Paper

Brain rhythm related to the subjective music preferences

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Abstract: Electroencephalogram (EEG) related to music preferences can be recorded when a participant has to evaluate preference score when listening to music excerpts. Whether EEG is related to decision-making regarding music preference remains unknown. In the present study, we separated listening-to-music and evaluating-preference (thinking) periods. Participants evaluated preferences using six-point Likert scales. F3γ power during the thinking period was significantly correlated with preference. The mean discrimination rate was around 70% using F3γ power. The results suggest that F3γ power may be related to deciding music preference.

Key Words: electroencephalography, subjective music preference, EEG-controlled music player

1. Introduction

Brain computer interfaces are a useful technique to control machines. Electroencephalogram (EEG) is a signal recorded from the human’s brain. Recently EEG-controlled devices have been studied [1–3]. Researchers have tried to control wheelchairs and robotic arms using EEG [12, 13]. More recently, studies have been conducted to develop a music player controlled using EEG to obtain music recommendations [14]. When the participants listen to consonant music, a central frontal θ rhythm is induced [4]. In a music preference task [5], participants evaluated musical preferences according to an arbitrary scale. The parietal β and frontal and occipital γ rhythms were correlated with music preference. Adamos et al. [14] found that the cross-frequency coupling of the left frontal β and γ were related to music preference. In both studies, music was presented to participants and just after presentation, the participants had to rate their preference. They analyzed the EEG recorded while participants listened to music. In the listening period, participants had to listen to music and rate their preferences. It has not yet been clarified whether there are EEG features related to the rating and decision-making of the preference. Thus, in the present study, we separated the listening-to-music (listening) and evaluating-preference (thinking) periods. We studied EEG features related to music preferences during the thinking and listening periods.
2. Method

2.1 Participants
Eleven healthy male participants (23.5 ± 0.85 years, mean age ± standard deviation [SD]) participated in the experiment. All participants were right-handed as assessed using the Edinburgh Handedness Inventory [6]. Informed consent was obtained from each participant before the experiment. All participants reported normal hearing and no history of neurological disease.

2.2 Music presentation
The excerpts of music were selected from the Real World Computing (RWC) Music Database [7]. The database includes 30 genres of music and each genre has three excerpts at a minimum. Before the experiment, participants completed a pre-questionnaire regarding musical genres. They had to rate their preference of the 30 musical genres in the database using a six-point Likert scale. Scores of 1–3 indicated dislike of the genre, and other scores indicated enjoyment of the genre.

A single trial of the task consisted of the participant sitting in front of a computer display, listening to the excerpts and rating their music preference (Fig. 1). A participant performed 30 trials in the task. The presented music excerpts were selected from 10 genres of the music database. The genres were selected from five liked and five disliked genres based on the pre-questionnaire. Three excerpts were selected from each genre. In total, 30 excerpts were presented to each participant. Thus, the selected excerpts depended on the participant. Prior to the beginning of each excerpt, there was a 20-sec resting period. Each participant was asked to keep their eyes open, focus on a central fixation point, and listen to the excerpts. An excerpt was presented for 60 sec. After listening to the excerpt, the participant provided their preference score using a six-point Likert scale in a 5-sec thinking period. A score of 1, 2, or 3 was classified as dislike; all other scores were classified as like. After the thinking period, the participant wrote their preference score on a sheet of paper in a 5-sec rating period. Vocal music was not included to avoid brain activation from lyrics processing. Among the 11 participants, two had a biased music preference, that is all ratings for excerpts were in either the like or dislike group.

2.3 EEG recording and analysis
EEG was recorded during the above music preference task. Fifteen electrodes (F7, F3, F4, F8, T3, C3, Cz, C4, T4, T5, P3, P4, T6, O1, and O2) were placed on the participant’s head following the international 10–20 system. Reference electrodes were placed on the left and right mastoid. The ground electrode was placed at Fpz. The EEG was recorded using a biological amplifier (Digitex Lab. Co., Ltd., JAPAN) and DAQ terminal (Intercross Co., JAPAN). The signal from the biological amplifier was filtered between 0.5 and 100 Hz and that from the DAQ terminal was filtered between 0.5 and 250 Hz. They were simultaneously recorded on a PC using LaBDAQ2000 (Matsuyama Advance

![Fig. 1. Sequence over time of a trial in the music preference task.](image)
Co., Ltd., JAPAN) signal recording software at a 1-kHz sampling rate. Electrooculogram (EOG) was also recorded in order to remove eye blink artifacts. The electrodes were placed above the external canthus and lateral area of the right eye. It was measured using a biological amplifier and recorded via LabDAQ2000.

