Further Analysis of the R-V Dynamics Illusion on Sense of Weight

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ABSTRACT

In mixed reality space, we can change appearances of a real object (R) and virtual object (V). In this study, we visually change movements of the real and virtual objects and observe the influences of the virtual object's dynamics on the sense of the weight of the real object.

1 INTRODUCTION

In the mixed reality (MR) environment, the appearance of touchable objects can be changed by superimposing a computer-generated image (CGI) onto them (we call this "MR visual stimulation") [1]. Using this specialty of MR technology we have studied the influence between the visual and haptic sensations. For example, we focused on the perception of the center-of-gravity (COG) and examined what could happen when superimposing a virtual object onto a real object which has different COG position. As a result, we confirmed that COG perception can be influenced by superimposed virtual objects, and we named this illusion the "Shape-COG Illusion [2]." In the experiments of "Shape-COG Illusion," we only focused on the rigid object for both real and virtual stimulation whose COG position is clear for the subject. However, through the experiments, new question has raised. That is, if real and/or virtual objects are non-rigid (deformable or having movable portion in it), how are they perceived?

In previous study, we firstly focused on a situation in which a virtual object that has movable portion is superimposed on a real rigid object, and confirmed that weight perception can be changed under this condition though the weight of real object is not changed [3].

As the next step, we conducted more detailed experiment to analyze influence of movement of a virtual object. In this paper, we explain this experiment, its results and discussion.

2 PUROSE AND PREPARATION

2.1 Purpose

The aim of the experiment was to examine the effect of virtual object's movement, acceleration in particular, of virtual liquid on R-V Dynamics Illusion. In this experiment the objective evaluation and subjective evaluation were conducted separately.

2.2 Experimental Environment

As with the previous experiments [1], we adopted an MR system with a video see-through mechanism that visually merges the real and virtual worlds (Fig. 1). Wearing a head-mounted display (HMD) (VH-2002, Canon Inc.) with a pair of built-in video cameras, the subject viewed the stereoscopic images that are computer-generated images (CGIs) in the scene in front of his/her eyes. Head position and position of real object were constantly tracked within six degrees of freedom (6-DOF) by a magnetic sensor (3SPACE FASTRAK, Polhemus Inc.), which allows the subject to move his/her head freely.

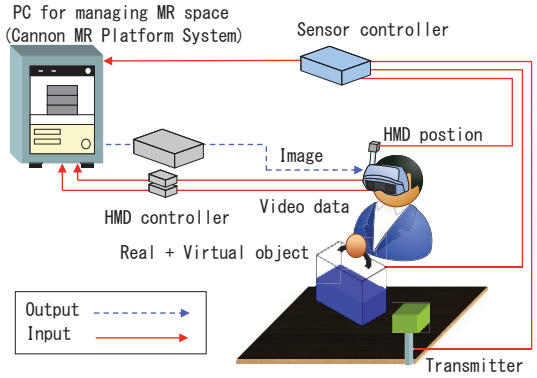


Fig. 1 System configuration

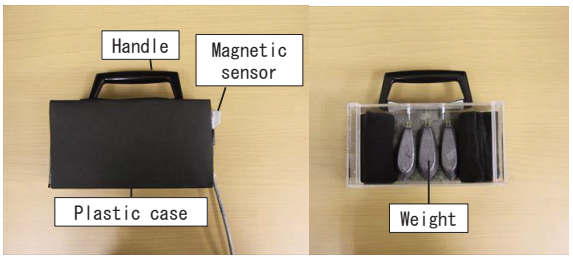


Fig. 2 Real object used in the experiment

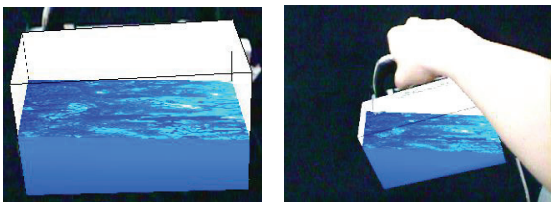


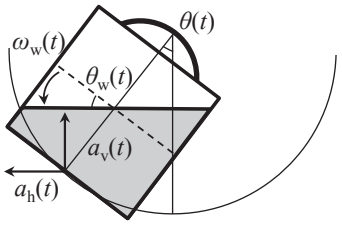
Fig. 3 MR visual stimulation used in the experiment

2.4 Real Object

The real rigid object used in the experiment was a plastic case (165 mm width × 90 mm height × 80 mm depth) with the handle (Fig. 2). The weight of the plastic case was adjusted to 750 g, which was the weight of a case filled with water up to the level of 45 mm (50 % of the case height).

