Project report

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Introduction

This project investigates the **physiological response to music, focusing on heart rate changes influenced by the type of music and participants' interoceptive sensitivity**. The dataset includes heart rate data from 52 participants who underwent structured experiments with various music stimuli. It provides detailed measurements of heart rate, music type, and valence ratings in a controlled environment, enabling an analysis of time-dependent neural and physiological changes.

Valence ratings represent the emotional tone of music, with low valence reflecting negative or somber sounds—often linked to feelings like sadness or anger—and high valence indicating positive, uplifting sounds that evoke emotions such as happiness or euphoria. Interoceptive sensitivity, an individual's ability to perceive and report physiological signals in response to emotional stimuli, is a central variable in this study. By exploring the interplay between music, emotional valence, and interoceptive sensitivity, this research seeks to better understand how music influences physiological and emotional states.

Methods

The data was organized into individual files for each participant, containing columns for session, music type, valence rating, RT, PPG music start, PPG response start, PPG ITI start, fMRI music start, fMRI response start, and fMRI ITI start. For our analysis, we selected the relevant columns—session, music type, valence rating, RT, and PPG response start—and combined them into a single Excel file to simplify the subsequent data analysis.

Due to the large volume of data, the cleaning process was carried out in stages to ensure accuracy. First, we added a participant ID column, with each ID derived from the file names, which were organized by subject. Next, we included a PPG column by referencing the time of the PPG start response. This allowed us to link the data to the correct participant and session files. From there, we identified the exact response start time and calculated the average of the relevant PPG data.

For the heartbeat data, we had two files per participant, one for each session. Each file contained two columns: one recording the time and the other tracking the PPG (change in heartbeat). During this task, participants listened to different types of music.

Each participant did a Heart beat discrimination task in which they were asked to determine if a beep sound was synchronized with their heartbeat when the beep was slightly delayed. The beep sound was presented right after the R-peak of their ECG (0 ms condition) or with a 150-, 300-, or 450-ms delay. Each participant listened to 10 beep sounds per trial and indicated whether the beep was synchronized with their heartbeat, our HBD data for each participant includes delay, confidence, and response.

Interoceptive Sensitivity (IS) was calculated using data from the Heartbeat Discrimination Task (HBD). The resting R-R interval (RRI) was extracted, and delays were normalized by dividing by the resting RRI in milliseconds. Responses were mapped as "Sync" = 1 and "Async" = 0, and sync ratios (proportion of "Sync" responses) were computed for each normalized delay. To model the relationship between sync ratio and delay, a Gaussian function was fitted:

$$y = Ae^{-\frac{(x-\mu)^2}{2\sigma^2}} + b$$

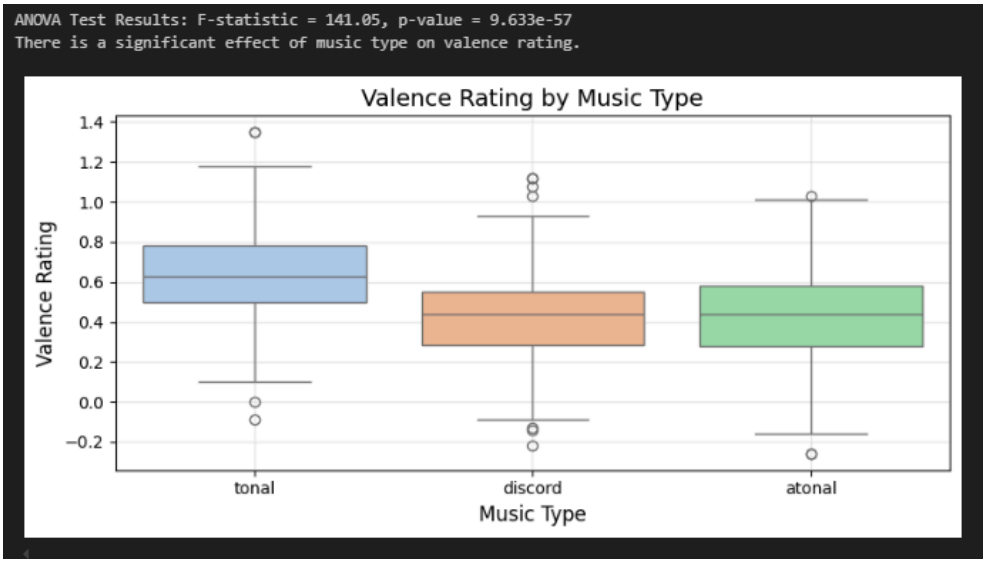
A represents the peak height of the curve. The IS score was then calculated as:

