A Study of Thermal Sensation with Visuo-Thermal Projection Interfaces

Yuki Yoshikawa, Daisuke Iwai, Kosuke Sato
Graduate School of Engineering Science, Osaka University
Machikaneyama1-3, Toyonaka, Osaka, 560-8531, Japan
Email: {yoshikawa, iwai, sato} @sens.sys.es.osaka-u.ac.jp

***Abstract*—In this study, we propose a visuo-thermal projection interface to provide a visible image and a thermal sensation with a distant user for tele-communication. Most previous systems providing a thermal sensation to a user require him/her to touch special devices. On the other hand, our proposed system consists of a visible light projector and a far-infrared light projector, which can simultaneously provide both visual and thermal information on a user's body without requiring him/her to touch such devices. We built a prototype system, and investigated how the thermal sensation of a user was affected by an overlapped visible image through psychophysical experiments.**

I. Introduction

Research and development of tele-communication have focused on realizing a system in which users, locating at distant sites, can communicate each other as if they could exist at a same place. To this end, researchers have increased the number of communication modalities. Thermal sensation is one of the important modalities for people to feel the aliveness of a person. We propose a visuo-thermal projection interface to provide a visible image and a thermal sensation with a user for tele-communication. Most of previous studies on thermal sensation feedback required a user to touch on a device such as Peltier devices. On the contrary, our system consists of a visible light projector and a far-infrared light projector, and consequently, can project or display visible and thermal information to a user's body, simultaneously without requiring him/her to touch on a device. Because such a mechanism has not been implemented, it is unknown that how the thermal sensation is affected by the overlapped visible information. Therfore, we investigate this issue using our prototype system through psychophysical experiments.

II. Visuo-Thermal Projection Interface

The proposed system is composed of two types of projectors; a visible light projector (K-10, Acer), a far-infrared projector; and a depth sensor (Kinect, Microsoft) used for the detection of the user's hands. First, this system detects the user's hands and acquires their positions in a 3D space. Second, two projectors emit both visual information and thermal information to the same portion of hands. The far-infrared projector is shown in Fig. 1. The source of the far-infrared light is a far-infrared heater (ERFT10JS, DAKIN). A mask and a focus mirror are used to collimate far-infrared light as parallel spot light. A mirror with a pan-tilt motor (DYNAMIXEL RX-28, BestTechnology Japan) reflects and irradiate it toward a desired direction. Our prototype far-infrared light projection system is shown in Fig. 2. This system provides the visual information and the thermal information at the same point simultaneously. A previous research [1] revealed that there was a cross-modal effect between thermal and visual sensations in a specific situation and the thermal sensation was changed by changing the visual information. Therefore there might be a cross-modal effect between thermal and visual sensations and the visual information changes the thermal sensation. We conducted two experiments to investigate the cross-modal effect between thermal and visual sensations. Considering the number of required pages, we describe one experiment in this paper.

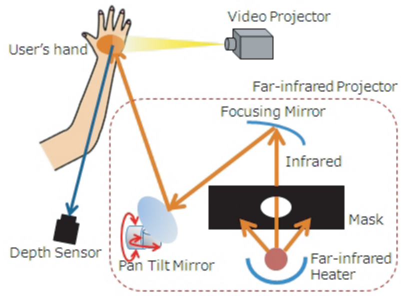

Fig. 1: Configuration of the proposed system

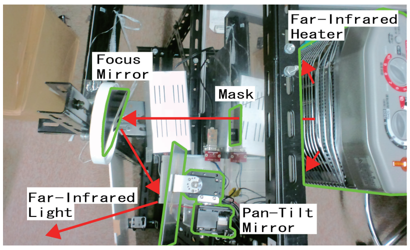

Fig. 2: Prototype system of far-infrared light projector

III. Experiment

The aim of this experiment was to test whether visual stimulus changes RT (Reaction Time) of human to radiant heat. The duration time from the irradiation of the far-infrared light to the reaction of warmth perception was measured. In this experiment, a far-infrared projector was rebuilt using a simpler design as shown in Fig. 3. A shutter mask was placed in front of the far-infrared source; the far-infrared light went through it to the hand of the subject. In this experiment,

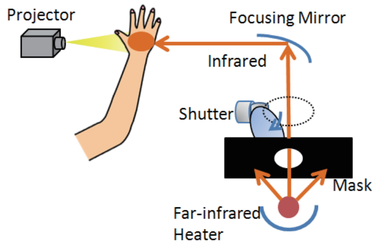

Fig. 3: System configuration of subjective experiments

VIS-no/IR	VIS-same/IR	VIS-early/IR	VIS-start/IR
40.0 %	22.0 %	22.5 %	25.0 %

(a)(*/IR)

