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An Auditory Approach to Pseudo Unseen Presence in the Metaverse Using HMD

Shiori Kinoshita[1] and Kenji Funahashi[1]

[1]Nagoya Institute of Technology, Japan

Abstract

When someone is behind you, you may feel an unseen-presence. We propose a new method of showing a pseudo-presence through auditory perception, using only a standard HMD with headphones. The goal is not to promote the clear perception of the five senses, but to somehow unconsciously sense a presence.

CCS Concepts

• ***Human-centered computing*** → *Human computer interaction (HCI);*

1. Introduction

Virtual reality (VR) technology is finding applications not only in amusement parks and home video games, but also in diverse fields such as medicine, architecture, and education. Along with this, the metaverse has also attracted attention, enabling immersive experiences centered on the visual and auditory senses; HMD (head-mounted displays) play a central role in these experiences. Although it is not possible to see directly behind you in the real world, it is possible to notify you such as ringing a bell in the metaverse environment, since the system knows the information around you. The recognition of information such as "presence" rather than direct notification is considered useful as a user interface of moderately grasping peripheral information. In the same way that some information processed by the brain is subconscious, presence is one of them. Previous studies show a presence-like sensation by humidity and water vapor [HKK*17], a part of sound emphasis [ZIK*12], a quasi-static electric field near CRT [SSA20], and an electrostatic field using Van de Graaf generators [KK21]. These goals are not to promote a clear perception of the five senses, but rather to somehow subconsciously perceive a sense of presence. Hopefully these techniques will be applied to the metaverse. However, it is difficult to implement these methods into the home-use metaverse because they require special equipment or environment. Furthermore, some studies do not assume that users are unaware of certain things on a subconscious level. In this study, we propose a novel method to show pseudo presence through auditory perception using only a standard HMD with headphones. This study aims to reproduce such presence through auditory cues, without the use of special devices. In particular, we examined whether it is possible to show a pseudo presence through auditory stimuli that are not clearly perceived but are perceived subconsciously. Our proposed method will allow users to receive information in moderation without significantly distracting them.

2. How to Express Pseudo Presence

The sensory threshold is the weakest stimulus that an organism can sense in psychophysics [Tre62]. The just-noticeable difference (JND) is the amount something must be changed in order for a difference to be noticeable [JP22]. And the temporal window of multisensory binding is the period where the brain perceives stimuli as occurring at the same time, even if they are slightly offset in time [PHW09]. There may be an ambiguous intermediate state near the sensory threshold. Similar ambiguity may also exist around the just noticeable difference and the temporal window of simultaneity. We hypothesized that we could present users with the sensation of someone approaching from behind as a pseudo-presence without them consciously noticing by applying stimuli near the threshold of consciousness such as subliminal perception. Sound pressure level, impedance, and frequency response are important speaker specifications, and these physical characteristics affect how the reproduced sound is heard. In particular, the frequency bandwidth that can be reproduced is substantially narrowed by the sound volume, so the frequency and volume must be designed with these characteristics in mind in order to reproduce and perceive small changes appropriately. In this study, headphones built into the HMD are used for sound presentation, we investigated a method to induce a sense of presence in an environment where background music is playing by making a very brief change in either the right or left channel. Specifically, the following three ways were examined:

1. slight increase or decrease in volume,
2. slight changes in frequency (up or down), and
3. slight delay in the time of sound.

Preliminary investigation showed that ways 1 and 3 had a strong

(a) *Appearance of evaluation* **(b)** *View through HMD*

Figure 1: *Evaluation by participant*

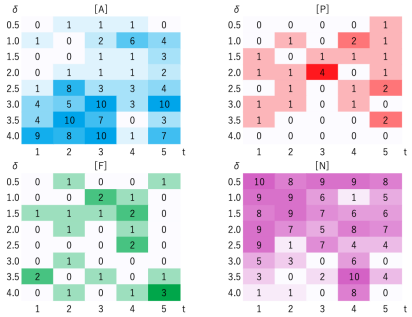

Figure 2: *Number of A, P, F and N, for each frequency difference* δ *and change duration t*

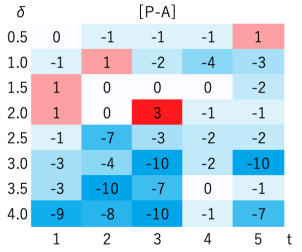

Figure 3: *Difference between P and A (P-A)*

influence on the directional perception of the sound source, causing discomfort and auditory fatigue. On the other hand, way 2 was judged to be the most suitable for reproducing pseudo-presence, with many respondents stating that they could not tell the difference and that they somehow felt something was there. Therefore we try to show a pseudo presence through auditory perception, by presenting partially processed music in either the right or left channel, that is adjusted the amount of frequency change and the duration of the change appropriately.

3. Evaluation and Conclusion

The proposed method was evaluated in a virtual environment built on Unity using the Meta Quest 3 HMD with built-in headphones (Figure 1 (a)). Participants were asked to play a visual sub task (three-shell game) at the same time so that they would not concentrate too much on auditory perception alone (Figure 1 (b)). The scenery projected on the HMD was the actual experience environment by the video see-through function, which was limited to a simple wall, and three-shell was drawn by CG. The viewing angle of the HMD was about 100 degrees, and it was assumed that the participants would experience it in a position where windows and other objects would not be reflected. The background music used was of a pop-country style. This style of music, with its moderate tempo and predictable rhythms, makes it easy to embed small auditory modulations without drawing attention to users. A total of 40 patterns were assigned to 10 university students in random order, with the frequency difference δ set from +0.5 Hz to +4.0 Hz (0.5 Hz intervals) and the change duration of time t set from 1 to 5 seconds (1 second intervals). Each pattern was assigned once per participant, for a total of 400 trials. Participants were instructed to press a button at the timing when they "felt a presence" during the trial, and after each trial, they reported whether they noticed the sound change and whether they felt a presence. The responses for each trial were divided into the following four categories:

- *A* (audible): noticed the sound change
- *P* (presence): did not notice the sound change, but felt the presence and the timing was correct
- *F* (false): reported that felt the presence, but the timing was off
- *N* (not felt): noticed neither the sound change nor the presence

The number of responses for each of all combinations is shown in Figure 2. Response *F* may indicate false positives or temporal mismatches, and *N* may show the perceptual threshold was not reached. These responses might help clarify the limitations of our method, but they are not discussed below because presence is not always felt and is not always correct. The participants are expected to measure the exact timing of the sense of presence and be unaware of the change in sound. The differences between *P* and *A* for each δ and t combination are shown in Figure 3. Overall, *P* slightly exceeds *A* in a band around (δ, t) = (+2.0, 1) ~(+0.5, 5), especially exceeds at (δ, t) = (+2.0, 3). On the other hand, the tendency is to be more aware of sound changes above +3.0 Hz.

These results suggest that pseudo-presence in auditory perception may be effective only in certain ranges of frequency difference and change duration. Future works include verifying the combined effect with visual presence presentation [FM23], and reconsideration of presentation methods using volume and delay.

Acknowledgment

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