An Implementation of a Pseudo-beat Presentation Device Affecting Emotion of a Smartphone Video Viewer

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Abstract: We have developed a pseudo-beat presentation device that represents visual and tactile movements around a smartphone for the purpose of affecting emotions of a video viewer. The device controls multiple solenoids attached to the back of the smartphone and moves them as if they were human heartbeats in accordance with an emotion of a video content on the smartphone. The results of a usability evaluation experiment of the device showed that the heart rate of viewers who felt the pseudo-beats as their own heartbeats increased, and that the pseudo-beats increased emotional arousal of a calm scene in a video.

1 INTRODUCTION

We have developed a device that enhances viewer's emotional experience by presenting pseudo-beats as visual, pressure, and vibration sensation while watching a video on a smartphone (see Figure1). As shown in Figure 2, the device consists of four solenoids attached around a smartphone. The movements of each solenoid are interlocked to make the smartphone appear to be moving like a human's heartbeat. The device is capable of presenting visual as well as tactile movements to smartphone users. Our goal is to emphasize the viewer's emotional experience by linking the beating cycle to a scene of a video.

The reason for our idea is that it is difficult to apply conventional methods of emphasizing emotional experiences, such as displaying video on a large screen or 4D technology that uses large-scale devices such as wind and water spray, to smartphones. Smartphone screens are getting larger every year, but they will never be as big as a TV or a movie theatre screen. Many smartphones are equipped with a vibration actuator as a tactile feedback device, but this vibration device only conveys notification information and does not provide enough stimulation to emphasize an emotional experience.

There is a close relationship between human physiological responses and emotions.

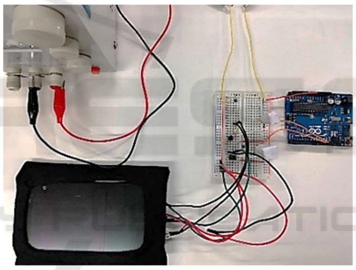

Figure 1: Pseudo-beat presentation device and its control circuit.

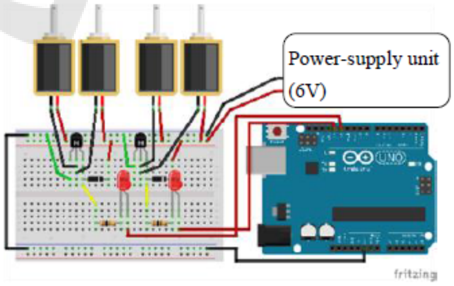

Figure 2: Substantial wiring diagram of the control circuit.

Conventionally, it has been thought that emotions are generated as a result of recognition of a situation in response to stimuli from the external world, and that they subsequently appear as changes in physiological responses such as facial expressions and pulse rates. However, in recent years, in the field of cognitive psychology, a theory that some kind of a

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physiological response to a stimulus appears first, and then the change is recognized and a specific emotion is generated, has been proposed and is supported positively (William, 1890, Stanley et al., 1962). In addition, it has been shown that even a pseudo-stimulus can affect emotions if the stimulus is presented as if it were a change in one's own bodily response and is perceived as one's own bodily response (Stuart, 1966).

In this paper, we examined how visual and tactile beating around a smartphone affected emotions of video viewers using the proposed device. In the verification experiment, we targeted emotions of fear and tension, which are closely related to the physiological and psychological responses to the pulse, and which we believe are likely to respond as negative emotions. We hypothesized that the emotions would be amplified when viewers perceived pseudo-beats linked to a scene while watching a video. We recorded the viewers' subjective evaluation of the emotional changes and their blood volume pulses (BVPs) as evaluation metrics.

The contributions of this paper are as follows:

- The presentation of pseudo-beats has an effect on pulse waves of a viewer. the heart rate of viewers who feel the pseudo-beats as their own heartbeats increases.
- The presentation of the pseudo-beats increases the emotional arousal of a calm scene in a video.

