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Physiological and Psychological Effects of Body Projection Mapping

身体へのプロジェクションマッピングが身体知覚に及ぼす影響

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Abstract: It is known that people's body image, e.g., perceptual, cognitive, or emotional body awareness, is updated continuously by sensory input. In this study, we projected visual information coherent to the real-world experience of pain, itch, warmth, and cold onto participants' bodies. We found that projecting images associated with pain and itch elicited significant physiological and psychological responses. More specifically, the participants' finger temperature decreased by about 1 ºC during the projection. They reported feeling pain and itchy, and this experience was rated as unpleasant and highly aroused. Our findings demonstrated that body projection mapping modulates one's body image, and the effect was reflected via physiological and psychological responses.

Keywords: *Body projection mapping, Body image, Bodily perception, Augmented reality*

1. Introduction

Projection mapping is a form of Augmented Reality and has diverse developments in the field of media arts, ranging from the large-scale projection onto buildings to body projection mapping, in which artistic patterns are projected onto the human body. In these applications, projection mapping provides "augmented visual expressions" to real-world objects through computer-generated images. The superimposed virtual information alters the viewer's ongoing perception of a real-world environment and creates an overwhelming new experience. Besides media arts, projection mapping also has been used for practical purposes. In medical practice, projection mapping technology has been developed to assist surgical operations by projecting images directly onto the patient's body surface and organs [1].

When considering the experience brought by the projection mapping, the focus is often placed on the viewer / the audience (i.e., the third person view). In the case of body projection mapping, the one being projected does not merely act as a display. S/he also sees the virtual information overlaid on their own skin (the first-person view). This fact raises the question: How would this augmented experience and virtual sensory input affect the body image of the one being projected?

It is known that people's body image, e.g., the perceptual, cognitive, or emotional awareness of the body, is updated continuously by sensory input [2]. For example, studies have shown that changing the colors of one's hand can affect people's temperature and pain perception [3][4]. In this present study, we investigated the physiological and psychological effects of body projection mapping. We projected visual information coherent to the real-world experience of pain, itch, warmth, and cold. We measured the skin temperature responses during the body projection mapping and gathered the self-reports of the experience afterward. Our findings show that people exhibited a significant decrease in skin temperature during pain projection condition. For self-reports, people reported feeling pain and itchy and the experience was rated as unpleasant and highly aroused in pain the itch conditions. Our findings demonstrate that body projection mapping can affect one's body image and the effect was reflected via physiological and psychological responses.

2. Experiment

Participants. Seven participants (four males and three females) aged between 21 and 22 participated in this experiment. They gave their informed consent before the start of the experiment.

