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ORIGINAL ARTICLE

Differences of Psychological and Physiological Responses between Mono- and Multi-sensory Information on Clothing Pressure Sensation

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Abstract: The purpose of our study is to investigate the effect of clothing pressure on physiological and psychological responses in order to create a method for evaluation of clothing comfort. We get much information through visual sensation, so studies on the influences of visual information on clothing pressure sensation is very important. In this paper, we have measured physiological and psychological responses in the clothing pressure sensation under 3 visual conditions; Condition 1 was that the subjects had their eyes open and looked forward, Condition 2 was that the subjects looked at themselves in a mirror, and Condition 3 was that the subjects without a waist belt look at other subjects who wore a fastened waist belt. We concluded that it is important to consider the effects of visual information as well as the effect of clothing pressure sensation in the evaluation of clothing comfort sensation.

Keywords: *Clothing pressure sensation, Visual sensation, Multisensory*

1. INTRODUCTION

The purpose of this study is to quantitatively clarify clothing pressure sensation by measuring the physiological and psychological responses when the information of clothing pressure fastened with waist belt is received from visual and pressure sensations in order to confirm the necessity of assessing clothing comfort from the viewpoint of multisensory integration.

Normally, we perceive and recognize clothing comfort not with a single organ but with multisensory integration. Clothing comfort can refer to feelings of a number of aspects, such as thermal comfort, tactile comfort, body-fit comfort, and esthetic comfort. This suggests that clothing comfort is multisensory and involves complex processes in which a large amount of information from clothing and external environments is communicated to the brain through multiple channels of sensory responses to form subject perceptions.

There are many reports about the multisensory integration [1-3]. For example, a typical is the McGurk effect in which a pronunciation is heard as “da” when the actual pronunciation of “ba” is synchronized with seeing the movement of the lips when pronouncing“ga” [4]. It is assumed that integrating information from various sensory organs generates a new perception which differs from the perception of a single organ.

There are few reports related to multisensory integration regarding evaluation of clothing comfort. We have reported that the physiological and psychological responses due to the clothing pressure was different in the states of closed eyes versus open eyes when we evaluated the sensation of pressure on the abdomen from a waist belt. That is, the physiological and psychological responses were different for the stimulation presentation that combined the sense of pressure with visual stimulus and the stimulation presentation of only the sense of pressure [5, 6]. In this paper, based on these results, we measured physiological and psychological responses to the stimulation presentation combining pressure sensation and visual sensation to evaluate clothing comfort from the viewpoint of multisensory integration.

Experiments for this research were conducted with the approval of Shinshu University’s Ethical Committee for Research on Humans.

2. EXPERIMENTALS

2.1 Experiment Method

The experiment to investigate the difference in psychological and physiological responses to mono-sensory information and to multi-sensory information was carried out under the following three conditions: clothing pressure stimulus by pressure sensation [Pressure sensation], clothing pressure stimulus by pressure and visual sensations [Pressure + Visual sensations], and clothing pressure stimulus by visual sensation [Visual sensation]. Figure 1 shows the three experimental conditions.

Pressure amounting to 90% of the subjects’ waist size was applied to their abdominal region by a waist belt. Assuming normal clothing pressure in daily life, the waist

