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Studies on annoyance in western popular music

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STUDIES ON ANNOYANCE IN WESTERN POPULAR MUSIC

by

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STUDIES ON ANNOYANCE IN WESTERN POPULAR MUSIC

RAYMOND JOSEPH HORVAT

ABSTRACT

This thesis studies the effect of the difference of felt emotion versus expressed emotion on the rate of annoyance in Western popular music. It consists of four experiments, the first of which looks at the general effect of the music and change of emotions. The second experiment looks at the effect of lyrics in songs on annoyance, the third at modality and loop type, and the fourth at rhythmic complexity. There is evidence found that a difference in felt versus expressed anger predicts an increase in the annoyance rating. The effect of the difference in happy ratings is not as consistent and depends on the song. Familiarity of the song had a slight effect on lowering the annoyance rating. Lyrics, modality, do not have a main effect on the rate of annoyance. Loop type did show a main effect on the rating of annoyance. The combination of faster tempos and simpler rhythms reduced annoyance ratings.

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ANOVA	Analysis of Variance
BOLD	Blood Oxygen Level Dependent
BPM	Beats Per Minute
WNBD	Weighted note-to-beat distance measure

CHAPTER 1: BACKGROUND

Perceived vs. Felt Emotions in Music

With the advances of research and techniques for understanding the human mind, we have gained much insight into how listeners perceive and understand emotions in music. Much research has been completed in the past 30 years into how a listener processes emotion in music. More specifically: how does a listener process the emotions music is expressing; does that effect the listener's own emotions; and how could the difference in the processes effect a listener's enjoyment of the music?

Juslin (2013) clarifies the further distinction between perception of emotions and arousal of emotions, perception being what the listener infers from the music, and arousal being an emotion that we feel. The difference in these emotions is clarified as 'aesthetic emotions' and 'everyday emotions'. Aesthetic emotions can also be described as an emotional response to music or other art forms. Juslin (2013) states that 'aesthetic emotions' are felt separately and can relate back to the assumption of realism in much previous music and emotion research. One assumes that music is of no consequence to a listener's goals, and our emotional system should respond accordingly. This, however, does not agree with other research (Juslin, 2011), which shows that music can arouse emotions in listeners.

Emery Schubert (2013), in a literature review, further explores the differences between emotions felt by the listener and those expressed by the music. Schubert (2013) uses Alf Gabrielsson's terminology of "internal locus of emotion" (IL) to mean the emotion that is felt by the listener, and "external locus of emotion" (EL) to mean the emotion that is expressed in the music. He then goes on to further define relationships between these loci, using three different relationships. The first two relationships, matched and unmatched, show how the expressed emotion relates to the felt emotion. Subcategories can then be added to include valence of the relationships (e.g., positive to positive matched valence). The third option is a complex/mixed relationship which allows for the possibility of both matched and/or unmatched occurring at the same time. He then states that this third relationship is "provided for completeness rather than necessity."

Patrik Juslin, et al. (2009) discuss a reason why a listener's emotional response may match what emotion the music is expressing. Emotional contagion occurs where the "listener perceives the emotion expressed in the music and then internally mimics the expression through afferent physiological feedback leading to the induction of the same emotion." (Juslin et al, 2009).

In their research Juslin et al. (2009) watched for different physiological reactions, including changes in zygomatic facial muscles, changes in heart rate, skin conductance, and finger temperature, while also including a self-reported emotional experience of the subject. Through studying these differences, they found that the listeners did react with the same emotions as the songs they were listening to, and showed that emotional contagion might be the cause of this reaction (Juslin et al., 2009).

Emery Schubert (2013) discusses different aspects of emotional contagion, and how most felt emotions are rated lower than the expressed emotions. One potential explanation through the emotional contagion theory is that of social circumstances of the study. In many of the studies, Schubert states that the circumstances of completing the survey in a group setting could cause the participants' felt emotions to be suppressed and affected by those around them. When one completes the study in a group, they may be affected in similar ways as those around them, thus experiencing both the emotional contagion effect of the music, and of the other participants.

Schubert also goes on to discuss dissociation theory, which can also be used to explain the difference in how a listener hears expressed emotions and feels those emotions. This theory of dissociation splits the emotions into different kinds of "feeling": emotional valence and affect valence. "Emotional valence is specific to emotional contemplation, without any necessary approach or withdrawal action readiness." Affect valence has to do with response qualities, or preferences. This usually is the result of music listening, and can involve the more aesthetic responses to music such as "Awe, spirituality, and being moved."

This valence distinction provides a cognitive theoretical standpoint from which, while listening to music, we can separate our emotions from associations with painful emotions. This distinction is used to better explain how a listener can enjoy listening to music with negative associations (Schubert 2013). It is also used to understand more complex situations in which music may induce a mix of emotions from the listener, and thus elicit more complex responses (Schubert 2013).

The theory of emotional contagion has many different aspects, but one of the most important aspects is the possibility of a listener's felt emotions to be different than that of the emotions that the piece of music is expressing. This may seem contradictory, but if a person can be feeling the same emotion as the music expresses, they can also be influenced to be feeling the opposite emotion. This insight also leads to more questions that Juslin's study did not address, for example, is the listener simply mimicking the emotion that the music is expressing, or are they changing their own emotional state? This is slightly explained in the theory of emotional dissociation but not thoroughly.

Patrick Hunter et. al (2010) discuss this topic in a study in which they had participants listen to 30-second clips and rate their perceptions of emotions in the music, along with their emotional responses to the same music. The researchers intentionally chose instrumental music so that lyrics would not affect the listeners' perceptions. Specifically, they used pieces composed by J.S. Bach. Listeners made six ratings for happy feelings, sad feelings, happy perceptions, sad perceptions, liking, and disliking. The authors found that overall feeling ratings were higher than perceiving ratings, and suggest that listener's feelings about songs are mediated by their perception. "Our findings suggest that the distinction between feeling and perceiving emotions when listening to music is primarily one of quantity (or intensity) rather than one of quality." (Hunter et. al, 2010, p. 53).

Hunter et. al (2010) question the validity of how easy it is for participants to differentiate their feelings and their perceptions of feelings in songs.

