[POSTER] Further Experiments and Considerations on Weight Perception Caused by Visual Diminishing of Real Objects

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ABSTRACT

Mixed reality (MR) technologies can virtually change the appearance of real objects in real time without changing the material attributes of the objects and the associated haptic stimuli. In this study, we use MR-based visuo–haptic to investigate the mechanisms by which vision and haptics interact. In contrast to MR, diminished reality (DR) can virtually erase a real object from our sight. Because DR visual and haptic experiences do not occur in daily life, the effects of DR on haptic sensations have not been previously investigated. Thus, in this paper, we also study the relationship between various ranges of DR-based visual effects and haptic sensations using stick-shaped real objects. The results indicate that, the sticks were perceived to be heavier than their actual weight when the visual length presented was made shorter by visually diminishing.

Keywords: Diminished Reality, Mixed Reality, Weight Perception.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

It is a well-documented fact that visual stimuli affect haptic sensation. Therefore, many illusionary phenomena in various types of stimuli have been found (Pseudo haptics [1], Size-weight illusion [2], etc.). Elucidating the mechanisms of these illusion phenomena will lead to new haptic feedback.

In classical approaches [3-5], researchers have conducted experiments to explain the mechanism of illusion by devising real objects. For example, the effect of the Size-weight illusion has been confirmed by researchers changing shapes and colours of real objects [3].

In recent years, many studies have utilized virtual reality (VR) to change objects' appearances systematically in experiments. VR is, therefore, considered a promising tool for providing new knowledge of mechanism investigation. Koike *et al.* attempted to elucidate Size-weight illusion in the VR space [4]. Also, A. Zenner *et al.* provided a compelling and dynamic passive haptic feedback and changed the weight perception of virtual objects [5].

From this background, our research group have studied the interaction and complementary effects of the visual sense and haptic sense using mixed reality (MR) [6]. In an MR space, interactions between the appearance impression by the virtual object and the real object happen when a difference between the virtual objects and the real haptic sensation is created.

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However, due to the characteristics of the MR space, when the real object is larger than the virtual object in the MR space, the outer shape of the real object protrudes from the virtual object. We solve this problem by introducing the opposing concept to MR: diminished reality (DR). DR technology can visually erase real objects by superimposing a photo-based background model onto an object to be diminished. Our research interest is in combining MR and DR to conduct extensive experiments exploring the interactions between visual and haptic sensations. When information is visually subtracted using DR technology, haptic sensation information exists without a visual stimulus. In such cases, it is worth studying, particularly in terms of perceptual psychological knowledge, whether the interaction between the visual and haptic sense occurs similarly to the MR space.

2 EXPERIMENTAL SETUPS

In this experiment, a video see-through type head-mounted display (HMD) and MR Platform System were used to implement DR effects. To allow the test subject to freely move his or her head during the experiments, the subject's head motion was acquired using magnetic sensors. The system operated at 30 fps. The subjects reported that they did not experience a time lag or shift in the preliminary experiments.

We adopted a simple method for erasing objects using DR for this study. We created a 3D model of the environment in **Figure 1** from multi-view images using a 3D reconstruction tool, Agisoft PhotoScan, in advance.

We used a 100g and a 235g stick of 24mm diameter and 600mm length. We defined a part of a stick within 100mm from the end to be grasped. The same material was wound on the sticks so that the difference in haptic sensation would be eliminated. The sticks were partially masked for Chroma-key composition of the above mentioned 3D environment model.

3 EXPERIMENT

3.1 Experiment Objective

In this experiment, we investigated the relationship between the visual range of the real objects and the weight perception. Specifically, we considered the following research questions:

1. When sticks are diminished by DR, depending on the range to be diminished, will subjects feel them as heavier as or lighter than normal?
2. Similarly, as we increase that range, does the weight perception change to become lighter or heavier uniformly?
3. Even if we use sticks of different weights, will the subjects feel them to be as heavy or as light as they are?

3.2 Experiment Conditions and Procedure

In this experiment, a 100g stick and a 235g stick were used. There were three patterns of visual stimuli: 200mm (**Figure 2**(a)), 400mm (Figure 2(b)), and 600mm (Figure 2(c)). The experiment was conducted separately for each weight of the stick.

In order to eliminate differences in the way that participants might swing the sticks, we instructed the subjects on how to swing the

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sticks the same way, by holding the handle part and swinging the sticks up and down with their right hand. Subjects held the sticks so that they could be seen on-screen. The degree of swing was 40 degrees, and the tempo was 140BPM. The number of attempts was ${}_4P_2$=12 times per person. The sample included 11 test subjects.

The test procedure was conducted as follows:

(1) Two swinging patterns were randomly selected from four patterns.
(2) Subjects were asked to swing the following the patterns.
(3) The subjects were asked to compare the weights of the two patterns.
(4) Steps 1-3 were repeated for all pairs.

To evaluate the perceived weight, we used Scheffé's paired comparison method. In this method, the psychological measure can then be easily constructed, and the order effect (influence introduced by the order of swinging the sticks) can be considered.

