR prototype [15]. The primary contribution of this paper lies in its detailed exploration and qualitative evaluation of HarmosphereVR. By employing usability testing, reaction cards, and contextual interviews, the study provides insights into the application's reception, user experience, and educational value. It offers evidence of the potential benefits and limitations of VR technology in music education.

2. HarmosphereVR

HarmosphereVR is a VR application developed to support harmony learning in music education [15]. It uses 6-degrees of freedom VR technology to offer an interactive and immersive experience, aiming to facilitate self-learning and enhance the understanding of musical harmony concepts by engaging users actively in the learning process.

The application features a practical exercise that allows users to construct harmonic progressions within the key of C major using four distinct chords (see Fig. 1 and Fig. 2). The interface incorporates a virtual piano keyboard for chord construction, with real-time auditory feedback for each chord played. This is complemented by a visual display of chords on a music staff, providing a learning experience that integrates both auditory and visual cues. To ensure user comfort and reduce the risk of VR-induced motion sickness, the design includes smooth locomotion for movement and a vignette effect to mitigate visual discomfort while moving with the use of controllers.

In the exploratory study that preceded the development of HarmosphereVR, secondary music school students were interviewed to uncover the nuanced challenges they encounter while studying harmony [15]. This involved a selection of six participants—students and recent graduates-who could provide varied insights into the learning process of music theory and harmony. These interviews were semi-structured to elicit detailed responses on several key aspects: the effectiveness of current teaching methods, the accessibility and utility of existing music theory resources (including digital tools and applications), and the students' personal struggles with understanding and applying harmony concepts. The data collected from these interviews revealed critical insights. Students expressed frustration over the lack of integration between theoretical concepts and practical application, highlighting a gap in current educational tools that failed to bridge this divide effectively. Many noted the absence of interactive resources that could make learning more engaging, pointing out that most available materials were too text-heavy and did not cater to the varied learning styles within their peer group. Additionally, the research identified a clear need for resources that could adapt to the individual learner's pace, allowing for a more personalized learning experience. This was particularly evident in the feedback regarding the difficulty of mastering complex harmony concepts through traditional classroom and textbook methods alone.

Following the exploratory research, user stories, value proposition canvas, and the creation of a storyboard were used as consecutive design process phases. Development of the HarmosphereVR prototype was performed using utilizing the Unity engine and targeting Meta Quest 2 headsets, the prototype was designed to offer a hands-on approach to learning harmony. This phase translated the research insights into a practical VR application. An example of gameplay is presented under the YouTube link [16].

3. Methods

3.1. Research questions

The main goal of the user research was to evaluate the intuitiveness and overall user experience of the HarmosphereVR prototype. This allowed highlighting its strengths and identifying potential problems. The second goal was to check the utility of the application in the process of learning harmony. This would determine whether the solution truly meets the users' needs related to music theory learning. Conducting the study also helped in defining the directions for further application development.

The following detailed research questions were defined:

- Are all interface elements understandable?
- Does the introduction adequately explain the rules of the task?
- Is the application intuitive?
- What are the most significant difficulties encountered by the participants?
- What are the strengths of this solution?
- What feelings do participants have while performing the exercise?
- How does the application affect the overall interest and engagement of users in learning harmony?

- How do participants evaluate the effectiveness of learning harmony with the application compared to traditional methods?
- What are the participants' needs in terms of further development of the application?

3.2. Reaction cards

We utilized reaction cards to facilitate participants in naming their feelings related to our solution. This method has been widely used for formative evaluation [17, 18]. The procedure involves showing participants paper cards with adjectives and asking them to familiarize themselves with them and then choose, with justification, the terms that best match their feelings associated with the application. We asked them, "Which of the cards best describes your impression of interacting with the HarmosphereVR application?" Subsequently, we asked them to first select five cards, then narrow these down to three and justify their choices. The participants had 39 paper cards at their disposal with the following adjectives: engaging, innovative, coherent, useful, interesting, accessible, encouraging, clear, friendly, energetic, transparent, professional, understandable, intuitive, attractive, fresh, simple, captivating, distracting, overwhelming, confusing, incomprehensible, inaccessible, boring, irritating, time-consuming, unclear, ineffective, difficult, pretty, frustrating, logical, cumbersome, unpredictable, ugly, annoying, inconsistent, outdated, complicated.

