Analysis of the R-V Dynamics Illusion Behavior in Terms of Auditory Stimulation

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ABSTRACT

The R-V Dynamics illusion is a phenomenon where weight perception is changed by superimposing a CG case with a movable portion (CG) onto a real object using mixed reality technology. In previous studies, it has been confirmed that weight perception is affected by the size/volume of the CG, and a virtual collision sound between the case and the movable portion could also be a cause of this illusionary phenomenon. However, in previous studies, only one virtual collision sound is applied. Therefore, in this study, we consider the influence of the physical characteristics of virtual collision sound such as the size and weight of the movable object in the phenomenon. As a result, it was confirmed that the weight perception changes according to the virtual collision sound, and participants lightly perceived the real object when a virtual collision sound is played with a smaller and lighter object.

CCS CONCEPTS

• Human-centered computing →Human computer interaction →Interaction paradigms → Mixed / augmented reality;

KEYWORDS

Mixed reality, Sense of weight, Visual stimulation

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1 INTRODUCTION

It is known that information obtained from the sensory organs mutually affects perception. This is called the cross-modal effect. Pseudo-haptics is a famous phenomenon caused by the cross-modal effect where external forces are perceived by displaying only visual stimuli linked to physical movement [1].

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The material-weight illusion (MWI) is a phenomenon that lightly perceives objects of heavy material despite having the same weight when lifting heavy and light materials [2]. Since the cross-modal effect can produce a tactile sense without any haptic device, it is expected to be applied to various interface developments.

On the other hand, using mixed reality (MR) technology, real and virtual worlds can be merged in real time, and users can experience the tactile feeling of a real object while viewing superimposed virtual data. This implies that the material and/or shape of the object can differ between visual, auditory, and tactual senses. In such a situation, we want to know which cross-modal phenomenon could be occurring.

Several cross-modal effects using a MR visual stimulus have been reported. The R-V Dynamics illusion [3] is an example of this illusionary phenomenon, where the weight perception of a rigid body changes by superimposing a CG case with a movable portion in it (e.g., liquid and ball). In previous studies, it was confirmed that a case was perceived lighter as when the movable portion (CG) was moving and when the size/volume of the movable portion was small. In addition, a virtual collision sound between the case and the movable portion could also be a cause of this illusionary phenomenon [4]. However, in previous studies, only one virtual collision sound is applied, and the size, weight, material, etc. of the object generating the collision sound have not been sufficiently examined.

In the MWI, a visually heavy material is perceived as light, but in the R-V Dynamics illusion visually lighter moving objects are more lightly perceived. When playing a collision sound with a lighter object, we want to know whether the object is perceived as lighter or heavier.

In this study, in order to analyze the influence of virtual collision sound on the R-V Dynamics illusion, we apply virtual collision sounds generated by objects with different sizes and weights. It has been confirmed in previous work that the size of the real object can be predicted from the collision sound even if the colliding object is not visible [5], but there are few studies analyzing the influence of the cross-modal effect between audiovisual perception and weight perception, so the knowledge obtained from this viewpoint is worthwhile.

2 EXPERIMENT

2.1 Purpose

We conducted an experiment to verify the effect of virtual collision sound (MR sound stimulation) on weight perception. Specifically, we consider the following questions:

(1) When the virtual sound of a heavy object colliding with a the case is played, is the case (real object) perceived as heavy or light?
(2) Is the weight of a case perceived differently depending on the size of the colliding object that generates a virtual collision sound?

2.2 MR system used in the experiment

In the experiment, participants wore a Canon HM-A1 head-mounted display (HMD) and headphones. They grasped a handle of an acrylic case (real object with size 165 x 80 x 90 mm and weight 750 g). The positions and the posture of the participants' heads and the real object were measured using magnetic sensors. The virtual case (MR visual stimulus), which was superimposed onto the real case, was the same size as the real case. The virtual case was white and the CG ball inside the case was black with a diameter of 45 mm (Figure 1 right). The ball moved in the virtual case as the participants swung the real case. As the MR sound stimulus, we recorded four collision sounds: four metal balls with the same material but different sizes (weights) were collided with an acrylic case. In the experiment, these sounds were played through the headphones at the same volume as the sounds recorded (Table 1).

2.3 Procedure

The experimental procedure was based on the Scheffé's paired comparison method,which constructs a psychological measure. The procedure of the experiment was as follows:

(1) Two patterns were randomly selected from six (Table 1).
(2) With each pattern, participants grasped the handle of the real case in a predetermined posture (elbow bent 90 degrees), and swung the object left and right in accordance with a metronome tempo (60 beats per minute). The degree of swing was 30 degrees.
(3) The participants stated which pattern they felt was heavier.
(4) (1)-(3) were repeated for the remaining combinations.

The number of attempts was ${}_6P_5 = 30$ per person, and there were 10 participants. The participants were given sufficient opportunity to practice in advance so they could perform the action as directed.

3 RESULT AND CONCLUSION

The results of experiment are shown in Figure 2. The number line in the figure represents the psychological scale of the weight for each presented pattern. Smaller value indicates that the participants perceived the case as heavier. Scheffé's test revealed significant differences ($F(2, 30) = 168.76$, $p < .05$) for all conditions except P1 and P2.

First, P4 was perceived as lighter than P3, and P4 and P3 were both perceived as lighter than P1 and P2. This means that the smaller the MR sound stimulation was, the lighter the case was perceived. This result shows that, unlike the illusion effect of the MWI, the participants perceived the case as heavier when the collision object was large and heavy.

Secondly, it can be seen that P3 and P4 were perceived as lighter than P5. This result shows that when the size and weight of the colliding object that generates the virtual collision sound was small and light, the case was perceived as lighter than without any collision sound.

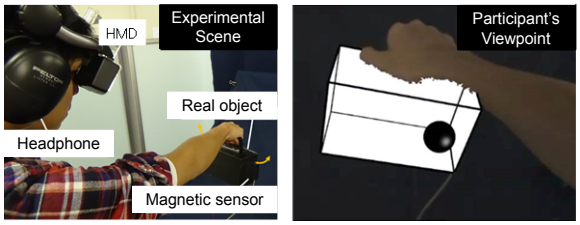

Figure 1: Environment of the experiment (left : experimental scene, right : participant's viewpoint)

Table 1: Variety of MR stimulation used in the experiments

Pattern	MR visual stimulus	MR sound stimulus	
		ball size/ weight of sound source	loudness of output sound
P1	A 45mm diameter CG ball moving in a virtual case	60mm/878g	79dB
P2		45mm/370g	79dB
P3		30mm/109g	72dB
P4		10mm/4g	66dB
P5		None	None
P6	None (Watch a black case)	None	None

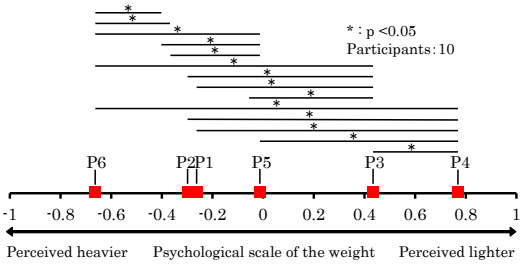

Figure 2: Result of the experiment

In this experiment, we have confirmed that the size of the collision object generating the virtual collision sounds changes the weight perception of the case. Due to the cross-modal effect of the audiovisual sense, there is a possibility that the range in which the weight perception can be manipulated could be expanded. However, depending on the parameters of collision sound (size and volume of the collision object), weight perception is not necessarily affected. In future research, we will clarify the conditions and laws under which this audiovisual cross-modal effect occurs by changing the parameters of collision sound.

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