Review Paper of An Affective Brain-Computer Music Interface

Yuhang Zhao

yuz036@ucsd.edu

1.Introduction and Motivation:

This project is about an Affective Brain-Computer Music Interface (aBCMI) that predicts human emotions and utilizes music to modify human emotions theoretically. In Daly et al. (2016), this concept was first proposed by Daly and his colleagues. They develop the basic model of this interface based on several neuroimaging data including functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), electrocardiogram (ECG), galvanic skin responses (GSR), and reparation rates.

Some other researchers also make some contributions in this area about the perception of musical emotions. The recognitions of musical emotions have been explored by several prior studies. However, it is still unclear whether humans can feel the target emotion in music while listening. There are two major theories – Cognitivism and Emotivism (Creel, 2021). Cognitivism means that people recognize the musical emotions without actually feeling them. In contrast, Emotivism is that people indeed actually get the same emotions when they listen to music that induced the target emotion.

Due to my early musical training background, I have a basic understanding for music and I really enjoy the process of exploring music-related phenomena. Therefore, I was motivated to develop a Brain-Computer Interface in the music field, with the help of EEG brainwave data. I was wondering if people can accurately identify the emotion inside a music clip. Therefore, I was trying to resolve this problem and to validate the theory of cognitivism, through the EEG data of music listeners.

2.Related Work:

In this COGS 189 course, we mainly focus on the analysis of Brain-Computer Interface based on EEG data. With the help of EEG data, scientists can directly see the human brain activity when they listen to music. This is extremely important in the research about human cognitions.

There are some existing studies related to this problem. In Fritz et al. (2009) paper, researchers explored human recognition of three basic emotions in music. They proved the hypothesis that the recognition of basic emotions is universal across different music. In addition, they did another experiment to examine how spectral manipulation of music influenced the pleasantness of music. They also brought up human recognition of musical emotion did not necessarily mean that they were experiencing the emotion at the same time when listening to the music. In other words, Fritz and his colleagues supported the Cognitivism Theory.

In Bella et al. (2001) paper, researchers did a developmental study of affective values in music. They found that some basic musical properties of music could largely influence human affective state. The mode and tempo of music could directly affect human evaluation about the affective value of a music clip, which implies that humans actually feel the same emotion as the target emotions in music.

From the Grekow (2016) paper, human characterization for music was divided into two dimensions – valence and arousal. It provided the early model to study how human perceived emotions. All music properties, tonality, tempo, pitch height, timbre, and loudness were considered when people recognized emotions in music. Therefore, this theory implied that musical emotions were recognized mainly by basic properties of music instead of feeling the same emotions. This research provided another support for Cognitivism.

3.Review

There are several papers exploring the perception of musical emotions. I have selected several of them here.

I. Daly et al. (2020) paper -- Affective Brain-Computer Music Interface

In Daly et al. (2020) study, researchers explored the neurological mechanism of human perception of musical emotions. They did several experiments to study how people react to music stimuli in physiological and neurological ways, based on neuroimaging data. They firstly introduced the Affective Brain-Computer Music Interface (aBCMI) to the cognitive field.

In this study, participants were 144 adults in total, aged from eighteen to sixty-six years old. The gender ratio of the participants was really balanced, which means that the number of females and the number of males were nearly equal.

All participants were presented with the pre-recorded music clips which could induce different emotions theoretically. During the process of listening to music, the neurological and physiological data were collected. For a really deep analysis, researchers collected several types of data when recording. They recorded functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), electrocardiogram (ECG), galvanic skin responses (GSR), and reparation rates. In general, researchers obtain around 150 hours recordings of data.

In this study, there were four datasets involved in total. The first one was the Film Clip dataset which contained the EEG recordings when participants listened to a music clip extracted from films. Thirty-one subjects were involved. They were presented with a series of 12 seconds music clips extracted from films and then were asked to finish a questionnaire designed to estimate their perception about the musical emotions. Eight questions on the questionnaire enable participants to successfully report their own feelings about the music. Then this reported feeling was compared to the target emotion that the clip induced. During each trail, EEG data was recorded for about 45 minutes from 19 channels.

The second dataset, which was the main part in the study, was the Brain-Computer Music Interface (aBCMI) dataset. Researchers developed the aBCMI in order to modify human affective state through music. More specifically, “the aBCMI attempted to identify a user’s current affective state and modify it by playing a sequence of generated music pieces in order to place the user in a more desirable affective state” (Daly et al., 2019). With the EEG recordings, researchers studied the brain activity of participants when they listened to the music clips. From the data they collected and analyzed, the aBCMI model they developed could successfully operate. The final online aBCMI could identify a user's affective state with the classification accuracies of up to 65 percent and then modulate the user's affective state significantly above chance level. This interface was what I am truly looking for. It was really useful in the study of human perception of musical emotions.

