Analyzing Brain Activity In Response To Music

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***Abstract*—Music has long been known for its ability to influence people's moods, but to what extent and in what way? This paper aims to compare two participants' emotional responses to different songs and uses EEG readings to quantify these responses, allowing direct comparisons between responses to the same song as well as different responses from the same participant with minimal participant bias in responses to study how individuals react to new songs, the difference in reactions between individuals with different music tastes, and an individual's reaction to different songs to their music taste.**

Keywords—music, emotional responses, music tastes

I. Introduction

Music is commonly employed in various forms of media to set the mood—movies will employ the eerie whine of violins to up the tension in an already tense scene, while games use upbeat, repetitive music to match the fast-paced action happening onscreen. Outside of media, even storefronts will play music while shoppers peruse their wares, one such example being the Christmas shopping season, where almost every store plays some kind of Christmas song, and it becomes remarkably clear that it is time to purchase presents.

Listeners also often save music they like in playlists to listen to later, with playlists sometimes sorted by topic or mood, or peruse playlists provided by other individuals on the internet in an attempt to influence their own mood. One such example of these playlists is on the YouTube channel Lo-Fi Girl, where curated lo-fi music playlists are streamed with the intent of helping students focus better on studying.

However, different people react to music differently and have very different preferences. With the vast number of genres and people's varied tastes, it can be difficult to predict how someone might respond to a piece of music. Being able to influence a listener's mood can be desirable for a variety of reasons. Media like movies and games often want to emphasize a certain message by making consumers feel a certain way to further the impact of the message, while storefronts want to make shoppers feel more compelled to make purchases.

The aim of this study is to better understand these changes in mood, and this is done through using brain data. To quantify people's emotional responses with minimal bias and study the intricacies of music's effects on mood, capturing brain data while a participant listens to music allows for values that can be easily compared and interpreted.

II. Background

As previously mentioned, music is used in applications like games as well as sleeping aid apps and can play a crucial role in shaping the user experience. In an action game, playing a high-tension song while a player is struggling with a level heightens their anxiety, while playing a repetitive and annoying track frustrates the player. Comparatively, games aimed towards providing a relaxing experience play calm, slow songs in the background. When done right, this can reduce player frustration and make for a better overall experience.

These concepts can also be expanded to applications in general, as users often get frustrated or bored as part of normal usage. The use of music, if standardized as a genuine part of the user experience in an application, can greatly enhance users' view of the app. Part of studying human-computer interaction is understanding how to improve the user experience, and playing music as part of that experience provides a quick and conceptually easy way for developers to do so.

Brain data devices use sensors to quantify users' feelings, which heavily influence how they interact with a computer, and with established quantities, developers have better control over what to do with the data as compared to general qualities. For example, suppose a recipe app is provided with only the information that the user is hungry. The algorithms in the app can only suggest recipes based on user-defined qualities like type of cuisine or diet. With a quantity representing hunger, the recipe app can then suggest more accurate recipes; without the quantity, if given a query for Southern recipes, it might suggest biscuit recipes alongside roast turkey recipes, whereas it would only suggest biscuit recipes if the user specified they were hungry for a snack, and roast turkey recipes if the user specified they needed a meal that would feed four people.

Employing brain data devices allows for a more objective view of participants, whereas the traditional method would be for participants to fill out a survey. Although this can make it harder to relate songs with specific emotions, knowing to what extent a song can affect someone's mood allows for extrapolation and additional theories to be formed.

EMOTIV *Insight* - The device we used to analyze brain data was the EMOTIV *Insight*. The EMOTIV *Insight* is a lightweight, wireless EEG headset designed to monitor brain activity in real-time. It uses a 5-channel sensor system along with integrated motion sensors to capture detailed neural and movement data. The device comes with companion software that can be installed on macOS, Windows, or Unix operating systems. The companion software allows for the export of readings in CSV format, which is essential for this study.

III. Methodology

This study follows an experimental design to assess the impact of music on a participant's EEG readings and any correlation between them. The experiment was initially supposed to be conducted on three participants but was finally limited to two participants due to technical difficulties. Before

the experiment, the participants were to curate a musical playlist tailored to their musical taste not exceeding four tracks or fifteen minutes in playback duration. The three participants had the following playlists curated respectively: Original Playlist 1 (OP1) - comprising four tracks that spanned multiple genres, Original Playlist 2 (OP2) - comprising four tracks from the Pop genre and its sub-genres, and lastly, Original Playlist 3 (OP3) - comprising four tracks from the J-Pop and EDM genres.

