



Synaesthesia Sound Design in Virtual Reality

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Abstract. To improve the authenticity of objects in virtual reality, this study explores the sound of ASMR (Autonomous sensory meridian response) to link the common senses and enhance the authenticity of virtual objects. The synesthesia associated with visual and auditory triggers ASMR leads to the haptic connection. This study created a synesthesia scene set up with two sound designs: the ASMR and general stereo sound. The pre-and post-measurement experiment of one group was applied in this research. The ITQ immersion experience as a measurement tool to test 53 junior college students. They filled out a questionnaire immediately after experiencing the virtual reality scene. The authors used SPSS as a statistical tool to compare the differences between the two sound configuration versions according to the paired sample *t*-test. The results showed that there is no significant difference between the two versions of sound effects in virtual cognition, sensory linkage, virtual reality, and self-exploration. The positive immersive experience was slightly better in ASMR sound effects than in general stereo sound placed in virtual reality.

Keywords: Synesthesia · Autonomous Sensory Meridian Response · Sound Design in Virtual Reality

1 Introduction

There is an idea that ordinary humans will someday be overtaken by artificially intelligent machines or cognitively enhanced biological intelligence [1] and such a prediction has moved from the realm of science fiction to serious debate. When the existing scientific and technological technology develops to a certain stage, it will produce events that completely overturn the original cognitive scope and even the development of civilization. Such fear seems to be eased after the pandemic of Covid-19. The “5 Trends Appear on The Gartner Hype Cycle for Emerging Technologies 2019 [2] before Covid-19 compared with their prediction of 2022 [3] after the epidemic breakout, the trend did not change much, people still are at the center of all business, and they need to digitalize all process; location independence requires technology to support new business

versions; organizations prepare to adapt to all kinds of disruptions. Among their reports, they suggested top strategic technology for 2021 including people centricity, location independence, and resilience delivery in a manner of combinatorial innovation.

While Facebook announced its name changed to Meta (Nov 5, 2021), which intended to cover your virtual by using metaverse on Facebook. Did Zuckerberg prescribe a possible solution to our future world? If it did, at least, billions of Facebook users will experience their new trend of using Facebook and the technology world will push forward with its related technology of virtual reality. Combining the above technological trends and a new development direction of the metaverse, how we can provide a better experience in virtual reality (VR) environments? Since VR engages users in an emerging environment involving visual and auditory senses, we explore the synesthesia effects associated with visual and sound design in virtual environments. In the following sections, we present the core technology of metaverse, two versions of sound effect designs, the Foley and the ASMR sound effects, testing design, and test results analysis.

2 The Core Technology of Metaverse

Metaverse is a combination of the real world and VR. Virtual reality creates a high virtual sense of three-dimensional (3D) simulation space for users. By wearing VR visors, users can interact with objects and can move freely within such a virtual space. All the processes will transmit from the VR devices through real-time computation and feedback to the user's visual and auditory sensations and then trigger other feelings. To enhance such an experience, we propose a sound design of synesthesia associated with visual and auditory triggers ASMR leads to the haptic connection. We design two versions of sound design; the Foley sound effects and ASMR sound effects.

3 Testing Design

This research adopts a single set of pre-and post-test experiments, and the research tools use "Synesthesia and Virtual Reality System" and "Immersion Experience in Virtual Reality Questionnaire." The questionnaire on an immersion experience was modified from the Immersion Experience Questionnaire [4] (IEQ), and the original questionnaire of the 2004 UQO Cyberpsychology Lab [5]. The ITQ Immersion Experience Questionnaire [6] has 4 dimensions: focus, impact, emotion, and gameplay (Table 1, the modified immersion experience questionnaire to adapt to this research). This model is the most often adopted and applies to game-related research. In the reliability test, Cronbach's alpha value is 0.78. To validate the questionnaire, we take a pretest. The four dimensions of Cronbach's α are 0.512–0.789, and the reliability and validity of the original questionnaire are shown in Table 2. These results established a validated questionnaire for the post-test measurement.

