# Thermocons: Evaluating the Thermal Haptic Perception of the Forehead

**Roshan Lalintha Peiris, Liwei Chan, Kouta Minamizawa**
Keio University Graduate School of Media Design
roshan, liwei, kouta @kmd.keio.ac.jp

## ABSTRACT
Thermocons describes our work in progress for evaluating thermal haptic feedback on the forehead as a viable feedback modality for integration with head mounted devices. The purpose was to identify the thermal perception for simultaneous feedback at three locations of the forehead. We provided hot-only, cold-only and hot/cold-mixed thermal stimulations at these location to identify the sensitivity for accurate perception. Our evaluation with 9 participants indicated that perceiving cold-only stimulations were significantly better with an accuracy of 88%. The perception accuracy for hot-only and hotcold-mixed stimulations were 66% and 65% respectively.

### Author Keywords
thermal haptics; head; forehead; haptics

### ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

## INTRODUCTION
The rise in the use of head mounted displays and eyewear devices presents an opportunity to embody haptic feedback with such devices. Their placement on the head allows us to explore the head as a suitable location to provide haptic feedback. Recent research has explored using vibrotactile actuators as a viable channel for haptic feedback on the head [1, 4]. However, these investigations indicate that the perception accuracy of multiple simultaneous feedback for vibrotactile feedback reduced significantly as two or more actuators were actuated [1, 4].

Thermal haptic feedback is another viable modality for providing feedback. Furthermore, the head has the highest density of thermoreceptors on the human body [2]. Therefore, the forehead is a potential location to introduce thermal feedback integrated with head worn devices. In addition, the forehead provides direct contact with head worn devices such as head mounted displays. Therefore, the objective of this research is to identify the perception accuracy of multiple simultaneous feedback with thermal stimulus on the forehead.


*UIST'16 Adjunct*, October 16-19, 2016, Tokyo, Japan
ACM 978-1-4503-4531-6/16/10.
http://dx.doi.org/10.1145/2984751.2984762

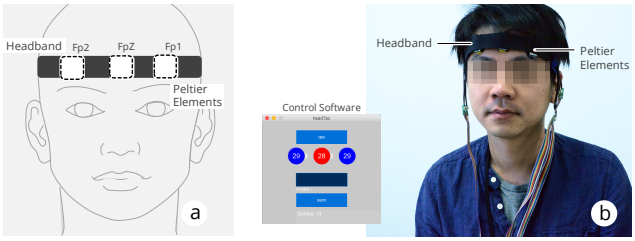


**Figure 1. (a) The Fp1, Fp2 and FpZ locations (standard EEG 10-20 system) for thermal stimulation (b) Experimental Setup and the control software used by the experimenter.**

## EVALUATING THERMAL STIMULUS ON THE FOREHEAD

### Stimulus Locations
Our approach investigates three locations on the forehead for simultaneous stimulation. The three locations on the forehead were determined by following the 10-20 system of electrode placement used for high-density electroencephalography (EEG) studies. We chose the Fp1, Fp2 and FpZ (Figure 1(a)) locations that are placed on the forehead.

### Apparatus and Temperatures
We used three 2cmX1.5cm peltier elements[1] placed on the forehead using a headband. Figure 1(b) denotes the setup. A custom software was used to enter the stimulus states and collect data. To provide the stimuli, starting from the skin temperature ( approx. $37^0$C), a $+3^0$C as the hot stimulus and a $-3^0$C as the cold stimulus was provided for within a second for each. This $3^0$C/s rate of stimulation is sufficient for detection of a temperature change on the skin [3]. After each stimuli, the temperature was allowed to return to the skin temperature monitored by the experimenter.

### Experimental Design
The main objectives of this research is to identify the perception accuracy of multiple simultaneous feedback with thermal stimulus on the forehead. Multiple simultaneous feedback stimuli allows more information to be

[1] http://www.kelk.co.jp/english/thermo/index.html

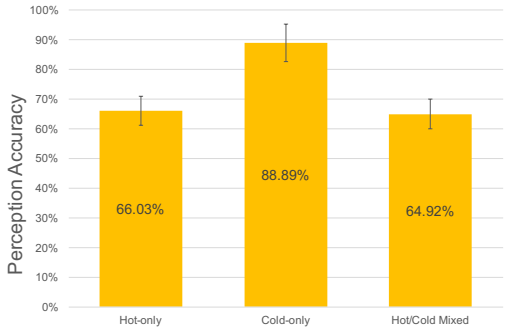


**Figure 2. Accuracy of Perception for Hot-only, Cold-only and Hot/Cold Mixed Stimulations.**

presented within a single feedback instance. We consider the forehead as it provides an unhindered contact to the thermal stimulus.

