From Plato to Pinker: Measuring the Tastiness of Auditory Cheesecake

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Abstract

We are interested in the inter-relationship between music, emotion and mood, specifically whether and which emotions are evoked by music and if this relationship is modulated by mood. To answer this question, we asked a large sample of research participants to listen to a wide variety of randomly selected musical excerpts and report the emotions evoked by this music. In addition, we also asked them to indicate their mood state at several points throughout the study. Doing so, we found that moods are better at impacting emotions evoked by a given set music excerpts than the other way around. However, the relationship is more complex as positive moods serve as a more robust predictor of emotional responses to music. A similar relationship holds when observing emotions as a function of moods, as positive moods are a better predictor of emotions. We conclude that music, mood, and emotion have a complex relationship which varies over time and which is contingent upon certain emotions and moods.

Introduction

Archaeologists trace the first musical instruments - such as bone flutes - to at least 50,000 years ago (Conard et al., 2009). Thus, music has played an important social role throughout history (Mithen, 2007). Moreover, music has been the subject of intellectual inquiry and discourse for philosophers such as Plato, Aristotle and Descartes as well as contemporary psychologists like Steven Pinker. However, despite this long-standing engagement with music, its impact on human emotion and cognition, the debate is ongoing - there is no consensus or agreement on the nature of music and its societal role. The purpose of our paper is to inform this debate by providing empirical evidence on how music evokes emotion, and the interplay between emotion and mood.

Importantly, it is necessary to first define what we mean by music, emotion and mood, as these terms are often used colloquially and interchangeably. Steven Pinker, in *How the Mind Works*, defines music - to distinguish it from other sounds as follows: “the notes are played and heard as discrete events with beginnings and ends and a target pitch or coloring” (Pinker, 1997). Music, in contrast to the erratic blaring of fire alarms or the constant flow of waterfalls, is defined by its structured patterns and clear rules governing its composition and rhythm. It is similarly difficult to distinguish the difference between mood and emotion. A common operational definition is based on what they affect, the idea being that emotion affects behavior while mood influences cognition (Davidson, 1994). Moreover, emotions might be evoked by specific circumstances or situations, while moods might be general states that color ongoing cognition in a more diffused fashion. It has been argued that while emotions can be changed directly, for instance by identifying and addressing their cause, altering a mood often necessitates engaging in activities like listening to music (Thayer, 1996).

This framework has been explored at length, for instance someone might react to a positive or negative event with a specific emotion (Alston, 1967), while intrinsic dispositions might dictate mood, regardless of the nature of the event. A meta-analysis found that the eight fundamental differences between mood and emotion are: duration, intensity, physiology, cause, awareness of cause, consequence, function, and intentionality (Lane, et al., 2005). However, interpretations of these terms aren't uniform across the psychological spectrum. A psychophysiologist might base definitions on the effects these states exert on the mind and body, while a psycholinguist might differentiate them based on linguistic patterns in daily

conversations (Lane, et al., 2005). Despite the challenges in clearly demarcating mood from emotion, it's crucial to do so, especially when exploring their triadic relationship with music.

Prior Research on the relationship between music, mood and emotion

Prior research has focused on the impact of music on "feelings" such as caring, clarity, vigor, hostility, fatigue, sadness, and tension (McCraty et al., 1998). They found that classical music reduced tension but did not impact any other feeling while grunge rock exacerbated feelings of hostility, fatigue, sadness, tension and reduced caring, relaxation, mental clarity, and vigor. In addition, they created "designer music[1]" that was intended to balance these feelings, which increased caring, relaxation, mental clarity, vigor while decreasing hostility, fatigue, sadness, and tension. However, this research conflates moods and emotions as "feelings", and also is too unspecific in terms of the auditory stimuli that remain on the level of "genre", which is arguably fairly broad.

Yet, there are dissenting views regarding whether music necessarily triggers emotional responses. For instance, Eduard Hanslick, in *The Beautiful in Music* presents a compelling argument of what music is and how it affects us. He contends "on the one hand it is said that the aim of music is to excite emotion […] on the other hand, the emotions are said to be the subject matter which musical works are intended to illustrate […] Both propositions are alike in this that one is as false as the other." (Hanslick, 1854). In other words, Hanslick proposes that music - an art - has no particular aim. It does not necessarily have a narrative structure or convey a message like literature does. Thus, music would not necessarily evoke emotions, as the purpose of art is to spur the imagination, not emotions. His argument rests on the fact that music cannot capture definite emotions because every emotion has a meaning or cause behind it. Taking happiness as an example, one must juxtapose it against a backdrop of prior unhappiness for it to be meaningful. Thus, given that emotions are intimately tethered to specific scenarios and causes, Hanslick concluded that such emotional phenomena elude musical evocation (Hanslick, 1854).