2 RELATED WORK

This section introduces some research studies on influencing users' emotions by using changes in pseudo-physiological responses.

Sakurai et al. developed "Communious Mouse" that rewrites user's perception of his/her skin temperature and pulse in his/her palm by representing false-bodily temperature and pulse beat in accordance with emotions, which are included in remarks pointed by the mouse cursor, in order to evoke his/her emotion (Sakurai et al., 2016). The mouse exhibited to over 150 people and it revealed that the mouse was able to help users to experience others' emotions. However, the score for "happiness" was lower than the valuations for other emotions. They reported that it seemed to be difficult to evoke "Happiness" only because of the physiological comfort.

Ueoka et al. developed an Emotion Hacking VR (EH-VR) that hacks one's heartbeat and controls it to accelerate scary VR experience by detecting user's heart rate in real time and calculates false heart rate, which is faster than the one observed. (Ueoka et al., 2016). The system edited a heartbeat sound as a sampling sound of a cycle of heartbeat for giving vibrotactile feedback.

Mikami et al. proposed a system to enhance listener's music experience by improving his/her immersive feelings toward the music by inscribing rhythm with his/her fingertip using electric muscle stimulator (Mikami et al., 2018). The results of their experiment showed that, although the system increased immersion in the music experience for some listeners, it decreased immersion for others because of differences in rhythmic timing and matching to the music due to differences in music preference and musical experience.

Fukushima et al. focused on piloerection which was a kind of involuntary emotional reaction and constructed a device that controlled the piloerection on listener's forearm by electrostatic force in order to enrich the quality of experiment (Fukushima et al., 2011). Their experiments showed that the device increased the value of surprise in the subjective evaluation and the duration of surprise in the skin conductance values.

The differences between the device proposed in this paper and the ones introduced here are that the proposed device is simpler, easier for users to handle, and more familiar to users because it targets emotions in video viewing with smartphones.

3 PSEUDO-BEAT PRESENTATION DEVICE

We installed a device around a smartphone that makes the smartphone appear to beat as a pseudo-heart in order to make a viewer feel as if his/her own heartbeats are changing in accordance with scenes in a video. In this section, we describe the implementation of the device in detail.

3.1 Design

Since the average normal pulse rate of a person over the age of 10 is between 60 bpm and 100 bpm (American Heart Association website, 2021), our system also sets five pulse rate levels: 60 bpm, 67 bpm, 75 bpm, 85 bpm, and 100 bpm.

In this study, we use Lang et al.'s two-dimensional emotion model (Lang, 1995), which consists of emotion valence and arousal, to handle emotions quantitatively. Emotional valence represents the positive and negative aspects of an emotion. On the other hand, the arousal level represents the intensity of the emotion.

As a relationship between the beating rate of the device and the emotion of a video scene, in a horror movie scene where the emotional value is negative and the arousal level is gradually increasing, the beating rate of the device is gradually increased from low to high in accordance with the deployment of the scene. On the other hand, in a landscape movie where the emotional value and arousal level are neutral, the beating rate is kept constant at 60 bpm.

3.2 Implementation

Four push-type solenoids (rated voltage DC 6 V - 48 V, 1.2 W) were used for the implementation of the beating. LG Nexus 4 (133.9 x 68.7 x 9.1mm) was used as the smartphone. Two of the solenoids were attached to the backside of the bezels of the two long sides of the smartphone, so that the movement direction of the moving parts was vertically outward from the long sides (see Figure 3). A wooden stick of the same length as the long side was attached to connect the moving parts of the two solenoids so that each long side would appear to be beating. To make these devices and the smartphone appear to be integrated, the entire bezel of the smartphone was covered with an elastic fabric, as shown in Figure 1.

Arduino UNO (Arduino, 2021)) and Processing (Fry and Reas, 2021) were used to control the pseudo-beat presentation device (see Figure 1 and 2). Since this is a prototype at this time, we used an external power supply of 6V to operate the solenoids, instead of the smartphone power supply. The LEDs on the breadboard shown in Figure 2 are feedback circuits for checking the operation, and are not directly related to the operation of the pseudo-beat presentation device.