VIS-no/IR-no	VIS-random/IR-no	VIS-start/IR-no
92.5%	90.0%	95.0%

(b)(*/IR-no)

Fig. 4: The ratio of force-quits

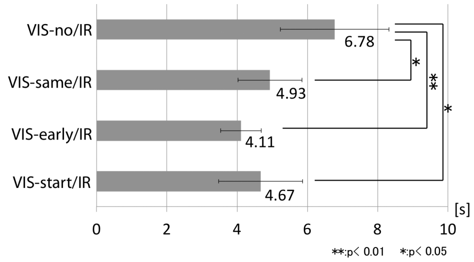

Fig. 5: Average and variance of reaction time in each case of IR

NT47-109 (Edmund) was used as a focus mirror. The far-infrared projector projects far-infrared light (radiant heat) and the visible projector projected visible light (visual stimulus) with a diameter of 50 mm on the dorsal surface of the fixed left hand of each subject.

A. Procedure

The subjects were given a keyboard. The trial started when they pressed a certain key. The radiant heat was projected on the subject's hand 5-10 seconds after the start of the trial. In this experiment, we had try and catch trials. In the try trials, the visual stimulus was presented under four conditions. The system projects radiant heat without visual stimulus (VIS-no/IR), with visible light at the same time (VIS-same/IR), with visible light two seconds before the radiant heat (VIS-early/IR), and with visible light all the time during the trial (VIS-start/IR). In the catch trials, the visual stimulus was not presented under three conditions. Without any heat or visual light (VIS-no/IR-no), the system projected only visible light 5-10 seconds after the start of trial (VIS-random/IR-no), and only visible light all the time of trial (VIS-start/IR-no) respectively. If the subjects perceived warmth on the dorsal surface of their left hand, they pressed a key. Each trial finished at response of the subjects. The RTs were measured under the conditions with radiant heat. The subjects observed the dorsal surface of their left hand during trials.

B. Result and Discussion

Ten healthy adults (right handed : 9, left handed : 1), aged from 20 to 23 years old, participated in the experiment. All participants were naïve as to the purpose of the experiments. The subjects' initial skin temperatures ranged from 26 to 34 degrees Celsius, and the ambient temperature and humidity in the experimental room ranged from 21 to 25 degrees Celsius and from 15 to 18 %, respectively. The subjects completed a total of 35 trials (5 trials in each condition). The trial order was randomized across the subjects. There were breaks of at least 30 seconds between trials. The experiment lasted about 30 minutes. The subjects listened to music during the trials in order not to hear the sound of the shutter. The ears of the subjects were covered with headphones. If the subject did not press any key 20 secs after the radiant heat, the trial was force-quit, as the subjects did not perceive the warmth. In the catch trials (*/IR-no), trials finished 30 sec after the start of trials. The ratio of force-quits is shown in Fig. 4 and this figure shows that the ratio of force-quits is 40 % when visual stimulus was not used, and about 15% lower when the visual stimulus was used. The average with radiant heat (*/IR) is shown in Fig. 5. One-way ANOVA was performed under radiant heat condition (*/IR). The analysis of the data shows that visual stimuli combined with radiant heat had a significant effect on RT ($p < 0.05$). Next, a t-test was performed. The analysis of the data revealed a significant relationship between the conditions in VIS-no/IR and VIS-same/IR, between the conditions in VIS-no/IR and VIS-start/IR ($p < 0.05$) and between the conditions in VIS-no/IR and VIS-early/IR ($p < 0.01$). Fig. 4(a) shows that warmth was perceived in only 60 % of the trials. This means that the stimulus intensity of the radiant heat had a low level in this experiment. Moreover, the ratio of perceived warmth under the conditions of given a visual stimulus is 15 % higher than the condition of given no visual stimulus, which means the perceived warmth threshold was lower under the conditions of given a visual stimulus. Fig. 4(b) shows that warmth was not perceived without the radiation heat and the result under radiant heat condition was not based on the uncertainty of the radiant heat. Fig. 5 shows that the RT to warmth with visual stimulus was 30-40 percent shorter than without a visual stimulus. This means the RT of warmth was affected by a visual stimulus.

IV. Conclusion

In this paper, we proposed and constructed a visuo-thermal projector for presenting thermal feedback to a user without any contact devices. Two experiments revealed that visual stimuli are likely to shorten RT and decrease the threshold.

Acknowledgment

This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas "Shitsukan" (No. 22135003) from MEXT, Japan.

References

[1] S. Kanaya, Y. Matsushima, K. Yokosawa: Does Seeing Ice Really Feel Cold? Visual-Thermal Interaction under an Illusory Body-Ownership, PLoS One, vol. 7, no. 11, e47293. (2012)