This train of thought has been furthered by Nick Zangwill, a contemporary philosopher. Zangwill argues that a distinction between intrinsic features of music and the subjective experience of music is essential. He points out that emotion is not an intrinsic feature of "absolute music" (non-representational music, often without lyrics); instead, it only occurs within the subjective experience of the listener. While musical pieces can elicit a spectrum of

[1] Designer Music: A genre of music that is designed to affect listeners in certain ways

moods across different moments (Zangwill, 2004) asserting that music directly engenders these emotions is a category error. This is because context is essential: the ambiance in which a song resonates, including mental or mood states, could influence our emotional response to the song. Zangwill concedes that music does have some effect as he writes: “I am less hostile to the idea that music can have the function of producing moods than to the idea that it can have the function of producing emotions.” (Zangwill, 2004). Zangwill’s argument greatly informs the hypothesis of the present study: how music affects emotional responses is indirect in the sense that it is moderated by the mood states of the listeners. Specifically, different emotional responses may be elicited by the same piece of music if the listener is in different mood states.

Music beyond art: Auditory Cheesecake

The effect of music on the emotional states of the listener has long been a topic of intellectual interest. For instance, Plato proposed a profound connection between music and the emotional and moral development of individuals, emphasizing its transformative potential to cultivate virtue and wisdom. He posited that while music can be entertaining, its influence extends beyond mere pleasure. A tangible illustration of this can be seen in the soothing effect of lullabies. Their gentle melodies have the capacity to pacify even the most restless infant, underscoring Plato's belief. He continues his argument by bringing in music’s power over our emotions: it can make us sober, courageous, and open our minds.

Furthermore, as exercise shapes a person’s physique, Plato believed music shapes a person’s soul, thus music is a powerful force that can lead a man to virtue or deform the soul. If a person’s mind is crafted and trained in the right manner using music, their emotions can guide them towards a virtuous life. For Plato, music was not merely an art form; it was an influential force with the primary mission of steering humanity towards moral rectitude and enlightening them on the righteous paths of life. He maintained that from our tender childhood years, the cadences of rhythm and the sequences of harmony insinuate themselves into our souls, exercising a profound dominion (Nazzaro, 2017). Therefore, it is important for children to acquaint themselves with music at a fairly young age, in order to nurture the infant soul early on. Otherwise, it could potentially corrupt a soul due to its ability to degrade one’s character and eventually lead us towards vice.

Following his predecessor, Aristotle distilled the essence of music into three primary objectives: amusement, leisure, and the cultivation of virtue (Rentmeester, 2022). He also

recognized the wide range of emotions that music has the ability to evoke, from calmness to brute rage, (Nazzaro, 2017). Building on the position that music creates emotions, Aristotle goes on to say that because of the wide range of emotions it has the ability to evoke, from calmness to brute rage, music should be treated with these powers in mind (Nazzaro, 2017).

A modern perspective that contrasts both Aristotle and Plato is provided by Steven Pinker. He - perhaps somewhat cheekily - terms it 'auditory cheesecake,' suggesting that while music is undeniably enjoyable and might even be addictive, it does not serve a biological purpose in our lives (Shintel, 2021). Instead, it is a "pure pleasure technology, a cocktail of recreational drugs that we ingest through the ear to stimulate a mass of pleasure circuits at once" (Pinker, 1997). If we compare it with other products of evolution such as language and vision, its disappearance would not alter our adaptive fitness. Music does not help us - in what philosophers over the years have argued - are the fundamental purpose of our existence: having offspring, attaining a longer life, predicting the future, learning something, or making the world a better place. Instead of attributing music's prevalence to Darwinian natural selection, Pinker suggests it emerged as a byproduct of our sophisticated cognitive abilities. Pinker concedes to the idea that music can influence our emotion through a concept of "emotional calls" where specific acoustic signals are associated with specific emotions.

On the one hand, as Pinker argues, music conveys vague emotions without a clear narrative. He quotes a story as an example "Boy meets girl, boy loses girl" (Pinker, 1997) to illustrate his perception of music. It is able to express tension and resolution through shifts between unstable and stable intervals and portrays happiness and sadness through shifts between major and minor intervals (Pinker, 1997). On the other hand, music can also be used to convey a convoluted message. As music often stems from language, it resembles some basic properties like syllables, pitch, and grouping of words. On a broader level, music is interconnected with six of our 'mental faculties': language, auditory scene analysis, emotional calls, habitat selection, motor control, and "something else" (Pinker, 1997).

To conclude, there is no agreement about what music is and what it means in our society. Its relationship with human life is undeniably complicated. So, the purpose of our work is to shed light on which of these theoretical possibilities has empirical support: Does music evoke specific emotions? Is it able to shift moods? If it does, how much does music matter - in other words, is

music auditory cheesecake, and if it is, how tasty is it?. For our purpose, we will focus on investigating types of emotional calls triggered by music.