In order to make the entire smartphone appear to be beating by the movement of the four solenoids, the left and right sides of the smartphone were made to look like an atrium and a ventricle, respectively, when it was placed horizontally. Specifically, the outward motion of the solenoids on the same side of the smartphone was set to the same timing, and the motion timing of the solenoids on the left and right sides was shifted by 150 ms. Figures (a) to (d) in Figure 4 show the sequence of the operation. Figure 4a shows that all solenoids are not energized and the all moving parts are extended. Figure 4b shows that the voltage is applied to the two solenoids on the left side, and the movable parts of them are contracted. Figure 4c shows that the right solenoids contract after a delay of 150ms while the left two solenoids are contracted. Figure 4d shows that the solenoids on the right side have contracted while the solenoids on the left side have extended to its original state with no voltage applied. Finally, the right side of the solenoids are also de-energized and return to the state shown in Figure 4a. The sequence of the movements is repeated according to the beat frequency specified by the software.

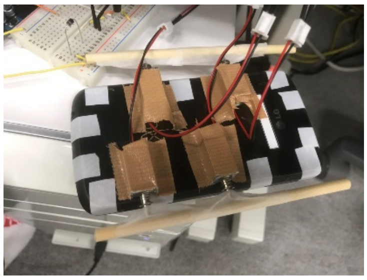

Figure 3: Arrangement of four solenoids and two wooden sticks.

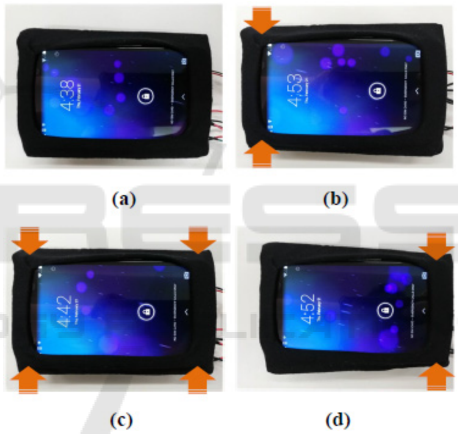

Figure 4: The movement of the pseudo-beat. The left and right solenoids expand and contract synchronously in the order from (a) to (d).

4 EXPERIMENT ON SELECTION OF EMOTIONAL VIDEOS

Before evaluating the effectiveness of our proposed pseudo-beat presentation device, we conducted an experiment to select videos to be presented in the evaluation experiment. In this experiment, we asked viewers to watch candidate videos and assess their emotions on the videos. Based on the results, we selected the videos whose emotional evaluation was far from neutral and whose variation was small among the viewers to evaluate the effectiveness of our proposed system.

4.1 Experimental Stimuli and Participants

We chose four horror videos, four landscape videos, four narrative TV commercial videos, and a roller coaster passenger's view video from YouTube as the videos used in this experiment. The horror videos and the narrative TV commercial videos were separated into some scenes in which we thought the levels of arousal changed within each video, and the participants were asked to assess emotions in the scenes.

Ten male undergraduate or graduate students between the ages from 19 to 23 participated in this experiment. All participants were in the habit of watching videos almost every day.

4.2 Experimental Environment and Procedure

We asked each participant to use his own smartphone for watching the videos. The location and time of viewing were not specified, but were decided freely by each participant. However, we instructed the participants not to use a tablet in order to avoid influence of screen size on their emotions (Hatada et al., 1979). We also instructed the participants to wear earphones or headphones in order to prevent sounds other than the video from coming from outside. Because we wanted the participants to accurately assess emotions of the videos, we instructed them that they could watch the videos multiple times.

We used the Self-Assessment Manikin (Bradley et al., 1994) as a questionnaire for the emotional assessment of each video and scene. The participants were presented with a chart showing nine levels of mannequins for emotional valence and arousal, and were asked to select one of the mannequins that corresponded to levels of emotional valence and arousal of a video or a scene they viewed. We used Google Form for the questionnaire survey.