Track #	Orig. Playlist 1 (OP1)	Orig. Playlist 2 (OP2)	Orig. Playlist 3 (OP3)
Track 1	Chamber pop	Pop	J-Pop
Track 2	Pop	Alt-rock	J-Pop
Track 3	Pop	Pop	EDM
Track 4	New-age	Pop rock	EDM

Table 1. Original track/genre distribution among playlists

The Playlist track/genre distribution had to be revised when the accuracy of the EEG readings from one of the participants, i.e., participant 3, was below the minimum threshold required to gather meaningful data. One single track from Playlist 3 was chosen randomly to replace any track from Playlists 1 and 2, provided there was no significant difference in track duration among them. Additionally, one track from Playlist 1 was selected randomly to replace a single track in Playlist 2 and vice versa to provide further points of comparison, and both playlists were reordered so that shared songs were played in the same order to account for any influence a previous song in the playlist would have on the listening experience of the next song. This resulted in the playlists in the following figure.

Track #	Revised Playlist 1 (RP1)	Revised Playlist 2 (RP2)
Track 1	J-Pop (track 1 from OP3)	J-Pop (track 1 from OP3)
Track 2	Chamber pop (track 1 from OP2)	Chamber pop (track 1 from OP2)
Track 3	Alt-rock (track 2 from OP1)	Alt-rock (track 2 from OP1)
Track 4	New-age (track 4 from OP2)	Pop rock (track 4 from OP1)

Table 2. Revised track/genre distribution among playlists

Fig. 1 a) Spotify Screen Grab: Revised playlist 1 (RP1)

Fig. 1 b) Spotify Screen Grab: Revised playlist (RP2)

A. Song Analysis

Each shared song in the playlist had key characteristics that made them a good point of comparison aside from being provided as a representation of a particular participant's music taste.

1) For Telepathy by DECO*27, it was unlikely for either participant to have ever heard the song before, as it was in a genre neither were familiar with, and it had just recently released upon the time the study was conducted. The song is sung in a language both participants do not speak and has a key shift as part of the chorus. Overall, it is a fast-paced J-Pop song, with a short genre shift to smooth jazz in the middle.

2) For Yesterday by the Beatles, both participants were likely to be familiar with the song, due to its status as a well-known Beatles song. The song itself is a slower melancholic song with the singer expressing a deep longing for the past throughout the lyrics.

3) What You Wanted by OneRepublic is characterized by its repeating ascending chords and frequent usage of repetition in the lyrics, with minimal shifts in tone or subject matter. At 4:01, it is the longest song in the playlist. The song was also 12 years old as of the time the study was conducted and was featured in a relatively successful movie, *The Fault in Our Stars (2014),* so it was uncertain but not unlikely that the other participant had heard it in some shape or form.

The song that was not shared was included in the playlist to provide a baseline comparison between songs that a participant liked.

IV. Data Analysis

After the data was collected, graphs of pleasure, arousal, and dominance values over time were made for each participant to visualize the data for comparison. Each individual song was also timestamped based on song structure to identify any correlation between changes in the song and the corresponding data collected.

A. Participant 1

Participant 1 overall had high pleasure values with an average of 0.863, moderate arousal values with an average of 0.439, and negative dominance values with an average of -0.137.

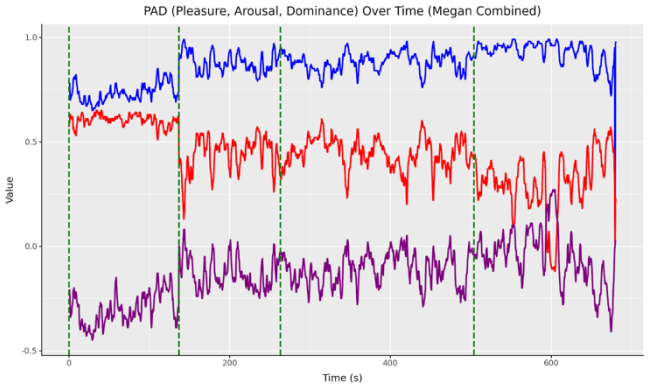

Fig. 2. A graph of PAD values over time for Participant 1. Note that the data for the first song was recorded in a separate session from the other three songs.

