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EVALUATION OF THE SOFTNESS AND ITS IMPRESSION OF VISUAL STIMULI IN VR SPACE

Masato SAKURAI[a], Taichi OZAWA[a], Hinata SUZUKI[a]

[a] *Shizuoka Institute of Science and Technology, Japan, sakurai.masato@sist.ac.jp*

ABSTRACT

To examine the softness and impression of visual objects in VR (Virtual Reality) space, the impression of the visual stimuli in VR space was measured using the subjective evaluation of a seven-rank scale by changing with each the value of the deformation resistance of the stimuli, of shapes, and colors. The value of the deformation resistance of the stimuli expresses the degree of deformation to return to the original of the object when touching it in VR space. The lower value indicates the larger deformation like pudding and the higher one is the smaller one like thick rubber they were used three types of values lower and higher, and no-deformation of the objects. The shapes of objects as the stimuli were three shapes (sphere, cube, pyramid). The colors of the stimuli were selected from five colors (red, green, green, gray, and white) and they have used two types of the feeling of materials (matte and metallic) in each color. Ten participants were asked to subjectively evaluate the softness and impression of the stimulus. In the results, the evaluation changes from soft to hard by increasing the values of deformation resistance in all the stimuli in VR space. It is suggested that the degree of the deformation to return to the original can express the softness of objects when touching them in VR space even though the user does not touch them physically. It also discussed the relationship between softness and its impression of the stimuli in VR space.

Keywords: *VR, softness, deformation, touch, subjective evaluation*

1 INTRODUCTION

Recently, due to Covid-19 related situation, ICT (Information and Communication Technology) that avoids the "Three Cs" (1: Closed spaces with poor ventilation, 2: Crowded places with many people nearby, 3: Close-contact settings such as close-range conversations) and is non-contact is desired. And the displaying and presentation of prototype stuff by remote technology using VR (Virtual Reality) are paying attention (Nikkei Inc., 2020). When prototypes are evaluated in a VR space, as mentioned above, the evaluation method has shown a certain degree of effectiveness in terms of appearance, and the previous study has shown that the impression of the prototype is not so different from that of the real object (Sakurai & Takenaka, 2021). On the other hand, there are still issues related to tactile impressions such as softness, weight, and robustness when touching objects in VR space. For example, when touching pudding or jelly, softness can be judged from the apparent deformation of the object's shape. In this study, it was presented visual stimuli that expressed tactile softness in a VR space and aimed to evaluate the softness of the stimuli in the VR space and their impressions.

2 METHODOLOGY

2.1 Stimuli

The visual stimuli used in this study have been expressed as the tactile softness that the user's hand was synchronously displayed in the VR space by hand tracking when the hand touched an object, the object was deformed accordingly. The degree of softness of the stimuli was selected in three levels: 0.1: very soft (deforms like a pudding and returns to its original shape), 1.0: slightly soft (deforms slightly and returns to its original shape), and no deformation (N). Three shapes (sphere, cube, and pyramid) were chosen. Five surface colors (red, green, blue, white, and gray) and two surface textures (metallic and matte) were selected. Thus, there were a total of 90 stimuli in this experiment. Figure 1 shows the examples of the stimuli in this experiment and the properties of shapes, colors, and surfaces. Figure 1(a) indicates the shapes in stimuli according to the survey of previous studies. Figure 1(b) represents the tactile softness of each stimulus when touching it. It can be seen in the changing shape when touching it. Figure 1(c) indicates each property of colors and surfaces as the stimulus image of the sphere. The visual stimuli and experimental applications in this study were created using Unity (Ver. 2021.1.14f1) and the asset Obi Softbody (Ver. 6.2).