4.3 Results

All four horror videos showed high arousal with negative emotional valence. The distribution of the responses of all participants in three scenes of one of the horror videos is shown in Figure 5.

Three of the landscape videos and three of the TV commercial videos resulted in lower arousal with positive emotional valence, as shown in Figure 6 and Figure 7, which are representative of one of them.

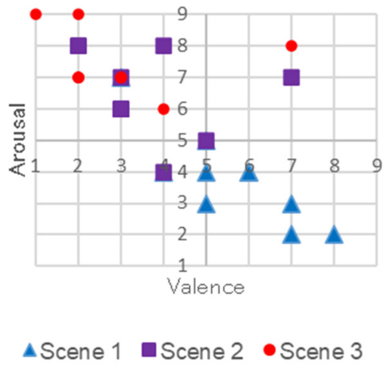

Figure 5: Emotional assessment results of a horror video.

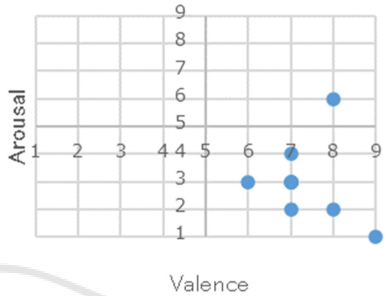

Figure 6: Emotional assessment results of a landscape video.

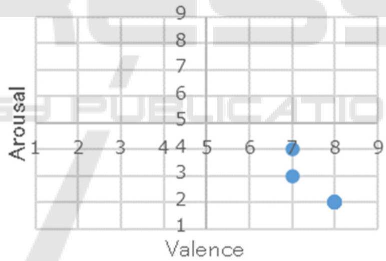

Figure 7: Emotional assessment results of a TV commercial video.

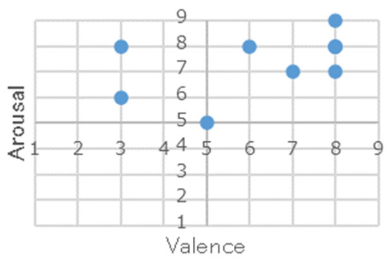

Figure 8: Emotional assessment results of a roller coaster video.

As shown in Figure 8, the video from the perspective of a passenger on a roller coaster had positive emotional valence and high arousal.

Based on the results, we decided to use 10 of the 13 videos to evaluate ours proposed system, excluding the videos whose emotion ratings were neutral in terms of both emotion valence and arousal and the videos whose individual differences were large. In addition, since the tendency of the emotional assessments of the landscape videos and the TV commercial videos was similar, both were classified as landscape videos in the next experiment.

5 EVALUATION EXPERIMENT OF PSEUDO-BEAT PRESENTATION DEVICE

We conducted an experiment to validate whether the use of a pseudo-beat presentation device while watching a video on a smartphone can increase the emotional response of the video viewer.

The independent variable in this experiment is the presence or absence of the pseudo-beat presentation device. The dependent variables are emotional valence, arousal, and dominance values of a video as subjectively evaluated by the viewers based on the three-dimensional emotion model (Lang, 1980) and pulse rate of the viewer's fingertip blood volume pulses (BVPs) as a psychophysiological index.

The participants were 10 male university students aged 19 to 22 years, and the design was a between-subjects design with five participants in the experimental group using the pseudo-beat presentation device and other five participants in the control group not using it. All participants were in the habit of watching videos almost every day.

5.1 Experimental Stimuli

The participants viewed the 10 videos selected in Section 4. Table 1 shows the numbers assigned to the videos, the genre of the videos, and the number of scenes in each video. Table 2 shows the number of beats of the pseudo-beat presentation assigned to each scene and its timing (elapsed time from the start of playback). The pseudo-beats continued to be presented throughout the viewing of the subjects in the experimental group. The number of beats and the timing of the beats were designed by the authors after watching the video scenes, and were pre-programmed into the pseudo-beat presentation system to change according to the contents of the scenes. The beats for the videos from No. 6 to No. 10(in the landscape genre) was kept constant at 60 bpm.

