Facilitating a Surprised Feeling by Artificial Control of Piloerection on the Forearm

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ABSTRACT
There have been many proposals that have added haptic stimulation to entertainment content such as music, games, and movies. These technologies enrich the quality of the experiences by improving the reality thereof. In contrast, we present a novel approach to enrich the quality of these experiences by facilitating the emotional feeling evoked by the content. In this paper, we focus on piloerection, which is a kind of involuntary emotional reaction. Our hypothesis is that not only is it an emotional "reaction", but it can also work as an emotional "input" that enhances the emotion itself. We have constructed a device that controls piloerection on the forearm through electrostatic force. Based on a psychophysical experiment, we confirm that the piloerection system enhances the feeling of surprise.

Categories and Subject Descriptors
H5.2 [**Information interfaces and presentation**]: User Interfaces - *Haptic I/O, User-centered design, Theory and methods*

General Terms
Design, Human Factors, Theory

Keywords
Enhancement of emotion, enhancement of feeling, piloerection, tactile interaction.

1. INTRODUCTION
1.1 Haptic Displays to Enrich Audio-Visual Entertainment
Adding haptic stimulation to audio visual entertainment such as listening to music, game playing, and viewing movies is a promising step to enrich these experiences. A number of previous studies have been conducted in this regard [1][2][3][4][5][6][7].

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With respect to listening to music, vibration was added via headphones and earphones, thereby improving the reality of the music by converting the low frequency component of the sound to vibration [1][2]. Surround Haptics [5] is a chair shaped tactile display that creates an immersive gaming environment by enhancing the audio and visual effects in games by a tactile modality. Tactile Jacket [3] is a jacket shaped tactile display, which creates an emotionally immersive experience by rendering emotional states of a movie character on the viewer's body as vibration. These technologies improve the reality of the entertainment by transferring various cues in the contents onto the body.

In contrast, we present a novel approach that enhances the emotional feeling evoked by the content, using haptic technologies. The quality of entertainment is typically evaluated from a variety of aspects (e.g., acting, drama, comedy, environment, etc). We speculated that the quantity of emotional feeling evoked by the contents is one of the most critical factors in determining the quality of the entertainment.

To enhance the emotional feeling using haptic technologies, we focus on sensations evoked by emotional body reactions (emotional body images), such as chilly or goose bumps sensations. Damasio et al. verified that the insula and second somatosensory cortex are constantly activated during emotional feelings (sadness, happiness, anger, and fear) [8]. Furthermore, they revealed that autonomic nervous responses associated with these feelings precede the actual feelings. From these results, they predicted that emotional feeling is evoked by the somatosensory areas that represent emotional body images such as the chilly and goose bumps sensations. Similar studies were reported on various experiences such as feeling of love [9], guilt [10], and listening to music that elicited a chilly sensation [11]. According to these studies, haptic displays for altering or enhancing these emotional body images should facilitate the emotional feeling.

1.2 Facilitating the Feeling of Surprise by Artificial Control of Piloerection
We focus on piloerection, which is an involuntarily reaction induced by a cold environment or when the person experiences emotion such as fear or surprise. We hypothesize that such emotional feelings can be facilitated by artificially reproducing piloerection through electrostatic force.

In this paper, we first describe the construction of a piloerection control device using electrostatic force. Next we carry out a

psychophysical experiment to verify our hypothesis that feelings of surprise can be facilitated by artificially reproducing piloerection, using two evaluation indexes, the skin conductance reaction and a questionnaire.

2. PRINCIPLE

We made forearm hairs stand using an electrostatic force (Figure 1). An acrylic plate (100×150×0.08mm) was placed 2cm above the forearm with a copper electrode sheet (38×100×0.08mm) on top. A crude rubber sheet was placed on the electrode. The electrode was connected to a high voltage source (HJPQ-30P1, Matsusada Precision Inc), and forearm was connected to ground. When a high voltage (0~20kV) is attached to the electrode, the acrylic plate is polarized and the forearm hair is attracted to the acrylic plate by the electrostatic force.