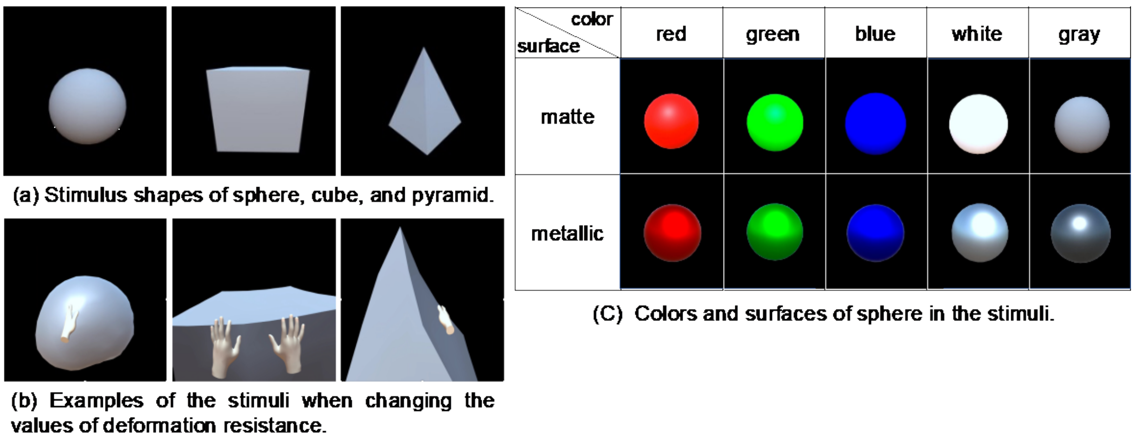

Figure 1. Example of the stimuli in this experiment and properties of shapes, colors, and surfaces.

It was necessary to measure the screen in the HMD (Head Mounted Display) to see what kind of color reproduction was achieved since there has been little research on colorimetry to color reproduction in VR space. The screen of HMD (Oculus Quest) used in this study was measured using the colorimeter (CS-200, Konica Minolta) and the luminance meter (CL-500A, Konica Minolta). Figure 2 shows the gamut of HMD in this experiment on the CIE1931 *xy*-chromaticity diagram compared with those of BT.709 (HDTV) (International Telecommunication Union, 2002) and BT.2020 (UHDTV) (International Telecommunication Union, 2015). This figure shows that there is little difference in the measurements of both measuring instruments and enough for gamut compared them.

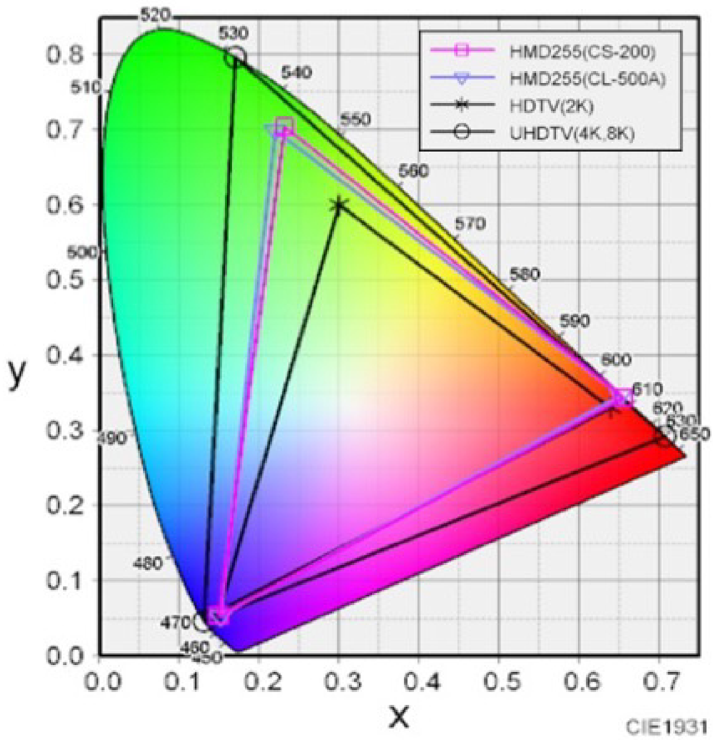

Figure 2. The Gamut of HMD in this experiment.

2.2 Procedure

The participants wore the HMD (Oculus Quest) and touched the randomly presented visual stimuli in the VR space with one hand and both hands, and responded verbally by rating the softness and its impression on a seven-rank scale in the subjective evaluation with five adjective pairs. The subjective evaluation used five adjective pairs: soft-hard, light-heavy, do not have touch feeling-have touch feeling, do not have a metallic feeling-have a metallic feeling, and cold-hot, and each adjective pair was placed on both poles, and a seven-rank bipolar evaluation using the degree of "extremely (-3), very (-2), slightly (-1), neither nor (0), slightly (1), very (2), and extremely (3)" was used. The evaluation was made on the seven-rank scale and for example, the light-heavy evaluation was as follows; -3: extremely light, -2: very light, -1: slightly light, 0: neither nor 1: slightly heavy, 2: very heavy, 3: extremely heavy. Before the evaluation in the experiment, the participants have enough time to practice.

