VIRTUAL REALITY AND SOUNDSCAPE METHODS: AN EXPERIMENTAL MODULE

Team **EchoXR**: Jaqueline S. Lopez, Vanina J. Nguemsop F., Aidan Link

Mentors: Dr. Merate Barakat, Dr. Eliot Winer, Dr. Kimberly Zarecor, Rhoda Asamoah, Jorge Yass, Mustafa Kilinc

PROBLEM STATEMENT

While soundscape and educational physical environments are closely related research fields, there is still a noticeable gap in soundscape implementation in Virtual Reality (VR) environments, which could otherwise enhance presence for student learning.

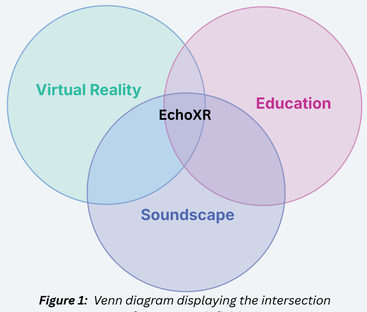

Figure 1: *Venn diagram displaying the intersection of the research fields*

RESEARCH OBJECTIVE

The study focuses on the integration of soundscape research methods into a VR system and its effects on presence, immersion, and engagement.

Figure 2: *The Unity environment used in this research is borrowed from the **EAGER-TechThrive** project*

BACKGROUND

VR is widely used as a safe and effective tool for both training and education [1,2]. Soundscape is an acoustic environment as perceived or experienced and/or understood by people, in context [3]. Integrating soundscape into VR systems has been shown to enhance user presence and engagement [4], creating more immersive experiences that support efficient student learning.

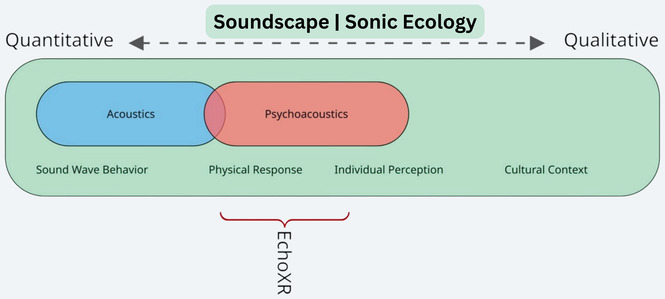

Figure 3: *EchoXR in Soundscape research*

METHODS

Soundwalk

A structured walk focused on **active listening** to environmental sounds at specific locations. EchoXR conducted a soundwalk to gather inspiration and identify potential ambient sounds to record for the project. Inspired by the soundwalk, the virtual environment is designed to be navigated using spatial audio cues for directionality.

Tools Used

The following tools were used to record and implement **bird sounds** into the given virtual **(EAGER-TechThrive)** environment.

- **Ambisonic microphone**: captured bird calls at ISU campus.
- **Bose QuietComfort headphones**: for critical listening and to test the environment after sound integration.

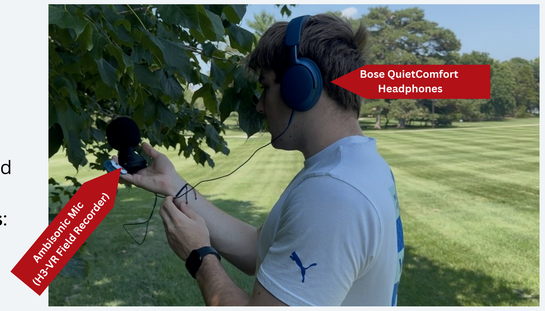

Figure 4: *Tools used for Sound Recording*

Sound Integration

The recorded and gathered sounds were edited in **Audacity.**

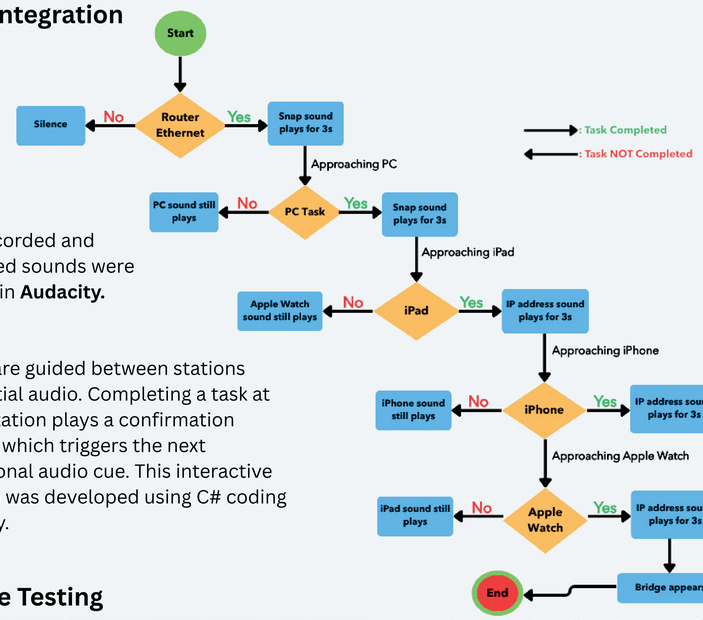

Figure 5: *Flowchart of the coding process of sound integration*

Users are guided between stations by spatial audio. Completing a task at each station plays a confirmation sound, which triggers the next directional audio cue. This interactive system was developed using C# coding in Unity.

