Estimation of Emotion by Electroencephalography for Music Therapy

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Abstract. A system for providing music employing electroencephalography for music therapy is described. Music therapy for the treatment of patients suffering mental illness has been attempted over a period of 20 years. To reduce stress, it is preferable to listen to music that matches a person's emotions. However, it is difficult to know exactly the person's emotion. It is necessary to calibrate the proposed system employing electroencephalography to emotions. We discuss a method of calibration especially used in canonical correlation analysis. Experimental results show that it is possible to roughly estimate feelings. We consider that it is possible to use our system in practice.

Keywords: electroencephalography, music therapy, canonical correlation analysis.

1 Introduction

In recent years, the media has focused on diseases such as depression and mental illness that result from stress in everyday life. It is empirically known that listening to music relaxes and heals the weary body and mind. Additionally, stress dissipates through a feeling of being uplifted. Music therapy that targets patients suffering from mental illness has been attempted for a period of 20 years. To reduce stress, it is preferable for a person to listen to music that matches their emotion [1]–[4]. However, it is difficult to know a person's emotion exactly.

In this study, to solve the above problem, we propose a system that provides music according to the results of electroencephalography. To estimate an emotion employing electroencephalography, it is necessary to perform a calibration. We discuss a method of calibration especially used in canonical correlation analysis.

2 System for Providing Music for Therapy Using Electroencephalography

2.1 Overview of the Music Therapy System

Figure 1 is an overview of the target system in this study. The system is designed to assist in healing and music therapy by providing the song that best matches the

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emotion of a subject estimated by electroencephalography. Figure 2 shows the flow of processing. First, an electroencephalogram (EEG) is recorded to examine the electrical activity of the brain for a subject. The EEG obtained is analyzed to estimate the emotion. The subject is provided with music that corresponds to the estimated emotion. This cycle is repeated.

The problem here is how to estimate the emotion from the EEG. First, there is a need to calibrate the relationship between the emotion and EEG for the system. Calibration requires an index expressing numerical emotions. We use the V–A plane of Russell as an indicator of emotion as shown in fig. 3. Emotion is expressed by an arousal value (vertical axis) and valence value (horizontal axis). This is described further in Section 2.2.

In this research, the subject listens to music for which the V–A value is known. At the same time, the EEG is recorded. By analyzing these data, a mapping of emotion and the EEG is realized. Canonical correlation analysis is employed. The estimation of emotion through this analysis is described in Chapter 2.5.

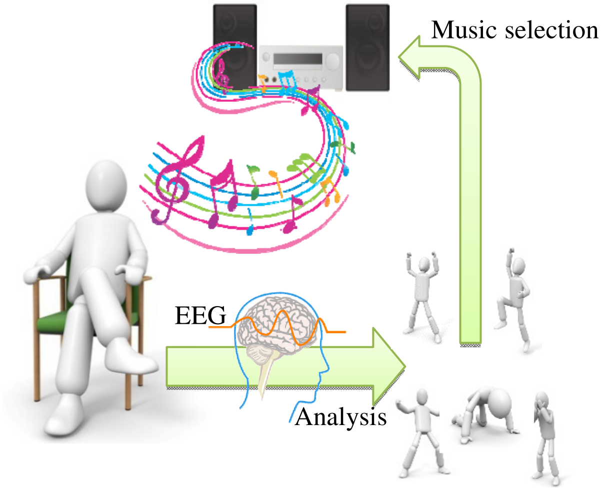

Fig. 1. Overview of our system of providing music employing electroencephalography for music therapy