Table 1: Videos as experimental stimuli.

No.	Genre	Num. of scenes and the scene No.
1	Horror	3 (1.1, 1.2, 1.3)
2	Horror	3 (2.1, 2.2, 2.3)
3	Horror	3 (3.1, 3.2, 3.3)
4	Horror	2 (4.1, 4.2)
5	Roller coaster	1
6	Landscape	1
7	Landscape	1
8	Landscape	1
9	Landscape	1
10	Landscape	1

Table 2: Timing and tempo of pseudo-beat changes.

No. of scene	Timing (sec): Num. of beats (bpm)
1.1	0: 60, 36: 67, 50: 60
1.2	0: 60, 14: 67, 20: 75, 25: 67, 36: 85, 42:85, 46: 75
1.3	0: 67, 8: 75, 18: 85, 35: 100, 56: 85, 69: 75, 78: 85, 87: 75
2.1	0: 60, 20: 67, 38: 75
2.2	0: 67, 9: 75, 21: 85, 30: 75, 63: 85, 71: 75
2.3	0: 75, 19: 85, 51: 100
3.1	0: 60, 8: 67
3.2	0: 67, 11: 75, 64: 67
3.3	0: 67, 19: 75, 31: 85, 83: 100
4.1	0: 60
4.2	0: 60, 7: 67, 19: 75, 88: 67, 105: 75, 111: 85, 132: 100
5	0: 60, 5: 67, 15: 75, 23: 85

5.2 Experimental Environment

Figure 9 shows the experimental environment and a participant watching a video. The experiment was conducted in a laboratory with a constant room temperature in order to control the influence of external factors on emotion and BVPs. In addition, the participants were asked to wear headphones in order to avoid the influence of external sounds.

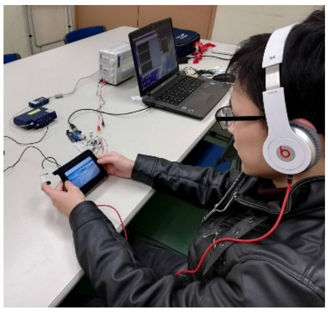

Figure 9: Experimental environment and task.

A Thought Technology's BVP sensor was used as the pulse wave sensor, and was attached to tip of index finger of the participant's non-dominant hand.

The signals of the sensor were recorded on a laptop computer via Thought Technology's ProComp Infiniti System.

5.3 Experimental Procedure

Informed consent was given before start of each participant's experiment.

In conducting the experiment for each participant, the experimenter first explained to a participant how to answer questionnaire survey. As in Section 4, the method of answering the questionnaire was to select one of the nine levels for emotional valence, arousal, and dominance for each scene. After the explanation, the participant was asked to play and stop a practice video for each scene and answer the three components of emotion in the scene as a practice. In between scenes, a slide showing the number of the next scene was displayed for 4 seconds.

Next, the experimenter attached the BVP sensor to the participant, asked him to close his eyes, and recorded his pulse waves during one minute of his normal condition.

After that, the participant repeated the experimental task of watching a scene from all the videos specified in random order and answering the three components of subjective emotion of the scene. At this time, the control group received no feedback on the pseudo-beats, while the experimental group received feedback on the pseudo-beats according to the scene based on Table 2. In the actual implementation, the number of beats and timing of the pseudo-beats were pre-programmed, but as a Wizard of Oz method, each participant of the experimental group was instructed that the beats were a feedback of their own pulses. Although the linkage between emotions and pseudo-beats was not mentioned at all during the experiment, the instruction led the participants of the experimental group to believe that their pulse waves were linked to the movements of the device around the smartphone.