Method

We used the following approach to answer these theoretical questions.

Participants

Over the course of the four years that this study was conducted, a total of 1,556 participants began the study. Due to the demanding nature of the study, 1,024 participants completed the study. As we will analyze the development of mood over time, we will only include the data from these participants in our analysis. These participants were primarily undergraduate students from New York University (NYU) who completed the study for course credit.

Procedure

We obtained informed consent from every participant prior to beginning the study. If they chose to proceed, a lab member would walk them through a tutorial of the study, briefing the participants on the types of questions they would encounter as well as how to answer them. Once the tutorial was completed, the lab member would exit the room, leaving the participant to begin the study. Upon completion, participants were debriefed as to the purpose of the study. All participants had the option of discontinuing at any point during the study, for any reason.
All procedures were approved by the New York University Institutional Review Board.

Stimuli and task

The study consisted of 801 trials. During each even trial, we presented participants with a musical excerpt. Each odd trial probed a variety of domains such as mood, personality or personal preferences.

The 10 trials that probed the current mood state of the participants were interspersed throughout the study at even intervals, including the very first and the very last trial to get a baseline mood assay before any stimuli were presented as well as a final mood appraisal at the end of the study. During these trials, participants indicated their current mood state in the following 4 dimensions: Enjoyment, Engagement, Fatigue and Distress by using a slider. All sliders were initialized at a random location. During each of the 400 evenly numbered trials, we presented excerpts from 1,000 songs from a wide variety of musical genres. Each of these trials began with users listening to a seven second clip, as we could previously show that an excerpt

with a duration of five seconds is sufficient to elicit a reliable psychological response that is close to that which would be evoked by the entire song (Philibotte et al., 2023; Spivack et al., 2019). The participant responded in each of these trials by indicating their familiarity with the song on a 5-point Likert scale, how much they liked the song on a 7 point Likert scale, how much the song energized them on a 7-point Likert scale and whether it evoked any of these 11 emotions: joy, nostalgia, groove, awe, sadness, anxiety, disgust, anger, nothing, reflection, and boredom by clicking a checkbox (whether the emotion was evoked or not).

Data Analysis

Our analysis is split into two logical sections: First, we analyze the change in mood as a function of the emotion evoked by the music, then the emotions evoked by the music as a function of mood. We hypothesize that emotions evoked by the music will significantly affect mood, but not vice versa.

To test our hypothesis, we divided the trials into 3 periods or intervals: The first 134 songs, the second 134 songs and the last 133 songs. As participants were asked to indicate their evoked emotions by songs presented in random order during these periods, we integrate how often during each period a given emotion was evoked, for all research participants. These summed emotions (how often an emotion was evoked) will serve as the independent variables for the first part of our analysis and as the dependent variable for the second part of the analysis. Conversely, the mood states at the boundaries of these intervals (before and after) will serve as the dependent variable for the first part of our analysis and as the independent variable for the second part. For each emotion, we divided participants into five groups, each roughly consisting of 204 participants, in order of how often this emotion was evoked during the interval. We employed a bootstrapping technique by randomly sampling from each of these groups 10,000 times.

For every bootstrap iteration, we randomly sampled with replacement from the five bins. This allowed us to fit a linear regression model between the five bins and their respective averages. For every iteration, we saved the beta value and whether it was negative, zero, or positive. We bootstrapped a total of 10,000 times and set alpha at 0.05 to test for significance. This analysis uses the average beta of all beta values. In total, we repeated this process a total of 14 times to get 12 beta values for every emotion (four moods and three intervals).

Results

1) Mood as a function of emotion

Here, we analyze mood as a function of emotion. Specifically, we are interested in whether the emotions evoked by songs have the ability to shift mood and if so, how specific and strong the shift is. See table 1 for a complete presentation of our results.