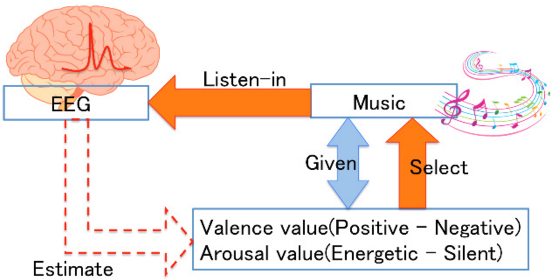

Fig. 2. Processing flow

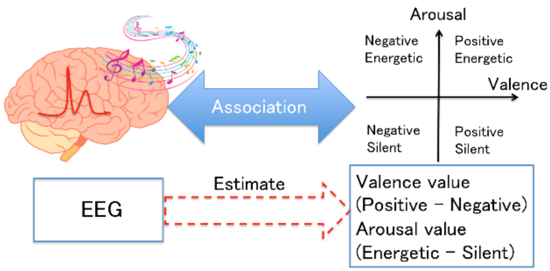

Fig. 3. Emotion indicator

2.2 V–A plane of Russell

Russell defined emotion on two axes of an arousal value and valence value. Figure 4 shows the V–A plane [5]. Emotions are classified into four quadrants generated by the two axes as shown in the figure. The pleasant-aroused quadrant includes emotions such as excitement and joy, the unpleasant-aroused quadrant emotions such as worry and anger, the unpleasant-unaroused quadrant emotions such as melancholy and sadness, and the pleasant-unaroused quadrant emotions such as satisfaction and relaxation.

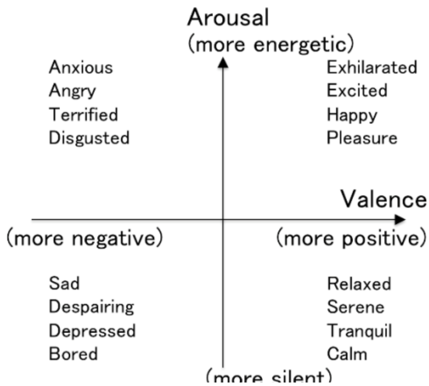

Fig. 4. V–A plane of Russell

2.3 Music Used for Emotion Occurrence

Correlation of the emotion estimated from the EEG requires indicators of emotion evoked by the music, which are discussed below. We used MoodSwing Lite Music as a music database [6]. The database comprises arousal and valence values for 10 to 20 subjects listening to music as determined by a subjective questionnaire. The values are given for 15-second sections of approximately 240 songs. The present study took 20 songs—five songs per quadrant—from the database as shown in fig. 5.

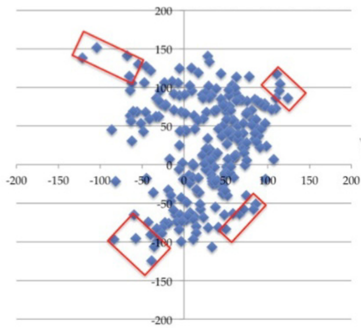

Fig. 5. Arousal and valence values when listening to music from MoodSwing

2.4 EEG data

The EEG was obtained using 14 electrode poles (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4) employing the internationally standardized 10-20 system. The EEG was divided into four bands using a band-pass filter. The four bands were 1–4 Hz (δ wave), 4–7 Hz (θ wave), 7–13 Hz (α wave) and 13–30 Hz (β wave). We took the set of values of the average power per second of each band.

2.5 Emotion Estimation Employing Canonical Correlation Analysis

Canonical correlation analysis is a multivariate technique of determining the relationships between groups of variables in a data set. The data set is split into two groups, let us say groups U and V, according to common characteristics. The purpose of canonical correlation analysis is then to find the relationship between U and V; i.e., we ask whether some form of U can represent V. In this study, U is the EEG that is divided into four bands, and V is the V–A values of the music.