$$IS = 1 - A$$

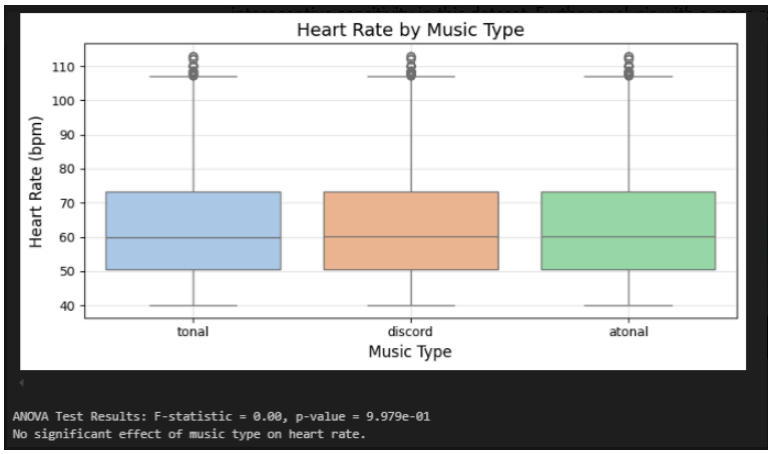
Where higher values indicate better interoceptive accuracy. If insufficient valid responses were available or curve fitting failed, IS was set to NaN. The final values were stored in the combined dataset for further analysis.

Results

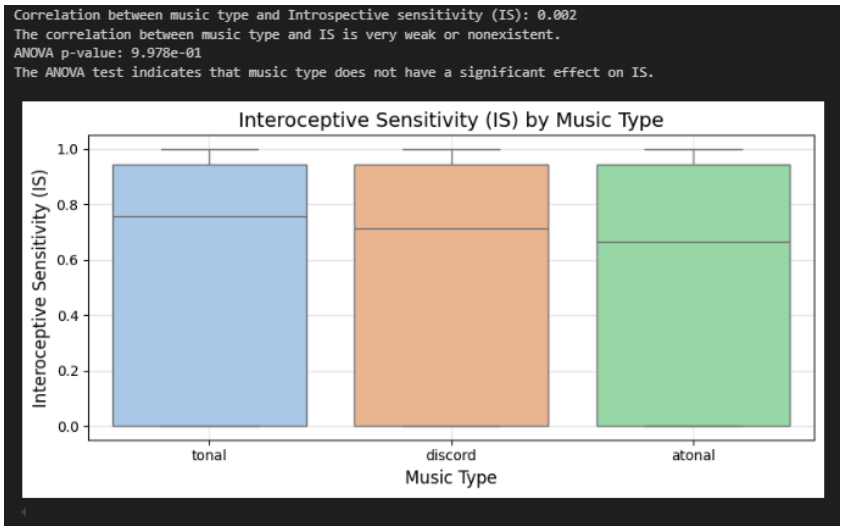
The scatter plot examines the relationship between mean valence score and interoceptive sensitivity (IS). Although a slight positive trend is observed in the regression line, the distribution of the data in the graph is extreme (either really high or really low). As a result, no significant correlation was found between these variables, suggesting that mean valence score does not reliably predict interoceptive sensitivity in this dataset. Further analysis with a more robust dataset may be necessary to clarify this relationship.