Blink artifacts were removed from the EEG using independent component analysis in EEGLAB [8]. The recorded EEG was resampled at 1024 Hz for subsequent fast Fourier transform (FFT) analysis. It was divided into two, like and dislike epochs. An epoch contained EEG from baseline, listening, and thinking periods. The epoch was analyzed using a short-time FFT (sFFT) with 1-sec time window and 50% overlap. The temporal change in the EEG powers of $\theta$ (4–8 Hz), $\alpha$ (8–13 Hz), $\beta$ (14–29 Hz), and $\gamma$ rhythms (30–100 Hz) were calculated. Zero sec on the time axis was set at the onset of the presentation of the excerpts. The mean power from $-2$ to 0 sec in the baseline period was subtracted from the temporal EEG power during the listening and thinking periods. The mean EEG power was calculated for 60 sec of the listening period and 2.5 sec of the thinking period. Pearson's correlation coefficients were calculated for the relationship between the EEG power and preference scores. Correlations at the $p < 0.05$ level were considered significant. In the classification experiment, the EEG powers that significantly correlated with the preference scores were used as classification features for each participant. Linear discrimination analysis was used to classify like and dislike groups. The discrimination rate was calculated using leave-one-out cross-validation (LOOCV) in each participant in order to evaluate the discrimination power of the individually trained classifier. We removed the data from the two participants who had the biased music preferences in the classification experiment where the classifier could not be trained because the training data only included one group. One of the 11 participants had noisy EEG recording. Hence, the participant was removed from the EEG analysis.

3. Results

During the listening period, EEG powers for $F3\beta$, $F8\alpha$, $T4\theta$, $C4\theta$, and $P4\theta$ correlated significantly with the music preference score in participant 6. Figure 2 shows the results of $F3\beta$, and $T4\theta$. EEG powers for $F3\theta$ and $\gamma$, and $T6\gamma$ also significantly correlated with the preference in the thinking period. The other participants, except participant 2, also had significant correlations between EEG powers and the music preferences in the listening and thinking periods (Table I). EEG powers in all participants were z-transformed with the individual average and variance, and Pearson's correlation coefficients were calculated. Figure 3 shows the EEG powers that were statistically significantly correlated with music preferences. In the listening period, there were no EEG powers that correlated with preference. In the thinking period, $F3\gamma$ power had a significantly negative correlation with preference ($r = -0.13$, $*p < 0.05$).

The correlation between EEG power and music preference among the participants was found only during the thinking period. We calculated the discrimination rates for each participant using the significantly correlated EEG $F3\gamma$ power during the thinking period. The dimension of the feature vector was one. Figure 4 shows the results. Except participant 2 and 9, the rates for all participants are above 60%. The mean rate was $69.5 \pm 13.6\%$. Finally, we calculated the discrimination rates using the significant and individually correlated EEG powers shown in Table I in the listening and thinking periods for each participant. Using the correlated EEG powers in the listening period, the discrimination rate reached 90% in participant 3 and the mean rate was $70.8 \pm 13.8\%$ (Fig. 5). Using the EEG powers in the thinking period, the rate reached 90% in participant 10 and the mean rate was $68.4 \pm 14.5\%$ (Fig. 5). The discrimination rates for the listening and thinking periods were not significantly different.

4. Discussion

The present study firstly found that $F3\gamma$ power was correlated with music preference in the thinking period without music. There was a thinking period in our protocol (Fig. 1). In this period, participants mainly thought about the score for music preference and determined their preference. A significant EEG correlation for left frontal $\gamma$ in this period was found (Fig. 3). Hadjidimitriou and
Fig. 2. EEG powers for listening and thinking periods had significant correlations with music preference scores in participant 6. Broken lines indicate regression lines.

