Physiological and Psychological Effects of Light-Emitting Chair in Synchronization with Heartbeat Rhythm

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ABSTRACT

In this study, we aim to develop a light-emitting chair in synchronization with heartbeat rhythm. The design of environment through a variety of means such as lighting and colors can stimulate perceptual and emotional responses. Interoception is the ability to sense the internal state of the body and includes the perception of physical sensations related to internal organ function such as heart beat. The increase of interoceptive sensitivity can lead to emotion inductions. We therefore propose and discuss a novel approach to bring a feeling of relaxation by using a light-emitting chair.

1. INTRODUCTION

In color psychology, colors in surroundings can affect human emotional states and behavioral responses. It has been broadly discussed that colors can cause certain psychological, physical, biological and metabolic reactions within humans. The design of an environment through a variety of means such as lighting and colors can stimulate perceptual and emotional responses [1].

Interoception is the ability to sense the internal state of the body and includes the perception of physical sensations related to internal organ function such as heart beat, respiration, as well as the autonomic nervous system (ANS) activity related to emotions. In the previous works [2,3], it can be assumed that the awareness of individual's bodily change is linked to the awareness of one's emotional state and the cognitive processes. However, this differs from the general association of physical changes and their perception as the basis of emotional experience. It is hypothesized that the sensitivity for one's bodily internal state promotes the ability of self-regulation to detect bodily changes more accurately and manage one's emotions. This concept can be related to the embodiment theory.

This paper presents a chair with an internal light source that emits light in synchronization with heartbeat rhythm. The pneumatic pressure sensor inserted into a cushion on the chair is used for detecting the ballistocardiograph (BCG) signal caused by human body movement cyclically arising from the ejection of blood into the great vessels with each heartbeat. Without any wearable device, the measurement system gathers the time-series data of the involuntary movement and the ANS activity. Moreover, we propose a fuzzy spiking neural network to extract heartbeat signal from the measured data. We furthermore investigated the effects of the developed light-emitting chair on physiological and psychological states.

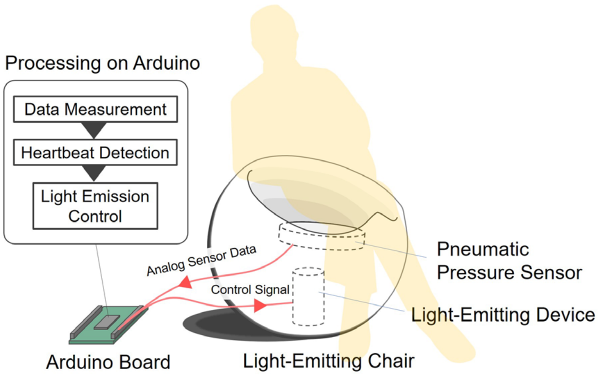

Fig. 1 System Architecture

Fig. 2 Light-Emitting Chair

2. Light-Emitting Chair

2.1 System Architecture

Figure 1 depicts the system architecture. The light-emitting chair is composed of two parts: heartbeat detection and light emitting control. In the heartbeat detection, a pneumatic pressure sensor is used. The measured data is transferred to a microcontroller board. The light-emitting is controlled by the microcontroller in synchronization with heartbeat signal. Figure 2 shows an example of the light emission. In this study, we use this developed system to encourage interoception awareness that can be characterized as the ability to perceive one's heartbeats accurately.

2.2 Heartbeat Detection

In this study, the measurement system with a pneumatic pressure sensor developed by NEW SENSOR Inc. is utilized for heart rate variability analysis. The pneumatic pressure sensor is embedded in a cushion on the chair as shown in Fig.1. The measurement system is based on the ballistocardiography (BCG) principle. Ballistocardiography is a non-invasive methodology for recording body movement occurring due to the contractions of the heart to pump the blood. The system consists of a pneumatic pressure sensor and rubber tube covered with polypropylene sheets. The inner pressure varying with the compression and expansion of the tube caused by the heart's recoil is detected by the pressure sensor. The sampling interval for the measurement is 2 ms. The sensor output is converted to a digital output, the data range of which is 0-1023, by using Arduino board.

Furthermore, we proposed a method of heartbeat detection with spiking neural network (SNN) that is composed of five neurons with the pulse neuron model for simulating heartbeat signal [4]. The neural network has a recurrent architecture consisting of input layer and output layer. The values of the weight parameters in each layer are empirically optimized by using a genetic algorithm. The SNN can produce the spike outputs corresponding to actual heartbeats. With the small computational complexity of the optimized neural network, we can realize the heart detection embedded in the measurement system.

3. EXPERIMENTAL RESULT

In this experiment, we investigated the physiological and psychological effects of the proposed system, comparing the developed chair between in and out of synchronization with heartbeat rhythm. Here the comparison emits light at even time intervals (1 [Hz]), regardless of detected heartbeat signals. The subjects consist of 8 male university students. We split them into two groups. Each subject was required to sit on the chair for 180 [s] and answer a questionnaire. We used a semantic differential scale to evaluate the effect on their emotional states. Furthermore, we investigated the color effect on individual's emotion and feeling, comparing between red and blue light emitting.

First, Fig.3 shows a comparative result between red and blue-colored light. From the results, the blue light promoted a feeling of relaxation and comfort more effectively than the red light. This means that the colored lights can affect the emotional valence depending on the contexts represented by the color change. Next, Fig.4 shows a result of comparing the systems between in and out of synchronization with heartbeat rhythm. In the figure, the subjects that faced the visual feedback synchronized with their heartbeats have more strong emotional reactions. We therefore assume that the feedback can increase individual's interoceptive sensitivity and emphasize the feelings.

4. SUMMARY

This paper presented a study to investigate the physiological and psychological effects of light-emitting chair. In this study, we developed a light-emitting chair that can emit light in synchronization with heartbeat rhythm, using pneumatic pressure sensor for heartbeat detection. To detect the heartbeat, we applied a fuzzy spiking neural network as a pulse oscillator to generate the simulated heartbeat signal. Furthermore, we conducted some comparative experiments to discuss the applicability of the proposed approach.

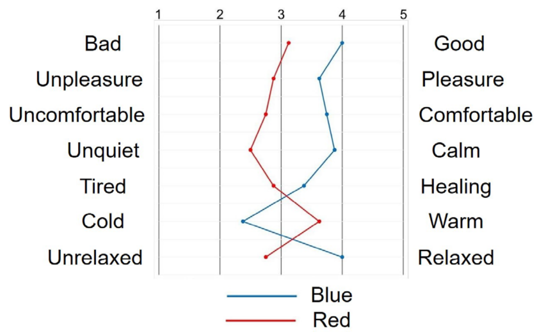

Fig. 3 Comparative Result between Red and Blue-Colored Light

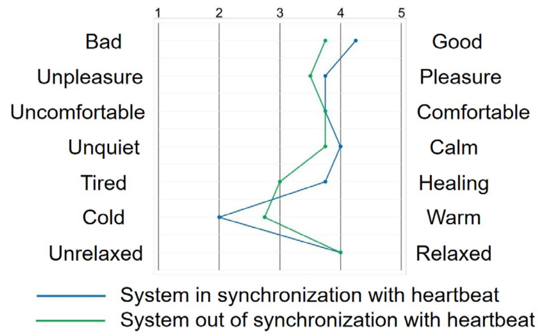

Fig. 4 Result of Comparing Systems between in and out of Synchronization with Heartbeat Rhythm

As future works, we intend to conduct some additional experiments to discuss a method of light emitting and colors to bring and encourage a feeling of relaxation. Moreover, we will develop a multi light-emitting chair system to work on a study of emotional contagion.

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