Development of Roller-Type Itch-Relief Device Employing Alternating Hot and Cold Stimuli

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ABSTRACT
Painful thermal stimulation is known to inhibit itch, which is a significant problem in many diseases. We focused on thermal grill illusion and synthetic heat, which are well-known phenomena that can generate pain or burning sensation without physical damage; we tried to achieve a similar effect via a harmless-range thermal stimulation. We developed a roller-type itch-relief device. When the device is rolled onto the user's skin, the skin is alternately exposed to hot and cold stimuli. The roller is composed of an aluminum pipe cut into two parts along the longitudinal axis. One part is set to hot and the other is set to cold by embedded Peltier devices. When the device is rolled on the user's skin, the skin is alternately exposed to hot and cold stimuli. In addition, vibration is applied so that a virtual scratching feeling is presented without damage to the skin. We evaluated the device by eliciting an itch using a lactic acid solution and then applying the device. The results showed that the device provides effective temporal relief from itch and that its effect continues for a few minutes.

Categories and Subject Descriptors
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J.3 LIFE AND MEDICAL SCIENCES: Health.

General Terms
Human Factors

Keywords
itch, thermal, heat stimulation, vibration.

1. INTRODUCTION
An itch sensation is common to many skin diseases such as atopic dermatitis and senile xerosis. It can be temporarily relieved by scratching, but this damages the skin and may lead to prolonged illness. Therefore, it is important to reduce the itch sensation without damaging the skin. In the treatment of atopic dermatitis, itch is commonly suppressed by the administration of a drug (e.g., a steroid or antihistamine). However, drug treatment has the risk of side effects (e.g., adrenal insufficiency, diabetes, and viral skin infection).

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Painful thermal stimulation is known to inhibit the itch sensation [1]. This may lead to a type of treatment without the risk of serious side effects; however, the heat causing the pain may burn the skin.

Based on these considerations, we thought that it would be better to utilize the itch-relief effect of heat at a harmless temperature for treatment of the itch sensation. We focused on the thermal grill illusion (TGI) [2][3] and synthetic heat [4], which are well-known perceptual phenomena that induce pain or burning sensations without damaging the skin through the simultaneous presentation of hot and cold stimuli to the skin. Although these phenomena are not what certainly occur, the presentation of both hot and cold sensations may be elicited at a lower temperature that does not damage the skin.

We developed and evaluated a roller-type itch-relief device, which we present in this paper. The roller contains embedded Peltier devices. The outer surface of the roller is divided into two parts: one is heated and the other is cooled. Rolling the roller onto the skin allows the two parts to alternately touch the skin. In addition, vibration is applied so that a virtual scratching sensation is presented without damage to the skin.

2. DEVICE
The system consists of an aluminum pipe (outside diameter: 20 mm, inside diameter: 18 mm, length: 40 mm), a potentiometer to measure the rotation angle, a vibrator (Tactile Labs, Haptuator Mark II), three Peltier devices (STS, T150-85-017S), a microcontroller (mbed NXP LPC1768), an audio amplifier (Rasteme Systems, SDA202), an ABS plastic exterior, and a voltage source (A&D, AD-8723D) (Figure 1 and Figure 2). To connect the voltage source and rotating Peltier devices, we used an audio plug and an audio jack as a rotary joint.