2.3 Apparatus

Figure 3 shows the actual space and VR space of the apparatus in this experiment. Figure 3(a) indicates the actual space in this experiment and the participants sat on the chair and wore the HMD in the experimental space. Figure 3(b) represents the VR space in this experiment and the participants could see the stimulus like this figure. The transparent wall in this figure was placed not to go somewhere the stimulus when touching it.

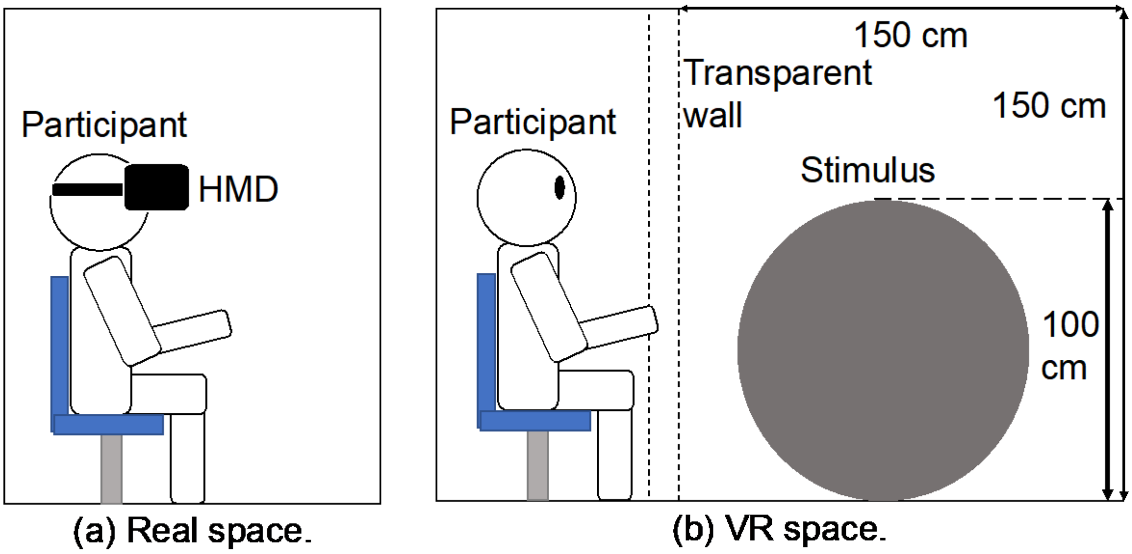

Figure 3. Apparatus in this experiment.

2.4 Participants

Ten students participated in this experiment. They were in their twenties. They have normal color vision.

3 RESULTS AND DISCUSSIONS

Figure 4(a) – (b) shows the average results in the impression of subjective evaluation in gray metallic surface and red matte surface based on all the participants' responses, respectively. The horizontal axis indicates the subjective evaluation value of the seven-rank scale. The vertical axis also indicates the adjective pairs on both poles. Each symbol corresponds to the top of this figure.

From both graphs, the stimulus with the softness of 0.1 in all the shapes is evaluated as extremely or very soft, 1.0 as slightly soft, and no deformation (N) is rated as very hard. Therefore, it is suggested that softness can be evaluated by the degree of deformation of the hand in the VR space synchronized with its hand movements, even if the hand is not physically touching the stimulus. It corresponds to the previous study report that different softness is felt depending on the deformation of the deformed virtual object and the movement of the plucked finger (Kato et al, 2017). In light-heavy adjective evaluation, the soft ones tended to feel lighter and the hard ones heavier. On the other hand, the evaluation of the touch feeling was in the "neither-nor" range, suggesting that further improvement of the touch feeling is desirable. Although from Figure 4(a), gray metallic stimuli feel metallic, the metallic feeling is suggested to be related to hardness rather than surface texture according to the overall results. From Figure 4(b), red color stimuli feel hot, and the hotness of red tended to be hotter, and the coolness of blue tended to be cooler, suggesting the warm-cool trend known in color psychology.