3.3. Experimental design

Given that the application utilizes VR technology and requires special equipment (in this case, Meta Quest 2 headsets), the studies were moderated and conducted in person. We incorporated elements of in-depth interviews into the usability tests to better understand the users' impressions after using the prototype and to learn about their previous experiences with VR.

The study commenced with an overview of the research procedure and the presentation of the informed consent form, which included contraindications for using virtual reality, objectives of the study, and consent for audio-visual recording. Following the acquisition of consent and clarification of any queries, participants were introduced to virtual reality with preliminary questions to gauge their knowledge and experience with the technology.

Subsequently, the task was explained. Depending on prior exposure to VR, more detailed guidance on controller operation was provided, technical questions were addressed, assistance was offered in adjusting the headsets, and the application was initiated. Participants then independently performed the exercise while their behavior was observed, and the display they viewed in the headsets was monitored on a computer.

Concluding the exercise, several summary questions were posed, and discussions were held regarding the reaction cards selected by the participants:

- What did you like most about the application?
- What was the most difficult or surprising?
- What was lacking in the application?
- How do you assess the application's impact on your motivation to learn harmony?
- What do you think of this application as a tool for learning harmony?

Each session lasted approximately 45 minutes.

3.4. Participants

The study group consisted of individuals who are either currently enrolled in or are graduates of secondary music schools. The sample comprised 6 participants, who were recruited using the snowball sampling method (through personal contact networks). The demographic details of the respondents are presented in Table 1. Participants numbered 4, 5, and 6 also took part in individual in-depth interviews conducted at an earlier stage of the research.

No.	Gender	Age
1	Male	22
2	Male	22
3	Female	18
4	Male	22
5	Male	20
6	Female	22

Table 1
Demographics of the study participants involved in the usability tests.

4. Results

During each research session, observations were recorded. Then, related sections of the notes were grouped into thematic clusters related to the same aspect of the prototype.

4.1. Perceptions of VR technology

All participants had very limited experience with VR. Indeed, 5 out of 6 participants were interacting with VR for the first time during these tests, yet all exhibited significant interest in this technology. Some mentioned that they had always wanted to try VR but never had the opportunity, primarily associating virtual reality with gaming. The impressions post-study were overwhelmingly positive, with no incidents of discomfort reported. Participants noted that the tests piqued their curiosity about virtual reality and its development, expressing hope that this would not be their last encounter with the technology.

4.2. Reaction cards

Reaction cards greatly assisted participants in opening up about their feelings towards the application. The adjectives on the cards helped them articulate their impressions and served as a good starting point for further discussion. Ultimately, participants selected very similar cards, which frequently recurred, including "**understandable**," "**interesting**," "**innovative**," "**captivating**," "**useful**," "**simple**," and "**clear**." They argued that the application's minimalist interface, presenting only the most essential functions, made it easier to know what to do and reduced the risk of getting lost. They were surprised by how easy it was to use despite their lack of previous VR experience, and they appreciated the novel and interesting integration of virtual reality with an educational application, having not heard of similar solutions before.

The immersive nature of the technology made them wish to use it for longer than the exercise lasted, and they would gladly repeat the exercise multiple times.

4.3. Understanding exercise mechanics and control

After familiarizing themselves with the introduction, participants had no major difficulties performing the exercise. The only initial challenge was unfamiliarity with the controller layout, due to the participants' lack of previous experience with VR devices. However, within a few minutes, they adjusted to the new equipment and seamlessly constructed successive chords. Participants often smiled during the tests, making joyful statements.

5. Discussion and future work

All participants believed that the HarmosphereVR application is beneficial for learning harmony, describing it as a great option for those beginning their journey with harmony. It demonstrates that the application somewhat gamifies sound exploration, potentially encouraging further exploration of the subject. One participant, who particularly disliked harmony in school, admitted that starting learning with such an application might have changed their attitude towards the subject. Below are sample quotes from the participants.