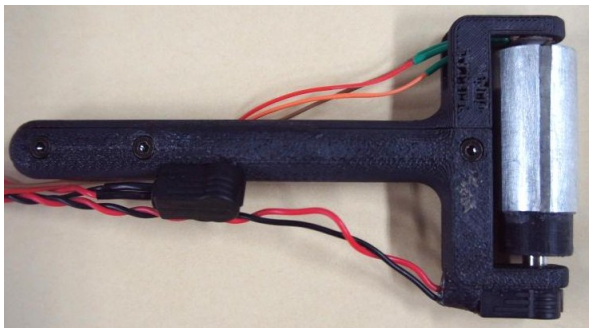

Figure 1: Overview of the device

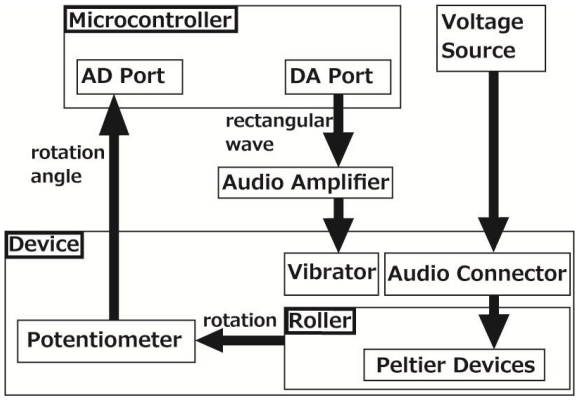

Figure 2: System overview

The roller portion is embedded with three Peltier devices piled up to achieve efficient heating and cooling (Figure 3). One side of the pile touches and heats one side of the cylinder, whereas the other side of the pile cools the other side of the cylinder. Through rotation of the roller, hot and cold stimuli are alternately presented to the skin. Figure 4 shows an image of the working device that is acquired using a thermal camera. Half of the device was heated to around 38 °C, and the other half was cooled to 18 °C.

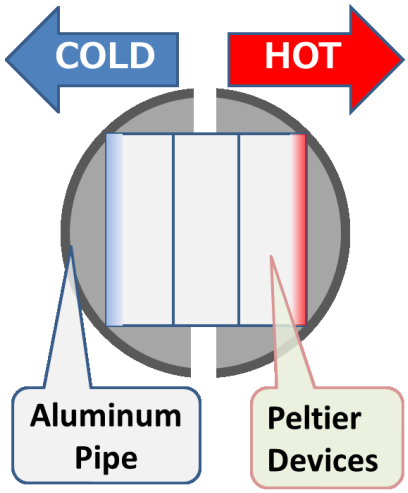

Figure 3: Cross-section of roller

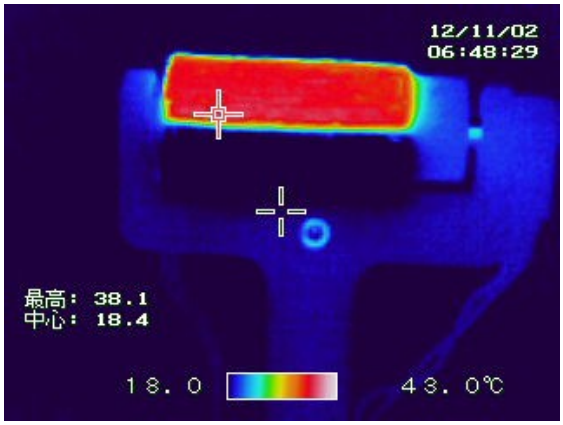

Figure 4: Working device observed by thermal camera

Normally, TGI is elicited by hot and cold stimuli presented simultaneously and close to each other. However, this simultaneous stimulation results in a large setup and consumes a great deal of energy. In contrast, we present hot and cold stimuli using a single cylinder, which simultaneously makes the device compact and energy-efficient because a single Peltier device works as both hot and cold thermal sources. We expect that TGI is generated through the alternating presentation of hot and cold stimuli to the skin through the rotation of the roller.

A vibrator is embedded in the grip of the proposed device to produce a virtual scratching sensation. The vibration is a rectangular wave with a frequency of 50 Hz to produce a sensation similar to scratching (as explained in the next section). The amplitude is set proportional to the speed of rotation, which is obtained from the potentiometer attached to the roller.

3. HARDWARE EVALUATION

3.1 Vibrator evaluation

We conducted an exploratory experiment to determine the vibration waveform. Six conditions were used in total: three vibrational frequencies (50, 100, and 250 Hz) and two waveforms (rectangular and sinusoidal waves). In this experiment, the roller was not used to present thermal sensation. Five healthy participants (four male and one female) between 23 and 26 years of age participated in the experiment. Each participant held the device in their dominant hand and rolled the device on their forearm.

The participants were first asked to use the device for 5 s under each condition as a practice session. Afterwards, they were asked to use the device again under each condition and to evaluate the sensation according to the similarity of the sensation with real scratching on a scale of 1–10 points. The experiment order was randomized.

