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Psychophysical Influence on Phantom Sensation of Temperature Perception by Mixed-Reality Visual Stimulation

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Abstract: Phantom Sensation (PhS) is a well-known tactile illusion. This illusion can provide a versatile stimulation by integrating visual and haptic information. Temperature perception is a tactile perception that confirms the occurrence of PhS; however, the illusion of temperature perception has not been analyzed with integrated visual and haptic information. Therefore, we confirmed the influence of temperature perception on PhS by presenting visual stimulation in mixed reality (MR) space. In two experiments, we analyzed how the percentage of occurrence and the perceived position were affected by MR visual Stimulation. We found that the percentage of occurrence increased upon MR visual Stimulation. The perceived position of the PhS was vague; however, we confirmed that the perceived position was affected by MR visual stimulation.

Keywords: Temperature Perception, Mixed Reality, Psychophysical Influence

1. Introduction

Using mixed reality (MR) technology, virtual objects can be superimposed on perceived tactile positions in real time and we can investigate the influence of interactions between visual and haptic perceptions. This influence can be combined with tactile illusions [1]. Phantom Sensation (PhS) is often utilized for this purpose. PhS is a phenomenon that is perceived at a point midway between two points stimulated on the skin at the same time. Usually, vibration perceptions of the PhS are utilized. This illusion can provide a versatile stimulation by integrating visual and haptic information [2]. Temperature perception is one of the tactile perceptions that confirm the occurrence of PhS; however, the effect of temperature perception illusion integrated with visual and haptic information has not been analyzed. Therefore, we confirmed the influence of temperature perception on the PhS using visual stimulation in MR space.

2. Objectives and Preparation

2.1. Objective

In this paper, we confirm the influence of temperature perception on the PhS using visual stimulation in MR space. In two experiments, we analyzed how the percentage of occurrence and the perceived position were affected by MR visual Stimulation.

2.2. Preparation

【Experimental Environment】

Figure 1 shows the MR Platform system configuration used in the experiment. In this experiment, a see-through-type video head-mounted display (HM-A1, a Canon Inc. Display with a resolution of 1280 × 1024 and a running frame rate of 30 fps.) was used. The position posture information for the head section of the test subject and actual object were acquired using magnetic sensors. The sampling rate of the magnetic sensor was 120 Hz.

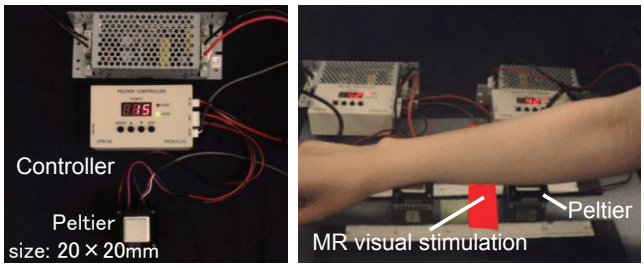

Figure 1: Peltier controller and MR visual stimulation.

【Warm and Cold Stimulations】

We introduced warm and cold stimulations using a Peltier (size: 20 × 20 mm^2) temperature controller set (VPE20-5-20S, Ltd. VICS, Figure 1). Considering the stability of the temperature stimulation, we applied the temperature stimulation on the inside of the forearm. The experiment was conducted in a room with a constant temperature of 25°C. We set the Peltier controller to produce temperature stimulations at six levels of temperature (cold stimulations: 11°C, 13°C, and 15°C; warm stimulations: 40°C, 42°C, and 44°C). The distance between the temperature stimulations was 90 mm. Temperature stimulations can be perceived as pain when the temperature reaches limit values (cold stimulation: 10°C and warm stimulation: 45°C); however, these preset temperatures did not exceed those values [3].

【MR Visual Stimulation】

The MR visual stimulation product is a simple rectangle with a length of 120 mm and width of 20 mm. The width of the virtual object is the adjusted size of the Peltier (size: 20 × 20 mm^2). The virtual object color is red (R: 255, G: 0, B: 0) in case of a warm stimulation and blue (R: 0, G: 0, B: 255) in case of a cold stimulation. In a preliminary experiment, we confirmed that the temperature perception was not affected by the object color. However, a subject can easily imagine a temperature perception using warm and cold colors. The position of MR visual stimulation was located at the same position as the temperature simulation (Figure 1).