The acrylic plate and crude rubber sheet were used to protect from electric shock. As the main factor for electric shock is current, rather than voltage, the current supply from the voltage source was limited to 1.0 mA. If the current exceeded 1.0mA, the voltage source instantly shut down.

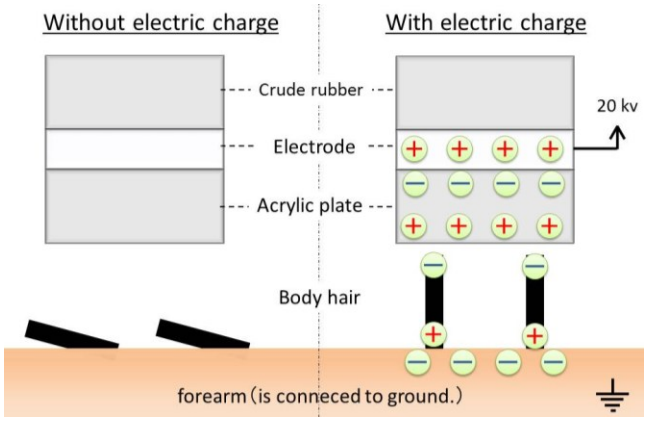

Figure 1: Principle of the prototype device

The principle was verified by a preliminary trial. Figure 2 shows forearm hairs when 0 or 14 kV voltage was applied.

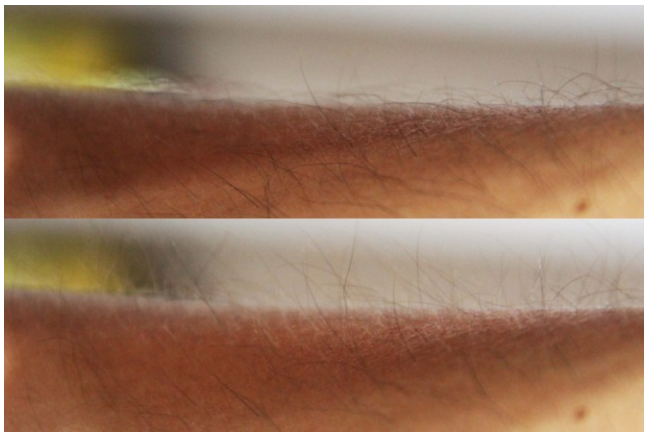

Figure 2: Forearm hair behavior without and with electrostatic force (Top: 0 V; Bottom: 14 kV)

3. EXPERIMENT ON FACILITATING SURPRISE WITH PILOERECTION

3.1 Overview

The purpose of the experiment was to verify our hypothesis that a surprise feeling was enhanced by piloerection of participant's body hair synchronized with subjective surprise feeling. To surprise the participants, we used audio warning alarm with 5 seconds duration [12]. Two conditions were prepared: one with only the audio stimulation, and the other with both audio stimulation and piloerection. We compared the two conditions by means of a questionnaire, asking the participant to quantify the amount of surprised feeling between 0 and 100, and by observing the skin conductance reaction.

3.2 Experimental Conditions

We recruited six male participants, aged 21 and 22. We could not find any female participants who did not shave their forearm hair. The participants were tested alternately under the two conditions (audio without piloerection and audio with piloerection), and the whole process was repeated ten times. We used the same audio stimulation in every trial. To remove any order effect bias, participants were divided into two groups. In the first group only audio stimulation was presented at the first trial, whereas in the other group both audio and piloerection were presented at the first trial.

3.3 Apparatus

3.3.1 Piloerection control device

We constructed a device that uniformly straddles a wide range of body hair on the forearm (Figure 3). The principle and the materials are the same as those used in Section 2. An acrylic plate was bent along the forearm with a copper electrode and a crude rubber sheet attached thereto. The diameter of the hole through which the arm is inserted, is about 90 mm. In this experiment, we applied 20 kV DC voltage for one second, synchronized with the start of the audio stimulation.

