

Analysis of R-V Dynamics Illusion Behavior Caused by Varying the Weight of Real Object

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ABSTRACT

Previously, we discovered the “R-V Dynamics Illusion [1],” a psychophysical phenomenon caused by the difference between the dynamics of real object (R) and virtual object (V) in mixed reality (MR) space. We confirmed that a real object with a movable portion (CG) is perceived lighter by MR visual stimulation [2]. Here, we analyze whether the difference in the mass of real objects affects the R-V Dynamics Illusion. We conducted experiments to determine the difference threshold of weights under the condition where the masses of real objects are 500, 750, and 1000g, and only the CG liquid level is changed. As a result, the difference in mass did not influence the difference threshold of weights by changing the virtual liquid level. On the other hand, with the same mass conditions, the difference threshold of weights becomes smaller when the R-V Dynamics Illusion occurs.

Keywords: Mixed Reality, Sense of Weight, Visual Stimulation, Psychophysical Influence.

Index Terms: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

1 INTRODUCTION

In mixed reality (MR) space, we can change the appearance of a real object (R) easily by superimposing a virtual object (V) onto it. We call such visual stimulation “MR visual stimulation” and have conducted experiments to analyze its influence in the haptic sense. In a previous study, we found that the sense of weight can be affected by MR visual stimulation with a “movable portion.” We refer to this psychophysical influence caused by the difference between the dynamics of real object and virtual object movement the “R-V Dynamics Illusion.” We conducted experiments under the condition where the real object is rigid or enclosed liquid, and a portion of the virtual object is moving or not. However, in those experiments, the mass of the real objects was the same (750g).

In this paper, we change the mass of the real object and analyze the influence on the R-V Dynamics Illusion.

2 EXPERIMENT

2.1 Purpose

In the real world, the difference threshold of weight varies depending on mass. Similarly, in this experiment, we investigate whether the difference threshold of weight varies depending on the masses of real objects under the condition of R-V Dynamics Illusion.

However, R-V Dynamics Illusion is a psychophysical phenomenon where weight is perceived differently due to the appearance and internal motion of a virtual object, although the actual mass is not changed. How can we measure the difference threshold of weight under the condition of R-V Dynamics Illusion?

From previous studies, we found that when the fluid volume (liquid level) of a virtual object is changed, the perceived weight also changes (as fluid volume increases, the object is perceived to be heavier). Therefore, in this experiment, we measure the difference threshold of weight by changing the liquid level of a virtual object rather than changing the mass of a real object. In addition, we compare these difference thresholds whose conditions of the mass of the real object differ.

2.2 Experimental Setup

In the experiment, a video see-through HMD (Canon HM-A1) was used to display MR visual stimulation. The positions and the posture of the subjects’ heads and the real object were measured using magnetic sensors.

For the real object grasped by the subjects, we used an acrylic case (165 x 80 x 90mm) with a handle attached (300g). Weights were enclosed and fastened in the case to adjust the mass of the case to 500, 750, or 1000g. We selected these mass conditions in preliminary experiments.

The virtual case (MR visual stimulation) superimposed onto the real case was the same size. The liquid part in the virtual case was light blue while the part without liquid was white. The movement conditions for MR visual stimulation included not moving and moving CG liquid (**Figure 1**). At this time, a simple model was set to imitate the movement of the liquid [1].

2.3 Conditions and Procedure

In the experiment, the difference thresholds of weight are estimated by changing the fluid volume (liquid level) and observing the points where subjects perceive a change in weight with standard stimulation. The liquid level is changed by 3mm increments from 27mm (minimum) to 63mm (maximum), i.e., 13 patterns in total.

As the standard stimulation, we prepared two liquid levels (27 and 63mm). Patterns I to IV in **Figure 2** show the combination of standard stimulations and comparison stimulation. In patterns I and II, a difference threshold when the liquid level is the

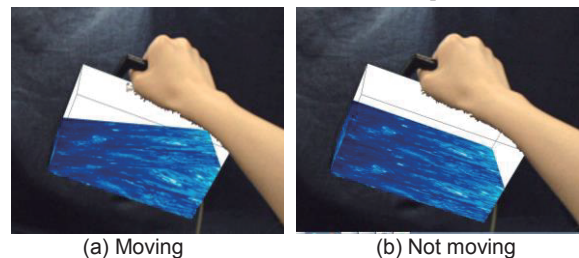


Figure 1: Visual stimulation

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minimum is obtained, and in patterns III and IV, a difference threshold when the liquid level is the maximum is obtained.