Results: Moods as a function of Emotion

Emotion	**Interval 1**	**Interval 2**	**Interval 3**
Familiarity	-0.0003, 0.0021*, -0.0006, 0.0008	0.0007, 0.0000, 0.0000, -0.0003	-0.0021, 0.0003, 0.0009, 0.0004
Liked	-0.0002, 0.0031*, 0.0011, 0.0025*	-0.0010, 0.0008, -0.0004, 0.0011	-0.0008, 0.0000, 0.0000, -0.0006
Arousal	0.0019, 0.0027, 0.0003, 0.0029	-0.0015, 0.0027, -0.0050*, 0.0024	-0.0005, -0.0011, 0.0019, -0.0004
Joy	-0.0076, -0.0039, 0.0040, -0.0020	0.0037, 0.0130*, -0.0026, 0.0083*	-0.0091*, 0.0029, 0.0026, 0.0014
Nostalgia	0.0018, 0.0018, 0.0012, 0.0034	-0.0021, 0.0044, 0.0032, 0.0116*	0.0008, -0.0075*, -0.0001, -0.0120*
Groove	-0.0009, 0.0053 0.0005, 0.0072*	-0.0031, 0.0018, 0.0018, 0.0056*	-0.0037, 0.0002 -0.0003, -0.0047
Awe	-0.0061, 0.0108, 0.0176*, 0.0112	-0.0116, -0.0009 0.0039, 0.0022	-0.0075, -0.0085, -0.0083, -0.0033
Sadness	0.0000, -0.0049 0.0105, 0.0203*	0.0061, 0.0023, 0.0041, -0.0169	-0.0130, 0.0164, -0.0124, 0.0068
Anxiety	0.0128, -0.0058, -0.0021, -0.0036	0.0197*, 0.0093, 0.0186*, -0.0178*	-0.0004, 0.0023, -0.0150, 0.0034
Disgust	0.0249*, -0.0223*, 0.0149, -0.0201*	0.0031, -0.0159, 0.0142, -0.0098	0.0118, 0.0052, 0.0146, -0.0056

Anger	0.0118, -0.0241, 0.0113, -0.0240	0.0150, -0.0056, -0.0092, 0.0000	0.0380*, -0.0028, 0.0172, -0.0171
Nothing	-0.0033, -0.0011, 0.00023, -0.0016	-0.0036, -0.0040, -0.0030, -0.0034	0.0074*, -0.0022, -0.0020, 0.0015
Reflection	-0.0083, 0.0095, 0.0088, 0.0153*	-0.0038, 0.0065, -0.0010, 0.0219*	-0.01302, 0.0168*, -0.0116, 0.0084
Boredom	0.0012, -0.0071, 0.0042, -0.0043	0.0064, 0.0027, -0.0008, 0.0040	-0.0022, -0.0053, 0.0033, -0.0019

Table 1: Betas are listed in order: Distress, Engagement, Fatigue, Enjoyment

'*' indicates a significant value (alpha = 0.05)

As there is so much information presented in this table, here is one example of how one could interpret this information (Column 1, Row 1): In interval 1, participants who were more familiar with the songs felt: a decrease in distress (but not significantly so), increase in engagement (significantly), decrease in in fatigue (but not significantly so), and increase in enjoyment (also not significantly)

We will now highlight some particularly interesting results in this table with a figure, and then discuss the figure, see figures below.

Music Liked

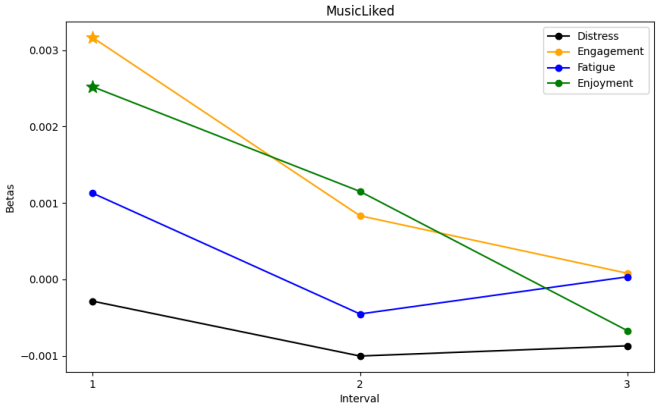

Figure 1: The four moods (Distress, Engagement, Fatigue, Enjoyment) as a function of music liked. X-axis: Interval, Y-axis: Average Bootstrapped Beta and '*' indicates significance at alpha = 0.05

There are two significant results here that merit further examination, especially given their temporal shifts. As the participants begin listening to the songs (the first 134), there is a significant difference between users who do like the songs and those who do not. This difference is evident only in engagement and enjoyment. Participants who favor the music report an augmented sense of engagement and enjoyment. However, this trend dissipates as the study progresses. It is interesting to note that the two significant results only come from the positive moods (engagement and enjoyment) which tells us there is virtually no relationship between how much users liked the songs and their shift in negative moods (distress and fatigue). This hints that users liking the songs and not liking the songs are experiencing a similar increase in fatigue and distress. Towards the end of the study, the four beta averages can be seen converging towards zero. This result is intriguing as we can conclude that after users have been listening to songs for a while, it begins to make no difference whether participants are liking the songs or not.