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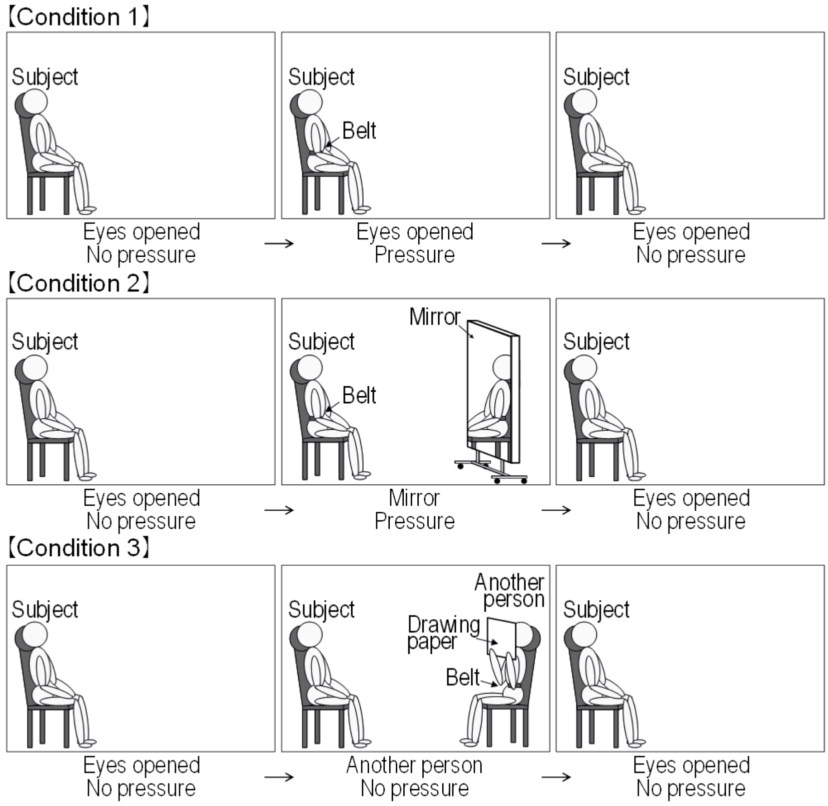

Figure 1: Experimental conditions

belt used in this study was of a non-elastic material and 4 centimeters in width. The clothing pressure stimulus that all subjects feel the tightness was decided based on Horiba et al.'s study [7].

We measured physiological and psychological responses in the clothing pressure sensation under three visual conditions; Condition 1 was that the subjects had their eyes open and looked forward, Condition 2 was that the subjects looked at themselves in a mirror, and Condition 3 was that the subjects without a waist belt look at other subjects who wore a fastened waist belt.

Figure 2 shows an experimental procedure. The procedure was repeated three times, once for each of the three experimental conditions. The break between conditions was 5 minutes. The three experimental conditions were carried out in random order to offset an order effect.

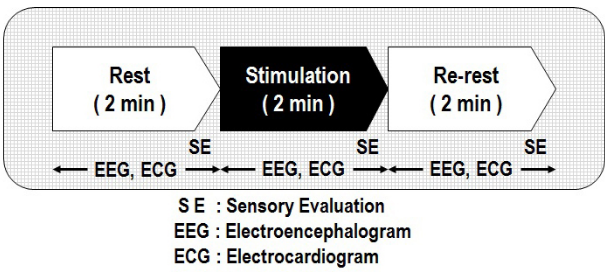

Figure 2: Experimental procedure

The influence of clothing pressure on mental and physical response was evaluated by the following measurements: electrocardiogram (ECG), electroencephalogram (EEG) and sensory evaluation. 10 healthy subjects were recruited, 6 males with ages of 22.0 ± 0.6 years old, waist sizes of 75.4 ± 11.3 centimeters and Body Mass Indexes (BMI) of 21.1 ± 4.8 kg/m^2, and 4 females with ages of 21.8 ± 1.0 years old, waist sizes of 72.6 ± 7.5 centimeters and BMI of 21.4 ± 2.7 kg/m^2. The subjects were prohibited from eating, drinking and smoking for two hours before the experiment started. All subjects were required to wear underwear, a short-sleeved shirt, and short pants. Atmospheric conditions in the room were maintained at a temperature of 25°C and a relative humidity of 60%. During the recording procedure subjects were seating in a reclining chair to maintain their posture. As shown in Figure 2, ECG and EEG were recorded for 6 minutes in total including rest state (2 minutes), stimulation state (2 minutes) and re-rest state (2 minutes). Sensory evaluation was carried out three times, once each in rest state, stimulation state and re-rest state.