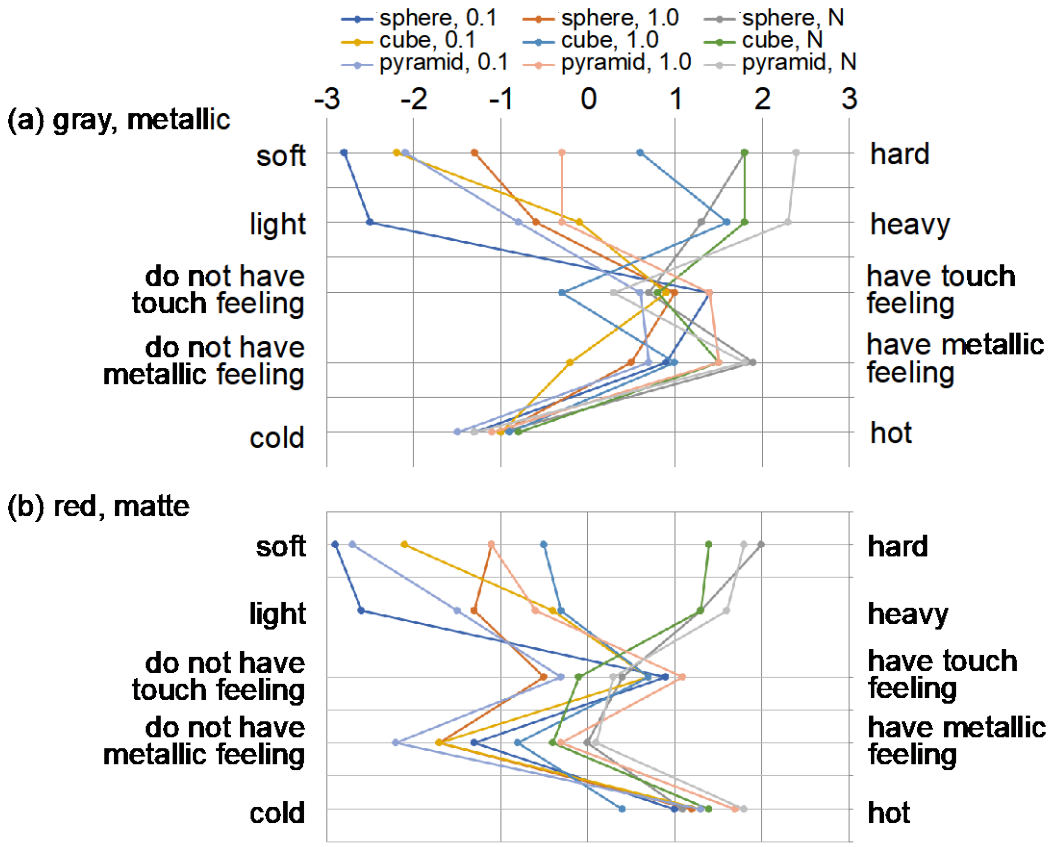

Figure 4. Average results in the impression of subjective evaluation in gray metallic surface and red matte surface. (a) gray, metallic surface, (b) red, matte surface.

4 CONCLUSION

To examine the softness and impression of visual objects in VR (Virtual Reality) space, the impression of the visual stimuli in VR space was measured using the subjective evaluation of a seven-point scale by changing with each the value of the deformation resistance of the stimuli, of shapes, and colors. The visual stimuli used in this study have been expressed as the tactile softness that the user's hand was synchronously displayed in the VR space by hand tracking. When the hand touched an object, the object was deformed accordingly. Three types of deformation resistance, three shapes of objects, five colors, and two surfaces were selected as stimuli in this experiment. Ten participants were asked to subjectively evaluate the softness and impression of the stimulus. In the results, the evaluation changes from soft to hard by increasing the values of deformation resistance in all the stimuli in VR space. It is suggested that the degree of the deformation to return to the original can express the softness of objects when touching them in VR space even though the user does not touch them physically. In light-heavy impressions, the soft ones tended to feel lighter and the hard ones heavier. On the other hand, the evaluation of the touch feeling was in the "neither-nor" range, suggesting that further improvement of the touch feeling is desirable. This finding could be utilized in a prototype evaluation system using VR.

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