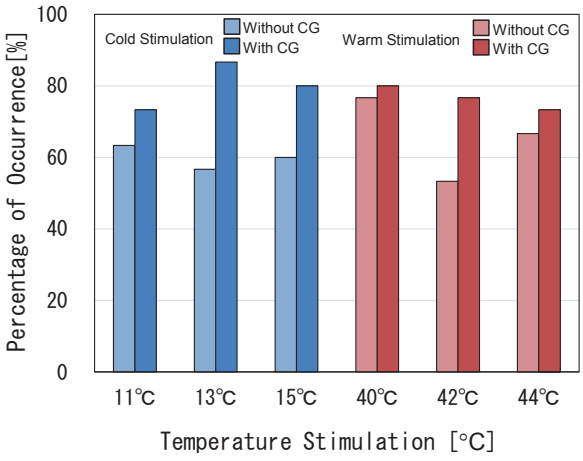

Figure 2: The percentage occurrence of PhS.

3. Experiment

3.1. The percentage of occurrence

In this experiment, we measured how the percentage of occurrences was affected by MR visual stimulation. There were six levels of temperature stimulation (cold stimulations: 11°C, 13°C, and 15°C; warm stimulations: 40°C, 42°C, and 44°C). The distance between the temperature stimulations was 90 mm. The MR visual stimulation was presented at the center of the forearm at the same time as the temperature simulation. In this experiment, we applied the temperature condition with and without MR visual stimulation. Ten subjects were asked whether PhS occurred. The results are shown in Figure 2. The results indicate that the percentage of occurrences increased with MR visual Stimulation.

3.2. The perceived position

In this experiment, we confirmed that the perceived position of the PhS was affected by MR visual stimulation. The temperature stimulations were the same as in the previous experiment. We changed the visual stimulation such that the center of the rectangular virtual object could be located at the center of the forearm, near the wrist, or near the elbow. Each position was set such that there was an interval of 27.5 mm between them. There were a total of 18 possible combinations of temperature levels and presentation positions that could be used as presentation patterns; these patterns were repeated three times. The subjects were five males in their twenties. The subjects had prior knowledge about PhS. The experiment procedures were as follows:

1) Measure the center position of the forearm;
2) Select one combination from the possible patterns and set the temperature;
3) Place the forearm on the temperature presenting device, and, at the same time, present MR visual stimulation;
4) Subjects record the position of the perceived temperature perception on a white piece of paper;
5) Change the piece of paper used to record the data;
6) Provide a sufficient interval to eliminate the effect of temperature changes on the skin; and
7) Repeat steps (2) - (6) for the remaining patterns.

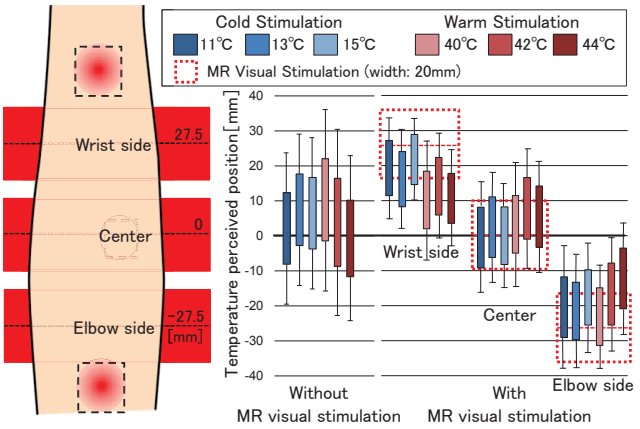

Figure 3: The perceived position of PhS.

The results are shown in Figure 3. The vertical axis indicates the position where the subjects perceived the temperature, and the horizontal axis indicates the position where the MR visual stimulation was presented. The results are as follows:

i) When the temperature simulation was presented without MR visual stimulation, the perceived position of PhS was near the center of the forearm. However, the perceived position of the PhS was vague.
ii) When MR visual stimulation was presented in the center of the forearm, the perceived position of PhS was near the position of MR visual stimulation.
iii) When MR visual stimulation was presented near the wrist or elbow, the perceived position of PhS was attracted toward the position of MR visual stimulation.

Therefore, we confirmed that the perceived position was affected by MR visual stimulation.

4. Conclusions

In this study, we focused on one tactile sensation, temperature perception. We confirmed that presenting MR visual stimulation has an effect on the perceived position of warm and cold stimulation. In the experiment, the percentage of occurrence increased with MR visual stimulation. The perceived position of PhS was vague; however, we confirmed that the perceived position was affected by MR visual stimulation.

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