2.2 Measurement

EEG was recorded from 4 Ag/AgCl electrodes (Central: C3, C4 and Parietal: P3, P4) located according to the

International 10-20 system. Ground electrodes were positioned on both ear lobes. ECG was measured in the limb leads. EEG and ECG were measured by the system of MP150WS (BIOPAC SYSTEMS, Inc.) with 200Hz sample frequency. The semantic differential (SD) method was used in rating subjective perception. Subjects were asked to rate the sensations of comfort, tightness and arousal on a 7-point equal-interval ordinal scale (+3 = feel extremely; +2 = feel very much; +1 = feel slightly; 0 = neither; -1 = don't feel slightly; -2 = don't feel very much; -3 = don't feel extremely).

2.3 Analysis

Brain wave data for 12 seconds immediately before and after measurements were eliminated to prevent the introduction of noise. We removed the trend of the brain waves, and then a 32Hz low-pass filter was applied to the sectioned EEG. The brain waves was processed by FFT with Hamming function to calculate the power spectrum for each frequency which were grouped into the theta ($4 \leq f < 8$Hz), alpha ($8 \leq f < 13$Hz), and beta ($13 \leq f < 30$Hz) frequency bands. Generally, there are many individual variations in power spectrums, so the values were standardized by calculating the rate of each wave to the sum of theta, alpha and beta as follows:

$$\theta_1 = \theta / (\theta + \alpha + \beta) \quad (1)$$

$$\alpha_1 = \alpha / (\theta + \alpha + \beta) \quad (2)$$

$$\beta_1 = \beta / (\theta + \alpha + \beta) \quad (3)$$

We removed the trend of ECG, and then a bandpass filter with a bandwidth of 5-40 Hz was applied. The ECG data for 5 seconds immediately before and after measurement were eliminated to prevent the introduction of noise. For analysis of the autonomic nerve system, the ECG data were processed by spectral analysis of heart rate variability [8-10]. After R-wave peaks were detected, RR interval time-series data were determined. The RR interval data were processed by spline interpolation, and a heart rate variability spectrum was calculated by FFT with Hamming window. Frequency ranges were as follows: low-frequency (LF):0.04-0.15Hz and high-frequency (HF):0.15-0.40Hz. LF/HF ratio was calculated as an index of sympathetic nerve system activity. HF/(LF+HF) ratio was also calculated as an index of parasympathetic nerve system activity.

All statistical analysis of measurement data was performed using the Excel statistical software package (Excel-Toukei 2010; Social Survey Research Information Co., Ltd.). The data were analyzed by the Bonferroni multiple comparison test.

3. RESULTS AND DISCUSSION

3.1 Autonomic Nerve Activity

The results for the sympathetic nerve activity are shown in Figure 3. In addition, error bars in this paper indicate standard deviation. In all three conditions, LF/HF decreased in the stimulation period. LF/HF decreased also in Condition 3 where the information of clothing pressure was added through only visual sensation. There were significant decreases in both Condition 1 and Condition 2 ($p<0.01$). In addition, there was no significant difference between Conditions 1 and 2 in the stimulation period. The results in Condition 2 with both pressure and visual sensations were similar to those in Condition 1 with only a sensation of pressure. It is considered that the results were due to the appearance of the physiological response for the pressure sensation stimulation that was common to these two conditions. Moreover, in the re-rest period, the values in Condition 2 were significantly higher than those in Condition 1 and Condition 3. The increase is considered to be due to the counteraction by release from the stimulation that was input through both visual and pressure sensations.

The results for the parasympathetic nerve activity are shown in Figure 4. In all three conditions, HF/(LF+HF) increased in the stimulation period. It is presumed that the accentuation of parasympathetic nerve activity was based on the homeostatic-maintaining mechanism that regards a change from a steady-state as stress [5, 6]. There were significant increases in both Condition 1 and Condition 2 ($p<0.01$). In addition, there was no significant difference between Conditions 1 and 2 in the stimulation period. The results in Condition 2 with both pressure and visual sensations were similar to those in Condition1 with only a sensation of pressure. It is considered that the results were due to appearance of the physiological response for the pressure sensation stimulation that was common to these