Joy

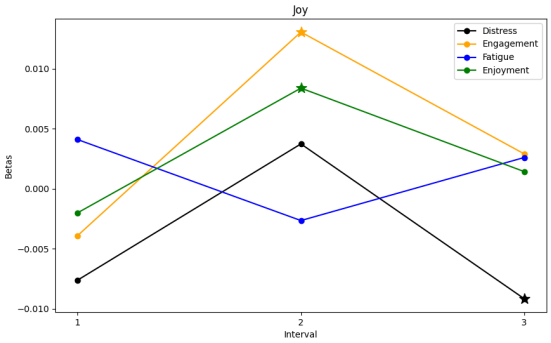

Figure 2: The four moods (Distress, Engagement, Fatigue, Enjoyment) as a function of Joy. X-axis: Interval, y-axis: Average Beta. A '*' indicates significance at alpha = 0.05

Joy is particularly an interesting emotion. Initially, during the first interval, joy does not demonstrate any significant influence of the four-mood metrics. Unexpectedly, there is a negative correlation between joy and engagement and a positive correlation between fatigue and joy, however this could be due to noise. As the study progresses, we begin to see significant results. In the second interval engagement and enjoyment have significant results. This illustrates that as participants felt more joy from the songs they were listening to, they were feeling an

increased sense of engagement and enjoyment relative to those who were not. Counterintuitively, there was no difference in how their distress and fatigue were shifting with their feeling of joy or their relative increase in enjoyment and engagement.

Disgust

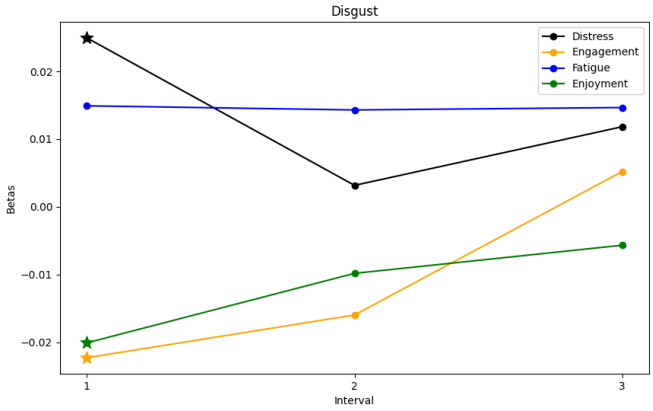

Figure 3: The four moods (Disgust, Engagement, Fatigue, Enjoyment) as a function of Disgust. X-axis: Interval, y-axis: Average Beta. '*' indicates significance at alpha = 0.05

In the first interval, disgust has the highest number of significant beta values which illustrates that it is a strong emotion when evoked. As participants felt more disgust from the songs, they reported heightened sense of distress. Although this trend is visible throughout the study, it is only significant in the first interval. Fatigue has a constant, insignificant, positive beta average. Initially, we see a significant decrease in engagement and enjoyment for participants who felt a higher disgust but that trend fades as the study progresses. This phenomenon can be explained by the fact that disgust is not a common emotion to evoke while listening to music. In fact, in the first interval it was evoked a total of 6.07% of the time, which decreases to 5.17% in the second interval and finally to 4.70% in the third interval. As the study progresses, participants generally evoked less disgust which could explain the shifts in beta averages.

2) Emotions as a function of mood

For the second part of this analysis, we focus on whether moods can influence what emotions are evoked by the music for a given participant. The method is similar to the first part, but we invert independent and dependent variables.

Again, we will start off with a table that contains a complete report of our results, see table 2.

Emotion	**Interval 1**	**Interval 2**	**Interval 3**
Familiarity	-0.6798, 0.4220, -0.3133, -0.2228	-1.1684, 1.4933, 0.0151, 0.8760	0.5657, 0.3451, -0.3365, 0.0948
Liked	-1.0726, 5.0181*, -0.2843, 3.7142*	-0.8372, 6.2741*, 0.0875, 5.8715*	-1.7124*, 5.6052*, -1.3707, 5.5059*
Arousal	-0.5972, 1.1740*, 0.8045, 0.5009	-0.0591, 2.0870*, -0.2227, 1.6132*	-0.1910, 2.0087*, -0.8948*, 1.3020*
Joy	-0.0181, 0.8854*, -0.0635, 1.0204*	-0.2659, 0.7245*, -0.1561, 0.8283*	-0.3578*, 1.0108*, -0.3688*, 1.0180*
Nostalgia	-0.4599*, 0.4544, 0.3011, -0.0408	-0.4078*, 0.7427*, 0.1604, 0.4382*	-0.3513*, 0.7487*, 0.0907, 0.7408*
Groove	-0.5717*, 0.9700*, 0.1846, 0.6553*	-0.5523*, 1.1812*, -0.1840, 1.3271*	-0.7213*, 1.0903*, -0.6008*, 1.2959*
Awe	0.0436, 0.3291*, 0.0410, 0.3395*	0.0170, 0.4404*, 0.0345, 0.4072*	-0.0355, 0.2447*, 0.0274, 0.2816
Sadness	0.0537, 0.1037, -0.0143, -0.0403	0.0572, 0.1290, 0.2637*, 0.1745*	-0.0392, 0.1224 0.1462*, 0.1265*
Anxiety	0.0630, -0.0214, 0.0414, -0.1204	0.1215, -0.0891, 0.0393, -0.0515	0.0268, 0.0678, 0.01318, -0.0239
Disgust	0.0247, -0.0440, 0.0717, 0.0094	0.0622, -0.2348*, 0.1497*, -0.0997	0.1940*, -0.2766*, 0.3075*, -0.1708*
Anger	0.0907, -0.1735*, 0.1742*, -0.0269	0.1027, -0.0384, 0.2090*, -0.0554	0.0484, -0.0327, 0.1262*, -0.0344
Nothing	0.2203, -0.6021*, 0.0404, -0.4351	0.2391, -0.0324, 0.1004, -0.3755	-0.1686, -0.4320, 0.1929, -0.6126*
Reflection	0.2315, -0.0554, -0.0983, -0.0627	0.1980, 0.1529, 0.0859, 0.2547*	0.0639, 0.2742*, 0.0484, 0.3239*

