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Simple Stress Quantitative Evaluation for Healthcare Using Daily KANSEI Detection with EEG Device — Relation Between Stress and Healthcare

Yasue Mitsukura[1], Brian Sumali[1], Takahiro Asano[1], Hideto Watanabe[1], Yuuki Tazawa[2], Taishiro Kishimoto[2], Koichi Fukunaga[2], and Masaru Mimura[2]

1. Department of System & Design Engineering, KEIO University, Japan

2. Department of Neuropsychiatry Keio University School of Medicine Tokyo, Japan

Abstract: In the Global Smart Society, we have many research themes such as smart architecture, smart grid, human-based network and information technologies including the collaboration with many countries. In the case of my researches, we focus on the human stress for the purpose of smart life on the super mature society. Many services that take personal preference into consideration have been provided in recent times. Hence, the process of the determination of personal preference, which was pioneered in Japan and is locally known as KANSEI, has been actively studied. Whereas sensitivity is generally inborn, KANSEI is considered to be a postnatal attribute. There are subjective and objective indexes in the method for determining personal preference. A subjective index is obtained by a questionnaire, whereas an objective index is determined by a bio-signal. In addition, an objective index can be quantified, which enables an objective and engineered approach. Incidentally, there have been many propositions regarding the relationship between an electroencephalograph (EEG) signal and the preference determined by KANSEI in the analysis of a bio-signals. The propositions are based on the idea that "the state of the brain should change if the state of the person changes because the brain governs the mind, consciousness, recognition, and senses", as well as other ideas. EEG is one of the bio-signals used as indexes for determining preference in the present study. On the basis of our study, we propose various preference measurement systems for the olfactory sense, acoustic sense, haptic sense, taste sense, and visual sense (generally referred to as the five senses) as well as for a combination of the acoustic and visual senses. In this study, we introduce the procedure for measuring the EEG and describe the analysis method. We also describe a sample application of the developed preference measurement systems, namely, "KANSEI analyzer".

Key words: stress detection, stress quantitative evaluation, healthcare, KANSEI

1. Introduction

An EEG is an electrical signal produced by the activity of the cerebral cortex. It enables flexible and noninvasive measurement of human brain activity with a high temporal resolution. It is well known that the EEG changes in accordance with the mental condition, cerebration, and emotion, and the measurement point is defined by the international 10-20 system. An EEG is generally measured on the basis of this system using multiple electrodes. However, there are some problems associated with the process. For example, more than 30 min is required to position the electrodes. In addition, the subject needs to use a gel as an electrolyte, and this can be stressful. This makes multiple-electrode EEG devices burdensome. We therefore present a simple EEG device that was developed in our collaboration. The EEG is easier to set up and its looseness makes it less stressful to the subject. Moreover, the proposed device measures the EEG activity at Fp1 (left frontal lobe) of the international 10-20 system (Fig. 1), using a

Corresponding author: Yasue Mitsukura, Professor; research areas/interests: bio-signal processing, medical engineering. E-mail: mitsukura@keio.jp.

sampling frequency of 128 Hz. The hair at this measurement point produces very little noise. Furthermore, changes in the EEG mainly occur in the prefrontal area. The simple EEG device is thus considered as being appropriate for EEG measurement to estimate human preference. In addition, the measurement method involves referential recording, wherein the reference electrode is placed on the left ear lobe and the exploring electrode is placed at Fp1. In this paper, we design the stress quantitative detection system using only EEG, and apply the proposed device to a real environment for obtaining every day's life log as a health care.

In the previous study, we have researched the stresss detection using the simple device and made the real product named KANSEI Analyzer (Fig. 2). KANSEI analyzer detect human's 5 moods, stress, concentration, like, calm, and interest levels as an online manner. This is the first technique of real time moods detection system. Stress detection is very important for us to make our daily life well [1].

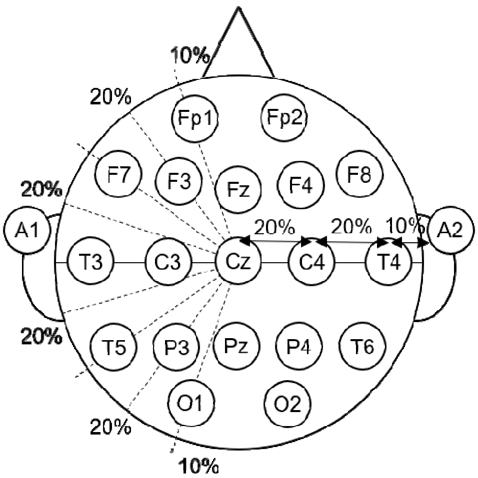

Fig. 1 International 10-20 method.