We evaluated the thermal perception under three feedback conditions. For each condition, the stimuli were provided simultaneously at each location. The stimuli locations were randomized. The feedback conditions were counter-balanced.

***Hot Only Condition:*** In this condition, only hot stimuli ($+3^0$C) were provided at the three stimulus locations. Therefore, for each condition, each of the stimulus locations could be hot or no change and each of these conditions were repeated 5 times. The condition of where all locations have no-change is not presented as it is the starting state.

***Cold Only Condition:*** This condition is similar to the Hot Only condition, but only cold ($-3^0$C) stimuli are provided.

***Mixed Condition:*** This condition introduces mixed hot/cold mixed stimuli. That is, for example, a stimuli could include Hot at FP1, Cold at FP2 and Hot FPZ.

### Procedure

9 healthy participants (7 male, average age 31) took part in the experiment held at $24^0$C room temperature. Initially, the stimulus locations were adjusted according to their head size and the headband was placed on their head. The participant was explained of the three feedback conditions and were given example stimulations of different conditions. Before each condition of the experiment, the participants were informed of the feedback condition they were evaluated. When a participant was provided a stimulus, they voiced out the perceived stimulus ("Hot", "Cold" or "No Change") for each location from left to right which was entered by the experimenter. A response where all three percieved stimuli matched the provided three stimuli was considered as an accurate response.

## RESULTS DISCUSSION

Figure 2 denotes the perception accuracy results for hot-only at 66% (SD 5%), cold-only at 88.8% (SD 6%) and mixed at 64.92% (SD 5%). The results show a significantly high accuracy for cold-only thermal stimulation perception. According to the results of one-way RM-ANOVA with Greenhouse-Geisser correction, there exists an significance between the conditions ((F(1.171, 22.257) = 21.032, p <0.0005)); Cold stimuli is significantly better than hot and mixed stimuli (both p <0.0001). However, there exists no significance between hot-only and mixed stimuli.

This result can be explained by the fact that afferent fibers of cold thermoreceptors conduct faster than warm afferent fibers [3]. In addition, it is reported that when a temperature change occurs closer to the pain threshold (above $45^0$C for hot and below $15^0$C cold) the skin adoption is faster [3]. Therefore since our hot stimulations were closer to the pain threoshold the quick adoption could confuse the perception for the user. This was observed in the mixed instance as well which needs further analysis and verification. However, for the current setup, cold thermal haptic feedback proved to be better for simultaneous stimulation for haptic feedback. As our future works, we wish to explore thermal stimuli on the head with temporal stimulations and expand to other locations such as the ear. In addition, we wish to explore new applications that can enhance the experience for head mounted displays.

## CONCLUSION

This research explores the presentation of thermal stimuli on the forehead. We provided hot-only, cold-only and hot/cold mixed stimuli on three locations of the forehead. Our evaluations with 9 participants indicated that cold-only thermal stimulation was best perceived during simultaneous thermal stimulations.

## ACKNOWLEDGEMENTS

This research was conducted as part of the JST-ACCEL "Embodied Media" project.

## REFERENCES

1. Dobrzynski, M. K., Mejri, S., Wischmann, S., and Floreano, D. Quantifying information transfer through a head-attached vibrotactile display: Principles for design and control. *IEEE Trans. on Biomedical Engineering 59*, 7 (2012), 2011–2018.
2. Green, B. G., and Cruz, A. "Warmth-insensitive fields": evidence of sparse and irregular innervation of human skin by the warmth sense. *Somatosens Mot Res 15*, 4 (1998), 269–275.
3. Jones, L. A., and Ho, H. N. Warm or cool, large or small? the challenge of thermal displays. *IEEE Transactions on Haptics 1*, 1 (2008), 53–70.
4. pakov, O., Rantala, J., and Isokoski, P. Sequential and simultaneous tactile stimulation with multiple actuators on head, neck and back for gaze cuing. In *World Haptics Conference (WHC), 2015 IEEE* (2015), 333–338.