Figure 3: Overview of the piloerection control device

3.3.2 Measurement of skin conductance reaction

To quantitatively evaluate the surprised feeling, we used SCR (Skin Conductance Reaction), a change in electrical conductance of the skin, which is known to vary with the intensity of the physiological arousal.

We measured the SCR with an SCR amplifier (DA-3b, Vega Systems). Since the measured SCR value included a DC component, we eliminated this using an analog high pass filter. Then we amplified the filtered voltage, and recorded this on a PC via an AD Interface Board (PCI-3523, Interface Corp.)

Figure 4 shows a typical waveform of the SCR during the trial. To quantify this waveform, we defined three indicators: amplitude, dimension, and duration. Amplitude denotes the maximum voltage of the waveform, dimension denotes the area size of the waveform, and duration gives the time that the SCR voltage was above the threshold. The threshold value was set to 0.5 V.

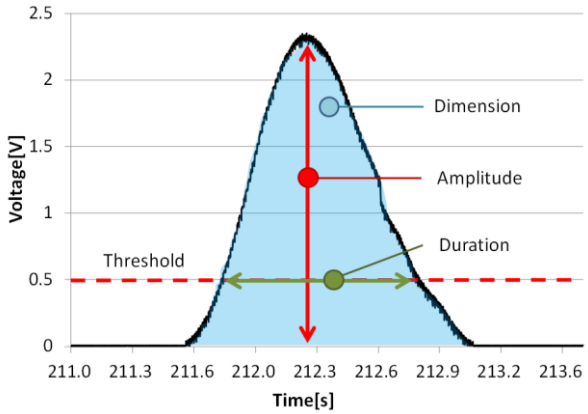

Figure 4: A typical waveform of SCR during the trial

3.4 Procedure

We first calibrated the amplitude gain of the skin conductance reaction to equalize its amplitude among participants. Electrodes were attached to the palm of the participants' left hands (Figure 6), and they were asked to breathe gently and deeply (a deep breath is known to elicit SCR, which is typically used for calibration). While participants were breathing, the investigator regulated the volume of the SCR amplifier to maintain the amplitude between 2 and 3 V.

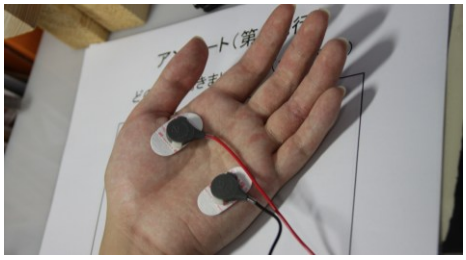

Figure 6: Attached positions of electrode seals

Figure 7: Overview of the experiment

After calibration, each participant was given an earphone to wear, and the experiment started. Experimental instructions were displayed on a PC monitor placed immediately in the front. Thirty seconds later, the first stimulus was presented. After the trial, the participants revealed the amount of their surprise on the questionnaire. The second trial was conducted 25 to 40 seconds later, with the interval randomly assigned. The participants repeated this trial 10 times.

3.5 Results

The results are shown in Figure 5A-D. The figures show averages and standard deviations under both conditions: audio with piloerection and audio without piloerection. During the experiment, some of the participants mistakenly moved their left hand (this occurred four times), and we could not record the data for one participant due to program error. Therefore, these data were removed from the results. Figure 5A shows the questionnaire data. A t-test revealed a significant difference between the two conditions (one-tail test: $t(41)=2.51$, $p<0.01$). Figure 5B shows the dimensions of the SCR value, with a t-test revealing a marginally significant difference between the two conditions (one-tail test: $t(41)=1.49$, $0.05<p<0.1$). Figure 5C shows the amplitudes of the SCR value. A t-test showed that the difference between the conditions is not statistically significant (one-tail test: $t(41)=0.71$, $p=0.23$). Figure 5D shows the durations of the SCR value, with a t-test revealing significant differences between the two conditions (one-tail test: $t(41)=1.96$, $p<0.05$).

