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Exploring Ownership of an Avatar's Cat Ears through Visual, Auditory, and Haptic Multimodal Feedback

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Abstract

Extensions of body parts that humans are not innately endowed with, such as supernumerary limbs, have attracted attention. Since these body parts resemble existing ones, their movements and sensations can be inferred from the innately existing body parts. However, the sense of ownership for imaginary body parts, such as cat ears, which humans have never possessed, has not been sufficiently investigated. This paper proposes an experiment to examine the changing sense of ownership of cat ears, a body part that humans are not innately endowed with, through multimodal feedback that integrates visual, auditory, and haptic stimuli. Using an avatar with cat ears attached to the top of the head, we suggest presenting visual stimuli of the avatar's cat ears along with spatially congruent auditory and haptic feedback to enhance the sense of ownership over imaginary cat ears.

CCS Concepts

• ***Human-centered computing*** → *Haptic devices;* ***Auditory feedback;***

1. Introduction

Extensions of body parts that humans are not innately endowed with, such as supernumerary limbs, have attracted attention. Because these body parts resemble existing body structures, their movements and sensations can often be inferred from experience. However, the sense of ownership for imaginary body parts, such as animal ears, has not been sufficiently examined. Enhancing the sense of ownership of imaginary animal ears is expected to increase the sense of immersion in the extended avatar with animal ears. Previous studies have reported that multimodal feedback spatially congruent with visual stimuli can elicit a sense of ownership even for imaginary body parts that differ in appearance from the real body, such as cat ears or wings [YKS24,ELS*16]. Nevertheless, previous studies have primarily focused on multimodal feedback combining vision and touch, and the effect of auditory stimuli on the ownership of animal ears has not yet been investigated. As a first step, this study proposes a system that combines haptic feedback generated by a soft actuator driven by shape memory alloy with auditory feedback recorded binaurally through dummy cat ears. Furthermore, we propose an experimental design employing this system to investigate changes in the sense of ownership of cat ears.

2. Proposed method

2.1. Experimental method

In this proposed experiment, we construct a Virtual Reality (VR) environment using Unity version 2019.4.31f1. Participants wear a head-mounted display (HMD: Meta, Meta Quest 3) and transform into an anime-style avatar with cat ears[†]. The scenario is designed such that the avatar's cat ears are stroked by a Non-Playable Character (NPC) avatar[‡] for two minutes, followed by spoken interaction from the NPC (Fig. 1). The experiment employs a 2 × 2 factorial design with two independent variables: the spatial congruency (congruent vs. incongruent) of auditory feedback, and the presence or absence of haptic feedback. The order of the conditions is randomized for each participant to control for order effects. For auditory feedback, binaural recordings are prepared individually for each participant. Before entering the VR environment, participants wear a dummy cat-ear accessory and attach binaural microphones (Roland, CS-10EM) to both the dummy cat ears or their innate ears for each condition (Fig. 2). A speaker (Audio-Technica, AT-MSP56TV) is positioned to the side of the dummy cat ears, and the NPC avatar's voice is recorded with an identical gain setting. The recording obtained from the microphones attached to the dummy cat ears is defined as the spatially congruent condition, while the recording obtained from the microphones attached to the innate ears is defined as the spatially incongruent condition. In the spatially congruent condition, the recorded sound is presented in synchrony with the animation of the NPC avatar speaking at the position of the cat ears, and the voice is perceived as originating laterally. In the spatially incongruent condition, the sound is presented as originating from an upper oblique position, with its volume attenuated relative to the congruent condition with distance.

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Table 1: *Questionnaire Items for Evaluating Ownership of Cat Ears.*

		Item
Ownership	Q1	I felt as if the virtual cat ears were part of my body.
	Q2	I felt as if the virtual cat ears belonged to me.
Referral of touch	Q3	It seemed as if I were feeling the touch of the stroking in the location where I saw the virtual cat ears touched.
	Q4	It seemed as if the touch I felt was caused by the NPC avatar's hand touching my virtual cat ears.
Referral of sound	Q5	It seemed as if I heard the NPC avatar's voice through the virtual cat ears on top of my head.
	Q6	It seemed as if the ears where I perceived the NPC avatar's voice were placed on top of my head.

To present haptic stimulation, the soft actuator used in a previous study is integrated into the HMD and attached to the participant's hair [YKS24]. When the actuator is activated in synchrony with the visual stimulus of the cat ears being stroked, the participant's hair is swung back and forth by the actuator, thereby providing spatially congruent haptic feedback with the avatar's cat ears.

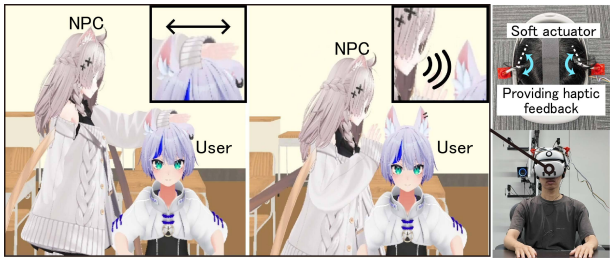

Figure 1: *Left: begin stroked on the cat's ears. Middle: being spoken to by an NPC avatar. Right: Soft actuator attached to the participant's hair that can be activated in the haptic condition.*

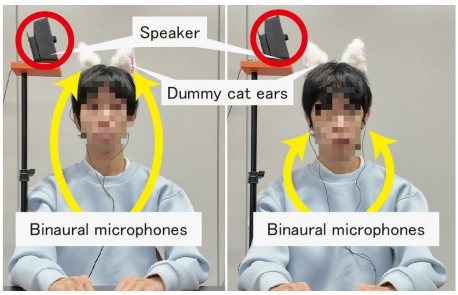

Figure 2: *Binaural recordings (Left: Spatially congruent condition. Right: Spatially incongruent condition.)*

2.2. Evaluation method

In the rubber hand illusion, it has been reported that the perceived hand drifts toward the rubber hand as the sense of ownership emerges [BC98], a phenomenon referred to as proprioceptive drift. In this study, we measure proprioceptive drift of the top of the head and the real ears as the body parts corresponding to the cat ears. We hypothesize that, as the sense of ownership of the cat ears emerges, participants will exhibit an upward drift in the direction where the cat ears are added. To measure proprioceptive drift, a whiteboard marked with a scale is placed beside the participant. At the end of each condition, participants are asked to indicate the position they perceive as the highest point of their head vertex and their real ears. The experimenter measures the actual positions of these body parts, and the vertical differences between the indicated and actual positions are compared to determine whether drift occurs. As a subjective evaluation, we designed a questionnaire regarding the sense of ownership of the cat ears. The questionnaire employs a 7-point Likert scale, ranging from 0 (strongly disagree) to 6 (strongly agree) (Table 1). The questionnaire items assessing the sense of ownership and referral of touch were adapted from questions used in previous related studies [BC98, LSK*08]. In contrast, since no corresponding items addressing the referral of sound were found in the previous research, new items were developed based on the context and aims of this work.

3. Conclusion

This paper proposes an experimental design to investigate changes in the sense of ownership of cat ears, an imaginary body part that humans are not innately endowed with, through multimodal feedback combining visual, auditory, and haptic stimuli. We present a system that provides spatially congruent haptic and auditory feedback in a scenario where an NPC avatar strokes the cat ears and subsequently speaks near the cat ears. In future work, we plan to conduct user studies to examine how multimodal feedback influences the sense of ownership of the cat ears.

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