Table 1. Immersion Experience Questionnaire

| Dimension | Items |
|------------|---|
| Focus 1 | Is easy for you to engage in the gameplay? |
| Focus 2 | Are you engaged in gameplay and cannot be easily distracted by others? |
| Focus 3 | Are you alert now? |
| Focus 4 | When you are focused, how you shield yourself from interference |
| Impact 1 | When you are immersed in the experience, can you feel nothing around you? |
| Impact 2 | How often do you find yourself closely aligned with virtual avatars in a virtual environment? |
| Impact 3 | Are you immersed in imagination and can't feel what's going on around you? |
| Impact 4 | When you are immersed in the experience, do you forget the time? |
| Impact 5 | Have you ever been so engrossed in virtual reality that you forgot about time? |
| Emotion 1 | Have you ever felt so real in your dreams that you woke up feeling disoriented? |
| Emotion 2 | Have you ever been excited during the experience? |
| Emotion 3 | Have you ever been afraid of what happened during the experience? |
| Emotion 4 | Have you been greatly impressed after the experience of VR? |
| Gameplay 1 | Are you immersed in the experience, as if you are in it rather than manipulating hand controllers or watching the virtual screen? |
| Gameplay 2 | Are you immersed in the experience and react as your reactions? |
| Gameplay 3 | How often do you experience VR? Often means every day or two days |

Table 2. Pre-test results

| Dimensions | Average | Deviation | Item number | Cronbach's Alpha Coefficient |
|------------|---------|-----------|-------------|------------------------------|
| Focus | 24.81 | 7.54 | 4 | |
| Impact | 15.33 | 8.67 | 5 | |
| Emotion | 14.25 | 6.70 | 4 | |
| Gameplay | 6.56 | 4.95 | 3 | |
| Total | 64.11 | 13.11 | 17 | .78 |

Synesthesia sound effects and VR system sets are created by Unity and related devices. The design and experiment procedure for gamers to take is displayed in the following Fig. 1, which is established by the system design. Table 3 displays the interior and exterior scenes. For gameplay to interact with the objects in the VR, we especially associate the visual object with sound effects (See Sect. 4 Sound Design). After the gameplay testing process, the user/gamers will take the questionnaire immediately after the gaming tests.

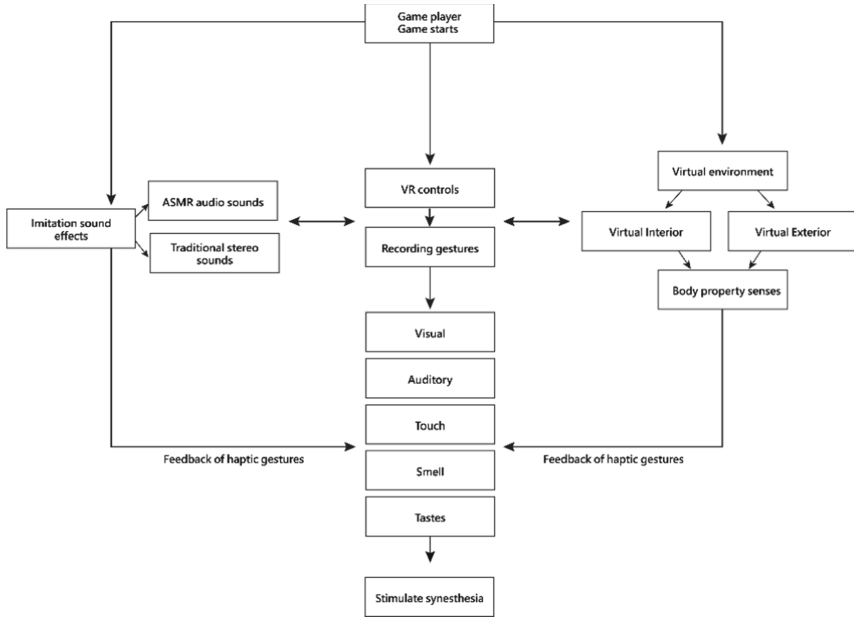


Fig. 1. Gameplay process.

Table 3. The system design-interior scene and exterior scene

| Panorama content | Interior scene | Exterior scene |
|------------------|---|--|
| Visual angle 1 |  |  |
| Visual angle 2 |  | |

4 Sound Design

This study explores the sound effects in the Head-related Transfer Function (HRTF) of traditional recording principles, and the possibility of triggering synesthesia and reducing the dizzy side effects of using VR visors. There is an Audio Source component setting in Unity by adjusting the 2D analog sound effect to 3D in the Spatial Blend. This sound effect can provide a 360° surrounding sound effect in which the user can clearly distinguish the sound source’s direction and distance. However, aimless free moving within the scene and totally relying solely on sight and hearing, can neither arouse human curiosity nor achieve synesthesia effects as we experience in the real world. To stimulate interest and then activate the synesthesia response in humans, we need the help