2.5 MR Visual Stimulation

The size of virtual object used for MR visual stimulation was the same as the real object (Fig. 3). In the virtual object, water colored virtual liquid was filled. We employed a simplified model that mimics the swaying of the liquid, without a detailed representation such as



$$a_w(t) = -(C - a_v(t))\cos\theta(t) + a_h(t)\sin\theta(t)$$

$a_w(t)$ Angular acceleration of a liquid
$\omega_w(t)$ Angular velocity of a liquid
$\theta_w(t)$ Angle of a liquid
$\theta(t)$ Angle of object
$a_v(t)$ Acceleration of object(vertical direction)
$a_h(t)$ Acceleration of object(horizontal direction)
C Acceleration value

Fig. 4 Simplified model of fluid movement

waves or splash (Fig. 4). *C* is a value affecting the acceleration of the liquid. The viscosity of liquid is perceived higher as the value *C* increases. In a preliminary experiment, the subjects felt our liquid model like the water when the value *C* was approximately 0.98 (deg/s^2). Therefore, we prepared five stimulations based on this 0.98 (A1 = 0.98 × 0.50, A2 = 0.98 × 0.75, A3 = 0.98 × 1.00, A4 = 0.98 × 1.25, A5 = 0.98 × 1.50).

3 EXPERIMENT

3.1 Evaluation Methods

We used Thurstone's paired comparison method for the subjective evaluation. This method is a simple psychological measure and can prevent confusion due to the large number of choices. The subjects were 10 people. The procedure of subjective evaluation is as follows.

(1) Two visual stimulations are randomly selected from the five (A1 - A5)
(2) The subjects are asked to swing two objects superimposing the visual stimulations selected at (1) right and left according to a metronome (100 strokes/min) one by one
(3) They are asked to compare weight of the two objects
(4) Repeat steps (1) through (3) for the remaining combinations of the five visual stimulations

In the objective experiment, we measured electro-myography (EMG) to evaluate the muscle activity for the supinator that performs the swinging operation. We used the %MVC (Maximal Voluntary Contraction) which indexes the activity of the muscle calculated from the amplitude information. %MVC is calculated after the full-wave rectified waveform obtained from electro-myography and normalized the MVC measured for each subject. The subjects were 5 people. The procedure of the objective evaluation is similar to the subjective evaluation;

(1) One visual stimulation is randomly selected from the five
(2) The subjects are asked to swing the object three times with enough recovery time between
(3) Repeat steps (1) & (2) for the remaining four stimulations

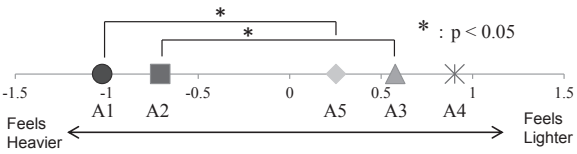


Fig. 5 Result of the subjective evaluation

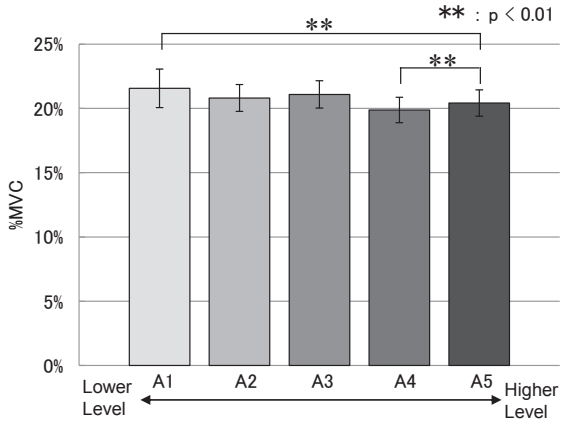


Fig. 6 Result of the average %MVC

4 RESULTS

Generally, in the experiment of subjective evaluation, when acceleration of liquid was higher, the lighter real object was perceived (Fig. 5). The experiment of objective evaluation had the same tendency as the experiment of subjective evaluation (Fig. 6). However, A5 had the different tendency in the experiment of subjective and objective evaluations. There could be a possibility that the subjects felt the virtual liquid unnatural and artificial in case A5, because the velocity of the liquid surface was too fast.

5 CONCLUSION

In this paper, we confirmed that when the liquid acceleration of MR visual stimulation was higher, the lighter the real object was perceived. This means that by only changing the "acceleration" of the virtual liquid in MR visual stimulation, the subjects perceived the differences of the object's weights. R-V Dynamics Illusion is a phenomenon which is still less well understood and hence we will conduct additional experiments to elucidate it. For the future, we will continue to study the occurrence of this illusion in other conditions.

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