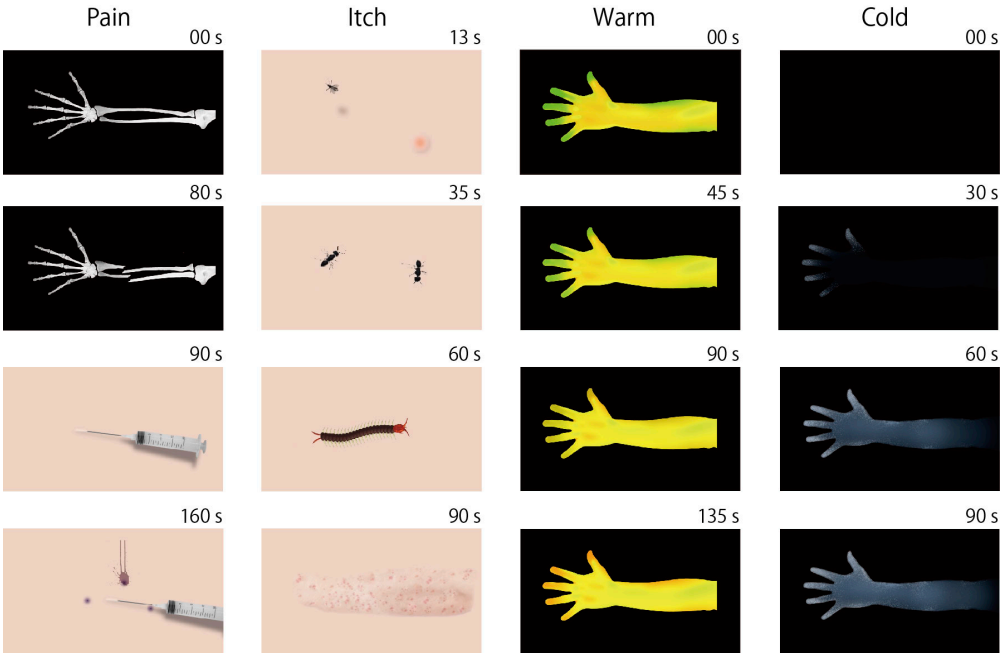

Fig. 1 The representative frames of the pain, itch, warm, and cold projection videos.
Each video lasted for 180 s. The timing of the frames is indicated at the upper right of each image.

Projection conditions. Five projection conditions were used in this experiment. Four test conditions provided visual information coherent to the real-world experience of pain, itch, warmth, and cold (Fig. 1). The other is the control condition, in which a monochromatic, unchanging image was projected. The image color was light brown (#9F8F84) and was chosen because it resembles natural skin color. The format of the projection videos was all 4K, 30 fps, and the duration was 180 seconds for each condition. The images were created using Adobe After Effects, Adobe Premiere Pro, Blender, and other painting software. The projection range covers the arm extending from the elbow to the fingertips.

In pain condition, images of bone fracture and injection were projected. An X-ray photograph of an arm bone was presented for 60 s, followed by a 30 s projection of the bone breaking. Next, a syringe appeared and injected in several places on the arm, resulting in bleeding from the injected places. The projection of injection lasted for 90 seconds. In itch condition, images of insects and skin inflammation were projected. First, scenarios related to insects were projected for a total of 90 seconds: mosquito bites, ants crawling on the arm, and a centipede crawling on the arm. Next, images of inflammation appearing on the skin were projected for 90 seconds. In warm condition, images of an arm as if captured by a thermal camera was projected, in which the color of the fingertips changed from green to red gradually. In the cold condition, images of frost and being gradually freezing were projected to the arm.

Procedure. The experimental setup is shown in Fig. 2. After receiving an explanation about the experiment, the participants sat down on a chair and placed their left arm on a platform (650 mm from the floor), with the back of the hand facing up. A 4K projector (Pro Beam BU50NST, LG Electronics) was placed 940 mm above the surface of the hand and was used to project the stimuli videos to the arm. The projection's scale factor was adjusted for each participant so that the image fit the arm.

At the beginning of each projection condition, a participant's initial skin temperature at the tip of the middle finger was measured with an infrared thermal meter (830-T1, Testo). The projection of the stimulus video started right after the initial skin temperature measurement. Participants were instructed not to move their left arm and look at their left arm. During the projection, the skin temperature of the left hand was measured with a thermal camera (FLIR C5).

After the projection was completed, the skin temperature at the tip of the middle finger was again measured with the infrared thermometer. The participants were asked to rate their perceptual and emotional experiences during the projection. The participants were asked to report their experience of pain and itching using an 8-point scale, with 0 depicting not at all, 1 very weak, 4 moderate, and 7 very strong. For the thermal experience, a 7-point scale was used, with 1 depicting very cold, 4 neutral, and 7 very warm. For emotional experience, the Self-Assessment Manikin (SAM) was used. SAM is a non-verbal pictorial assessment technique that measures a person's pleasure and arousal levels with a 5-point scale. SAM has effectively measured emotional responses in various situations [5].

The order of the five projection conditions (pain, itch, warm, cold, and control) was randomized. The time required to complete the whole experiment was about 30 minutes per participant.