After watching all the videos, the participant answered a question about whether he felt the pseudo-beats were linked to his own pulses or not.

5.4 Results

5.4.1 Questionnaire on Emotion

Figure 10 shows the results of the assessments of the emotional valences of all participants for each scene with and without the presentation of the pseudo-beat. The vertical axis of the graph shows the emotional valence, with 5 being neutral among the nine levels, and the higher the value, the more positive the emotion, and the lower the value, the more negative the emotion. The results of a Wilcoxon rank sum test showed that the difference in emotional valence between the videos with and without pseudo-beats was significantly closer to neutral and the degree of negativity was weaker in the horror videos (No. 1 to 4) ($p < 0.05$). For the roller coaster video (No. 5), it was found that the presentation of the pseudo-beats resulted in a significantly negative response ($p < 0.05$). As a scene-by-scene test, the emotional valences of scenes 1.3 and 3.2 were found to be significantly closer to neutral ($p < 0.05$) when the pseudo-beat was presented.

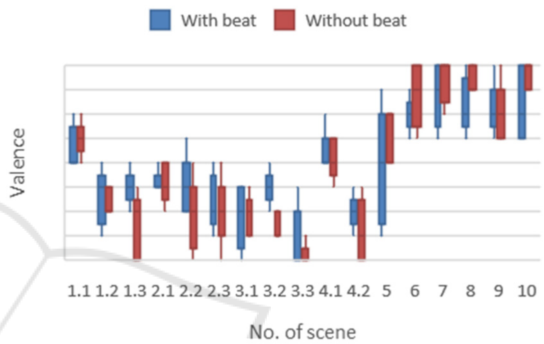

Figure 10: Results of subjective emotional valence.

Figure 11 shows the results of the evaluation of the arousal level of all participants for each scene with and without the presentation of the pseudo-beat. The vertical axis of it shows the level of arousal, with 5 being neutral among the nine levels. The higher the value, the higher the level of arousal, and the lower the value, the lower the level of arousal. As a result, for each scene in the horror movie, some scenes showed an increase in arousal due to the presentation of the pseudo-beats, while others showed a decrease. A Wilcoxon rank sum test was performed on the results of the landscape videos, and it was found that the presentation of the pseudo-beats tended to increase the level of arousal ($p < 0.1$). As a result of the test for each scene, it was found that the presentation of the pseudo-beats tended to increase the level of arousal in scene 2.1 ($p < 0.1$).

Figure 12 shows the results of the dominance of all participants in each scene with and without the pseudo-beat. As in the previous figures, 5 is neutral, and a value lower than 5 indicates less dominance, while a value higher than 5 indicates more dominance. From the figure, it can be seen that the variance of the assessment value becomes smaller when the pseudo-beats were presented in the horror videos (No. 1 to 4). The test of homogeneity of variance showed that the variance was smaller when the pseudo-beats were presented than when they were not presented in scenes 1.1, 1.2, 1.3, 2.1, 3.2, and 4.1. There were no significant differences for the presence or absence of pseudo-beat in any of the scenes.

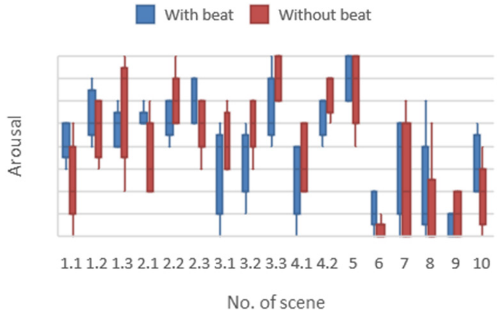

Figure 11: Results of subjective emotional arousal.

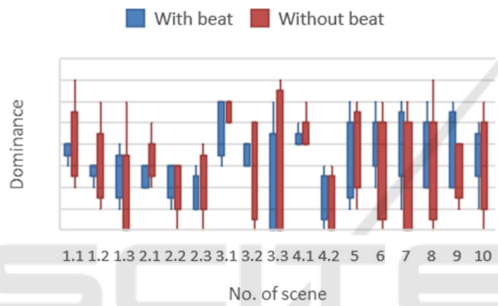

Figure 12: Results of subjective emotional dominance.