Formula (1) is obtained by canonical correlation analysis.

$$\begin{cases} s_1(t) = \sum_{m=1}^{M} a_m u_m(t) \\ s_1'(t) = \begin{pmatrix} d_{Valence} & d_{Arousal} \end{pmatrix} \begin{pmatrix} v_{Valence}(t) \\ v_{Arousal}(t) \end{pmatrix} \end{cases}$$
$$\begin{cases} s_2(t) = \sum_{m=1}^{M} b_m u_m(t) \\ s_2'(t) = \begin{pmatrix} e_{Valence} & e_{Arousal} \end{pmatrix} \begin{pmatrix} v_{Valence}(t) \\ v_{Arousal}(t) \end{pmatrix} \end{cases} \tag{1}$$

$M = E \times W$ ($E = 14$: number of electrodes, $W = 4$: number of bands)

Here a_m represents the linear combination coefficients of the first canonical correlation score on brain waves (14 poles × 4 bands), b_m represents the linear combination coefficients of the second canonical correlation score on brain waves (14 poles × 4 bands), $d_{Valence}$ and $d_{Arousal}$ are the linear combination coefficients of the first canonical correlation score on V-A values of music, $u_m(t)$ is the potential of brain waves at time t, and $v_m(t)$ represents the V-A values of music at time t. Additionally, from the canonical correlation analysis, canonical correlation coefficients C_1 and C_2 are obtained. The relationship of the canonical correlation coefficients and canonical variable scores is expressed by equation (2).

$$\begin{cases} s_1(t) = C_1 s_1'(t) \\ s_2(t) = C_2 s_2'(t) \end{cases}$$

$$(Corr(s_1(t), s_1'(t)) \approx C_1, Corr(s_2(t), s_2'(t)) \approx C_2) \tag{2}$$

$v_{Valence}$ corresponding to the valence value and $v_{Arousal}$ corresponding to the arousal value are estimated using equations (1) and (2).

3 Experiment

Estimation performance was examined to calibrate the emotion estimation system employing canonical correlation analysis. An experiment was carried out on 10 healthy men and women (eight males and two females aged 21–25 years). Subjects listened to music with known V–A values for 15 seconds after silence for a period of 15 seconds. This was performed as many as 20 times, while the EEG was measured. The subjects had their eyes closed and wore an eye mask. We used the Emotiv EPOC manufactured by Emotiv Corporation as an EEG measuring device.

Table 2 gives the first canonical correlation coefficient, second canonical correlation coefficient and estimation error for the 10 subjects. The correlation canonical coefficients are high; in particular, the first correlation canonical coefficient is at least 0.7. The coefficients are strongly related to the EEG and emotions that are evoked by music are shown.

Table 1. First canonical correlation coefficient, second canonical correlation coefficient and estimated error

	First canonical correlation coefficient C_1	Second canonical correlation coefficient C_2	Estimation error
Subject 1	0.89	0.55	1.32
Subject 2	0.73	0.55	1.50
Subject 3	0.72	0.60	1.46
Subject 4	0.66	0.53	1.65
Subject 5	0.81	0.54	1.41
Subject 6	0.73	0.60	1.43
Subject 7	0.79	0.54	1.48
Subject 8	0.79	0.58	1.40
Subject 9	0.78	0.55	1.40
Subject 10	0.72	0.64	1.33
Average	0.76	0.57	1.44