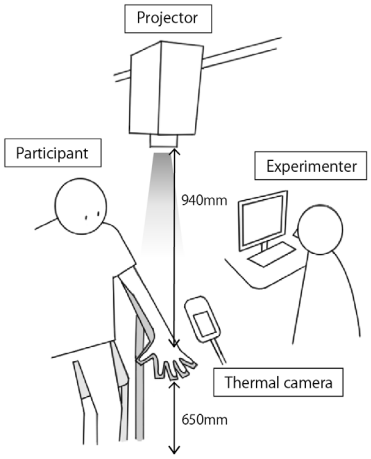

Fig. 2. The experimental setup

3. Results

3.1 Physiological responses

The changes in skin temperature during 180 s of body projection mapping as a function of projection condition are shown in Fig. 3. A significant increase in skin temperature was found under the control condition (mean=0.9 ºC, t(6)=2.82, p=0.03), which could be due to the warmth of the projection light. Paired-tests were conducted between the skin temperature changes under each test condition and control condition to account for the thermal influence from the projection light. The results revealed that the pain condition elicited a decrease in skin temperature, and this temperature change was significantly different from that under the control condition (t(6)=-2.65, p=0.04). Our data indicated that projection mapping of visually painful stimuli, such as syringe injection, on one's forearm exerted a significant physiological impact, which can be viewed as the response to the emotional stress created by the pain projection.

3.2 Psychological responses

As the ratings are ordinal data, boxplots and Wilcoxon signed-rank tests were used to represent and analyze the data. The results of the pain, itch, and warm/cold ratings after 180 s of body projection mapping are shown in Fig. 4. Here, the ratings of the control conditions are not significantly different from 0 (not at all) for pain and itch ratings, and 4 (neutral) for the warm/cold ratings, indicating that the control condition didn't elicit any particular pain, itch, and warm/cold perception.

When comparing the test condition with the control condition, we found that the pain ratings of the pain and itch conditions (Fig 4A) are significantly higher than those of the control condition (pain v.s. control: z=2.20, p=0.02; itch v.s. control: z=2.02, p=0.03). So did the itch ratings of the pain and itch conditions (Fig 4B, pain v.s. control: z=2.02, p=0.03; itch v.s. control: z=2.37, p=0.01). For the warm/cold ratings (Fig 4C), no significant difference is found between any test condition and control condition. These data indicate that pain and itch conditions exerted a significant psychological impact on the participants.

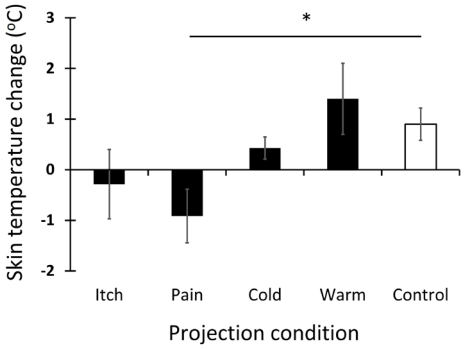

Fig 3. Group mean change in skin temperature during 180 s of body projection mapping as a function of projection stimuli condition. Error bars show SEM.