Fig. 2 KANSEI Analyzer (DENTSU science JAM [3, 4]).

This KANSEI analyzer is the simple device, it takes 10 seconds for ready to measure the moods. It enable us to measure every time everywhere. By using this device, we investing the relationship between human calmness and the living environment, i.e., every day exercise, living and bathroom temperature, and so on. This technique is very important for us to make not only our health but also our mental health [2]. We analyze 2-types analysis and discussions. First one is to analyze the evaluation of the simple exercise. Second one is to evaluate the difference in brain functions of those who live in cold houses and those who live in warm houses.

2. About Simple EEG Device

This study employed a simple band-type EEG developed by the Dentsu Science JAM co. Ltd [3, 4]. Fig. 2 shows the EEG device which our used. The conventional EEG is expensive, large, and cannot be used in a natural environment. The physical features of the device make its use burdensome to the subject. In contrast, the EGG used in the present study is compact, measuring 120 mm (W) × 135 mm (D) × 35 mm (H), which makes it less burdensome to the subject. It can also be used in a natural environment. The electrode is fixed to the headband and is positioned at Fp1 of the international 10-20 system, which is shown in Fig. 1. Discrete time data are obtained and the EEG measurement is analyzed every second at a frequency of 24 Hz using 1 Hz intervals. A band filter between 4 and 22 Hz is employed, together with a time series data of each frequency component between 4 and 22 Hz.

Fig. 3 Our proposed simple EEG device.

The EEG device in Fig. 4 is of the conventional type, which requires a long time to wear.

The conventional device in the left picture requires 45 min to wear, and that in the right picture requires about 30 min. In contrast, our simple EEG device requires only 30 s to wear. It has only one electrode, which makes it easy to wear. The advantages of our device are as follows:

- Reduced number of electrodes.
- Does not require a gel to be worn.
- The subject can easily wear it by himself or herself at anytime and anywhere.

3. Analysis of the EEG

EEG is an electrical signal produced by the activity of the cerebral cortex. It enables flexible and noninvasive measurement of human brain activity with a high temporal resolution. It is well known that EEG changes in accordance with the mental condition, cerebration, and emotion, and the measurement point is defined by the international 10-20 system. EEG is generally measured based on this system using multiple electrodes. However, there are some problems associated with the process. For example, more than 30 min is required to position the electrodes. In addition, the subject needs to use a gel as an electrolyte, and this can be stressful. This makes multiple-electrode EEG burdensome. We therefore present a simple EEG device that was developed in our collaboration. The electroencephalograph is easier to wear and its looseness makes it less stressful to the subject. Moreover, the proposed device measures the EEG activity at Fp1 (left frontal lobe) of the international 10-20 system, using a sampling frequency of 128 Hz. The hair at this measurement point produces very little noise. Furthermore, changes in the EEG mainly occur in the prefrontal area. The simple EEG device is thus considered as being appropriate for EEG measurement to estimate human preference. In addition, the measurement method involves referential recording, wherein the reference electrode is placed on the left ear lobe and the exploring electrode is placed at Fp1. The EEG data is analyzed every second by a fast Fourier transform, and the amplitude spectra can be obtained in the frequency range of 1-64 Hz.

Fig. 4 Conventional EEG devices.

4. Pre-processing for Noise, Data Mining, and Pattern Recognition

Pre-processing is used to enable detection of the EEG. The available methods include FA [5], ICA, PCA, and multiple regression. The data obtained from the pre-processing are then mined using a stochastic method such as incremental PCA, FLDA, SPCA, AMUSE, or SFLDA. The pattern recognition method is subsequently applied to the adopted system. The procedure is illustrated in Fig. 5.

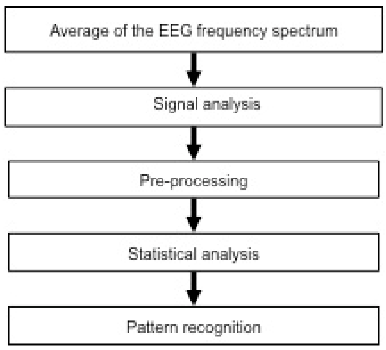

Fig. 5 Principle of the proposed method.

4.1 Experiment 1

In this research, in order to measure the relationship between the daily stress and the thermal environment of the house, first, paying attention to the thermal environment of the house and the stress reduction degree, an experiment protocol was constructed as follows:

Step1: [0-1(min.)] EEG measuring

Step2: [1-6(min.)] Exercise with Task

Step3: [6-7(min.)] EEG measuring.