Iterative Testing

Figure 6: *Participant testing the environment*

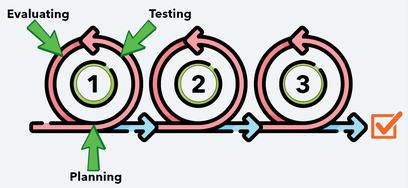

Figure 7: *Iterative testing process*

EVALUATION

Conducted three iterations to collect user feedback

- **First Iteration** - optimized environment to increased FPS, edited harsh sounds like the PC and watch noise, and changed how the sounds activated in the environment.
- **Second Iteratio**n - reduced the background noise of bird sounds and added more Steam Audio features such as air absorption and occlusion.
- **Final Iteration -** There is a subtle improvement over the three rounds of iterative testing.

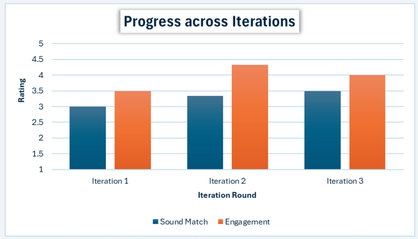

Figure 8: *Evaluation of the users' engagement and sound matching across iterations*

Conducted user study comparing with and without sound using Five Point Likert scale

- The addition of sound **improved user immersion, engagement and task clarity**. Spatial audio cues motivated users to interact with different objects and helped guide them through the environment by providing clear directional feedback.

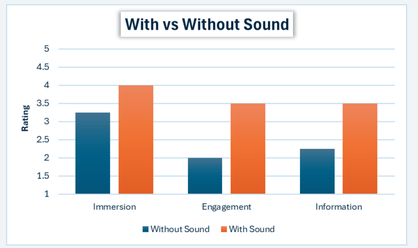

Figure 9: *Evaluation of the users' engagement, immersion and takeaway with and without sound*

Compare Frame Rate with and without sound

- The sounds have **no noticeable effect** on the **FPS (Frames Per Second)** of the environment. This is likely due to the audio computation happening on the CPU (Central Processing Unit) and not the GPU (Graphical Processing Unit).

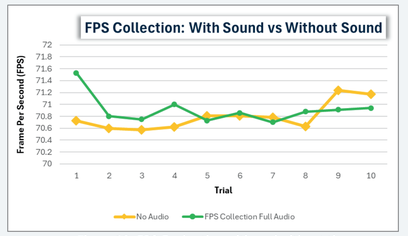

Figure 10: *FPS Evaluation with and without the sound*

FUTURE WORKS

- Expand Sample Size testing
- Collect objective data using an **Emotibit** or **EEG (electroencephalogram).**
- Gather subjective data through a validated questionnaire
- Test in different environments

Sound Analysis (in depth):

- Frequency
- Sound Levels (Loudness)
- Recording Quality

REFERENCES

[[1] - Cooper, N., Millela, F., Cant, I., White, M. D., & Meyer, G. (2021). Transfer of training—Virtual reality training with augmented multisensory cues improves user experience during training and task performance in the real world. PLOS ONE, 16(3), e0248225. *https://doi.org/10.1371/journal.pone.0248225*

[2] - Nurjanah, E. A., Mustofa, R. H., Suranto, Yustiana, L. N., Zemafi, O. D., & Yuliantina, D. (2025). Navigating educational disruption: Harnessing virtual reality for mitigating learning loss during the COVID-19 pandemic. 020071. https://doi.org/10.1063/5.0262209

[3] - Çankaya Topak, S., & Yılmazer, S. (2022). A comparative study on indoor soundscape assessment via a mixed method: A case of the high school environment. Applied Acoustics, 189, 108554. *https://doi.org/10.1016/j.apacoust.2021.108554*

[4] - Li, Y., Ch'ng, E., & Cobb, S. (2023). Factors Influencing Engagement in Hybrid Virtual and Augmented Reality. ACM Transactions on Computer-Human Interaction, 30(4), 1–27. https://doi.org/10.1145/3589952

IOWA STATE UNIVERSITY
VRAC Research Center

EchoXR Sounds
Connect with us

Grant No. (2244586)