Boredom	-0.2586, -0.1624, -0.1582, -0.2349	-0.3333, -0.4719*, -0.2187, -0.7468*	-0.0700, -0.2864, -0.1331, -0.3346

Table 2: Betas are listed in order: Distress, Engagement, Fatigue, Enjoyment

Again, as this is a lot of information, we provide a sample interpretation for a particular cell (Column 1, Row 2): Participants who came into the study with an increased distressed did not like the music as much (insignificant), participants who came into the study more engaged liked the music more (significantly), participants who came into the study feeling fatigued did not like the music as much (insignificant), and participants who came in an enjoyable mood liked the music more (significantly).

Like in the first part, we now highlight several particularly interesting results with a figure as well as a discussion of each figure, see below.

Arousal

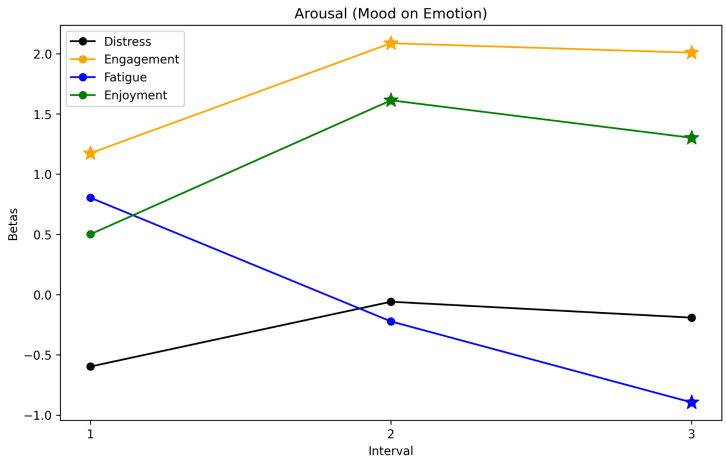

Figure 4: Arousal as a function of the four moods: distress, engagement, fatigue, enjoyment. X-axis: Average beta, y-axis: Interval. A '*' indicates significance at alpha = 0.05

Arousal has an intriguing relationship with engagement. Participants who felt more engaged as they were about to listen to a set of songs felt more aroused by the songs they listened to. This is particularly interesting because of the constant significant results seen throughout the study. Enjoyment follows a similar pattern but we see significant differences in intervals two and three. However, it is surprising to see that participants who were fatigued and distressed were not significantly different than those who were not when being aroused by the songs with the only exception coming in the third interval. This could mean that the difference

between participants who are fatigued and not as fatigued only shows beyond a certain point in the study. Those who are more fatigued in the third interval display a significantly less sense of arousal in the last 133 songs they listen to.

Joy

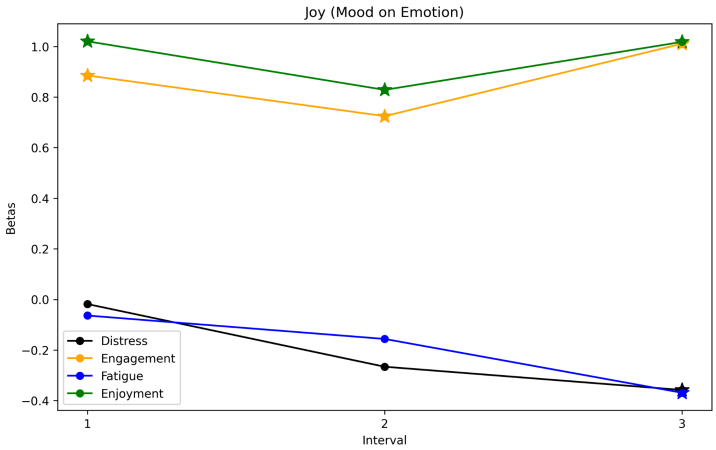

Figure 5: Joy as a function of the four moods: Distress, Engagement, Fatigue, Enjoyment. X-axis: Interval, y-axis: Average Beta. A '*' indicates significance at alpha = 0.05