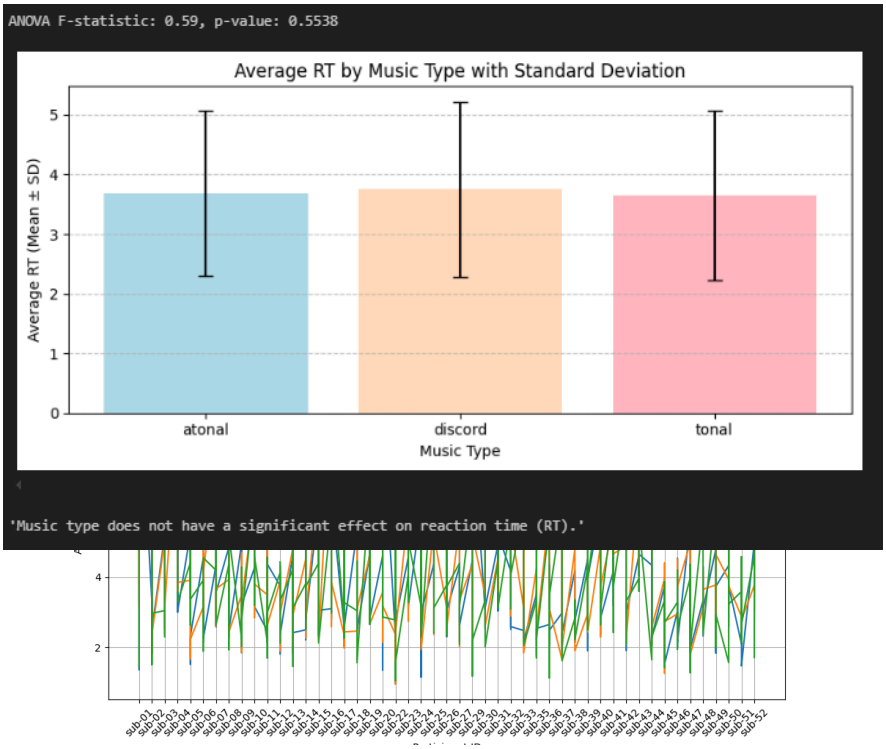
The ANOVA test results of the relation between valence rate and music type indicates a significant effect of music type on valence rating ($F = 141.05$, $p < 0.0001$). The box plot shows distinct differences among the three music types, with tonal music receiving the highest valence ratings, discord music the lowest, and atonal music falling in between. These findings suggest that musical structure strongly influences emotional perception, with tonal music being perceived as more positive compared to discordant or atonal compositions.



We also analyse heart rate distribution across the three music types. The median heart rates and overall distributions appear similar across all conditions, with some outliers present. An ANOVA test was conducted to determine if music type had a significant effect on heart rate, yielding an F-statistic of 0.00 and a p-value of 0.9979. Since the p-value is far above the conventional significance threshold (0.05), the results indicate no significant effect of music type on heart rate, suggesting that different musical structures do not meaningfully influence physiological arousal in this dataset.



Similar to the previous analysis the ANOVA test (p-value=9.9) shows no difference between the introspective sensitivity reaction to different types of music even though there is a correlation between IS and valence rate and a difference in valence rate between types of music



The analisis between reaction time to music type shows constant results through all types of music, nonetheless because of the variability between individuals and the complexity of this analisis, we did a second analysis where we can see the difference in response to in each subject, the second analisis confirmed what we saw in the first, there is no significant variability in reaction time to music type.

Discussion

The present study aimed to explore open questions regarding the relationship between interoceptive sensitivity (IS) and emotional responses to musical stimuli. Specifically, we sought to determine whether individual differences in IS influence the connection between subjective emotional intensity and physiological signals, such as pulse rate, in response to music. To examine this, we utilized an index of IS derived from the heartbeat discrimination task. We got to this value through a series of steps in

complicated data and signal processing, a method for measuring an individual’s ability to accurately perceive internal bodily signals.

Our findings showed a link between IS and valence ratings, indicating that people with higher IS tend to feel more intense emotional responses depending on the emotional tone of the music. However, we did not find any connection between IS and the type of music even though there is a difference in music mood depending on its type. Nonetheless our findings suggest that the genre or style of music does not significantly influence physiological signals such as pulse rate. Instead, the emotional tone or mood of the music appears to play a larger role in shaping both emotional and physiological reactions. However, because of the inconsistency in results between the difference in valence rating of the music by type of music and the non existent difference in the physical responses to type of music we believe a more deep study and broader music types have to be studied. In conclusion these results highlight how an individual's sensitivity to internal bodily signals directly affects their emotional and physical responses to music, deepening our understanding of the interplay between interoception, emotion, and physiology.