Harmosphere VR: Enhancing Harmonic Learning in Music Schools Through Virtual Reality

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Abstract: In this pilot study, we investigate the potential of Virtual Reality in supporting music education through a prototype application designed to facilitate self-learning of harmony. The selection of this topic stemmed from exploratory research, particularly in-depth interviews with secondary music students (N=6), which delved into the challenges and obstacles faced during their education. Additionally, we conducted a thorough examination of available applications and websites for music theory learning. Building upon the research findings, we proceeded with user modeling using personas and empathy mapping. The design of the solution began with the formulation of user stories, value proposition canvas, and the creation of a storyboard. Subsequently, we developed the preliminary outline of the solution - the HarmosphereVR application. Following this phase, a prototype of a practical exercise in Unity was prepared, focusing on constructing a harmonic progression in the key of C major, comprising four chords. The application was developed in Unity engine for Meta Quest 2 headsets.

1 INTRODUCTION

The rapid development of digital technologies affects many, if not all, aspects of human life. It is not indifferent, equally, to education – daily interaction with technology transforms the way we learn. Simultaneously, increasingly newer and more advanced devices are becoming accessible to many members of society. They are starting to appear in universities, schools, and homes. The prevalence of technology introduces numerous novel possibilities and prospects for supporting the education sector. Mobile applications and solutions in the field of virtual and augmented reality provide learners with an immersive and interactive learning experience, enabling them to understand challenging concepts and ideas more efficiently and effectively (Marougkas et al., 2023). However, it seems that in artistic education, traditional teaching methods based on chalkboards and books still prevail. Due to the specific nature of artistic subjects such as singing or playing a musical instrument, maintaining direct contact with the teacher and applying more traditional teaching methods is necessary. Nevertheless, the curriculum also includes theoretical subjects, such as music theory and harmony. These classes require knowledge of numerous rules and analytical thinking. Many individuals face challenges in navigating through the abundance of principles that need to be learned and adeptly applied to tasks. Consequently, the integration of virtual reality with the teaching of theoretical artistic subjects, such as harmony, poses an intriguing question worthy of further exploration.

Certainly, there are numerous challenges associated with the utilization of virtual reality in artistic education. One of them is the issue of physical discomfort accompanying the use of these devices. VR goggles are often quite bulky and enclosed, leading to potential discomfort or overheating when worn for extended periods. Additionally, some individuals suffer from simulator sickness, experiencing symptoms such as nausea, headaches, and dizziness while using VR technology. This is often due to a lack of synchronization between the images in the goggles and the user's movements, for instance, when the user moves in the game but their physical body remains stationary. While there are increasing methods to mitigate this phenomenon, it still remains a problem. Another challenge is the relatively high cost of the devices. Many of them, to enjoy high-quality and advanced

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graphics, require a powerful computer with a high-end graphics card, which can be costly. Consequently, only a limited number of people can afford to purchase such setups. Spatial constraints also present a limitation. Small spaces do not allow for full utilization of the possibilities of virtual reality, and collisions between the user and objects in their surroundings can pose safety risks. Furthermore, a significant challenge lies in the technology required to provide immersion to users by engaging their various senses, tracking movements, and displaying high-quality images, particularly realistic graphics. Limitations regarding resolution, data compression, and bandwidth can also impact the smooth operation of VR systems (Keshavarz and Golding, 2022).

However, the rapid development of virtual and augmented reality has the potential to address most of these challenges. Given the increasingly prominent presence of this technology in education overall, its utilization in artistic education is worth considering.

The contributions of this paper are as follows:

1. We conducted an exploratory study aimed at gaining deeper insights into the needs and challenges encountered in secondary music education.;
2. We introduced an immersive interactive virtual environment designed to facilitate the learning of harmony at the secondary music education level.

2 RELATED WORKS

To ascertain the current state of knowledge regarding the utilization of virtual reality tools to support the learning of music theory, a literature review was conducted using databases such as Scopus, Web of Science, Google Scholar, as well as ResearchGate. The search syntax involved the use of key term combinations: ”music,” ”theory,” ”harmony,” ”teaching,” ”learning,”, ”AR” and ”VR” in various configurations, with the limitation of the search to Polish and English languages.