The subjects compare the weight of the comparison stimulation and standard stimulation. Here the liquid level of the comparison stimulation is increased/decreased until the subjects feel the weight is different (in patterns II and III) or when they feel the weight is the same (in patterns I and IV). In this way, we confirm the difference threshold of weights when the mass of the real object is 500, 750, or 1000g, and the virtual object is either moving or not moving.

Ten subjects participated in the experiment. The experiment was performed using the following procedure.

- (1) A moving or not moving virtual liquid state is selected randomly.
- (2) The mass of the real object is selected randomly (500, 750, or 1000g).
- (3) A pattern is selected randomly (patterns I to IV, Figure 2).
- (4) The subjects swing the object right and left like a metronome (100 strokes/min).
- (5) The standard stimulation and comparison stimulation are compared, and the subject indicates when they perceive the weights as the same or having changed with a standard stimulation.
- (6) We repeat (1)-(5) for the unselected conditions.

2.4 Result

The results of the experiment are shown in **Figure 3**. The figure shows the results of the difference thresholds of weight and the result of a significant difference test (Tukey-Kramer method) for each mass when the liquid level is 27 or 63mm with a moving or not moving liquid state. We derive the following from the experimental results.

- (i) There is no significant difference in the difference threshold of weight for each mass in this condition.

In the real world, when the difference threshold of weight is measured using a real object, the difference threshold increases as mass increases. However, from the experimental results, with each mass, no significant difference was found in the difference threshold of weight even if the liquid level was visually changed.

- (ii) In each presentation pattern, there is less difference threshold of weight with moving than with not moving the liquid state.

Comparing the moving and not moving liquid states, the difference threshold of weight is significantly small with motion. On the other hand, there was no significant difference between each mass. From our previous studies, we know that the weight of the object onto which virtual liquid is superimposed is perceived lighter when the virtual liquid state is moving compared to when it is not moving. In other words, in this experiment, the difference in the mass of the real object did not affect the difference threshold, but when the weight was perceived lightly by R-V Dynamics Illusion, the difference threshold of the weight was reduced.

3 CONCLUSION AND FUTURE WORK

In this paper, we analyzed the influence of R-V Dynamics Illusion on weight perception by changing the mass of a real object and CG liquid levels to determine the difference threshold of the weight perceived under various conditions. As a result, we found the following.

- With the same MR visual stimulation, we could not find any significant difference of the difference threshold of the weight by changing the mass of the real object.

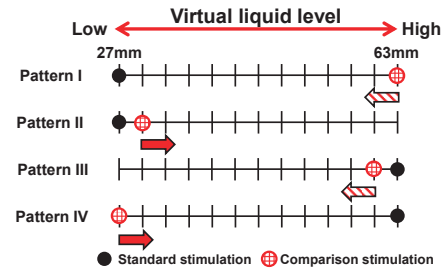
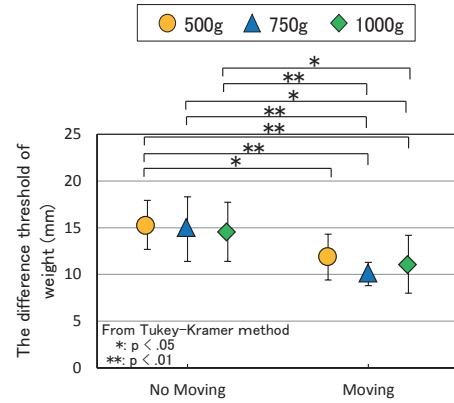
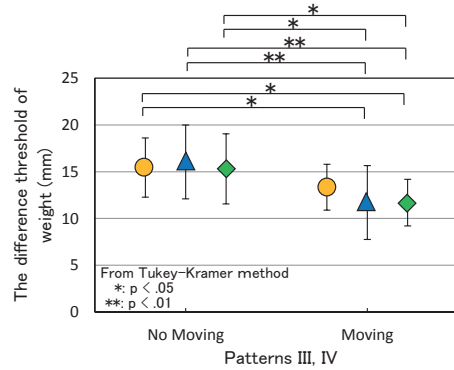


Figure 2: Experimental patterns



(a) Liquid level: 27mm



(b) Liquid level: 63mm

Figure 3: Result of Subjective Experiment

- On the other hand, the difference threshold of weight changes significantly when the influence from visual stimulation is strong.

From the above results, we consider that visual stimulation influences the difference threshold of weight.

In future, we plan to quantify the change of perceived weight caused by R-V Dynamics Illusion. We also plan to conduct experiments to examine the conditions required to effectively create the illusion.

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