"*Harmony learning starts with children, and children like games. Overall, it's a super idea and a fun technology, more attractive than a notebook.*"

"*A completely new experience, as if I entered the world of music, perfectly illustrates what harmony is about, combining notes, sound, and how it looks on an instrument.*"

No critical issues were detected during the studies, but there are areas that require enhancements. Some participants felt that moving along the keyboard was somewhat time-consuming. Increasing the speed of movement could potentially improve this situation. There was also a suggestion that even in a practical exercise, theoretical tips should be available, as beginners might still need help. Participants expressed a desire to play a more developed version with different tonalities and more complex chords. One person mentioned that it would be interesting to receive points for correctly constructed combinations and to compete with classmates. This indicates that introducing gamification in the future could be appealing to users.

The potential for employing VR in music education is significant, offering numerous possibilities for growth and enhancement. Our findings are consistent with contemporary research advocating for the use of immersive technologies in music education, as seen in recent publications [19, 20, 21]. Notably, the study [21] indicates a positive moderate correlation between student motivation and academic performance in a group practicing with VR compared to the control group. Given our findings and those reported in the literature, we anticipate that the role of VR in music education will continue to expand. However, challenges remain, such as bridging the gap between the implementation and development of digital multimedia VR in the arts, enhancing teachers' operational proficiency with digital multimedia VR, and addressing regional disparities [20].

There are several advantages of VR technology compared to other media. VR's immersive nature allows students to experience musical structures and relationships in three dimensions, offering a visceral understanding of harmony that flat, 2D representations on tablets or mobile

screens cannot provide. This deepens the learning experience and aids in the retention of complex theoretical concepts. The engaging, interactive capabilities of VR turn the learning process into an exciting and enjoyable activity, potentially increasing student motivation and engagement compared to static 2D applications, where interaction is limited to touch. VR supports kinesthetic learning styles by allowing students to use physical movements to manipulate musical elements, thus offering a more hands-on learning experience than is possible with the drag-and-drop interfaces of 2D applications. Through VR, students can simulate real-life music creation and theory application with virtual instruments that respond dynamically to their actions, providing a practical, real-world application of harmony that is not as effectively replicated on a tablet or mobile screen. VR technology not only adapts to individual learning paces but does so in an intuitive manner that mimics natural human interaction, making complex theoretical concepts more accessible and easier to understand for students at all levels.

The limitations of the presented study on the HarmosphereVR application include a relatively small sample size, which may not fully represent the broader population of secondary music school students, restricting the generalizability of the findings. Additionally, the study encompassed only one prototype exercise in the key of C major, limiting the scope of the harmony concepts explored. Moreover, the research was conducted in a controlled environment, which might not accurately reflect a natural learning setting, potentially affecting the application's perceived usability and effectiveness. Lastly, since the testing involved a novel technology in virtual reality, participants' limited prior exposure to VR might have influenced their interaction with the application, introducing a novelty effect that could skew the results.

Building on the feedback received, future versions could include a broader range of exercises encompassing different levels of difficulty, tonalities, and chord types to cater to a wider spectrum of learners. The introduction of gamification elements, such as scoring systems and competitive features, could enhance engagement and motivation. Furthermore, incorporating theoretical content within the practical exercises could support beginners in understanding the fundamentals of harmony. Expanding the application to support group learning scenarios, where students can collaborate or compete with one another, might also foster a more interactive learning environment. Lastly, exploring the integration of artificial intelligence to tailor exercises to the user's skill level and learning pace could provide a highly personalized learning experience. While the paper primarily focuses on qualitative data from participant feedback, incorporating quantitative data analysis, such as statistical measures of usability or user satisfaction ratings, could provide additional insights and strengthen the findings in the future evaluation.

6. Conclusion

In conclusion, the exploratory study and subsequent usability testing of HarmosphereVR have demonstrated the application's potential as an innovative tool for enhancing harmony learning in music education.

Our findings suggest that VR, by providing an immersive, engaging, and kinesthetic learning environment, offers substantial advantages over traditional 2D applications. These include deeper conceptual understanding, higher engagement and motivation, and more effective simulation of real-world musical interaction. Therefore, VR holds significant promise for revolu-

tionizing music education, particularly in complex areas such as harmony, where understanding spatial and relational aspects are crucial. The feedback from participants highlights the application's intuitiveness, ease of use, and educational value, suggesting that such technological solutions can effectively complement traditional music education methods.

As VR technology continues to evolve, applications like HarmosphereVR present a promising avenue for making music theory learning more accessible, interactive, and enjoyable. We hope that the insights gained from this study not only inform the further development of HarmosphereVR but also contribute to the broader discourse on the integration of VR in educational settings.

