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Chromaesthetica: A Virtual Reality App for Learning Musical Theory Using Sound-Colour Cross-Modal Associations

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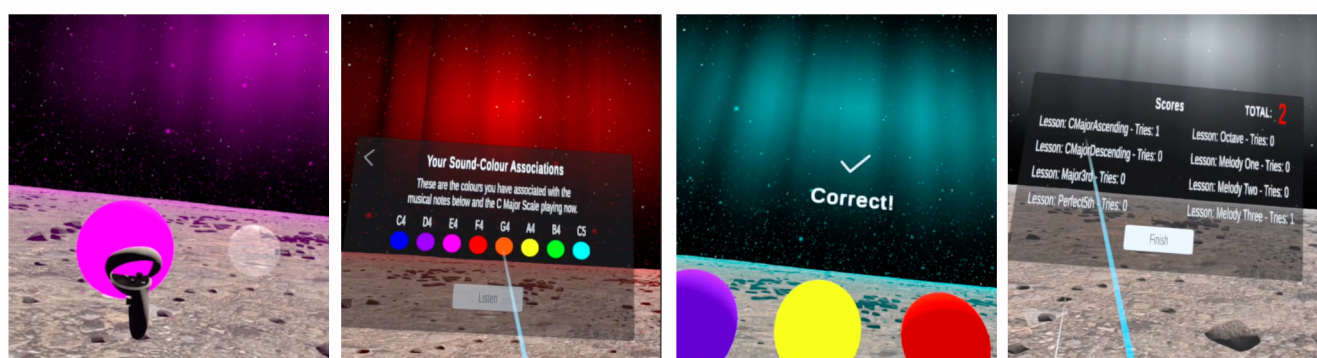


Figure 1: Chromaesthetica VR Application

Abstract

This demo paper presents a Virtual Reality (VR) application designed to explore innovative methods of learning basic music theory through sound-colour cross-modal associations. Leveraging the immersive capabilities of the latest head-mounted displays, the application provides an interactive and engaging platform with significant potential for music education. The demo marks an initial step in investigating how VR’s immersive features can enhance the understanding of sound-colour associations and their role in learning musical concepts, specifically intervals and melodies within the C Major scale. Two groups will participate in the study: a control group will learn using a predefined sound-colour mapping, while the experimental group will create their own personalised mappings through a pre-test in VR, which will be applied in subsequent lessons. The forthcoming study aims to provide valuable insights into the effectiveness of VR and cross-modality in facilitating music theory education.

CCS Concepts

• **Human-centered computing** → **Virtual reality**; • **Applied computing** → **Sound and music computing**; *Psychology*; Interactive learning environments.

Keywords

virtual reality, music, e-learning, visuals, colour, synaesthesia, cross-modal associations

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1 Introduction & Background

The way we engage with music and learn it is continually evolving alongside advancements in technology. As we become more digitally dependent, traditional methods of learning music are adapting. Numerous e-learning and m-learning applications, such as Yousician [8], Aurelia [2], and Duolingo [1], now supplement music education. While music theory and song learning have adapted

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to new technologies [20], Virtual Reality (VR) has yet to fully realise its potential as a platform for teaching musical concepts to beginners.

VR development has expanded as the technology has become more accessible to the general public [15], and research using VR has increased across many fields [10, 12, 14, 18]. Historically, research in VR has lacked focus on auditory aspects; however, studies in this area have grown in recent years [11], with most attention previously placed on the visual sense in VR research [17]. VR offers the possibility of highly immersive, multi-modal environments where users can engage with and understand musical theory in ways that are impossible on traditional computers or mobile devices. While some VR applications focus on music, particularly on interacting with virtual instruments [5–7, 21], few focus on learning music theory or concepts [4]. Furthermore, these applications have not fully exploited VR's immersive features to create cross-modal learning experiences.

This research also explores cross-modal associations and synaesthesia, and how these phenomena can be harnessed in an immersive VR environment to create a fun, engaging, and effective platform for music education. Synaesthesia, which affects about 2–4% of the population, is a condition where stimulation in one sensory modality triggers a sensation in another [13]. Cross-modal associations, which are similar to synaesthesia but more general, are experienced by both synaesthetes and non-synaesthetes alike [13]. Several studies have investigated the prevalence of synaesthesia and its varying manifestations. Some suggest that the binary view of being either a synaesthete or not is too simplistic, as individuals may exhibit varying strengths of sensory associations [22]. Moreover, one study demonstrated that letter-colour synaesthesia could be trained in adults [9].