> Considering our findings jointly with these other [cited at the end] we speculate that differences between feeling and perceiving ratings stem from instances when (1) participants recognize the intended emotion of the piece without actually feeling the emotion, (2) the perception is more or less obvious but the feeling is relatively subtle, or (3) the feeling is a consequence of a manipulation (e.g., exercise) or association that has no effect on listeners' perception. (Evans & Schubert, 2008; Schubert 2007a;

> 2007b; Dribben, 2004, Juslin & Laukka, 2004; Zentner et al., 2008) (Hunter et. al, 2010, p. 54).

Some of the general terminology used in this thesis is further defined and clarified in Table 1.

Table 1. Definitions of Terms adapted and combined from *Handbook of Music and Emotions, From Everyday emotions (Juslin 2013), and Emotion Felt By Listener (Schubert 2013)*	
Affect	an umbrella term that covers all evaluative — or 'valanced' (positive/negative) — states (e.g., emotion, mood, preference). The term denotes such phenomena in general. If that is not intended, a more precise term (e.g., emotion, preference) is used.
Emotion	a quite brief but intense affective reaction that usually involves several sub-components-subjective feeling, physiological arousal, expression, action tendency, and regulation- that are more or less 'synchronized'. Emotions focus on specific 'objects' and last minutes to a few hours (e.g., *happiness, sadness).*
Mood	affective states that are lower in intensity than emotions, that do not have a clear 'object', and that are much longer lasting than emotions, several hours to days (e.g., gloomy)
Feeling	the subjective experience of emotions or moods. One component of an emotion that is typically measured via verbal self-report.
Arousal	physical activation of the autonomic nervous system. Physiological arousal is one of the components of an emotional response but could also occur in the absence of emotion (e.g., due to exercise). Arousal is often reflected in the 'feeling' component (i.e., the subjective experience).
Preference	more long-term affective evaluations of objects or persons with a low intensity (e.g., liking of a particular piece or style of music)
Aesthetic judgement	a subjective evaluation of a piece of music as art based on an individual set of subjective criteria.

While most of these previous studies used music that was thought to be unfamiliar to the participants, they could not guarantee that the listener had any previous experiences that may have influenced their emotional responses.

Olivia Landinig and E. Glenn Schellenberg (2012) study how the unfamiliarity of songs would affect participants' emotional responses. They used different musical stimuli that consisted of 48 excerpts. One fourth of the excerpts were picked to cue happiness with faster tempos and major modes. Another fourth of the excerpts were picked for cues to sadness, with slow tempos and minor keys. The last half of the excepts had inconsistent cues, e.g., slow tempo and major mode (Landinig, and Schellenberg 2012). Participants would then listen to all 48 excerpts and rate the perceived complexity, liking, intensity of their emotional response, and which emotion they felt (Landinig, and Schellenberg 2012).

The authors found that the greatest emotional intensity was identified in higher levels of felt happy music, and similarly with higher levels of felt sadness. Liking the excerpts was correlated with a positive happy response. The same was correlated negatively with feeling sad. They also looked at what they called “musical structure” but this consisted only of the small-scale structure of tempo and mode. They compared the tempos and liking ratings using ANOVAs, and found that liking ratings were higher for fast than they were for slow tempos. They also showed that pieces with consistent cues had higher intensity of rating than those with mixed cues. Their results indicated that people liked happier music and tended to dislike sad music (Landinig and Schellenberg 2012).

One of the most significant correlations that the authors found is between openness to experience and liking of music. If someone is more open to experience and agreeable, they rate highly intense and highly complex music as more to their liking. This study intentionally focused on the personality characteristics of someone listening, and not where or why they were listening.

> Instead of asking when and where listeners like music that evokes sadness or mixed feelings, we asked who likes music that makes them feel sad. Our results were consistent with our hypotheses. Liking music that evoked sadness tended to be stronger among participants who scored (a) high in Introversion (or low in Extroversion), which is characterized by seeking internal stimulation and avoiding social contexts; or (b) high in Openness-to-Experience, which is characterized by curiosity, imagination, and the appreciation of a variety of experiences (Landinig and Schellenberg 2012, p. 151)

This study's research into likability of songs based on personality is important to the research in this thesis.

Annoyance and Likeability in Music

Since the research in this thesis focuses on annoyance in music, we need to discuss what annoyance means and how we can define and contextualize it in relation to previous research.

While annoyance can be related to likability, they are not opposites. Annoyance may manifest for many reasons in music, some intentional and some not. For example, if lyrics are describing something annoying that is happening, and the music matches the lyrics, then it could be perceived as annoying. Perhaps this song is meant to make a listener uncomfortable, and therefore comes across as annoying. There are also many non-intentional reasons that music could be experienced as annoying, such as previously associated memories with a specific song, or certain chord progressions, or repetitions of a song, or even repetitions of aspects of a song.

While all of these could make a song annoying, the intentional reasons can shed insight into how likability and annoyance are not opposites but are more complexly related. For example, imagine an aria in an opera that is sung by a weaselly character, who explains their idea to foil the protagonist's plan. The aria is not supposed to be great; you're not supposed to like the character singing it, and maybe the composer doesn't want you to like the music. Therefore, the song comes off as annoying for this reason, but if you knew beforehand (from previous context in the imaginary opera) that this character was annoying, you might expect this aria to be annoying. When the listener's expectations of a song match with what they hear, they may enjoy it more, and may be likely to rate an annoying song as something they like. While hypothetical, this is one potential explanation for why annoyance and likability have a more complex relationship.

This relationship provides an ideal starting point for this study of annoyance. While likability and annoyance are not opposites, they are similar enough in nature to compare. Many studies have looked at likeability in music, and their models are a good guide to studying listeners' perceptions of emotions and annoyance in music. While Landinig et. al (2011) found that participants had higher likability ratings for music with cues to happiness (fast tempo and major mode), this is not always found to be consistent (Galan, 2009). Fast tempo is a better indicator of arousal rather than a specific emotion (Schubert, 2004), and major mode is not always consistent with happy responses from listeners (Collier, 2001). This research did not, however, discuss more complex situations, such as why someone may like music that is sad, and it only partially discussed music with mixed cues.

Likeability in music is closely related to emotions in music. Emery Schubert (2016) discusses the more complex process of why listeners enjoy sad music. Here Schubert shows evidence for the Parallel Processes Hypothesis, where a listener can identify the aspects of the music that they enjoy while also separating the negative emotion in the music.

