Pressure sensation elicited by rapid temperature changes

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Abstract. We found that force or tactile sensation occurred when temperature of thermal elements which were statically touched by subject's skin changes rapidly. This study aims to clarify its mechanism and to investigate its nature. In this paper, we conducted an experiment to verify incidence rate and quality of this thermal-tactile illusion. As result of the experiment, some kinds of vertical sensation were occurred and interpretations of occurred sensation were various.

Keywords: Thermal-tactile illusion, haptic illusion

1 Introduction

We found that illusional force or tactile sensation occurred when temperature of thermal elements which were statically touched by subject's skin changes rapidly. Illusional upward moving, pressure or force sensation elicited when stimulus temperature rise rapidly. On the other hand, illusional downward moving or pulling sensation elicited when stimulus temperature decline rapidly. This study aims to clarify its mechanism and to investigate its nature. In this paper, we conducted an experiment to verify incidence rate and quality of this thermal-tactile illusion.

2 Experiment

2.1 Experiment system

Thermal stimulator consists of heatsink, fan, thermistors, Peltier erements (**Fig. 1**). Applied voltage to Peltier erements was PID controlled by motordriver. Area of presenting thermal stimulus was 40mm×80mm.

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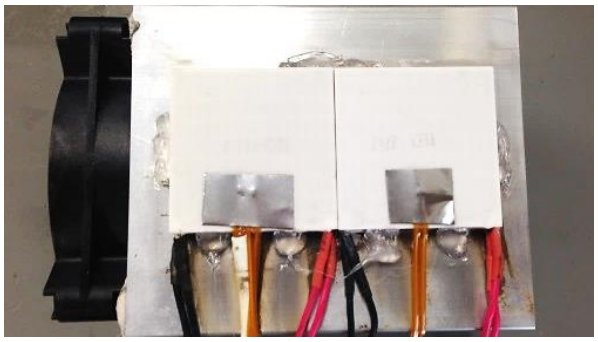

Fig. 1. Thermal stimurator

2.2 Condition

Six male participants aged between 21 and 25 years participated in the study. The experiment was conducted in a room maintained at 28 °C. Thermal stimulator presented following 3 conditons of thermal stimuli.

(a) Constant 37 °C
(b) Constant 27 °C
(c) 0.25 Hz sin wave 27 °C to 32 °C

Both of temperature 37 °C and 27 °C which do not damage the skin has 5 °C difference from skin temperature 32 °C [1].

2.3 Procedure

Participants touched thermal stimulator which presenting one of stimuli condition with right hand and kept their hand statically during 30 sec. After 30 sec, participants release their hand from the stimulator and answered whether some kind of vertical sensation (moving, tactile or force) were occurred, and what specifically kind of sensation were perceived. All participants participated in 30 trials (10 trials per a stimulus condition).

2.4 Result

Fig. 2 shows answer rate of vertical sensation occurrence. In condition (a) and (b) which presented constant temperature, occurrence rates were very low (around 10 %). In contrast, in condition (c) which presented constant temperature, occurrence rate was high (a little under 80 %). As result of Holm's law tests, there were significant differences ($p < 0.05$) between (a) and (c), (b) and (c).

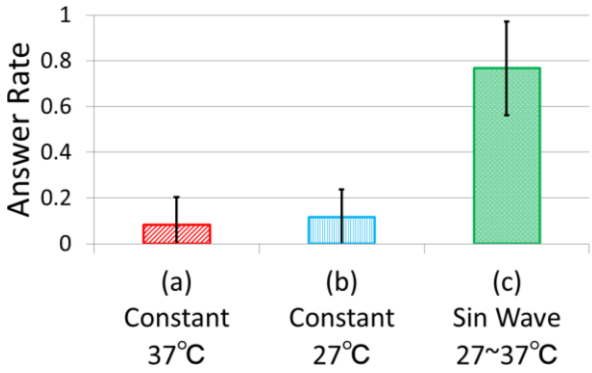

Fig. 2. Answer rate of vertical sensation occurrence

Interpretations of occurred sensation were various. Typical sensation were following answers.

- I take some to feel vertical sensation since touching stimulator.
- Vertical moving sensation elicited in synchronization with temperature change.
- Downward pulling sensation elicited when stimulus temperature declined.
- It was felt that the stimulator contacted by hand was expanding when stimulus temperature rose.
- Burning sensation was occurred when temperature changed.

All Six participants' answers had in common that upward sensation elicited when stimulus temperature rose and downward sensation elicited when stimulus temperature declined.

3 Disucussion

As a result of the experiment, it is certain that some kind of vertical sensation were occurred. We focus that this illusion has similarities to active touch. When we touch some material, rapidly temperature change is occurred at the boundary between skin and material. In condition (c) which presented rapidly temperature change recurred important factor of active touch. Therefore, participants may perceived tactile sensation like active touch when stimulus temperature was rapidly changing. There were associated studies that pressure sensation could elicit by high temperature water vapor and controlling speed of temperature change when moment of fingers touching some material could provide the illusion that like touching different material [2][3].

In the experiment, it was reported that occurring burning sensation which was known as characteristic sensation of a kind of thermal illusion which is known Thermal Grill Illusion (TGI) or Synthetic Heat (SH) [4][5][6]. TGI (SH) was well-known perceptual phenomenon that induces pain or burning sensations through the presentation of nonpainful hot and cold stimuli to the skin. Generally, TGI elicit simultaneous hot and cold temperature stimulation. However, TGI could occur by time differential

two thermal stimuli [7]. Therefore, TGI might occur when stimulus temperature changed in the experiment.

4 Conclusion

We found that illusional force or tactile sensation occurred when temperature of thermal elements which were statically touched by subject's skin changes rapidly. In this paper, we conducted an experiment to verify incidence rate and quality of this thermal-tactile illusion. As result of the experiment, some kinds of vertical sensation were occurred and interpretations of occurred sensation were various (moving, tactile or force). In the future, we compare between this thermal-tactile illusion and real force or movement.

References

1. ISO13732-1: Ergonomics of The Thermal Environment-Methods for The Assessment of Human Responses to Contact with Surfaces (Part1: Hot Surfaces), 2006.
2. Kai, T., Kojima, Y., Hashimoto, Y., Kajimoto,H., "Mechanism of Pressure Sensation Generated by Hot Steam", ISVRI, 2011.
3. Yamamoto, A., Yamamoto, H., Cros, B., Hashimoto, H., and Higuchi, T., "Thermal Tactile Presentation Based on Prediction of Contact Temperature", Journal of Robotics and Mechatronics Vol.18 No.3, 2006.
4. Green, B. G., "Synthetic heat at mild temperatures." *Somatosensory & motor research*, 19(2), pp. 130-138, 2002.
5. Craig, A. D., and M. C. Bushnell. "The thermal grill illusion: unmasking the burn of cold pain." *Science*, Vol. 265, pp. 252-255, 1994.
6. Bach, P., Becker, S., Kleinböhl, D., & Hölzl, R. "The thermal grill illusion and what is painful about it." *Neuroscience letters*, 505(1), pp. 31-35, 2011.
7. Watanabe, R., Saito, N., Mori, Y., Hachisu, T., Sato, M, Fukushima, S., and Kajimoto, H., "Evaluation of roller-type itch-relief device employing hot and cold alternating stimuli," *ACM CHI Extended Abstracts*, 2013.