5.4.2 BVP

Figure 13 shows the differences between the average pulse rate during normal condition and the average pulse rate while watching each scene for all participants with and without pseudo-beating. Therefore, 0 in this graph indicates that there was no difference from the normal value, and the positive side indicates that the value was higher during the viewing. A Wilcoxon rank sum test was used to test the difference in pulse rate between those with and without the pseudo-beats. The results showed that the pulse rate was significantly higher when the pseudo-beats were presented than when they were not.

About the question, “Did the pseudo-beats feel like your own pulses?,” three out of five participants of the experimental group answered that they felt it. Figure 14 shows the pulse differences between the three who answered that they felt their own pulse, and Figure 15 shows the pulse differences between the two who answered that they did not feel them. As can be seen from these graphs, the pulse rates of the three participants who felt that the pseudo-pulses were their own pulses were higher than normal, while the pulse rates of the two participants who did not feel them were lower than normal.

6 DISCUSSIONS

The results of the questionnaire on emotional valence show that the experimental group’s rating values were closer to neutral than those of the control group. This suggests that the pseudo-beat had the effect of reducing the amplitude of the emotional valence. This may be due to the fact that the beating interfered with the viewer’s concentration on the video contents.

The results of the questionnaire on arousal show that when pseudo-beats are presented, the level of arousal tends to be higher or lower depending on the scene in horror videos. The scenes with a lower level of arousal were 1.3, 2.2, 3.1, 3.2, 3.3, 4.1, and 4.2. Among them, the surprising scenes where something suddenly appears with a loud sound are 1.3, 2.2, 3.2, 3.3, and 4.2. This indicates that the proposed system is not effective enough to further increase level of arousal in such a scene where the level suddenly increases. A reason for the result may be that the beating was always given in this experiment and the changes in heart rate were discrete. In this experiment, the beating was always given to the experimental group because the difference between the two groups was investigated. However, in actual use, we believe that the effect of the beating can be more clearly shown by setting a scene in which the beating is presented and another scene in which it is not presented at all. Additionally, in a future improvement, based on physiological findings, we are considering a continuous gradual increase and decrease of the heart rate according to a scene and an actual heart rate of a viewer. Since the presentation of pseudo-beats tends to increase arousal in scenes with gradual changes in arousal, such as landscape videos, it is expected to be effective in increasing arousal in videos with gradual changes in arousal.

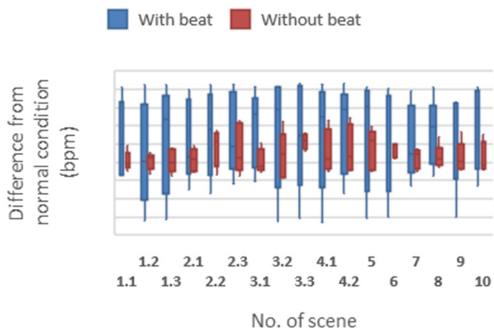

Figure 13: Results of difference in heart rates from normal.

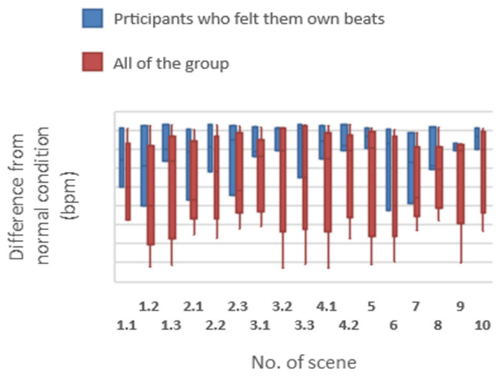

Figure 14: Differences in heart rates of participants who felt the pseudo-beats as their own pulses.