3.3 Result

The results of experiment are shown in **Figure 3**. Figure 3(a) shows the results for the 100g stick, and Figure 3(b) shows the result for the 235g stick. These figures show the psychological measure of weight. A small value indicates that the subject felt the stick as heavy and large value indicates that the subject felt the stick as light. Scheffé's test reveals significant differences (100g: [$F(2, 32) = 220.37$, $p < 0.01$], 235g: [$F(2, 32) = 55.11$, $p < 0.01$]) among all of the conditions of both weights.

These results revealed the following points:

(i) The sticks were perceived to be heavier when presented with a shorter visual length.

The appearance of the sticks influenced the weight perception, and, as the visual length of the sticks became consecutively shorter (in the order of 600mm, 400mm, and 200mm), the subject perceived the sticks as heavier. This tendency is consistent with the Size-weight illusion.

(ii) Even if the mass of the real objects were different, similar significant differences were obtained between the conditions.

In the case where two objects had different mass, they were perceived as lighter when the presenting range of the sticks was increased. Results (i) and (ii) confirm that when DR is performed, the Size-weight illusion occurs. It is, therefore, suggested that visual-haptic sense interaction occurs by DR-based visual stimulation.

4 Discussion and Conclusion

In this study, we have confirmed that haptic sensations change when a real object is visually erased by DR. From the results of the experiment, we demonstrated the following:

(a) The weight perception associated with Size-weight illusion is caused by visual diminishing.
(b) The visual diminishing producing the opposite effect of MR visual stimulus on weight perception.

In the Size-weight illusion, small objects feel heavier than larger objects of the same mass. In the experimental results, when the object was visually erased, that is, when the surface area became small, the object was perceived as heavy. Therefore, we confirmed the effect on weight perception as similar to the Size-weight illusion.

Also, we confirmed that the real object is perceived as light by a MR visual stimulus in previous study [6]. However, the real object did not feel heavy, because the real object is smaller than the virtual objects. On the other hand, if the shape of the real object was made smaller by visual erasure, it was perceived as heavier. Therefore, combining MR and DR could provide the possibility for expanding the range in which the weight sense can be controlled.

However, the combination of MR and DR does not always produce the same effect on weight perception. In future work, we will explore how the simultaneous use of MR and DR obeys the laws of real space and/or virtual space.

Acknowledgment

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References

[1] A. Lecuyer, *et al.*: "Pseudo-haptic feedback: can isometric input devices simulate force feedback?," IEEE VR 2000, pp. 83 - 90, 2000.

[2] A. Charpentier: "Experimental study of some aspects of weight perception," *Archives de Physiologie Normales et Pathologiques*, Vol. 3, pp. 122 - 135, 1891.

[3] K.R. Alexander, *et al.*: "Influence of hue, value, and chroma on the perceived heaviness of colors," *Attention, Perception, & Psychophysics*, Vol. 19, No. 1, pp. 72 - 74, 1976.

[4] Y. Koike, *et al.*: "Role of stiffness in weight perception," *Japanese Psychological Research*, Vol. 48, No. 3. pp. 174 - 187, 2006.

[5] A. Zenner, *et al.*: "Shifty: A Weight-Shifting Dynamic Passive Haptic Proxy to Enhance Object Perception in Virtual Reality," *IEEE Transactions on Visualization and Computer Graphics*, Vol. 23, No. 4, pp. 1285 - 1294, 2017.

[6] S. Hashiguchi, *et al.*: "R-V dynamics illusion: Psychophysical influence on sense of weight by mixed-reality visual stimulation of moving object," HCII 2014, pp. 55 - 64, 2014.

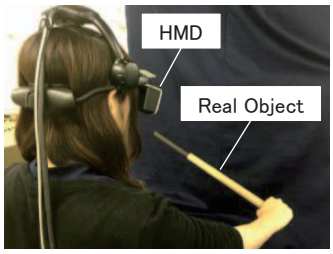
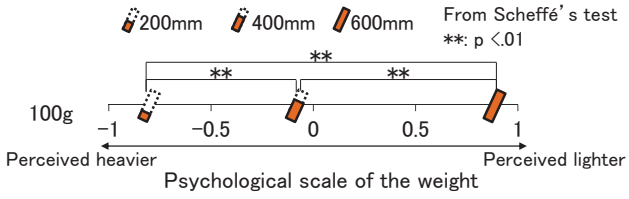


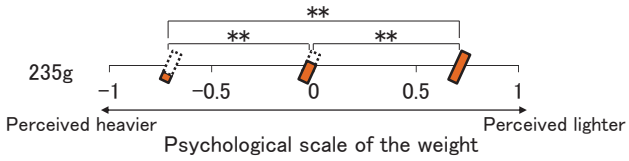
Figure 1: Experimental scene

(a) 200mm (b) 400mm (c) 600mm

Figure 2: Patterns of visual stimulation in experiment



(a) The case of the 100g stick



(b) The case of the 235g stick

Figure 3: Results of experiment