The study of music theory has been a fundamental component of traditional music education for years. Despite the raised doubts in recent years about the value and place of these contents in music education, research indicates that music theory remains a highly valuable subject of study. At the same time, there is an emphasis on the necessity to tailor teaching methods and tools to the needs of the students(Gutierrez, 2018). From the student’s perspective main concerns revolve round the inadequate integration of course content with related subject areas, leading to unanswered questions about its broader context. The neglect of diverse aspects, including cultural, physical, psychological, and metaphorical considerations, hinder students from connecting musical theories with their broader musical experiences. Over-reliance on the keyboard, varied perceptions of the purpose of theory study among instrument groups, and the lack of diversity in non-common practice genres and traditions are significant issues (Gutierrez, 2019).

Also educators recognize the importance of seeking solutions to support their music theory teaching. The experience of remote teaching during the COVID-19 pandemic has driven teachers to embrace new technologies and tools for music education. Their desire is to continue utilizing existing tools and to explore new ones, as they firmly believe in the enhancement of the overall quality of learning (Camlin and Lisboa, 2021). Utilizing technological solutions to support classroom teaching and incorporating them into students’ independent work allows for administering crucial discussions about music outside of class and helps create an engaging environment (Deloy, 2022).

Research confirms the propositions put forth by students and teachers. Online training courses support music education as they allow individuals to work at their own pace, collaborate with others, and contribute to a deeper understanding of music (Li et al., 2022). The application of digital technologies, specifically wikis, simulators, and social networks, enables students to engage in seamless communication with teachers and peers, thereby increasing their interest in learning (Zainuddin et al., 2019).

Several virtual reality tools for learning music theory have been identified, targeting various groups of end users. ”**Singing-Blocks**” is a serious game project aimed at young adults without musical education, created in 2018. It enables the learning of basic harmony principles, including chord construction and progression, by arranging colorful blocks shaped like walls in the right positions. The game consists of multiple levels with a progression of difficulty. The effectiveness of the solution has not been verified to date (Timoney et al., 2018).

Another proposal is ”**ChordAR**”. It is a serious game designed for children to aid in learning the basics of music theory, including concepts such as chords. Initially, survey research was conducted to identify the problems and needs of preschool-aged children. The results of these surveys were taken into account in the development of the solution. The game features a storyline and levels of varying difficulty. It involves arranging LEGO blocks to symbolize individual chords in accordance with what is displayed on the screen. The correct arrangement of blocks is shown against a background image from the camera

(Augmented Reality), allowing users to easily replicate what they see. The prototype was tested with twelve individuals aged 4 to 7. The research indicated that the game was well-received by children, taught them chord construction, and sparked their curiosity for further music theory learning (Lu et al., 2022).

Another identified solution is **a multisensory AR handbook** for children aged 4 to 12. It teaches the composition of an orchestra and the characteristics of the instruments within it. In addition to the physical handbook, a mobile application was designed that utilizes augmented reality technology. Through this application, children can explore the sounds of various instruments, complete quizzes, and even attend a virtual concert. Usability tests were conducted with 497 preschool-aged users from different regions of Taiwan. The satisfaction with learning using the handbook was rated at 4.998 out of 5, which is an impressive result. This confirms the effectiveness of AR technology in creating music educational materials for children (Ho et al., 2023). Despite identifying virtual and augmented reality tools for learning music, no solutions directly supporting the study of harmony were found. However, many websites, applications, and courses for learning music theory, mainly in the English language, both paid and free, have been identified.

"**MyMusicTheory**" is a website for learning music theory. On this platform, you can find publicly accessible educational materials at various levels as well as video courses. The "Grade 6 Music Theory Course" covers the basics of harmony, preparing students for the Music Theory Grade 6 exam organized by the Associated Board of the Royal Schools of Music (ABRSM), a renowned educational organization issuing international certificates that officially document one's musical education. The course lasts for 15 weeks, is available in English, and includes 5 hours of video content, a document with notes, and exercises to complete. It also comes in an enhanced version, offering additional teacher-assessed evaluations for all tasks. The course's price ranges from £60 to £225. Alternatively, there are free resources available on the website. The knowledge base accessible in the free version is truly impressive, resembling a textbook in its form (Williams, 2024).

Among other websites, it is worth highlighting the course titled "**Four-part Harmony**". It is available on Udemy, covering the fundamentals of four-part harmony through video lessons, articles, quizzes, and exercises for solving (Peters, 2024).

Despite the identification of tools for learning music theory, especially harmony, it should be emphasized that they do not cater to the needs of the target group, which comprises students in secondary-level music schools. The majority of the available tools focus only on very basic topics, which students are already well acquainted with. Conversely, more advanced materials are minimally interactive, resembling traditional textbooks in their format. Literary studies validate the rationale behind developing an interactive tool that supports the learning of music theory, tailored to meet the requirements of students in secondary-level music schools.