> The listener can enjoy negative emotion in music not necessarily because it is accompanied by something that is somehow positive. The sadness itself seems to be enjoyed, and the awareness that the sadness does not cause "actual" harm is possible because of the context being aesthetic, rather than a day-to-day, real-life event (Schubert, 2016, p. 4).

Schubert also goes on to state that the emotions uncouple from each other, so that we can engage with other emotions going on around us without directly letting those perceptions affect personally felt emotions. He attributes this phenomenon to a suspension of real-life feelings and to the role of play. "Play is something in which one may engage simply for its own sake." (Van Leeuwen and Westwood, 2008) This world of play allows an individual to experience different emotions in a "safe" environment. Music is a cognitive activity in which different experiences, including emotional experiences, can be explored in a safe environment, allowing a listener to experience it at various levels of comfort. This idea is closely related to the dissociation theory discussed in section one of this chapter. Dissociation occurs where a listener can differentiate between the activity happening in their music and their own, and can view listening to music as separate from their personal emotional experience.

Repetition, Emotions, and Annoyance

Repetition is important to consider when looking at annoyance. One may think that overly repetitive patterns could annoy a listener. Someone could turn on the radio and say, "I hate this song, I've heard it too many times." Repetition would seem to have a direct effect on annoyance. When looked at in depth, though it is often that listeners enjoy repetition in music. Elizabeth Margulis's (2013) article "Repetition and Emotive Communications in Music versus Speech" and her 2014 book *On Repeat* discuss various aspects of the interplay of emotions and repetition.

Margulis (2013) compares the differences between repetition in music and in speech. She states that musical repetition is one of the very few universals across different musical traditions. Speech is an important type of human communication and is very commonly compared with music in music cognition research about repetition. Margulis argues that direct repetition is something special that happens in music that is not as common in speech patterns. The most common place that it happens in speech would be repetition of a line or phrase in poetry. Margulis states that repetition in speech invites the listener to pay attention to that phrase again and focuses us to recontextualize that phrase in a different manner, usually on a lower level (2013b)

Usually, when a spoken phrase is repeated, the listener processes the repetition to the phrase's "lower-level prosodic aspects". For example, if someone constantly repeats a word, a listener may not process each one syntactically and only hears different syllables or differences in sounds between repetitions (Margulis, 2013b). Margulis goes on to argue that the opposite happens in musical repetitions. Instead of only moving to lower-level prosodic aspects, listeners can move in either direction, both to lower-level and higher-level aspects of the music. She speculates that the decision of going up to a higher level or to a lower level could be dependent on the hierarchical complexity of the music itself, and the number of repetitions (2013b).

In 2011, Livingstone et. al studied the large-scale effect that formal repetition has on participants' emotional responses and arousal. They found that arousal went up when sections were contrasting, and arousal went down when a participant was listening to a section that was being repeated. They used *Pizzicato Polka* by Johan Strauss Jr., which opens with an ABA' form, which is repeated exactly later in the music. They found that both times the music would repeat from the first A section to the B section, arousal peaked. They also found that when the A' section appeared, arousal went back down as the material was already familiar to the participants. The research showed that these boundary points between sections could be accurately predicted algorithmically by participants' emotional arousal (Livingstone, 2011).

In her book, Margulis (2014) discusses the different ways that humans process spoken thoughts as compared to musical thoughts. The difference, according to her, is gist vs verbatim thoughts. Gist memory remembers the general idea of the statement, while verbatim memory involves remembering the statement word for word. Margulis states how most communication by speech is processed mostly as gist memory. When someone is asked to complete a task, they do not remember the exact words or phrasing that was said to them, but often only remember the task they need to complete and a general idea of how it was said to them. They can often repeat back what they must do, but not in the exact words that were spoken to them (Margulis, 2014).

When looking into how repetition can affect emotions, Margulis draws the comparison of a ritual, or some repetitive act that one does every day. These rituals, such as a morning routine, consist of a combination of small tasks, like making the bed, brewing coffee, etc., and can act as a script of episodes. It is easier to recall these emotions as episodes, but excessively repeating these brings the focus down to the lower-level properties of the ritual, like the exact motions you make in making the bed. Margulis also states that excessive repetitions can signal intentionality, showing what gestures and ties to the social community the ritual's participant views as significant. Margulis says that this "…might underlie the capacity for a special kind of emotional engagement" (2013b). In her study she found interesting results concerning intentionality and emotions in music.

> Margulis arbitrarily inserted repetitions into excerpts of contemporary art music by renowned composers Elliott Carter and Luciano Berio, and everyday listeners without special training or experience with the genre rated the repetition-hacked examples as more likely to have been composed by a human artist and the original versions as more likely to have been randomly generated by a computer. Repetition in music, like repetition in ritual, then, can serve to signal intentionality, and this recognition of intentionality might facilitate the capacity to engage with sounds as emotionally communicative (Margulis, 2013b p. 2).

In her 2014 book, Margulis talks about the case of a listener's repeatedly listening to a song in relation to earworms. One aspect of repetition is intentional repetition, Margulis found that repetition in music is often an enjoyable aspect of the music (2014). Often, listeners would intentionally listen to the same song over and over again, often listening to different aspects or listening at higher or lower levels.

An earworm is a repetitive musical loop that plays on repeat in a listener's mind often involuntarily and can often be hard to ignore (Margulis, 2014). The musical imagery created often only consists of melody, and only in few cases consists of harmony along with the melody (Margulis 2014). Liikkanen (2008) suggested that about 90 percent of people experience involuntary musical imagery at least once a week, while 25 percent experience it several times a day. Bailes (2007) randomly sent requests throughout the day, asking participants if they were experiencing involuntary musical imagery at that moment. They found that during between 10 percent and half of randomly selected moments, a participant was experiencing involuntary musical imagery. The most common activity in which the participants were involved at the time of the musical imagery was a time filler activity like waiting in line, and more often in social contexts (Margulis, 2014). Often an earworm is a pleasant experience to the participant, and they enjoy the music that is playing in their head (Margulis 2014).

The studies investigating musical repetition shed insight on how repeated phrases in music can differ from speech, and how both can affect annoyance during listening. Musical repetition is often an enjoyed aspect of music and can provide intentionality to music. This raises different questions pertaining to likability and annoyance. Is a song with more repetition likely to not be rated annoying? What about a song with no repetition at all? What aspect of the song is repeating, and how do lower-level repetitions compare to higher level-repetitions (repetitions at a formal level)? While repetition is not the main factor being researched in this thesis, it is an important area to address and study alongside with the emotional responses of participants.