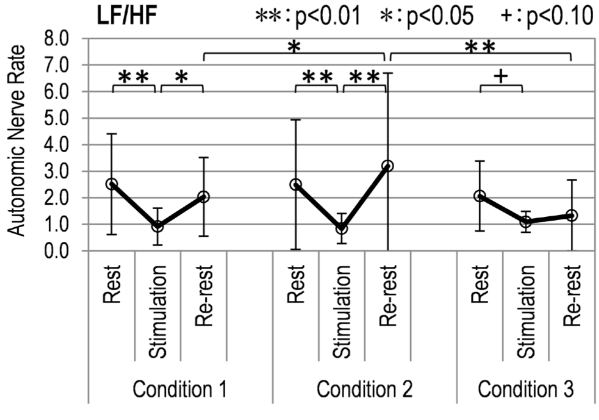

Figure 3: Sympathetic nerve activity

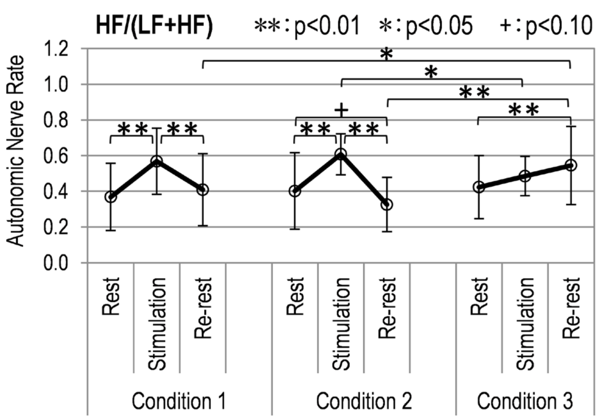

Figure 4: Parasympathetic nerve activity

two conditions. Further, the results in Condition 2 in the stimulation period were significantly higher than the values in Condition 1. It is considered that the information of clothing pressure from not only visual sensation but also pressure sensation caused HF/(LF+HF) to increase.

3.2 Brain Activity

The results for the brain activity are shown in Figure 5. In Condition 1 under clothing pressure information by only pressure sensation without visual sensation, there were no significant changes in theta, alpha and beta waves. On the other hand, in both Condition 2 and Condition 3 under clothing pressure information through visual sensation, the alpha waves increased significantly in the re-rest period. The theta waves in Condition 2 increased significantly in the stimulation period, and decreased significantly in the re-rest period. For beta waves, there were no significant changes in all three conditions. The above results would suggest that the brain activity is affected by the information of clothing pressure through visual sensation.

3.3 Sensory Evaluation

The results for the sensory evaluation are shown in Figure 6. In all three conditions, when the stimulation is applied, comfort feeling decreased and tightness and arousal feelings increased. The pressure sensation increased significantly when only clothing pressure information from visual sensation in Condition 3 is presented as stimulation. It decreased significantly in the re-rest period. These results mean that visual information that another person has received clothing pressure affected the subject's own psychological response. In Condition 2, the score of tightness feeling in the re-rest period was higher than in the rest period. We guess that the reason for this result is that stimulation from both pressure sensation and visual sensation hindered recovery from the mental stress of clothing pressure.