In this protocol, stress in normal and after exercise is detected by electroencephalogram measurement, and the degree of stress relief is detected by comparison between before and after. Dual task walking was used as exercise here. Dual task walking is "to walk while saying the three numbers that flowed in reverse.Temperature measurement of the subjects' houses was conducted in November and the temperature of the total of 6 locations including the living room rack position, the living room floor, the bedroom shelf position, the bedroom floor, the clothing room, and the bed were measured. Here, the temperature measurement was carried out using an Otori Jr (T & D Co.). As shown in Table 1, the temperature inside the house varies depending on households. In the dressing room, the average was 13.5°C, but the difference was 7°C, the maximum was 18.0°C, the minimum was 10.7°C. Such a difference in the temperature inside the house depends on the insulation performance of the house itself and the performance of heating, so it is difficult to be conscious unless you compare it with other houses.

4.1.1 Subjects

Subjects are 59 peoples (40-80 years) who live in Yusuhara-cho in Kochi Prefecture in Japan. 42.3% of the population of Yusuhara-cho is the elderly.

Table 1 Temperature by location in residential area.

°C	Living	Floor	Bedroom	Bedfloor	Dressingroom	In bed
Ave.	16.2	14.9	14.3	13.7	13.5	17.7
Max.	23.2	18.7	19.8	17.3	18.0	23.5
Min.	11.2	12.1	11.3	10.6	10.7	12.8

4.1.2 Results

Analysis based on the sample data of 60 seconds stress level obtained from electroencephalogram analysis revealed that the average stress level before exercise was 38.3% and the average after exercise was 27.5% and therefore decreased by 10.8% confirmed.

By t test, $p < 0.05$ was obtained and significant difference was confirmed. From these results, it was shown that stress is reduced by exercising with a double task. Next, we describe the relationship between the thermal environment of housing and stress, which is the main subject of this research. Focusing on the degree of stress reduction before and after the exercise and the thermal environment of the house, it was shown that there was a significant difference in the degree of stress change due to the coldness of the dressing room out of the six places measured (Fig. 7).

Subjects who lived in a cold dressing room residence that was less than 13.5 degrees, which is the average temperature of the dressing room, had an average degree of stress reduction of 8.84% before and after walking, whereas in subjects who were warm at 13.5 degree. In the living subjects, the degree of stress

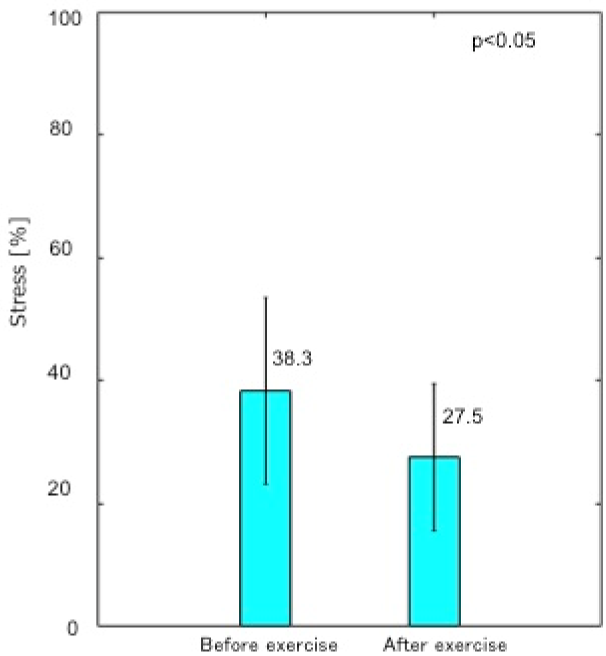

Fig. 6 Stress average before and after walking.

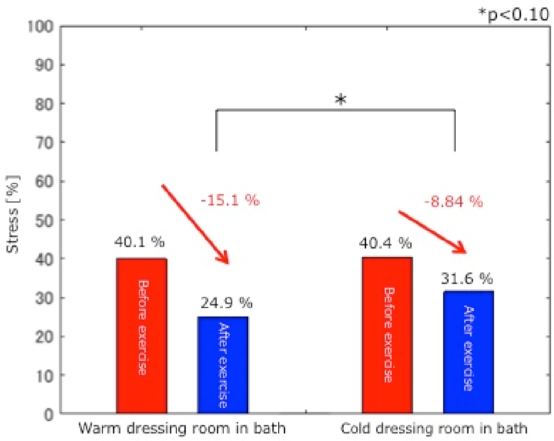

Fig. 7 The degree of stress reduction before and after walking in cold and warm dressing room.

reduction was 15.1%. From these results, it was found that by keeping the dressing room warmer, the degree of stress reduction increases even with the same momentum. In 59 experimental subjects, people living in warm houses were able to capture the phenomenon that stress tended to decrease with a little exercise.