Acknowledgments

Contribution of M. Igras-Cybulska was partially supported by the National Centre for Research and Development (NCBiR) under Grant No. 0230/L-11/2019.

References

[1] J. A. Gutierrez, Students evaluate music theory courses: A reddit community survey, in: College Music Symposium, volume 58, JSTOR, 2018, pp. 1–27.

[2] J. Gutierrez, An enactive approach to learning music theory? obstacles and openings, in: Frontiers in Education, volume 4, Frontiers Media SA, 2019, p. 133.

[3] D. A. Camlin, T. Lisboa, The digital 'turn'in music education, Music Education Research 23 (2021) 129–138.

[4] D. Deloy, Teaching music theory through COVID-19, Master's thesis. University of Nebraska-Lincoln, 2022 (2022).

[5] X. Li, Y. Yang, S. K. W. Chu, Z. Zainuddin, Y. Zhang, Applying blended synchronous teaching and learning for flexible learning in higher education: an action research study at a university in Hong Kong, Asia Pacific Journal of Education 42 (2022) 211–227.

[6] Z. Zainuddin, M. Shujahat, S. K. Chu, H. Haruna, R. Farida, The effects of gamified flipped instruction on learner performance and need satisfaction: A study in a low-tech setting, Information and Learning Sciences 120 (2019) 789–802.

[7] J. Timoney, B. Faghih, A. Gibney, B. Korady, G. Young, Singing-blocks: Considerations for a Virtual Reality game to create chords and progressions (2018).

[8] Y. Lu, X. Wang, J. Gong, Y. Liang, et al., Chordar: An educational AR game design for children's music theory learning, Wireless Communications and Mobile Computing 2022 (2022).

[9] C.-L. Ho, T.-G. Lin, C.-R. Chang, Interactive multi-sensory and volumetric content integration for music education applications, Multimedia Tools and Applications 82 (2023) 4847–4862.

[10] X. Han, Design of vocal music education system based on vr technology, Procedia Computer Science 208 (2022) 5–11.

[11] Y. Feng, Design and research of music teaching system based on virtual reality system in the context of education informatization, Plos one 18 (2023) e0285331.

[12] E. K. Orman, H. E. Price, C. R. Russell, Feasibility of using an augmented immersive virtual reality learning environment to enhance music conducting skills, Journal of Music Teacher Education 27 (2017) 24–35.
[13] A. J. Stanbury, I. Said, H. J. Kang, Holokeys: Interactive piano education using augmented reality and iot, in: Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology, 2021, pp. 1–3.
[14] ZarApps, Pianovision, 2024. Available at YouTube: https://www.meta.com/en-us/experiences/5271074762922599/.
[15] W. Stachurska, A. Witoszek-Kubicka, M. Igras-Cybulska, Harmosphere VR: Enhancing harmonic learning in music schools through virtual reality, in: Proceedings of the 16th International Conference on Computer Supported Education - Volume 1, 2024, pp. 773–779.
[16] W. Stachurska, HarmosphereVR gameplay, 2024. Available at YouTube: https://www.youtube.com/watch?v=IZ_1iVLNoKw.
[17] T. Merčun, Evaluation of information visualization techniques: analysing user experience with reaction cards, in: Proceedings of the Fifth Workshop on Beyond Time and Errors: Novel Evaluation Methods for Visualization, 2014, pp. 103–109.
[18] M. L. Costello, A. Weldon, P. Brunner, Reaction cards as a formative evaluation tool: Students' perceptions of how their use impacted classes, Assessment & Evaluation in Higher Education 27 (2002) 23–33.
[19] O. Pavlenko, I. Shcherbak, H. Viktoriia, V. Lihus, I. Maidaniuk, T. Skoryk, Development of music education in virtual and extended reality, BRAIN. Broad Research in Artificial Intelligence and Neuroscience 13 (2022) 308–319.
[20] H. Xiao, et al., Innovation of digital multimedia vr technology in music education curriculum in colleges and universities, Scientific Programming 2022 (2022).
[21] Y.-h. Wu, T.-t. Tao, Improving music education using virtual reality techniques, Revista Música Hodie 22 (2022).