Areas of Interest for This Research

The research and studies in this thesis use these theories of emotional contagion, dissociation, and decoupling of emotions as a basis, but are primarily interested in how the difference in EL and IL can affect a participant's view of music as annoying or irritating. I study this by using similar frameworks to previous studies on how emotions can affect likability, but applying them to annoyance rather than likeability. The thesis consists of four different research studies, the first of which consists of a basic study to test how the differences between felt and perceived emotions in music can be used as a predictor for participants' finding a piece of music annoying. The second study investigates what effect lyrics may have on the rating of annoyance, using a similar model to the one in the first study. The third study focuses in on underlying structures of the music, and tests what effect different chord progressions and/or loops will have on listener's responses and annoyance rating. The fourth study resembles the third, but will instead investigate the role of tempo and complexity and their effect on listeners' annoyance response.

Chapter 2: Felt Versus Perceived Emotions in Western Popular Music

Background

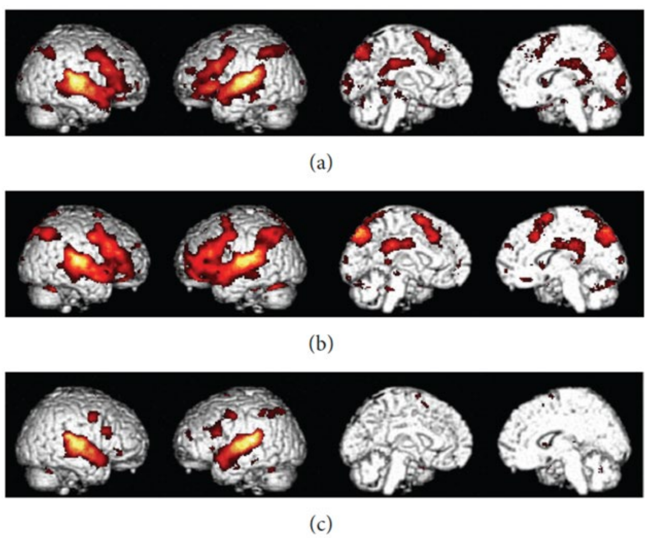
This study investigates what effects felt versus perceived emotions have on the rating of annoyance after listening to a selected song sample. It investigates what factors may influence a felt rating and an expressed rating, and how the difference between the two correlates to annoyance. Previous research into expressed and felt emotions has looked at the difference between the two, including from the neurological perspective.

Ken-ichi Tabei (2015) showed that different parts of the brain are activated when understanding expressed emotions versus felt. He cites evidence from previous studies, involving patients with brain damage, that suggested that the functions could be in different parts of the brain.

> A patient with damage to the parietal lobe in his right cerebral hemisphere who had selective impairment of felt emotion while listening to music; however, the patient's intellectual function, memory, constructional ability, and perception of emotional expression of the music remained normal (Satoh, et al, 2011) (Tabei, 2015 p. 2)

This study and others like it led him to further study what this difference was. He had participants listen to different musical examples that were randomized, with 16 being happy, 16 sad, 16 scary, and 16 peaceful. One group of listeners judged which of those four emotions they experienced as feeling as a result of listening, while a second group rated what emotion they perceived (Tabei, 2015). The participants completed these surveys while in an MRI machine, so that the researchers could measure activity in different parts of the brain.

Perceived emotions on average were stronger than felt emotions in participant ratings. Perceived emotions were correlated with increased activity in the bilateral inferior frontal gyri. Felt emotions correlated with activity in the precuneus region of the brain. These can be seen clearly in Figure 2.1. Previous research suggests that the precuneus region is more responsible for "self-representation," and is activated when involving judgements from a first-person perspective (Cavanna, 2006). Tabei (2015) suggests that because of this, the precuneus region is involved with evaluating a listener's cognitive emotional changes when listening to music.



2.1 Cortical areas where the blood-oxygen-level dependent signals increased with the perceived emotion (a), felt emotion (b), and passive listening (c) tasks; voxel level after correction for false discovery rate (p<0.05) borrowed from Tabei, 2015.

As for the perceived emotions, Tabei (2015) found that the dorsolateral prefrontal cortex was activated in the assessment of emotions. This is the same region of the brain that is activated when listeners judge the tonality of music (Mizuno, 2007). Tabei (2015) suggests that this area of the brain may be activated because the stimuli used many different major and minor tonalities (Tabei, 2015).

Thus understanding the separation of expressed emotion versus felt emotion in music, I completed a pilot study that looked at what effect felt and expressed emotions had on the rating of annoyance for a song. I took songs that were explicitly expressing certain emotions, one thought to be annoying and another thought to be enjoyable. These were chosen from lists compiled in an earlier survey in which participants were asked to supply songs expressing happiness, sadness, anger, and calm that they enjoyed listening to, as well as ones they thought to be annoying.

I found that expressed emotions and felt emotions themselves did not influence the rating of annoyance. When factoring the difference of the two, though, there was a significant influence on the rate of annoyance. I found strong evidence that if there is a difference between the expressed and the felt emotions, there is a correlation to a higher annoyance rating.

For example, the song “The Story” by Brandi Carlile was expected to be sad but not annoying, while the song “My Heart Will Go On” by Celine Dion was expected to be sad and annoying. When participants listened to “The Story” they were more likely to rate the expressed emotions in a similar way as to how they felt so there was not a large difference. However, in “My Heart Will Go On” they were more likely to rate the song as expressing sadness, but they would not rate the same level of felt sadness the song was expressing. This was associated with a higher annoyance rating.

This study is the basis for all the experiments in this thesis. This first experiment is an exact replication of this experiment; the further experiments will focus on different aspects of the music that may be causing annoyance.

Hypothesis

Based on the pilot study, if the expressed emotions in a piece of music have a similar rating to the felt emotions by a listener, the song will be rated as less annoying. Based on previous research, I expected the overall expressed emotion rating to be in general higher than that of the felt emotion. However, I expected that the larger differences will be correlated with a higher annoyance rating. If the perceived emotion of a song does not have a similar rating to the felt emotion of a listener, it will be rated as more annoying. I expected the number of times the participant has heard the song to not have an effect on the annoyance rating.