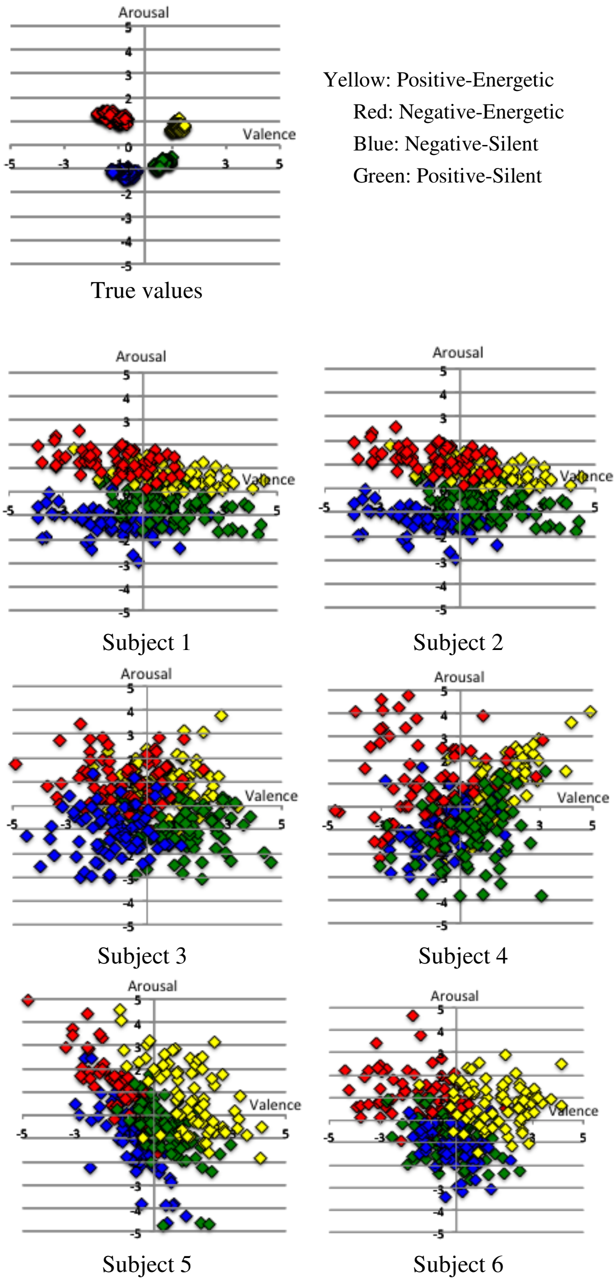

Fig. 6. True values and distributions of estimated values

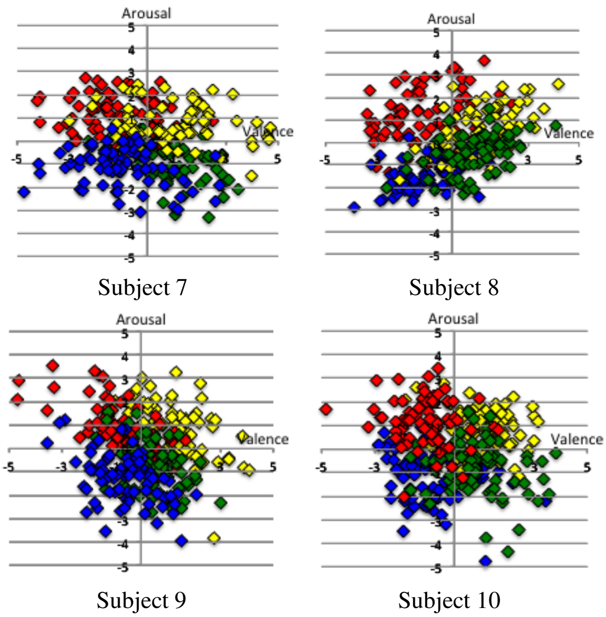

Fig. 6. (*Continued*)

Figure 6 shows the distributions of the estimated values and the true values. Estimations of V–A values were more widely distributed than the true values. This is because they are approximated directly using the approximate straight line obtained from the canonical correlation analysis. We thus expect the generalization performance to fall. Therefore, for the estimation of 15-second segments of music that were not used in the experiment, which quadrants the segments fall into is determined by majority decision. Table 2 presents the estimation results. Music is presented for only 15 seconds. The accuracy rate was about 60% overall.

Table 2. The estimation results of whether the music is which quadrant by majority decision

Presentation \ Estimation	Positive - Energetic	Negative - Energetic	Negative - Silent	Positive – Silent
Positive - Energetic	67	15	9	9
Negative - Energetic	20	55	15	10
Negative - Silent	5	7	68	20
Positive - Silent	12	16	27	45

4 Conclusion

In this study, we proposed a system for providing music for therapy. The system estimates emotion from an EEG, and presents the music that best matches the emotion. Because of differences among individuals, the EEG needs to be calibrated for each individual. Experiments on calibration were carried out, and it was found to be possible to roughly estimate feelings. We consider that our system can be applied in practice.

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