One of the most significantly relevant findings was how mood impacts the joy we feel when listening to music. Participants who are more engaged and feeling more enjoyable throughout the study evoke more joy in the songs they listen to. Even though these songs were randomly sampled, their moods translated to how they felt about the songs that were played. However, this has no effect on distress and fatigue until the third interval. Again, this shows that the difference between participants feeling tired and distressed only begins to show when the study reaches the final stage.

Disgust

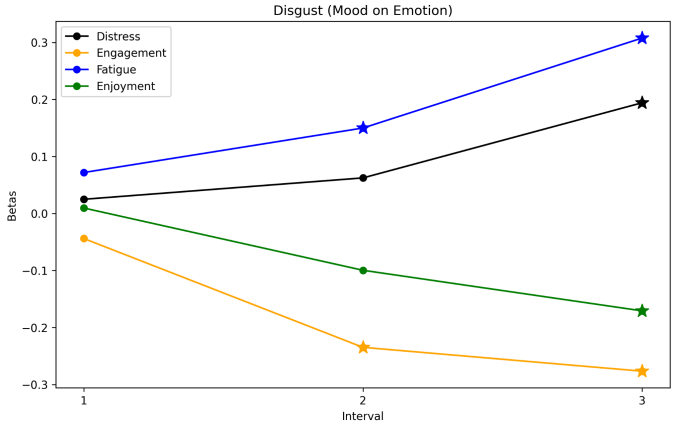

Figure 6: Disgust as a function of the four moods: Distress, Engagement, Fatigue, Enjoyment. X-axis: Interval, y-axis: Average Beta. A '*' indicates significance at alpha = 0.05

A compelling insight from the analysis is the relationship between the four moods and disgust. As previously mentioned, disgust is not a commonly evoked emotion from listening to music. However, as the graph above shows, the four beta averages initially hover around zero but progressively diverge away from zero and from each other. In the second interval, we see the results start to become significant. Participants who were more fatigued felt a higher disgust and those who were highly engaged evoked lower levels of disgust. In the third interval, we see all four moods have a significant beta. Fatigued and distressed participants feel more disgust and those in a more enjoyable and engaged mood show less disgust.

Groove

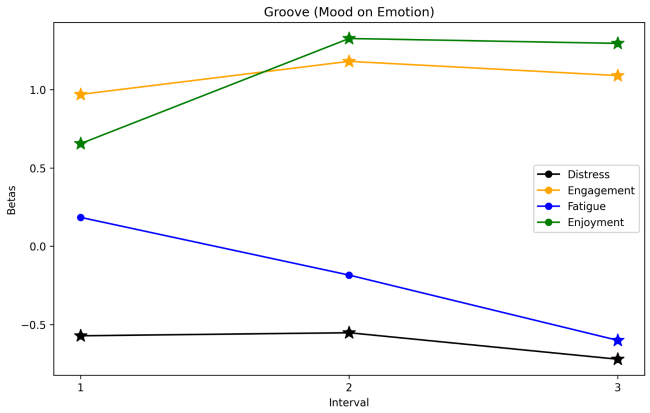

Figure 7: Groove as a function of the four moods: Distress, Engagement, Fatigue, Enjoyment. X-axis: Interval, y-axis: Average Beta. A '*' indicates significance at alpha = 0.05

From the emotions this study analyzes, one of the more positive but specific ones is groove and it is noteworthy to further investigate its relationship with moods. We see a consistently significant and positive relationship between participants' initial engagement and enjoyment and their feeling of groove from the songs. Groove is a concise emotion with a very particular meaning and this could explain why it is significantly associated with enjoyment and engagement. It could also explain why it is significantly negatively related to distress. Participants who were more distressed throughout the study felt less groove overall.

Discussion

We aimed to further the understanding of the triangular interaction between music, mood, and emotions, by considering the temporal dimension. Interestingly, in the first part of the

analysis, we observed a total of 25 significant beta values with 10 coming from the first interval, nine from the second and six from the third. This gradual decline of significant betas suggests that emotions are both less frequent and less impactful at shifting moods as the study progresses. Although the emotions evoked by music do have a significant effect on shifting mood, this effect was less pronounced than one would have expected in light of an "auditory cheesecake" account of music. To summarize the results, there were a total of six significant engagement betas, 11 significant enjoyment betas, five significant distress betas, and three significant fatigue betas. This phenomenon illustrates how emotions have a higher probability of shifting our positive moods (engagement and enjoyment) than our negative moods (fatigue and distress). If we divide the emotions into positive[2] and negative[3], we see that there is an almost even split of significant betas (10 positive and nine negative), thus positive and negative emotions have a similar effect on shifting mood.