Table 4. Analysis of pre-and post-test measurement

| Dimensions | Mean (Standard deviation) | | Degrees of freedom | <i>t</i> -value | <i>p</i> -value |
|------------|---------------------------|--------------|--------------------|-----------------|-----------------|
| | Pre-test | Post-test | | | |
| Focus 1 | 4.59 (1.219) | 4.78 (1.189) | 50 | -1.649 | 0.105 |
| Focus 2 | 4.16 (1.405) | 4.12 (1.519) | 50 | .280 | 0.780 |
| Focus 3 | 4.94 (1.190) | 4.80 (1.217) | 50 | 1.632 | 0.109 |
| Focus 4 | 3.53 (1.102) | 3.47 (1.007) | 50 | .490 | 0.627 |
| Impact 1 | 4.04 (1.428) | 4.10 (1.473) | 50 | -.358 | 0.722 |
| Impact 2 | 4.10 (1.375) | 4.08 (1.262) | 50 | .129 | 0.898 |
| Impact 3 | 3.75 (1.309) | 3.84 (1.377) | 50 | -.590 | 0.558 |
| Impact 4 | 4.10 (1.552) | 4.06 (1.256) | 50 | .248 | 0.805 |
| Impact 5 | 3.75 (1.598) | 3.86 (1.523) | 50 | -.759 | 0.452 |
| Emotion 1 | 4.43 (1.473) | 4.24 (1.692) | 50 | 1.183 | 0.242 |
| Emotion 2 | 4.22 (1.527) | 4.02 (1.407) | 50 | 1.121 | 0.268 |
| Emotion 3 | 3.59 (1.472) | 3.78 (1.419) | 50 | -1.093 | 0.280 |
| Emotion 4 | 4.22 (1.316) | 4.35 (1.214) | 50 | -.961 | 0.341 |
| Gameplay 1 | 4.14 (1.371) | 4.18 (1.352) | 50 | -.240 | 0.811 |
| Gameplay 2 | 4.25 (1.214) | 4.18 (1.228) | 50 | .423 | 0.674 |
| Gameplay 3 | 2.29 (.923) | 2.27 (.827) | 50 | .167 | 0.868 |

of human curiosity for new things and new patterns by the five senses [6] (Davies, 2014). We might take advantage of our five senses and guide the users through sight, hearing, touch, smell to taste which activate the synesthesia response and haptic actions. In this research we expect synesthesia to be stimulated by the associated visual and auditory senses. In this research, we design objects associated with auditory sound effects and guide the users through the first and most important synesthesia senses while exploring in the VR scenes. With considerations of creating synesthesia sound effects, we create the Foley sound effects and ASMR sound effects, two versions for the gameplayer to explore.

5 Test Results

To analyze the single matched sample *t*-test, we found that after experiencing the Foley sound effects and the ASMR version, players did not discern significant differences between these two (Table 4). With a *t*-value between -1.694 and 1.6325, and a two-tail tests significance of between 0.105 and 0.898, both are not lesser than 0.05, indicating that the ASMR version is not much different from stereo settings in terms of concentration, sensory synesthesia, immersion, and improving the fun of exploration, but there are

still differences in the data, and researchers will discuss the differences in the following sections.

Foley sound effects sound more natural than the ASMR sound effects:

Focus items of 2, 3, and 4, emotion items 1 and 2, and gameplay items of 2 and 3, the average values are slightly higher than the ASMR design. In other words, the traditional VR version can engage the gameplayer more than the ASMR version. The authentic VR scene on emotional items reflects the positive emotional reactions. On self-exploration and gameplay dimensions, the traditional VR version is more natural than the ASMR one.

ASMR sound effects sound more immersive than the Foley sound effects:

In Focus item 1, Impact items 1, 3, and 5, Emotion items 3 and 4, and Gameplay item 1 Face, the ASMR sound effects display the immersion experience recognized and immersed more than the Foley sound effects. The degree of impact displays the interactions and relationships between the five senses. The emotional reactions to the authentic VR scenes seem to be impressive but the emotional reactions did not reflect the impacts. The dimension of self-exploration and gameplay in the ASMR sound effects display more immersive than in the Foley sound effects.

6 Conclusion

After the comparison of the above differences, the Foley and the ASMR sound effects, the researchers believe that there is not much difference between the sound sources directly related to the sound effects in our experiments. Besides, gameplayers have taken pre-and post-tests, which lead to decreased focus and self-exploration in cognition, but in the second experience, from the post-test results, we know repeated experience reinforces synesthesia responses. The head position would change the receiver's perception of sound source distance and directions. However, researchers cannot predict how the player perceives the sound effects or what is the player's head position. In future experiments, researchers will use different methods to record sounds and edit sound effects in Unity. Let the ASMR sound effects direct the gameplayer's auditory perception and judgment of the sound source, and then the ASMR can finally display its characteristics and produce more effects on users. But this will be the next experiment soon.

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