Methodology

The experiment consisted of a self-report survey completed by participants. The participants initially answered demographic questions about their gender, age, years of music training, and emotions they were feeling at the time (Happiness, Sadness, Anger, Calm, Annoyed). All emotions were rated on a 7-point Likert scale, where a lower rating means that emotion is not apparent, and a higher rating means that emotion is apparent.

The participants then listened to a short 30 second clip of the chorus of a song, and rated what emotions the song was expressing, using the attributes happy, sad, angry, and calm/relaxed on the 7-point Likert scale. They then rated emotions for how the song made them feel for the similar attributes happy, sad, angry, and calm. However, annoyed was also added in the felt section of the ratings.

Eight clips were selected for this experiment. The songs were chosen from results of the pilot experiment. Two songs were studied for each emotion; one song of each emotion was thought to be enjoyable to listen to, and another was thought to evoke annoyance. The songs and their associated emotions can be seen in Figure 2.2.

	Not Annoying	**Annoying**
Happy	September- Earth, Wind, and Fire	Happy- Pharrell Williams
Sad	The Story- Brandi Carlile	My Heart Will Go On- Celine Dion
Angry	Bulls on Parade- Rage Against the Machine	Bring Me to Life- Evanescence
Relaxed	Sunflower- Post Malone	When She's Dancing- Fly By Midnight

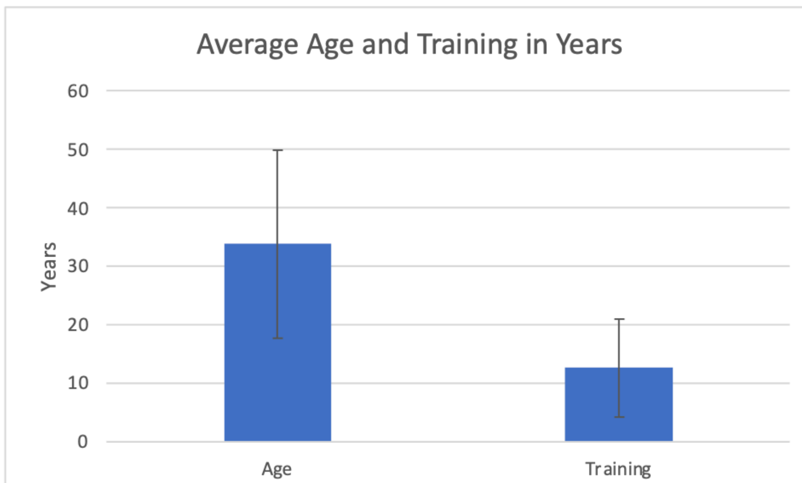
Figure 2.2. Chart of songs used in the experiment.

Songs were then made anonymous as to avoid name bias before the participants listened to the song clip. Each song was labeled with a symbol (!,@,#,$). Then, three surveys were created, and the song clips were randomized for each survey. Each link was placed on a redirect website called Allocate.Monster. This allowed participants to receive one link and be randomly redirected to one of the three surveys.

At the end of each song, participants were asked, to the best of their knowledge, how many times they had heard the song before, and if they had any previous memories associated with this song. If they did have any previous associated memories, they were invited to share them. The shared memories can invite further study as to why the participant responded the way they did and could open further areas of research later in this thesis.

Results

A total of 40 participants completed the survey, and one had to be excluded, as they informed me that they did additional research on the songs while listening. Out of the remaining participants, 15 were male, 21 female, and 3 identified as non-binary. The average age was 33.77 years, with a standard deviation (SD) of 15.86 years. The average years of musical training was 12.6 years, with a SD of 8.32 years. These can be seen in Figure 2.3. Before starting the survey, the average happy rating was 4.55 with a SD of 1.32 (out of the 7-point Likert scale); sad was 2.4 SD of 1.7; anger was 1.45 SD of 1.07; relaxed was 5.05 SD of 1.4; and annoyed was 1.93 SD of 1.51. These can be seen in Figure 2.4.



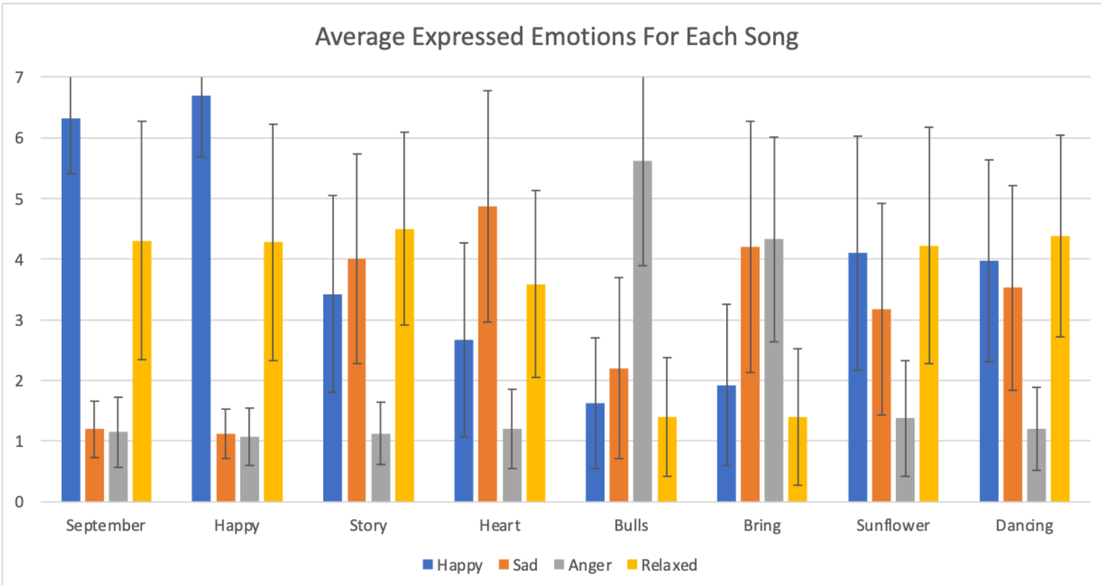
2.3 Average ages of participants and average training of participants in years

Figure 2.5 gives the averages of all the expressed emotions and their standard deviations. This figure shows that the songs expressed the emotions they had been chosen to express. This agrees with the pilot study. "Bring Me To Life" had a similarly high rating for both sadness and anger, but the anger rating

	Happy	Sad	Anger	Relaxed	Annoyed
Mean	4.55	2.40	1.45	5.05	1.93
Standard Deviation	1.34	1.72	1.08	1.41	1.53

2.4 Average emotions of participants before starting the survey.

was still on average slightly higher. The relaxed songs similarly had high ratings for happiness, but the relaxed rating was still on average higher.