The results we observed in the second part of the analysis were perhaps even more surprising. In total, there were 64 significant beta values. Based on prior research, we expected moods to be more stable and durable. Consequently, there were a total of 14 significant betas in the first interval, 22 in the second interval, and 28 in the third interval. This increasing trend is best explained by how mood differs from emotions. Interestingly, the beta values predominantly lean in one direction, suggesting that music amplifies our existing moods, making us feel more intensely what we are already experiencing. If we divide the moods into two categories: positive (enjoyment and engagement) and negative (fatigue and distress), we see 45 significant betas for positive moods and 19 significant betas for negative moods. This insight hints that music has a stronger influence on shifting our positive moods rather than our negative moods.

Our research indicates that music's influence lies more in amplifying our existing moods rather than altering them completely. This discovery suggests that the concerns raised by Plato and Aristotle about music's power to sway human emotions might have been exaggerated. Instead, we find a more significant correlation between our current moods and the emotions that music evokes in us. Consequently, music seems to be more reflective of an individual's existing state rather than shaping it. In terms of cause and effect, contrary to what Aristotle and Plato

[2] Positive: Arousal, Joy, Nostalgia, Groove, Awe
[3] Negative: Sadness, Disgust, Anger, Nothing, Boredom

proposed—that music is a catalyst for goodness in the human soul—our findings lean towards music being a consequence of the soul's existing condition.

Limitations

There are several limitations to this work that provide opportunities for future research. One such limitation was that we demanded a lot from our participants - given that each participant was expected to complete more than 800 trials (plus the tutorial), the study routinely took longer than 3 hours to complete. This is a concern, as mood reliably declines in all research studies in general (Jangraw et al., 2023). In other words, we do not have a stable baseline of mood that is only impacted by the music encountered. With this in mind, the strongest effect one could expect is an overall decline in mood over time, through the study. This is precisely what we observe as well, see figure 8.

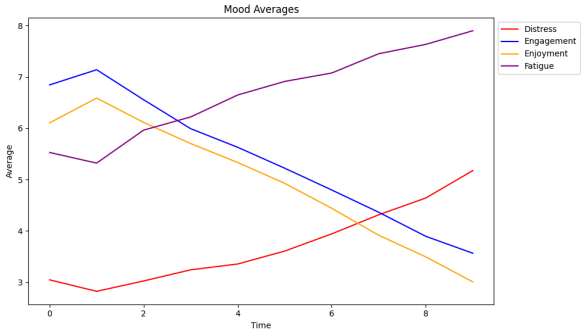

Figure 8: Mood averages as the study progressed. X-axis: Mood check-in screen, y-axis: Average mood for all participants

This figure depicts a striking decline in positive mood, and an increase in fatigue, which could explain why the mood shifting effect of music was relatively modest. We propose future research on this topic to be somewhat shortened, perhaps by about a third to a quarter less trials.

Another limitation of this study was how participants indicated their moods. We used a slider that users could move from left to right for each mood, effectively using a visual analogue scale or VAS (Aitken, 1969). However, as we did not output the numbers that the slider setting corresponded to, and as every mood trial started with a randomly placed slider setting, it is perhaps possible that participants were not able to report their mood in a reliable fashion, which would add a considerable amount of noise to our measures, a problem which has been observed previously (Wewers & Lowe, 1990).

For future research, we propose to instead use a Likert scale to report mood, and instead of resetting it at random, simply leave it off where it was at the last trial. Another limitation consists in the fact that we exposed our participants to brief snippets of these songs. While it is true that a given clip might evoke a particular flavor - or combination of emotions - that is the same as the song, it might do so much more faintly. In other words, listening to full songs might have a more powerful impact on mood. Whether listening to whole songs would move moods more strongly - which is plausible, given that moods are more stable in general - is an interesting question that lends itself to empirical research in the future.

Conclusion

We conclude that the philosophical questions we considered when starting our work have empirical answers. Our response to Hanslick and Zangwill is that music does have the ability to evoke emotions. In response to Aristotle and Plato, we conclude that music does have a powerful impact, but that it is perhaps not as powerful as one might worry, although this might be due to the fact that we used only brief snippets. As for auditory cheesecake, although music has no biological function, it is able to shift positive moods. Thus, we believe music can indeed be likened to an auditory delicacy, offering both rich complexity and appeal.

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