3 EXPLORATORY STUDY

To design a VR solution to support the learning of harmony, independent research was conducted to deepen the understanding of the challenges in teaching harmony in music schools.

Three main research objectives were established. The first one aimed at identifying the difficulties encountered by second-degree music school students during the study of music theory, with a particular focus on the areas of harmony and musical principles. Acquiring an understanding of the issues young musicians grapple with narrowed down the areas of focus in the subsequent research process. The second objective was to recognize the methods students employ in assimilating knowledge in the realm of harmony. This facilitated a deeper comprehension of how they currently navigate the presented challenges. The third objective was to identify the needs associated with the learning of music theory, subsequently taken into account during the project development. To achieve the research objectives, six research questions were formulated:

- Q1: What is the current state of music theory education in music schools?
- Q2: Which part of the curriculum poses the greatest challenges?
- Q3: What sources do students utilize for learning?
- Q4: What would facilitate their knowledge acquisition?
- Q5: Which learning approach proves most effective for them?
- Q6: What is lacking in current teaching methods?

To accomplish defined research objectives, the decision was made to utilize qualitative research in the form of individual in-depth interviews. This method is deemed appropriate for research that serves as the foundation for designing solutions, such as VR applications as in such studies a more profound understanding of the needs and problems of the exam-

ined group is deemed more crucial than the potential for generalizing conclusions to the population (DURSUN, 2023). The study included participants who were both students and graduates of a second-degree music school. Six interviews were conducted with individuals recruited for the study through the snowball sampling method. The research was conducted onsite during the period from January to February 2023. Each interview lasted approximately 30 minutes.

The analysis of the research results was based on notes prepared from recorded conversations. In the case of one individual who did not consent to audio recording, notes were taken during the interview. Additionally, immediately following each interview, the interviewer documented observations regarding the facial expressions and behavior of the respondents. Subsequently, data for cluster analysis was prepared. Based on the notes, a table was created in the FigJam software, which allows the recording of brief notes on colored cards, known as "sticky notes," and their flexible arrangement on the board. This facilitates the identification of patterns and similarities. Subsequently, the information was categorized using affinity diagram. Ultimately, 20 clusters were identified, forming 5 categories of analysis: motivation for music education, learning harmony in the music school, study methods, challenges, and additional resources(Figma, 2024).

The motivation for music education category pertains to the factors that influenced the respondents to enroll in a music school. This includes responses associated, among other factors, with family influence and exposure to music since childhood. The subsequent category, learning harmony in the music school, encompasses information about opinions on the subject, the conduct of classes, teachers, and the proficiency level of other individuals in the class. This category facilitates a multidimensional and detailed understanding of the current situation of the students.

The next category, learning methods, includes responses regarding finding suitable methods tailored to individual needs, changing attitudes, instrumental learning, problem-solving, systematic study, and attentiveness during classes. It illustrates how the respondents approach the learning of this subject and how they cope with challenges. Another category - challenges, encompasses information about catching up on backlog, the time-consuming nature of learning, piano skills, understanding principles, and the lack of materials. This category highlights the difficulties students in second-degree music schools face in learning harmony. The final category is additional resources, referring to how respondents obtained supplementary information for their studies.

In each of the six designated categories, challenges and needs related to the current state of music theory education by students were identified. The gathered information allows for formulating recommendations regarding the characteristics of a tool that would support students in learning music theory: The solution should: enable a systematic learning of music theory (R1), focusing on a thorough mastery of fundamentals (R2). An advantageous approach would involve a more interactive solution (R3) than traditional materials like books, aiming to engage users more actively in learning and distinguish itself from conventional materials. It is essential to consider the students' schedule and avoid time-consuming tasks (R4). Simplicity (R5) in language and accurate translation of theoretical concepts (R6) are crucial. It would be valuable to demonstrate the application of theory into practice (R7) and utilize sound for learning (R8) to familiarize individuals with the sound of different harmonic combinations, facilitating a better understanding of principles.

4 THE SOLUTION

4.1 Setup

The prototype was implemented in Unity 2021 LTS, using OpenXR standard and XR Interaction Toolkit, for Meta Quest 2 headset with two controllers (Fig. 4).

4.2 The Exercise

The prototype consists of one harmonic exercise. It has a practical nature and resembles tasks from lessons and exams in music school harmony classes. It involves building a harmonic progression in the key of C major, consisting of four chords. Its aim is to practice constructing and connecting triad chords without inversion: tonic, subdominant, and dominant.