1) This song shows the lowest recorded dominance and highest recorded arousal, suggesting that the participant was highly engaged and did not feel an urge to take

action, such as changing or turning off the song. This song was in a genre and language unfamiliar to the participant, which could also explain the high arousal, as the participant may have been extra attentive to this new experience.

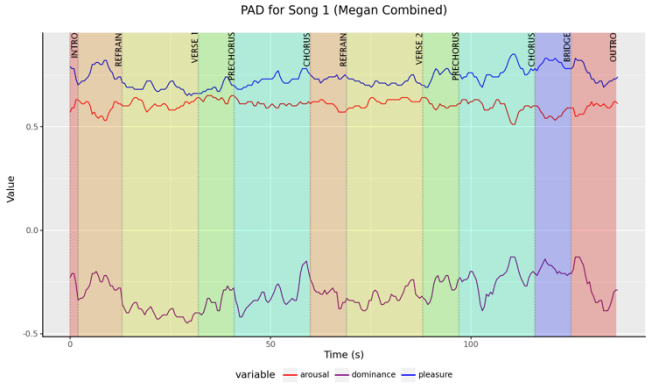

Fig. 3. A graph of PAD values over time for the first song with timestamps for track sections per song.

By overlaying the timestamps of the song structure, an upward trend in pleasure can be seen during the prechorus and chorus sections, with a spike around halfway through the chorus alongside a spike in dominance, where the melody is shifted down by one semitone. This spike is more pronounced in the second chorus and is accompanied by a dip in arousal, which suggests that the participant may have been anticipating the change in key, leading to a spike in pleasure and dominance because the anticipation paid off but became less attentive because they recognized it.

2) The graph shows the greatest spike in pleasure, dip in arousal, and spike in dominance near the beginning of the song.

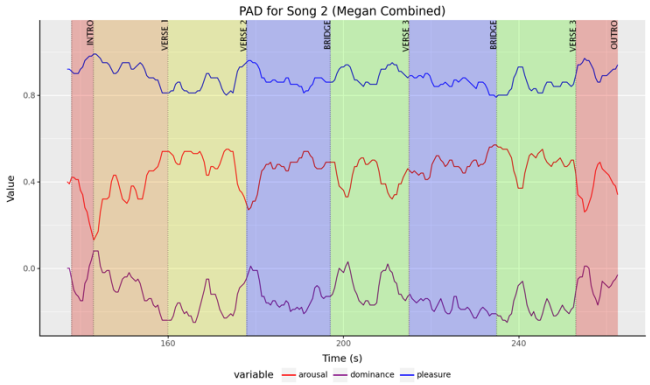

Fig. 4. A graph of PAD values over time for the second song with timestamps for track sections per song.

After applying section timestamps, most of the larger changes in values occur during changes between sections. This may be due to some familiarity with the song, so the changes would be due to whether or not the anticipation for the following section pays off or not.

3) Ranges for PAD values resemble that of Song 2, with only a few notable events, specifically with the arousal levels. There is a significant drop in arousal during the second verse, which could suggest a decrease in engagement. The participant could have started move towards boredom during this verse given that it uses the same musical elements as the first verse without any new or exciting components. There is another notable spike and drop in arousal during the 3rd chorus. In this track, each iteration of the chorus utilizes additional layers of musical elements so that the song increases in intensity over time. This could explain the spike in arousal/engagement as the final chorus starts. The drop in arousal towards the end of this section could perhaps be explained because this is the longest song in the playlist by far, and the participant may have started to experience a lack of interest. However, the arousal levels generally even out for the rest of the song, although the participant may have understood that they were listening to the outro and knew that the track would be ending soon.

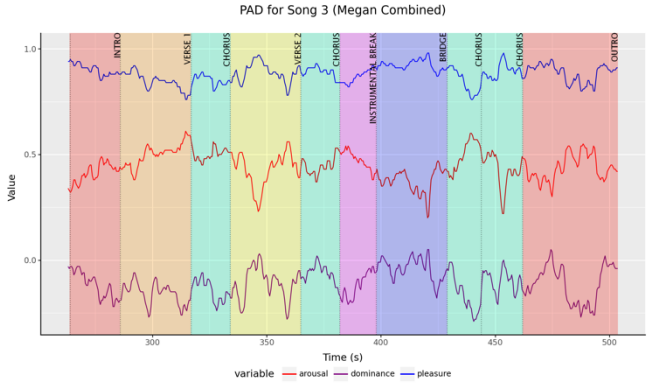

Fig. 5. A graph of PAD values over time for the third song with timestamps for track sections per song.