The results are shown in Figure 5. The vertical axis indicates the average number of points. The figure clearly shows that a 50-Hz rectangular wave was found to be most similar to scratching among the various conditions tested. Therefore, we used a 50-Hz rectangular wave vibration for the device.

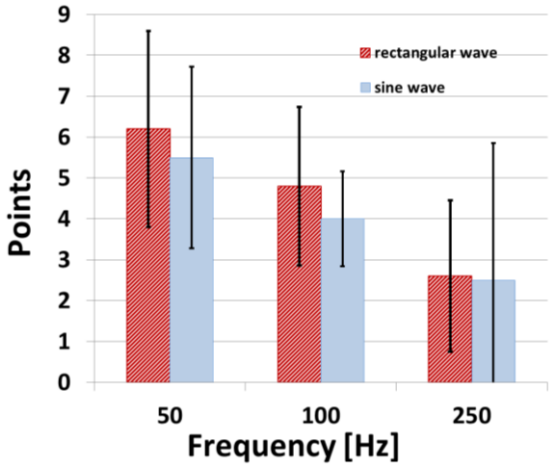

Figure 5: Similarity between the presented vibration and real scratching

We measured the acceleration of the vibration using an accelerometer (Kionix, KXM-52-1050) attached to the shaft of the device. Figure 6 shows the result. During the measurement, the device was in contact with the arm and held by hand so that the

situation would be similar to real usage. The measured acceleration was similar to a triangular waveform.

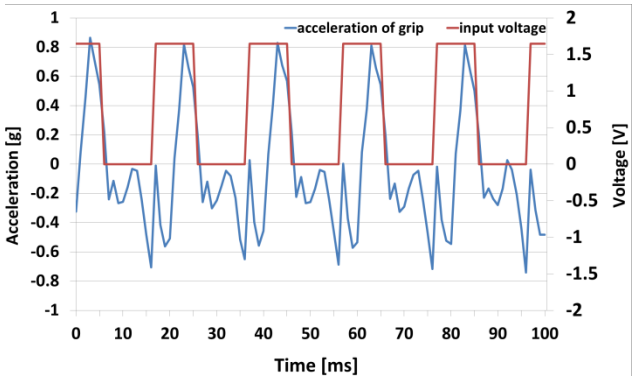

Figure 6: Acceleration measured by accelerometer on the grip

3.2 Heat source evaluation

To ensure safe use, the temperature of the roller surface must be within a range that does not damage the skin. Since there is a risk of burning when the skin is exposed to a temperature of 44 °C for 6 h and the permissible exposure time becomes shorter above this temperature [5][6], we adjusted the voltage applied to the Peltier device to keep the roller surface below 44 °C. Figure 7 shows the surface temperatures of the two sides of the roller when a voltage of 1 V was applied to the Peltier devices. The room temperature was 27 °C. The measurement was carried out for 30 min, and the temperature was maintained below 43 °C.

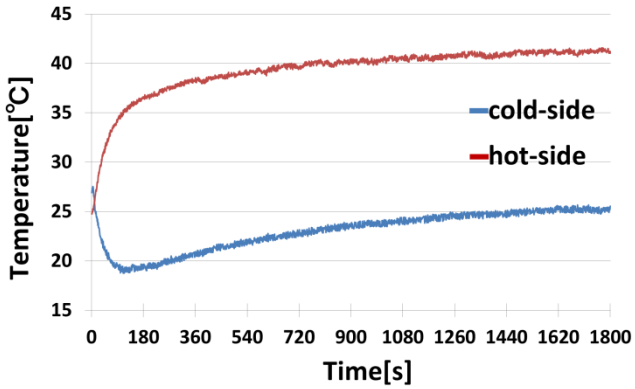

Figure 7: Surface temperature of roller

4. EVALUATION

We evaluated the manufactured device under real itch conditions. All procedures were approved by the ethics committee of the Shiseido Research Center.

4.1 Participants

Twenty-nine healthy male participants between 26 and 63 years of age participated in the study. None had atopic eczema or chronic skin disease.