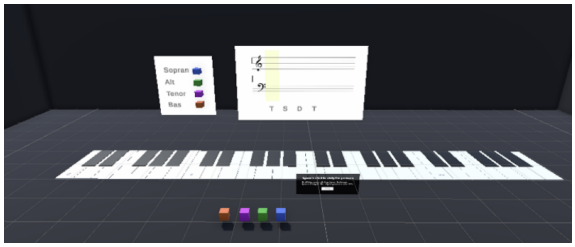

Figure 1: Main scene in HarmosphereVR.

The user has the ability to listen to the chord they create, as well as the entire exercise, which ensures

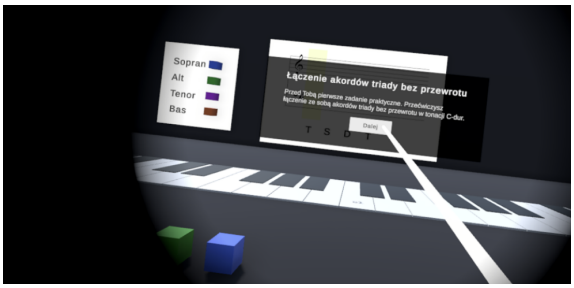

Figure 2: Introduction into the game with visible vignette effect.

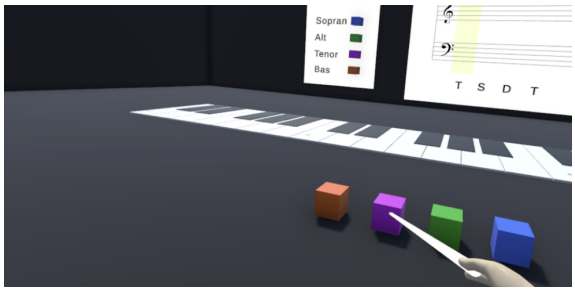

Figure 3: The white ray indicates the possibility of lifting the colored block from a distance.

the use of sound in learning. Additionally, chord construction is based on the piano keyboard - mimicking learning with the instrument. For the purposes of the prototype, we decided to omit the theoretical introduction, the possibility of returning to previous chords, checking the correctness of the exercise at the end, and handling black piano keys.

4.3 The Scene Design

The prototype consists of one scene (Fig. 1). The user is positioned in a room with dark walls and no ceiling. Above, they see a clear sky and the sun, which serves as the light source. On the ground lie four walls in different colors: orange, pink, green, and blue. A nearly flat piano keyboard is positioned a little further away, with each key having a larger width than the walls. Each key, representing the note "C," is labeled with an indication of its octave. The keyboard contains notes from C (uppercase) to B3 (B with three sharps). Behind the keyboard is a white board with two staves: one with a treble clef and the other with a bass clef, as well as the letters T, S, D, T, which denote chords. A light yellow rectangle indicates the current chord to be built. On the left side of the board, there is a legend for the colored blocks - labels representing the voices. The controllers resemble hands and are beige in color.

We decided to utilize smooth locomotion to ensure that users can easily navigate my application in various conditions - whether sitting, standing, or having limited space around them. To mitigate the risk of virtual reality sickness among participants, I employed the vignette effect (Fernandes and Feiner, 2016). Utilizing the vignette effect in VR can significantly enhance user immersion, gently guiding the player's focus towards the central action while subtly diminishing peripheral distractions. This effect not only elevates the visual narrative but also aids in reducing potential VR discomfort, making for a more comfortable and engaging experience.

4.4 The Gameplay

Upon starting the game, the user is presented with an interface introducing the task (Fig. 2). It consists of three steps: the first is the most general and welcoming, the second describes the exercise, and the third explains which buttons on the controller trigger essential application functions. The user navigates between the steps using the "Next" and "Back" buttons. Upon pressing the menu button on the left controller, a screen similar to the third step of the introduction appears - providing information about the button functions. Movement within the scene is facilitated by the analog sticks - the left one for walking and the right one for rotating the camera. The colored cubes can be lifted by holding one of the grip buttons, both up close and from a distance (the ability to grasp the block is indicated by a white ray (Fig. 3).