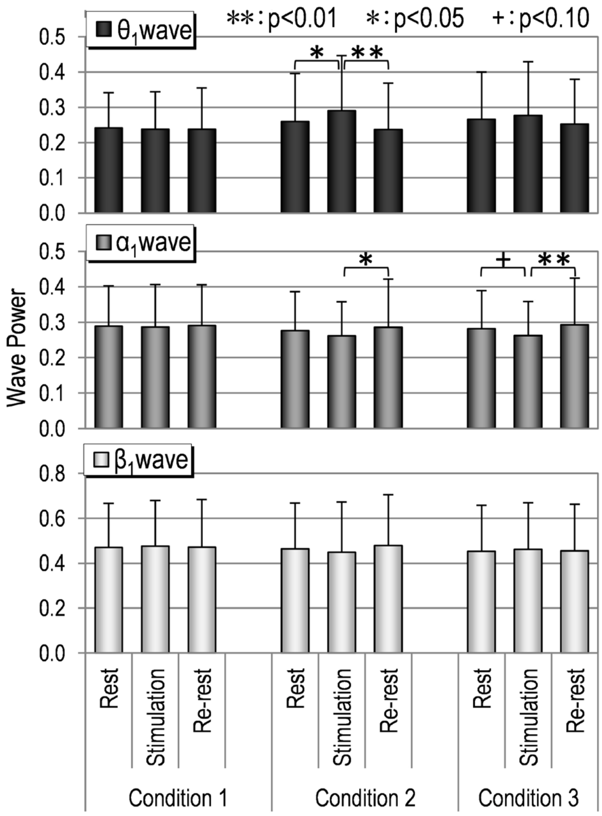

Figure 5: Brain activity

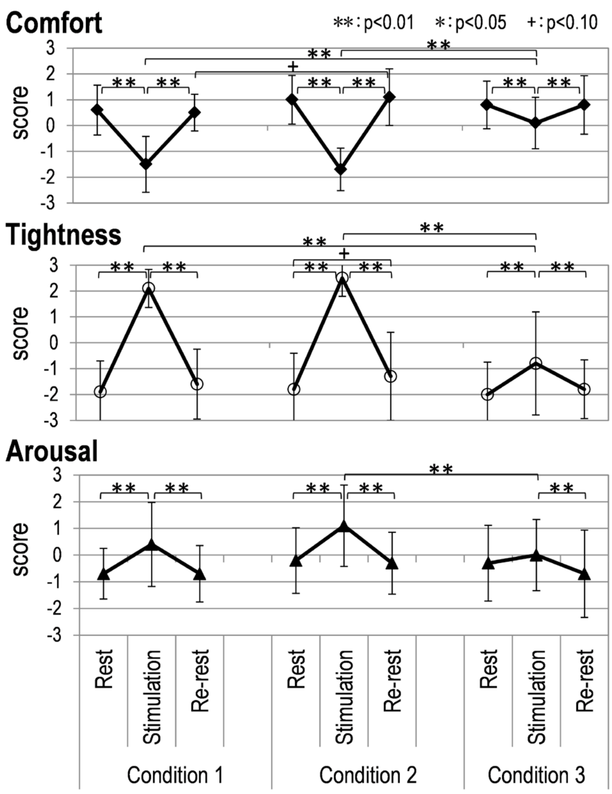

Figure 6: Results of sensory evaluation

4. CONCLUSIONS

We investigated the differences of psychological and physiological responses between mono-sensory information and multi-sensory information regarding about clothing pressure.

For autonomic nerve activity, the change tendency in the state of seeing other subjects who wore a fastened waist belt was similar to the tendencies both in the state of wearing a fastened waist belt and in the state of seeing such posture in a mirror. Further, in the experimental condition that clothing pressure information was input through senses of both pressure and visual, there was the reactionary response that autonomic nerve activity in the re-rest period exceeds the activity in the rest period. It is inferred that the response to pressure stimulation was larger than the response to visual stimulation.

For sensory evaluation, it was shown that clothing pressure information through visual sensation increased the score of the tightness feeling. Moreover, it was suggested that the stimulation from both pressure sensation and visual sensation hindered recovery from the mental stress caused by clothing pressure.

In the state of clothing pressure information by only pressure sensation, there were no significant changes in all four brainwave regions. On the other hand, in the state of clothing pressure information by visual sensation, we confirmed a significant decrease in the alpha wave and a significant increase in the theta wave.

The above results would suggest that the information of clothing pressure through visual sensation influenced psychological and physiological responses. Further, it was shown that the physiological response when the clothing pressure information was input from both pressure sensation and visual sensation was not a simple reaction, such as the average or sum of the respective responses when the information was input from a single sensation. These results are considered to be due to the appearance of the physiology response to a relatively strong stimulus in the mechanism of multisensory integration. It seems that there is no absolute advantage between senses. We think that the new physiology responses were caused by multisensory integration. Therefore, clothing comfort sensation might, in near future, need to be evaluated by taking into consideration multisensory integration to all stimuli such as clothing pressure, temperature property, tactile property, appearance, odor, and rustling of clothes. Further work will be needed to investigate the differences in sex or physical constitution.

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