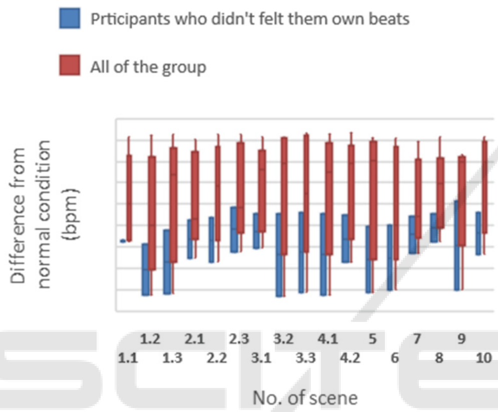

Figure 15: Differences in heart rates of participants who did not feel the pseudo-beat as their own pulses.

The results of the questionnaire survey on dominance show that the variance of the evaluation value becomes smaller when the pseudo-beat is presented. The reason for this is that the same pseudo-beats were presented to the participants in the experimental group at the same timing, suggests that the presentation of pseudo-beats may cause viewers to be more synchronized to the assessments of the dominances. On the other hand, there was almost no difference in the bias of the dominance assessment values between the experimental group and the control group, indicates that the presentation of the pseudo-beats did not have any effect on reversing the dominance.

The results of the BVP analyses show that when viewers feel the pseudo-beat as their own pulses, their pulse rate increases. Therefore, if we can make the pseudo-beats feel more like their own pulse in terms of movement and period, we think that the system will be able to intentionally influence or intentionally control the physiological responses of viewers. To meet the new challenge, we are planning to link actual pulse waves of a viewer to the pseudo-beat as a future improvement. Specifically, we will design a system that acquires pulse waves and heart rate from a smartwatch or similar device while watching a video, passes them through a Psychophysiological effector to generate intended pseudo-pulse waves, and then reflects them to the pseudo-pulse presentation device. In addition, we will implement the loop that acquires and evaluates changes in viewer's pulse waves and heart rate during presentation of the pseudo-beats, and adjusts them to move toward the more intended changes.

7 CONCLUSIONS

In this study, we aimed to control viewer's emotion by presenting visual and tactile pseudo-beats around a smartphone during video viewing. For the purpose, we attached four solenoids to a smartphone and moved them as if they were beating of a human heart, and set their beating cycles according to contents of a video.

Using the device, we conducted an experiment in which participants in the experimental group were asked to experience pseudo-beats while watching horror, roller coaster, and landscape videos, and were compared to the control group in which no pseudo-beats were presented. The results of the questionnaire survey showed that neither emotional valence, arousal, nor dominance were generally raised or lowered by the pseudo-beats, but there was a tendency for them to be raised or lowered depending on the scene of the video.

On the other hand, physiological BVPs showed that the heart rate was significantly higher in the experimental group in which the pseudo-beat was presented than in the control group in which it was not presented. In particular, the heart rates of the participants who felt that the pseudo-beats were their own pulses were higher than normal conditions of them.

Based on the results, we conclude that while the presentation of pseudo-beats using the proposed system has an effect on the physiological pulse waves, it does not have a strong effect on the subjective emotional assessments. However, since physiological and psychological findings indicate that changes in physiological responses may influence psychological responses (Stuart, 1966), we will improve our system to provide intended influence on subjective emotions as well.

In our future research, we will implement a function to link the pseudo-beat presentation device to actual pulse waves of a video viewer. Specifically, we plan to implement a data logger that acquires pulse waves from the viewer's smartwatch during video viewing, an effector that intentionally increases or suppresses the emotions in the video content, an analyser that automatically calculates the emotional valence, arousal, and dominance from the video and audio of each scene, and a synthesizer that controls the pseudo-beat presentation device according to the results of the analyser and the effector, and conduct the same evaluation experiments as in this paper. Furthermore, as a long-term experiment, we plan to investigate effects on emotions during initial use and after long-term use, and to validate temporal changes in habituation to our proposed device.

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