4.2 Experiment 2

As the survey contents, measurement of room temperature (1.1 m above the floor in the living room and bedroom, 0.1 m above the floor, a total of 5 items for the dressing room, every 10 minutes), simple electroencephalogram measurement, respiratory function measurement, MRI measurement were carried out. Electroencephalogram measurement was performed with a 2-minute resting closed eye, respiratory function measurement was performed from 2 years after the survey, and effort spirometry was measured.

4.2.1 Subjects

In this study, 90 male and female male and female living in Ikuhara-machi, Takaoka-gun, Kochi prefecture, were covered twice from early October 2016 to February 2018 and 59 people in September 2018 We conducted an investigation after two years.

4.2.2 Analysis

First, in order to investigate the influence of residential thermal environment on respiratory function / brain function, the upper and lower 25% of the room temperature average value is set as the warming group/cold group respectively, and the significant difference test of respiratory function/ brain function (significance level 10%) was carried out. Room temperature was calculated for the same period in each year. Regarding respiratory function, 1 second rate was calculated. The 1 second rate is the ratio of the amount of air discharged during the first one second to the acquired effortive vital capacity. Regarding brain function, BHQ calculated cerebral cortex amount (GM BHQ) of whole brain and quality of nerve fiber (FA BHQ) from MRI result. For the brain waves, the power spectrum was calculated for each band. Subsequently, the effect of respiratory function on brain function was investigated. Since the diagnosis of COPD is made when the 1 second rate falls below 70%, a significant difference test of brain function (significance level 10%) is classified into abnormal group of respiratory function and normal group with 1 second rate of 70% as a threshold Carried out.

5. Results and Discussions

5.1 Influence on Respiratory Function and Brain Function of Thermal Environment in House

As a result of conducting the t test of respiratory function against room temperature, it was confirmed that 1 second rate of cold subjects at bedroom 0.1 m room temperature was significantly lower. Similarly, as a result of t test of brain function, it was confirmed that the score of GM BHQ of cold subjects at bedroom 0.1 m room temperature was significantly lower (see Fig. 1-A). Therefore, subjects living in cold houses in bedroom had lower respiratory function and less cerebral cortex compared to subjects living in warm houses.

5.2 Respiratory Function and Brain Function

As a result of conducting t-test of brain functions on respiratory function, the subjects in the abnormal group showed that the score of GM BHQ was

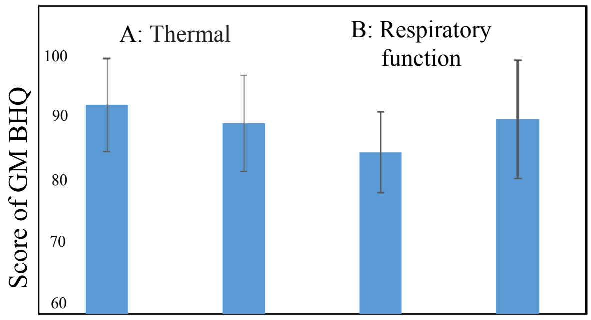

Fig. 8 Points of GM BHQ by type of cold/respiratory function.

significantly lower (see Fig. 1-B). Furthermore, in the t test of brain waves, the power spectrum of the θ band was significantly larger in the abnormal group. Since there is a report that the disorder of the cognitive function is stronger as the activity of the θ band is larger [3], both of the above results indicate a tendency of brain function of the abnormal group to decrease.

Finally, as shown in Fig. 8, the score of GM BHQ decreased in the cold group and the abnormal group versus the warm group/normal group, and the score in the abnormal group was lower in the GM BHQ than in the cold group. Therefore, together with the results in section 4.1, it became clear that the brain function was further decreased due to the influence of respiratory function decline due to living in cold houses.

6. Conclusions

In this study, we aimed to investigate the effect of thermal environment of houses on stress, and conducted EEG analysis for stress detection. By electroencephalogram analysis, stress showed a tendency to decrease by exercising. In addition, focusing on the thermal environment of the subjects' houses, it was found that the temperature of the dressing room has an influence on the degree of stress reduction, and when the dressing room is mild, the degree of stress reduction is large even with the same momentum. It was also found that people living in warm houses may be able to reduce stress with a little exercise compared to people living in cold houses. Moreover, focusing on the effect of decreased respiratory function, the purpose was to investigate the influence of the thermal environment inside the house on the brain function. As a result of the survey, it was revealed that brain function was decreased due to the influence of cold room temperature respiratory function lower than the cold room temperature decrease of brain function. From the above, it was possible to clarify the causal relation between the influence on respiratory function and cognitive function by living in a cold housing.

From now on, we plan to investigate the basis for this phenomenon from the viewpoint of neuroscience.

Acknowledgement

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