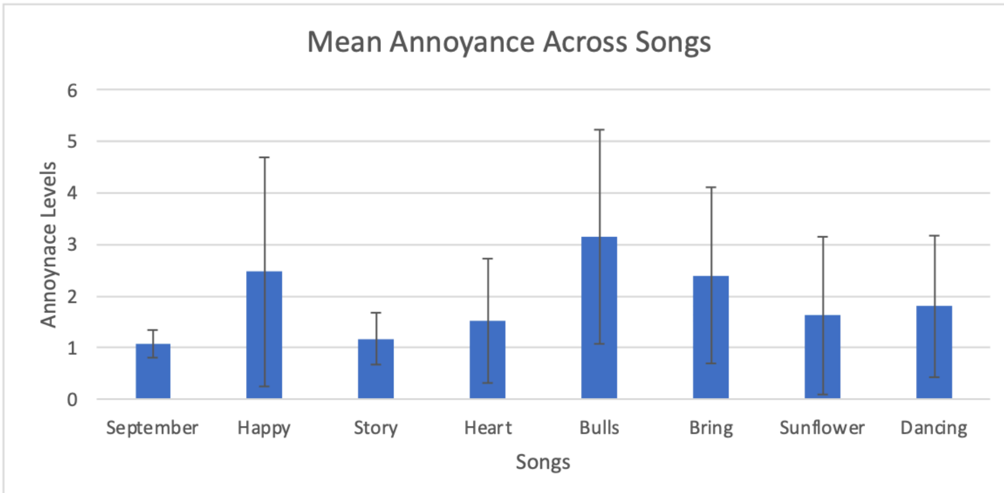


2.5 Average expressed emotions for each song and their standard deviations.

As for overall annoyance, as seen in figure 2.6 and 2.7, the songs that were chosen to be more annoying were rated as more annoying by the participants. The only difference involved the songs that were chosen for the emotion of anger. Both songs were rated as more annoying than any of the other songs. “Bring Me To Life”, selected as the annoying choice, was seen as less annoying than “Bulls On Parade”. While there are differences in annoyance rating between each song, within the emotions of sad, anger, and relaxed there are not very large differences.

	September	Happy	Story	Heart	Bulls	Bring	Sunflower	Dancing
Mean Annoyance	1.08	2.48	1.18	1.53	3.15	2.40	1.63	1.80
SD	0.27	2.22	0.50	1.20	2.07	1.71	1.53	1.38

2.6 Mean annoyance and standard deviation for each song.



2.7 Mean annoyance and standard deviation for each song.

To further analyze the data, I ran a stepwise multiple regression to see if there were any main effects of each song on the rated annoyance level, and to also see if there were any interactions between songs and the difference in rated expressed emotion and felt emotion by the participants. The stepwise multiple regression used was in both directions. This means that the initial regression included the influence of all possible variables on annoyance. The program then systematically either removes or adds back in different variables, while keeping the low significance by maintaining a consistent R^2. By the end of the process, what is left is a smaller, more manageable regression that shows the statistical significance for the most influential variables.

All regressions were run through the statistics software R. Interpretation of the categorical variable (song) and its interactions is complicated by the fact that R breaks this into seven binary variables and treats the alphabetically first song ("Bring Me To Life") as the default value. For this regression all categorical song variables are being compared to the variable of the song "Bring Me To Life". I wanted to study how the difference between the felt versus expressed emotions effected the annoyance rating. To do this, I created four new categories in the data consisting of the absolute value of the perceived emotion subtracted from the felt emotion. These are represented in the regressions as happydif (happy difference), saddif, angerdif, and relaxeddif respectively.

To test the significance of song as a factor I ran an ANOVA test on the regression, and a null regression. The null regression is the exact same regression, but it removes song as a factor. The factor of song proved significant with an F=15.9 and a p=2.20e-16.

Model 1: Annoyed2 ~ Happydif + Angerdif + Times + Participant + Song:Happydif + Song:Angerdif
Model 2: Annoyed2 ~ Song + Happydif + Angerdif + Times + Participant + Song:Happydif + Song:Angerdif

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)	
1	265	470.46					
2	258	328.64	7	141.82	15.905	2.20E-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

2.8b ANOVA of regressions used to determine significance of song factor.

In the first regression, one can see the trends of coefficients of the individual songs. Compared to the song "Bring Me to Life", songs tended to be rated as less annoying, with songs like "The Story" being rated lower than the others. The song "Bulls On Parade" had a significantly higher coefficient of 1.74, meaning that this song had a higher annoyance rating than the song "Bring Me to Life." Different features of the songs themselves led to different patterns in annoyance ratings.

Times listened to the song was significant in the regression, with a coefficient of –-0.12 and a p=.007. This shows that the number of times listened influences level of annoyance. More specifically, for around every 10 more times that someone listened to a song, the annoyance rating for that song was lowered by 0.12.

Then, looking at the effects of difference in felt versus expressed emotions, we can see in the results that they do not show as a main effect. They do, however, show notable changes in the interaction with song. This means that happy difference and anger difference are predictive in annoyance for certain songs but not others.

When looking at the changes in the coefficients from happy difference to the interaction of happy difference and song, we can see trends among the songs. For the Song "Happy" we can see an increase of 0.51in the coefficients. This means that for every increase in the happy difference by 2 the rate of annoyance would increase by 1.02. The difference for the other coefficients mostly stayed between 0.1 and -0.1 and did not show consistent trends in the positive or negative direction. However, for the song "Bulls on Parade" it showed a change of -0.6; this means that for every increase of 1 in the rating of happy difference, the annoyance rating of the song went down by 0.6.

The changes in the coefficients for anger difference showed more consistent trends. Overall, the interaction of the difference in felt anger and expressed anger, and song, showed a positive trend in the change of coefficients. The song "Happy" showed a change of 0.58 in the coefficients. This positive trend was seen across the songs "When She's Dancing," "My Heart Will Go On," "Happy," "September," and "Sunflower." The song “Bulls on Parade” saw the opposite results with a change in the coefficient of -0.35; this means that for every increase in the anger difference by 3, the annoyance rating would go down by 1.