4) The average pleasure value appears to be the highest for this song, while the average arousal value is the lowest and dips into the negatives around the middle of the song, alongside a spike in dominance. The middle of the song is where a change in the melody is heard as it switches to a different section, so this suggests that the participant wasn't as engaged, but still enjoyed the song and was compelled to act because of this change in the melody. This same section with the same change occurs around one-fourth of the way into the song and shows a similar but lesser drop in arousal alongside a spike in dominance. Dominance and pleasure values follow a downward trend with an upward trend in arousal near the end of the song, which suggests that the participant might not have been as familiar with the end of the song compared to the rest of the song. In comparison with the other participant-chosen song, song 2, song 4 has the higher average pleasure value and the lower average arousal value, implying that the participant might enjoy song 4 more, but isn't as engaged with it. A possible reason for this might be because the song is purely instrumental, and it stands to reason that an individual would be more engaged with a song with lyrics because they would have to concentrate on understanding and interpreting the lyrics.

B. Participant 2

Participant 2 overall had high pleasure values with an average of 0.904, moderate arousal values with an average of 0.369, and negative dominance values with an average of -0.094.

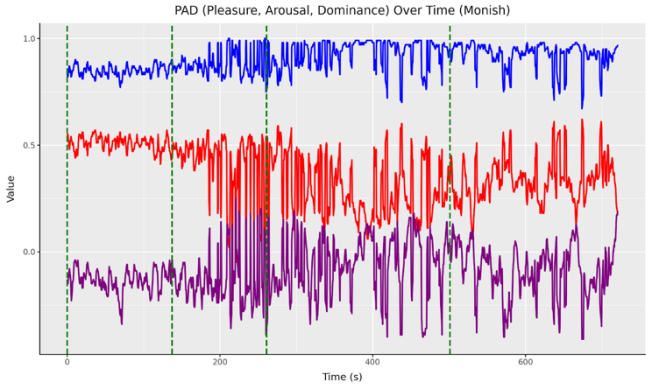

Fig. 6. A graph of PAD values over time for Participant 2.

1) Pleasure, arousal, and dominance remained mostly consistent, with a notable sharp drop in dominance around the timestamp when the genre shift occurred in the song. This drop corresponds with the genre in question, as smooth jazz is known for being relaxing, and the contrast with the surrounding high-energy sections would've increased its impact. The low overall mean deviations, relatively high average arousal value, and relatively low average pleasure value were likely a result of the novelty of the song. It is important to note that besides the dominance drop during the genre shift, the PAD levels remained more consistent than what was recorded for any of the other songs. This may be due to the fact that the song was in a language unfamiliar to the participant. It would be harder for the participant to differentiate between verses and track segments in this song than in other, more familiar songs.
2) The transition into the second song was characterized by a mild decrease in arousal. Values remained mostly consistent for the first third of the song, before the variability increased sharply during the first bridge section of the song and remained similarly variable throughout the rest of the song. From the overall higher average pleasure value past the bridge, this variability may be due to a preference for the second half of the song compared to the first half.
3) Pleasure starts off low before following the variability of the second half of the previous song, while arousal on average is lower, and dominance starts off low before becoming extremely variable. Comparing the graphs for song 1 and the beginning of song 3 suggests that the participant was unfamiliar with at least the introduction of the song and was either familiar with the main chorus or quickly got used to the song. Of interest is the stable readings for pleasure, arousal, and dominance around the middle of the song, where the instrumental break would've occurred. Based on the graph, it appears that pleasure was consistently high, while arousal was consistently low, and dominance was consistently positive. This suggests that the participant was most relaxed during the instrumental part.
4) The range of variability of the values resembles the second half of the second song and the third song, without any clear notable events. Dominance values are mostly negative, and large changes in values are less common compared to the second song and third song.