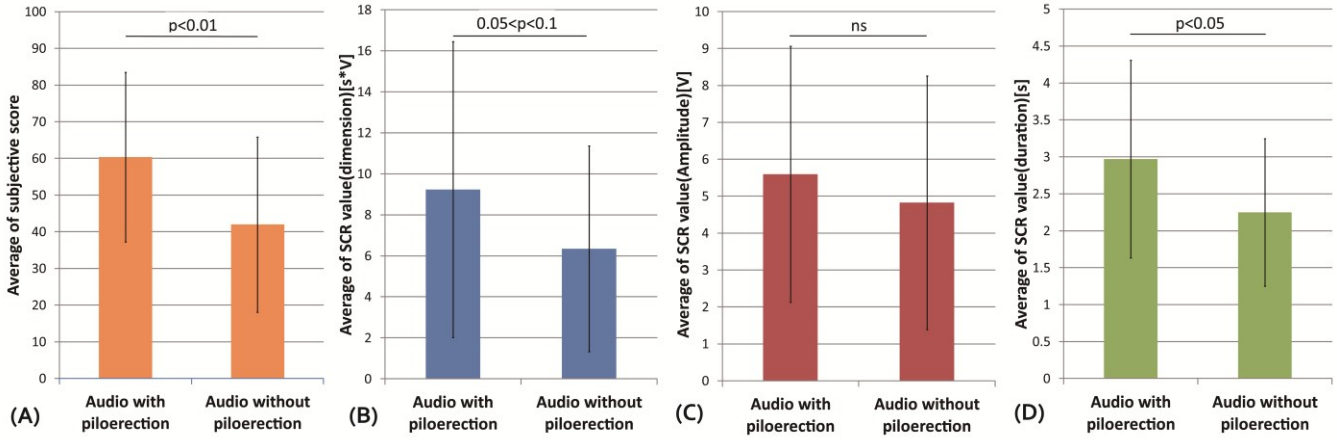

Figure 5: Results of the amount of surprise (A), dimension (B), amplitude (C), and duration (D)

3.6 Discussion

As expected, both the amount of subjective surprise and the SCR value (duration index) increased significantly when piloerection was added to the audio emotional stimulation. After the experiment, some of the participants made the following comment: "chilly sensation was evoked on the whole body when audio stimulation and piloerection were presented, but it was not evoked with only audio stimulation". This comment seems to reflect the experimental results.

After the experiment, the investigator asked participants to verbally express the sensation of artificial piloerection. All participants stated that, "this sensation resembles a wind sensation". Two participants said: "I felt like I was wearing aura or cotton". Since participants had never previously experienced this piloerection, they used various haptic sensations to describe it.

4. CONCLUSION AND FUTURE WORKS

In this paper, we presented a novel approach to facilitate the emotional feelings evoked by entertainment content by artificially enhancing emotional body images using haptic technologies. As one example of the approach, we focused on piloerection, which is a kind of emotional body image, and constructed a novel haptic display that artificially controls piloerection through electrostatic force. In a psychophysical experiment, we verified our hypothesis that the feeling of surprise is facilitated by adding artificial piloerection to the simulation of surprise.

We considered that a surprised feeling was facilitated as a result of the body image alteration that was induced by artificial piloerection. However, the mechanism for the emotion facilitation effect is still not clear in the present evaluation. As a future work, we will compare the effect of the piloerection control device and other haptic stimulations such as simple vibration, to reveal the specificity of the piloerection display.

Besides the surprised feeling, piloerection is induced by various other emotions such as fear, nostalgia, pleasure, awe, admiration, and sexual arousal. We intend verifying the emotion enhancement effect on these emotions.

Finally, in order to apply this haptic display to various entertainment applications, we will implement a chair shaped piloerection control device that is able to induce piloerection of the hair either over the whole body, or on an effective part of the body through electrostatic force.

5. ACKNOWLEDGMENTS

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