Discussion

The number of times someone has heard the song before proved to be slightly significant on the rating of annoyance. Based on the comparison of the results found in the regression, number of times listened leads to a lower rating of annoyance. This agreed with my prediction and is consistent with results mentioned by Elizabeth Margulis (2014).

This study did find similar results as previous research, in which participants are actively able to differentiate between expressed emotions verses felt emotions (Schubert, 2013. Juslin 2009). It also shows that certain correlations with the difference in expressed versus felt emotions and how they influence the annoyance rating could be due to an inability of the song to make the listener feel the emotion it is expressing. With the rating for the song “Happy”, the listener heard that the song was expressing happiness but did not feel the same level of happiness, and rated it higher on the annoyance level.

The results point to song being a main factor for the annoyance rating. Two out of the four songs chosen to not be as annoying were reported as not annoying, while the angry songs showed up as consistently annoying in the ratings. Each song also influenced the rating of annoyance, while the previous emotional ratings and difference in ratings only show no significant results. This could be due to previous associations with the song itself, or the style of music.

The interaction of difference in anger ratings with song was not predicted, but falls in line with previous research (Averill, 1983, Doorley, & Kashdan, 2021). Averill (1983) concludes that annoyance is a lower-level version of anger that is more associated with an individual's interactions with the world. While anger is a higher-level and more personal and a character trait, he still associates these very closely with each other.

In the interaction of the song and happy difference, the song "Happy" by Pharrell Williams showed a positive change in the rating of annoyance. This positive change was not consistent across all interactions for happy difference and song. This could mean that if a listener heard that the song "Happy" was expressing happiness and they did not feel the same happiness, it could have led them to rate the song as more annoying. There was a similar change in the positive direction in the interaction of "Happy" and anger difference. This interaction could be happening for similar reasons that the change in annoyance happened for difference in happy rating. If a participant knew the song was expressing happiness and not anger, but it did not make them feel happy, that understanding of the lack of feeling happy could have led them to feet more anger, and thus rated the song as more annoying.

This could be due to a previous association with the song. While this study asked if there was a previous association with this song, I did not study it specifically. I could not ascertain if it influenced the annoyance rating, nor did I ask if the association is positive or negative. This could represent an influence on the ratings. Juslin (2013) discusses the effect of previous associations as well as physiological associations. He states that some of these associations could be learned and affect a listener's enjoyment as well as their physical response to music, while associations could be more genetic and physiological. These could potentially be future areas of study for research into what causes musical annoyance.

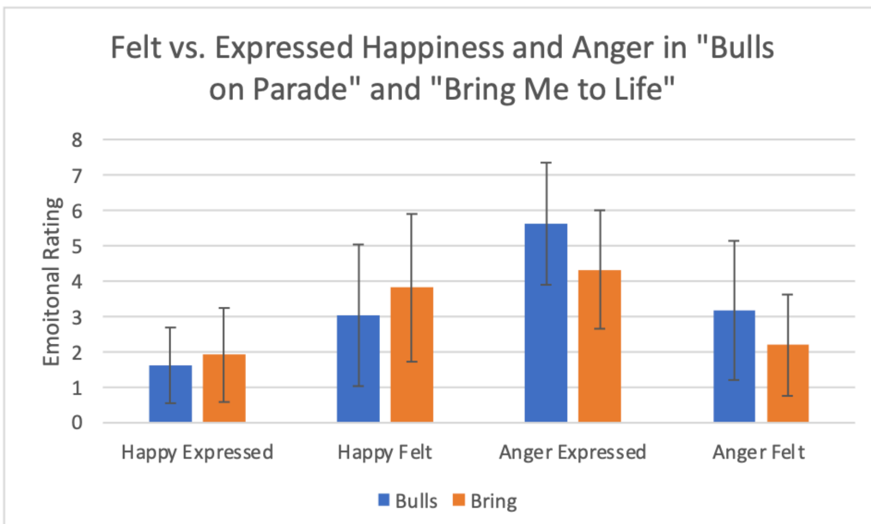
In the interaction of happy difference and song, the song “Bulls on Parade” showed a negative effect on coefficients. A similar result was seen for this song in the interaction of song and difference in anger. The reason for this could be that the listener understood that the song was expressing anger, but the emotion did not transfer directly to the listener. They also could have understood that the song is not expressing a lot of happiness, but it still made them feel happy.

This change in emotion could be due to using music as an emotional processor as described by Thoma (2012). This study showed that people use music in many ways, and one is for emotional regulation. The reasoning for these results could be that of emotional regulation. The participants listened to the music that expressed a lot of anger and little happiness, and in listening it helped them to process any anger they had, making them mark the felt anger lower and the felt happiness higher, while also lowering the annoyance rating. While this study did not directly study emotional regulation, it could have influenced these results.

Looking at the raw data in Figures 2.9 and 2.10, one can see that there are significant changes in the felt versus expressed emotions for these songs. While participants knew that the songs were expressing these emotions, the emotions did not transfer directly to the participants. Even though the songs were not expressing happiness, they still made them feel happy, and in the case of “Bulls On Parade” this lowered the annoyance rating.

	Bulls	Bring
Happy Expressed	1.625	1.925
Happy Felt	3.025	3.825
Anger Expressed	5.625	4.325
Anger Felt	3.175	2.2

2.9 Comparison of averages of expressed happiness and anger, vs felt happiness and anger in "Bulls on Parade" and "Bring me to Life."



2.10 Comparison of averages of expressed happiness and anger, vs felt happiness and anger in "Bulls on Parade" and "Bring me to Life."

While this study found significant results, there is still a lot of room for research into what causes higher annoyance ratings in songs. This study could not clearly determine if some of the factors such as age or years of musical training influenced annoyance rating or not. This study also did not directly compare the difference of likability as compared to annoyance. There were some considerations that were not studied in this survey, such as any prior emotional associations with the song they were listening to. While this survey did ask that question, it was to help guide further study in this area, and not as a variable for study in this analysis.

Another consideration for annoyance would be that of emotional regulation, mentioned before, and that of emotional trajectory (Warmbrodt et. al, 2022). This is the process in which a person is listening to music with the intent of changing their emotional trajectory, for example from happy to sad. Whether or not the emotional trajectory was successfully achieved by the music could be an important factor in whether a participant views the music as annoying.