When a cube is placed on a piano key, a sound is heard, which would occur in reality upon pressing the key. As the block rests on the piano, a note appears on the board in the corresponding color, reflecting its position. If the note is black, it means that the pitch is outside the range of the voice symbolized by the cube. Upon removing the block from the piano key, the note on the board disappears. Pressing button A on the right controller allows the user to play the current arrangement of blocks on the piano and listen to whether the chord sounds as it should. Button B enables saving the current chord and proceeding to the next one. The trigger button on the right controller triggers the playback of the sequence of saved chords. (Fig. 4). The exercise concludes after saving four chords (Fig. 5).

An example gameplay is presented under the link (Stachurska, 2024).

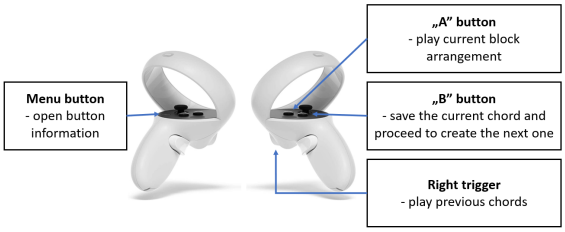

Figure 4: Commands associated with the controller buttons.

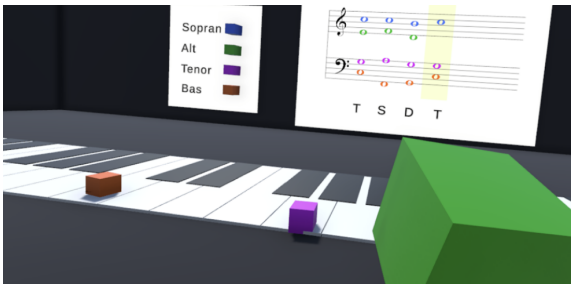

Figure 5: The view after saving several chords.

5 DISCUSSION AND CONCLUSION

The aim of this work was to create a prototype application utilizing virtual reality technology for facilitating self-learning of harmony. The development of the solutions was preceded by an analysis of scientific publications and available applications and websites for music theory learning. Subsequently, in-depth individual interviews were conducted with six participants, each having completed secondary music school education. The next step involved the development of the preliminary outline of the solution - the HarmosphereVR application. The implemented exercise involve constructing harmonic progressions in the key of C major, comprising four chords each. The prototypes were tested with users using Meta Quest 2 goggles.

During the work, certain limitations were met. They included, among others, the sample size during in-depth individual interviews. This resulted from limited access to individuals from a tightly defined population. Conducting research on a larger number of people than six could be beneficial. Another limitation was that only one exercise was implemented, leaving space for further works.

Our solution, next to SingingBlocks, ChordAR, and Interactive AR Handbook, confirms that virtual/augmented reality and music theory learning may provide a good combination. Interactive exercises using immersive technology motivate learners to explore new concepts and facilitate music theory learning. The HarmosphereVR applications differ from the aforementioned projects in that they target a different target audience - students and graduates of secondary music schools. This is due, among other things, to the prerequisite of prior knowledge of music theory fundamentals, necessary to begin learning harmony. Other solutions focus on uncomplicated topics that children or adults without musical education learn at the beginning of their musical journey. Our projects focus on material from the curriculum of the harmony subject in secondary music schools. This is their innovative and pioneering character. Additionally, in ChordAR and SingingBlocks, sounds are represented by individual blocks, one block per sound. In HarmosphereVR, colored blocks symbolize voices, and the sounds they produce depend on their arrangement on the keyboard. This allows for the construction of a greater quantity and more complicated chords. Additionally, the boards show the users in real-time how the constructed chords look in notes, which is not present in other solutions.

In the context of evaluating the effectiveness and user experience of the current stage of HarmosphereVR prototype, a mixed-methods study approach will be applied. This methodology combines both quantitative and qualitative research methods to gain comprehensive insights. Quantitatively, user engagement and learning outcomes will be measured through pre and post-tests on harmony knowledge, along with tracking usage statistics within the VR application, such as session length and frequency of use. Qualitatively, semi-structured interviews and focus groups with students and educators will provide deeper understanding of the user experience, including perceived usability, enjoyment, and educational value. Also hybrid methods like reaction cards will be used. This dual approach enables a holistic evaluation of the VR application's impact on learning and its potential to enhance musical education by capturing both numerical data and personal user experiences.

Our work leaves a very broad field for further development. Implementing other practical exercises and creating theoretical ones would bring significant value. Additionally, the current tasks could be expanded with new keys and chord functions. There is also potential to introduce gamification to make the applications even more engaging. It would also be interesting to test the solutions in schools during harmony class to see how students apply their freshly acquired theoretical knowledge in practice.

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