Plus, an additional Brain-Computer Music Interface related to tempo was constructed. This special aBCMI Tempo helped users to control the tempo of music through brain activity.This is closely related to the tempo-emotion theory in Bella et al. (2001) paper. Both groups of people believed that tempo was an important factor in the perception of musical emotions.

II. Bird et al. (2019) - Sentiment Classification with EEG-based BCI

Another study I want to mention here is the Bird et al. (2019). Based on EEG brainwave data, Bird and his colleagues examined the classification of human emotional experiences. Although they did not include music in their study, they made a great contribution to the human emotion classification research. They performed an extraction of several brainwave data – alpha, beta, theta, delta, and gamma brainwaves – when doing the data analysis. A classification model of human emotion was developed in the process. Researchers attend an accuracy of about ninety-seven percent to predict human emotions after the induced activity.

Several machine learning algorithms were applied in this study. The first one was the One Rule (OneR) classification. They used this to identify the strongest attribute within the dataset. Another algorithm was the Decision Tree which was a tree-like structure of attributes. They also used Support Vector Machines (SVM) to do the data classification. Based on the location information on a hyperplane, all data points were classified and a model was optimized. All of those algorithms were really common in EEG data research. In most cases, they were used together when doing the data filtering and cleaning part.

For the result part, researchers successfully developed a method of classification of human emotional EEG data. They found that low resolution EEG headband data could be used to classify human emotional state, suggesting future potential algorithms for EEG data classification.

Although this study is not directly related to musical emotions, it still helped show people how normal emotions were processed in human brain activity based on the neuroimage data. After I connected this classification algorithm to the aBCMI developed in the former study, I found that the human effective state could be easily identified and modulated by humans themselves. Those EEG-based algorithms did a great job in finding the correlation between human emotion and music.

4.Discussion:

Those readings really give people a general preview about the BCI algorithm in human affective state analysis. I personally believe that neuroimaging data is really important in analysis of human cognition. Since scientists need direct proof of human brain activities for their cognitive behavior. The ideal aBCMI is able to act as a predictor and a modulator for human emotions in music.

Also, sometimes, music can really induce emotions for humans. But different people may have different perceptions for the same music clip, due to their different experiences. This is a really interesting phenomena to think about. The classification algorithm for human emotion in Bird et al. (2019) paper helped build up the basis for the aBCMI model developed in Daly et al. (2020) paper.

I believe that scientists still need to do a lot in order to improve this special interface aBCMI. Applications of EEG data gradually become more and more crucial for the study of human cognition. I want to see more about the research of this aBCMI model in the future. Instead of using music to control human emotions, researchers can try to explore how humans enable music to convey a certain emotion. This is the opposite study direction of the aBCMI model.

There are some possible applications of this Brain-Computer Music Interface. For example, scientists can utilize it for some psychological illness, like depressive disorder. In the future, music therapy for mental illness can be a really promising field.

References

Bella, et al. (2001). A developmental study of the affective value of tempo and mode in music.

Bird, Jordan & Ekart, Aniko & Buckingham, Christopher & Faria, Diego. (2019). Mental Emotional Sentiment Classification with an EEG-based Brain-machine Interface.

Creel, Sarah. (2021). Lecture ,"Music and Emotion", COGS 157 Music and Mind. University of San Diego.https://canvaskaf.ucsd.edu/media/t/1_booqgmp0/193458083

Daly, Ian & Williams, Duncan & Kirke, Alexis & Weaver, James & Malik, Asad & Hwang, Faustina & Miranda, Eduardo & Nasuto, Slawomir. (2016). Affective brain–computer music interfacing. Journal of Neural Engineering. 13. 046022. 10.1088/1741-2560/13/4/046022.

Daly, Ian & Nicolaou, Nicoletta & Williams, Duncan & Hwang, Faustina & Kirke, Alexis & Miranda, Eduardo & Nasuto, Slawomir. (2020). Neural and physiological data from participants listening to affective music. Scientific Data. 7. 10.1038/s41597-020-0507-6.

Fritz et al. (2009). Universal Recognition of Three Basic Emotions In Music, Current Biology.

Grekow, Jacek. (2016). Music Emotion Maps in Arousal-Valence Space. 9842. 697-706. 10.1007/978-3-319-45378-1_60.