Table I. EEG powers that are significantly correlated with preference.

| Participants | Listening period | Thinking period |
|--------------|------------------|-----------------|
| 1            | Czβ, C4β, T5β,γ, P3β, O1θ | T5α,β,γ, P3β,γ, O1θ |
| 2            | None              | None            |
| 3            | F7θ, F4α, T4θ    | F7θ, T4θ        |
| 4            | C4θ, O1γ         | F4β, C4θ, O1γ   |
| 5            | F7β,γ, T6β,γ, F3β,γ, T3β,γ, C3θ, Czβ,γ, C4β,γ, T5β,γ, P3β,γ, P4β,γ, O1β,γ, O2α,β,γ | T6γ, P3β,γ, P4α,β, O2α,β |
| 6            | F3β, F8α, T4θ, C4θ, P4θ | T6γ, F3β,γ     |
| 7            | Czθ, T5γ, O1θ    | T5β,γ, P3γ, O1θ |
| 8            | F7β, F3β, F8θ    | F8θ, P3γ, P4γ, O1γ |
| 9            | Czθ, C4θ, T5θ,α, P3θ,α, P4θ,α, O1θ,α, O2θ,α | Czθ, C4θ, T5θ,α, P3θ,α, P4θ,α, O1θ,α, O2θ,α |
| 10           | Czθ              | Czθ, O1α        |

Hadjileontiadis [5] and Adamos et al. [14] also reported that left frontal γ power correlated with preference. The discrimination rates calculated using F3γ power in the thinking period are comparable to those obtained by the rates calculated using the individually most correlated EEG powers shown in Table I. Therefore, left frontal γ rhythm will be related to the decision-making process for music preference.

Previous studies [5, 14] found that EEG features that were related to subjective music preference
Fig. 3. EEG power that had significant correlation with music preference score was found only during the thinking period using all participants’ EEG data. The F3γ power source is shown (black circle). The figure shows the top view of the participant’s head.

Fig. 4. The discrimination rates for music preferences. The numbers on the x-axis indicate the participant number. The horizontal red line indicates the chance level. Red bars indicate discrimination rates using F3γ power in thinking period in each participant. Error bars indicate SD.

during the listening period. Hadjidimitriou and Hadjileontiadis [5] made participants listen to excerpts from various genres and evaluate their preference score immediately after listening. They found that the left frontal β and left frontal, central, and left occipital γ were related to preference. Adamos et al. [14] found that the cross-frequency coupling of the left frontal β and γ was related to music preference. In their studies, the participants both listened to excerpts and rated music preference while listening to the music. Thus, the correlated EEG powers that they found may include the music element preference, for example, tempo, pitch, and harmony preference. The excerpts were also selected by the experimenter or participants, and were fixed. Music preference is affected by tempo, pitch change, and music mode (major and minor) [15–17]. Thus, the EEG activity may represent preference for tempo, pitch change, and music mode. Hadjidimitriou and Hadjileontiadis [5] reported that β rhythm was correlated with musical preference. The β rhythm is correlated with musical tempo [15]. Thus in their study, participants may have preferences for the musical tempo.

Each participant had EEG powers that were significantly correlated with music preference scores
Fig. 5. The discrimination rates for music preferences. The numbers on the x-axis indicate the participant number. The horizontal red line indicates chance level. Blue and red bars indicate the discrimination rates using the significantly correlated EEG powers in each individual in the listening and thinking periods, respectively. There are no results for participant 2, because he had no correlated EEG powers shown in Table I. Participant 4 and 5 had correlated EEG’s and a biased preference, thus they have no results for the discrimination rates. Error bars indicate SD.

during listening and thinking periods (Table I). In the thinking period, retrieving the music is necessary when considering the music preference ratings. The participants decided the preference dependent on different aspects of the music, for example, on tempo, pitch change, and mode change. Participants had several correlated EEG powers in the thinking period that differed between individuals. The mean discrimination rates in almost all participant were around 70% (Fig. 5). The rates in two participants reached over 80%. Hadjidimitriou and Hadjileontiadis [5] also calculated the rate. The present discrimination rates are almost the same as their results.

5. Conclusion
In conclusion, the left frontal $\gamma$ rhythm in thinking period was correlated with the music preference score. The rhythm will be related to the decision-making process for music preference. Using the EEG power, liked music can be discriminated from disliked music at an accuracy of approximately 70%. EEG-controlled music players may be developed using individual classifiers using left frontal $\gamma$ rhythm.

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