In the context of VR, a few studies have attempted to investigate or replicate synaesthesia-like experiences using this technology. One study examined how total immersion in VR might lead to such experiences, defining immersion as an “emotional phenomenon” [18]. This raises intriguing questions about the role of emotion in the relationship between cross-modal associations and synaesthesia. Palmer et al.'s emotional mediation hypothesis posits that emotion plays a key role in cross-modal associations between auditory and visual senses [16]. Given the similarities between cross-modal associations and synaesthesia, it is possible that emotion also mediates the sensory experiences of synaesthetes [13].

This demo provides an application to explore the relatively under-researched intersection of synaesthesia and cross-modal associations in immersive VR experiences. It aims to investigate the potential of VR not only as a multi-modal but also as a cross-modal platform for music education using VR head-mounted displays (HMDs).

2 Usability Test

In a previous study, a usability test was conducted to explore user preferences when interacting with auditory-visual tasks in a virtual environment (submitted for publication). The test examined how participants associated notes from the C Major scale with colour hues and size in the visual modality. Users engaged with the task in two distinct environments: a natural “forest” setting and

a more otherworldly “space” setting. Each environment featured unique locomotion controls, as well as different audio and visual presentations.

The results indicated that users had diverse preferences regarding the environment, locomotion controls, and audio-visual presentations. Notably, participants reported significantly higher motion sickness symptoms in the “forest” environment, while they were less distracted from the auditory-visual task in the “space” setting.

Based on user feedback and quantitative analysis of various usability metrics, key design decisions were made. A more minimal environment, with simpler controls and adjustable options for locomotion and visual intensity, was implemented to assist users in making sound-colour choices. These decisions informed the development of the Chromaesthetica application presented in this demo paper.

3 Technology

The VR application was developed using the Unity game engine, with the XRI toolkit managing all interactions and movement. The Oculus Quest 2 HMD was used for testing and will also be used in the upcoming study. The Quest 2 headset has a resolution of 1832 x 1920 pixels per eye and supports refresh rates of up to 120Hz. Its field of view (FOV) is 104 degrees horizontally. The device is powered by a Qualcomm Snapdragon XR2 chip, featuring an Octa-core Kryo 585 CPU and an Adreno 650 GPU [3].

The Chromaesthetica VR application runs directly on the Oculus Quest 2, with over-ear headphones used to output sound. Sound-colour profiles are stored on the Quest 2 in a JSON file, which is loaded into the application during the music lessons.

4 Generalised vs Personalised Associations

In the demo, users can either proceed directly to the music lessons, which feature a generalised sound-colour profile based on research into cross-modal associations in the general population, or explore the environment, engaging with musical orbs to create their own personalised colour associations with the musical notes played.

The generalised sound-colour profile is based on studies showing that cross-modal correspondences exist between pitch and colour, with lower-pitched notes associated with darker colours and higher-pitched notes with brighter colours [16, 19, 23]. The personalised path allows users to create their own colour associations with the musical notes, inspired by research into sound-colour synaesthesia. People who experience sound-colour synaesthesia either “see” colours externally or have an internal sense of “knowing” the colours [13]. Some studies suggest that certain types of synaesthesia could be innate in everyone, but some individuals experience it at a heightened level [22].

The immersive nature of this VR application aims to engage users by utilising interactive visuals, spatial audio, and active interaction with objects to help them focus on the task at hand.

5 Conclusion & Future Study

It is an exciting time for research in VR, with rapidly advancing technologies and growing user adoption. Many fields stand to benefit from its applications. In music, VR has opened up new ways to explore the relationship between the auditory and visual senses,

offering fresh perspectives on long-standing research questions. As with past advancements, technology continues to drive research, building on previous knowledge and generating new insights. The Chromaesthetica application represents the beginning of an exploration into designing immersive VR tools that leverage cross-modal research for learning music theory. The next stage of this research focuses on two key questions: first, whether sound-colour cross-modality in VR can enhance users' ability to learn basic music lessons; and second, whether generalised or personalised colour associations with musical notes improve learning outcomes in these exercises.

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