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Body-Penetrating Tactile Phantom Sensations Enhanced by Sound

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***Abstract*—We propose a multisensory system that integrates auditory and tactile stimuli to enhance body-penetrating phantom sensations. The system synchronizes penetration-related sounds with vibrotactile feedback, leading to improved perceived realism and user satisfaction. Furthermore, our results demonstrate that semantic variations in auditory stimuli significantly influence the perception of body penetration, extending previous findings that primarily focused on tactile stimulation alone.**

***Index Terms*—Tactile phantom sensation, body penetration, multisensory perception, sound, vibration**

I. Introduction

To enable seamless interaction in virtual environments, it is crucial to provide rich sensory feedback that closely replicates real-world experiences. Haptic illusions, which use precisely controlled stimuli to produce unexpected percepts, offer unique opportunities to enhance such experiences. One notable example is the body-penetrating phantom sensation [1], a tactile illusion where the perceived stimulus shifts between the dorsal and ventral sides of the body, creating a vivid impression of an object passing through the body.

In this demonstration, we provide an enhanced illusory experience of body penetration by combining tactile and auditory stimuli, improving both the perceived authenticity of the body-penetrating illusion and overall user satisfaction. This demo accompanies a paper entitled "Enhancing Body-Penetrating Phantom Sensations Through Multisensory Integration of Sound and Vibration" that will be presented at the 2025 WHC by the same authors.

II. System Overview

As shown in Figure 1, our system consists of two sensory devices: (1) a vibrotactile belt with linear resonant actuators (LRAs), enclosed in 3D-printed casings on the ventral (abdomen) and dorsal (back) sides, and (2) noise-canceling headphones that deliver auditory stimuli synchronized with the vibrotactile stimuli, powered by a low-latency audio processor.

The vibrotactile belt stimulates the center of the torso using two actuators that generate 120-Hz sinusoidal vibrations. The vibration envelope is shaped by an amplitude modulation profile with an exponential decay (exponent $=$ 3). This vibrotactile stimulus starts with the auditory stimulus and ends when the auditory loudness falls below a perceptual threshold defined as the point when no impactful sound is perceived.

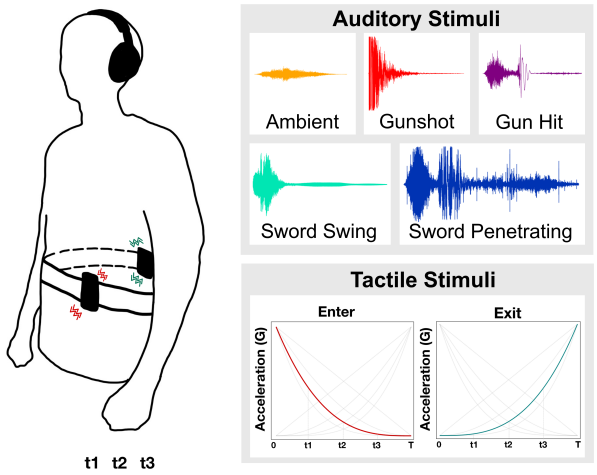

Fig. 1. Concept of providing an auditory stimulus with a body-penetrating tactile phantom sensation.

The headphones deliver one of five sound effects commonly encountered in gaming contexts: two associated with initiating body-penetrating events (i.e., gunshot and sword swing), two with receiving impacts (gun hit and sword penetration), and one ambient alert sound from the game League of Legends.

In this demo, participants can experience multisensory body-penetrating phantom sensations by wearing the vibrotactile belt and noise-canceling headphones. In the first phase, they experience the vibration—classified as dynamic (body-penetrating illusion) or static (simultaneous vibration)—and sound stimuli separately to become familiar with each modality. In the second phase, synchronized vibrotactile and auditory stimuli are presented to simulate a body-penetrating illusion. These paired stimuli can evoke a vivid and compelling sensation of an invisible object passing through the torso. In addition, no visual stimuli are provided with the vibration. Our demo elucidates that semantic variations in auditory stimuli significantly affect the perception of body-penetrating illusion and improve realism.

References

[1] J. Kim, S. Oh, C. Park, and S. Choi, "Body-penetrating tactile phantom sensations," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2020, pp. 1–13.