4.2 Environment

The experiment was conducted in a room maintained at 22 °C and 45% humidity.

4.3 Procedure

Participants washed and dried their cheeks and acclimated to the room for 10 min. They then placed a cotton pad containing 7 mL of 2.5% lactic acid solution onto their cheeks to elicit an itch sensation [7]. The liquid is known to elicit an itch sensation that lasts for a few minutes and then disappears. After 8 min, the cotton pad was removed. After another 1 min, the participants began rolling the device on their cheek, and they continued using the device for 1 min.

Under one experimental condition, the device presented hot and cold temperatures and vibration. Under another (control) condition, the temperature of the device was set to body temperature (33 °C) beforehand, and vibration was not presented. Participants were asked to rate the intensity of the itch sensation for 8 min. After one trial under one experimental condition, the trial was repeated for the other cheek under the other condition. The order of conditions and the order of cheeks (left or right) were randomized.

The participants were asked to rate the itch sensation using a visual analogue scale (VAS) immediately before the removal of the cotton pad, immediately after the removal of the cotton pad, 1 min after the removal of the cotton pad, immediately after using the device, and every minute for 8 min after using the device. The left end of the VAS corresponds to there being "no itch," and the right end corresponds to there being "an itch that was irresistible to scratch."

4.4 Data analyses

Three participants who did not perceive an itch sensation were excluded from the analysis. The VAS ratings between the two conditions were compared through t-tests.

4.5 Result

Figure 8 shows the temporal change in the itch sensation. The working device clearly suppressed the itch sensation immediately after application ($p = 0.0018$). This effect was maintained for some time ($p = 0.0481$ after 1 min).

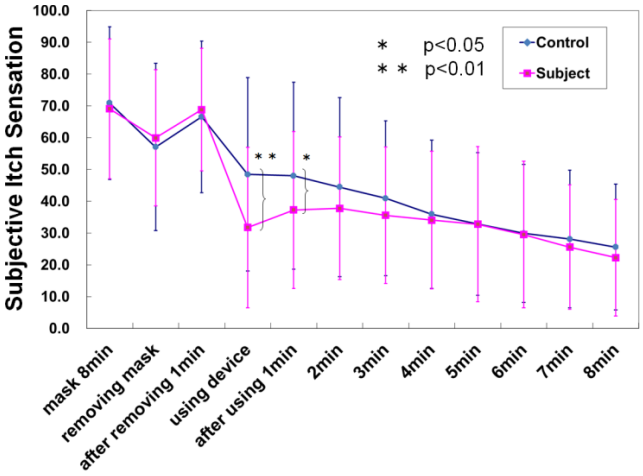

Figure 8: Intensity of itch sensation under two experimental conditions

5. CONCLUSION

To relieve the itch sensation, which is a significant problem in many skin diseases, we proposed the simultaneous use of both hot and cold stimulation and vibration. The former generates a painful sensation that is known to relieve the itch sensation, and the latter conveys to the user a feeling of scratching.

A roller-type handheld device was manufactured using Peltier devices, a potentiometer, and a vibrator. We assumed that the device should be handheld as itch can present at any time.

Through hardware evaluation, the voltage of the Peltier devices was determined to maintain safety, and the vibration waveform was set to induce a scratching feeling.

The device was evaluated to see if it can reduce the itch sensation. The results clearly showed that the device is effective in terms of relieving the itch sensation immediately after use, and the effect seemed to continue for a few minutes. Compared with scratching [8], which also suppresses itch temporarily, the device has the advantage of not damaging the skin.

We must continue the development and evaluation of the proposed device. Future works include subjective evaluation using only vibration or thermal stimulation because the current evaluation only focused on the mixed condition. In addition, the hardware should be optimized by modifying the diameter of the roller, which affects the interval of hot and cold stimuli and is important for TGI.

6. REFERENCES

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Additional Author Information

Taku Hachisu, Michi Sato, and Shogo Fukushima are also with the Japan Society for the Promotion of Science. Hiroyuki Kajimoto is also with the Japan Science and Technology Agency.