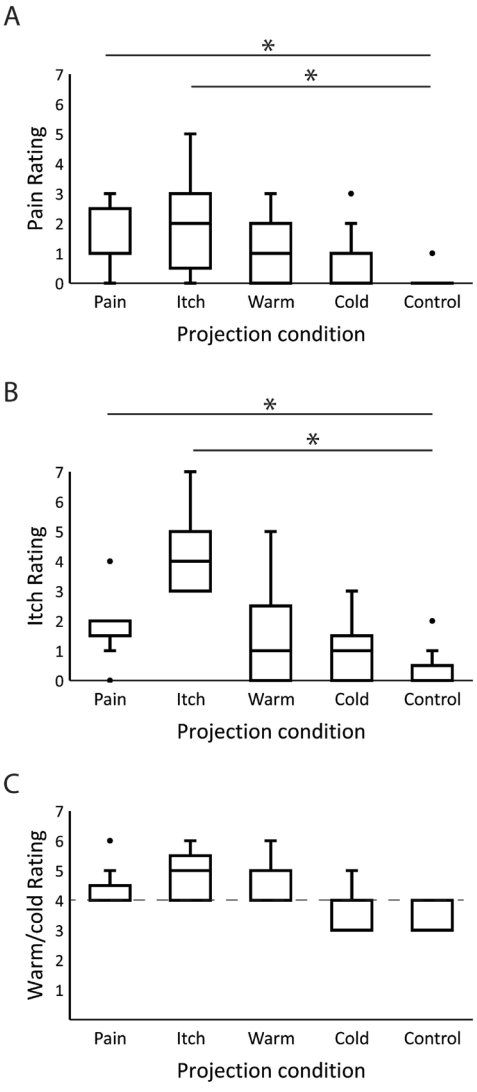

Fig 4. Boxplots of the pain (A), itch (B), and warm/cold ratings (C) as a function of projection condition.

The valence and arousal ratings as a function of the projection conditions are shown in Fig. 5. Our data show that the valence ratings of the itch condition are significantly lower than those of the control condition (Fig 5A, itch v.s. control: z=-2.20, p=0.02). For arousal ratings, both the pain and itch conditions have significantly higher ratings than the control condition (Fig 5B, pain v.s. control: z=2.20, p=0.02; itch v.s. control: z=2.20, p=0.02). Our results indicate that pain and itch conditions elicited strong emotional responses from the participants.

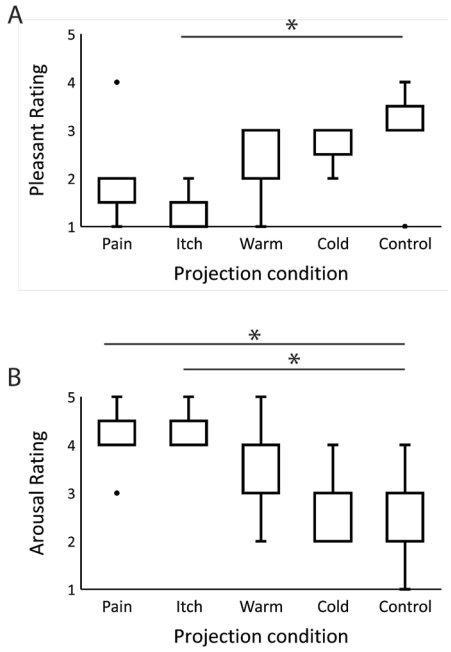

Fig 5. Boxplots of the valence (A) and arousal ratings (B) as a function of projection condition.

4. Discussion

Our results demonstrated that body projection mapping could modulate one's body image, and the effect was reflected via physiological and psychological responses. Among the four test projection conditions in which the visual information is coherent to the real-world experience of pain, itch, warmth, and cold, significant physiological and psychological effects were observed in the pain and itch conditions. The participants perceived pain and itching under these two conditions (Fig 3), and the experience was highly unpleasant and aroused (Fig 4). In particular, in the pain condition, participants' finger temperature decreased by about 1°C in the pain condition (Fig 5). Previous studies have shown that in response to emotional stress, the sympathetic nervous system constricts blood vessels in the extremities and induces sweating. Both reactions cause a decrease in skin temperature [5]. Together with the results from the self-reports, our findings indicate that the participants experienced emotional stress when viewing the computer-generated painful and itch visual information overlayed on the skin. Some participants stated that they knew clearly that it was "just" a projection, indicating that this effect occurred even when the participants could distinguish between the real and the virtual sensory inputs. We didn't find any effect in warm and cold conditions. Some participants pointed out that several images used in these two conditions gave a different impression from what we had planned. For example, the frost in the cold condition looked like mold instead. Thus, it is necessary to verify whether the pattern images are appropriate for future studies.

In sum, this study investigates the physiological and psychological responses when the projected images are viewed by the person being projected (first person view). In terms of future applications, such as entertainment, we believe that body projection mapping can be used to create various types of emotional content, such as fear and so on. It is also expected that body projection mapping can be applied to establish a treatment for "entomophobia" by providing a realistic exposure to counteract the pathological fear [6], just as Virtual Reality applications have been utilized to treat heights phobia [7].

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