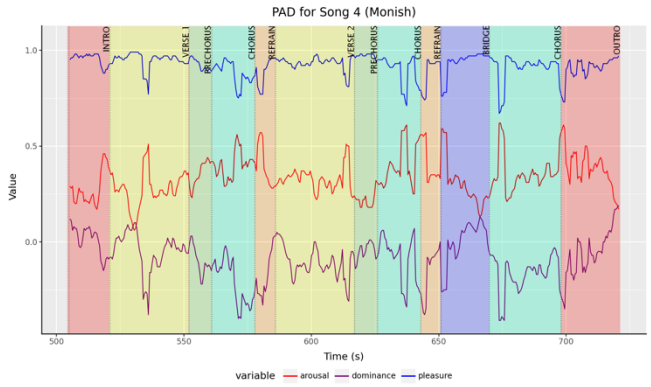

Fig. 7. A graph of PAD values over time for the fourth song with timestamps for track sections per song.

After overlaying the timestamps of the song structure, it can be seen that dominance is generally lowest during the chorus while arousal is the highest. Also of note is that values are more stable during the bridge, where pleasure on average is the highest, with a sudden drop in arousal and spike in dominance in the middle of the bridge, which suggests that the bridge was enjoyable, but on average, not as engaging as the rest of the song.

When comparing song 4 to song 3, these are two very different datasets, which supports the conclusion that a person's music taste does not correspond to their reaction to a song.

C. Comparisons

In both participants, high pleasure, moderate arousal, and low dominance were observed. On average, Participant 2 had higher values in all categories, and the data for both participants supported the conclusion that an individual reacts differently to different songs to their music taste.

1) Both participants had their lowest average pleasure value by song, lowest average dominance value by song, and highest average arousal value by song. Participant 1 had a lower average pleasure value and average dominance value, but higher average arousal value. This suggests that individuals are usually more engaged and more passive when listening to a new song.
2) Participant 2 has higher pleasure values throughout the second half of the song whereas peaks in pleasure for Participant 1 are evenly distributed. This supports the theory that Participant 2 prefers the second half of the song whereas Participant 1 does not have any preference. Participant 2 was also more compelled to action shown by the higher dominance values whereas this spike was not present in Participant 1's graph.
3) Participant 1 remained engaged at a similar level throughout the song, and dominance levels stayed negative throughout most of the song, whereas Participant 2 appears to have become less engaged during the instrumental section and had many more spikes in

dominance where values became positive, with an overall lower average arousal rate.

D. Complications

Some issues encountered during the study were that the EEG device used made using headphones impossible, causing the first participant to have to put half of their headphones to their ear, which led to the headphones to stop playing music mid-session, creating a disconnect between the session for the first song and the later songs as shown in the graphs. In comparison, the second participant had brought earbuds and did not run into this issue.

As previously mentioned, it was possible for the EEG device to not have a high enough connectivity to collect usable data, which limited the amount of data collected.

In the process of analyzing the data, it was also difficult to identify sections within songs for comparison purposes, as aside from the third song and Participant 2's fourth song, songs did not follow the standard verse-chorus structure, making it harder to do in-depth comparisons within songs.

V. Conclusions

This study provides valuable insights into the emotional responses of individuals to music, specifically in relation to their preferences and the effects of song structure on mood. By employing EEG technology, we were able to quantify the emotional responses of two participants to various songs, capturing the variations in pleasure, arousal, and dominance over time. The results indicate that individual music tastes significantly influence the emotional reactions to songs, with Participant 2 showing higher levels of pleasure and dominance during their preferred songs. In contrast, Participant 1 exhibited more consistent engagement with songs, with relatively lower pleasure and dominance values, particularly during unfamiliar music.

The findings suggest that the emotional impact of music is not only dependent on the song itself but also on the listener's familiarity and preference for the genre, indicating the importance of tailoring music selection to the audience for optimal emotional engagement. Moreover, the study highlights the complexity of music's influence on emotional states, as different structural elements of songs, such as genre shifts or instrumental breaks; elicited distinct responses from the participants.

Despite the promising insights, the study faced limitations, including technical difficulties with the EEG equipment and challenges in identifying clear song structures, which impacted the depth of data analysis. Future research could address these challenges by ensuring clearer data collection and testing a larger sample size. Additionally, investigating the impact of individual song elements, such as lyrics and instrumentation, on emotional responses could further refine our understanding of music's power to influence mood. Future studies could also explore the use EEG data to create personalized music playlists that align with an individual's emotional responses, enhancing the effectiveness of music in various applications such as entertainment, wellness, and education.