The remaining studies in this thesis look at other specific factors in the music to determine if they have a large influence on annoyance rating and emotional communication in the songs. The next study specifically looks at what effects lyrics have on the communication of these emotions, and if the presence or absence of lyrics has an influence on the annoyance ratings.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ 1 + Song * Happydif + Song * Saddif + Song * Angerdif + Song * Relaxeddif + Age + Training + Times + Participant + Gender + Happy + Sad + Angry + Relaxed + Annoyed , data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song + Happydif + Angerdif + Times + Participant + Song:Happydif + Song:Angerdif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-3.1975	-0.5554	-0.0962	0.4473	4.6315

Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	2.62219	0.52652	4.98	1.16E-06	***
SongBulls	1.74646	0.504	3.465	0.00062	***
SongDancing	-1.67046	0.46876	-3.564	0.000436	***
SongHappy	-1.78345	0.44658	-3.994	8.49E-05	***
SongHeart	-1.66938	0.43891	-3.803	0.000178	***
SongSeptember	-1.80777	0.43406	-4.165	4.25E-05	***
SongStory	-2.22915	0.45058	-4.947	1.36E-06	***
SongSunflower	-1.50547	0.43247	-3.481	0.000586	***
Happydif	-0.12157	0.0999	-1.217	0.224716	
Angerdif	-0.16999	0.13001	-1.308	0.192173	
Times	-0.12224	0.04471	-2.734	0.006692	**
ParticipantAA	0.98214	0.59157	1.66	0.098082	.
ParticipantAB	2.38408	0.57872	4.12	5.12E-05	***
ParticipantAC	1.24068	0.56955	2.178	0.030287	*
ParticipantAD	1.01848	0.58454	1.742	0.082636	.
ParticipantAE	0.50071	0.57593	0.869	0.385438	
ParticipantAF	0.15238	0.56743	0.269	0.788495	
ParticipantAG	0.02858	0.57257	0.05	0.960224	
ParticipantAH	0.33077	0.57606	0.574	0.566343	
ParticipantAI	0.97171	0.57039	1.704	0.089661	.
ParticipantAJ	0.30413	0.49606	0.613	0.540363	
ParticipantAK	1.66143	0.51019	3.257	0.001279	**

ParticipantAl	0.83938	0.58084	1.445	0.149637	
ParticipantB	0.30033	0.58755	0.511	0.609682	
ParticipantC	1.41142	0.60196	2.345	0.0198	*
ParticipantD	0.19011	0.57027	0.333	0.739132	
ParticipantE	-0.17113	0.56721	-0.302	0.763124	
ParticipantF	1.34917	0.56945	2.369	0.01856	*
ParticipantG	-0.15472	0.58952	-0.262	0.793177	
ParticipantH	1.17373	0.56944	2.061	0.040287	*
ParticipantI	1.40118	0.57049	2.456	0.014704	*
ParticipantJ	1.30448	0.57518	2.268	0.02416	*
ParticipantK	0.56758	0.57544	0.986	0.324884	
ParticipantL	-0.02709	0.5759	-0.047	0.962524	
ParticipantM	1.42807	0.57459	2.485	0.013575	*
ParticipantN	1.11096	0.57948	1.917	0.056323	.
ParticipantO	0.41824	0.57419	0.728	0.467035	
ParticipantP	1.24485	0.57769	2.155	0.032097	*
ParticipantQ	0.06386	0.5856	0.109	0.913253	
ParticipantR	0.66769	0.57318	1.165	0.24514	
ParticipantS	0.55564	0.57993	0.958	0.338907	
ParticipantT	1.06194	0.57293	1.854	0.064947	.
ParticipantU	2.52041	0.58599	4.301	2.41E-05	***
ParticipantV	-0.2929	0.58659	-0.499	0.617983	
ParticipantW	1.07275	0.58272	1.841	0.066782	.
ParticipantX	0.62258	0.57141	1.09	0.276926	
ParticipantY	1.38704	0.58844	2.357	0.019163	*
ParticipantZ	1.17799	0.58273	2.022	0.044258	*
SongBulls:Happydif	-0.483	0.14749	-3.275	0.001202	**
SongDancing:Happydif	0.06644	0.21728	0.306	0.760013	
SongHappy:Happydif	0.6296	0.1437	4.381	1.72E-05	***
SongHeart:Happydif	0.19031	0.1579	1.205	0.229221	
SongSeptember:Happydif	0.0707	0.23159	0.305	0.760398	
SongStory:Happydif	0.14924	0.20866	0.715	0.475113	
SongSunflower:Happydif	-0.08892	0.20137	-0.442	0.659173	
SongBulls:Angerdif	-0.19441	0.16401	-1.185	0.236988	
SongDancing:Angerdif	0.73826	0.31061	2.377	0.018195	*
SongHappy:Angerdif	0.75452	0.19689	3.832	0.00016	***
SongHeart:Angerdif	0.63565	0.2458	2.586	0.010258	*

SongSeptember:Angerdif	0.31039	0.35911	0.864	0.388206	
SongStory:Angerdif	1.19625	0.87744	1.363	0.173966	
SongSunflower:Angerdif	0.59786	0.26051	2.295	0.022537	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.129 on 258 degrees of freedom
Multiple R-squared: 0.6134, Adjusted R-squared: 0.5219
F-statistic: 6.71 on 61 and 258 DF, p-value: < 2.2e-16

2.8a Stepwise regression on independent variables effect on annoyance rating

Chapter 3: Lyrics and Emotion in Music

Background

Popular music has many ways of communicating the emotions it is trying to express to the listener. One way is through the actual music itself, whether that be the harmonies it uses, the instrumentation, tempo, and rhythm. A second way is through the lyrics. There have been multiple studies on how the lyrics of songs may affect felt and perceived emotions, and how this can compare to the spoken or written word.

Omar Ali and Zehra Peynircioglu (2006) discuss the emotional effect that melodies have on listeners compared to what effect the lyrics have on a listener's perceived emotion. Their study consisted of 4 different experiments. They created stimuli consisting of melodies with and without lyrics attached. The melodies were chosen to represent different emotions of happy, sad, calm, and angry. For the melodies that had lyrics included, the lyrics were paired so they matched the emotion that the melody was trying to express.

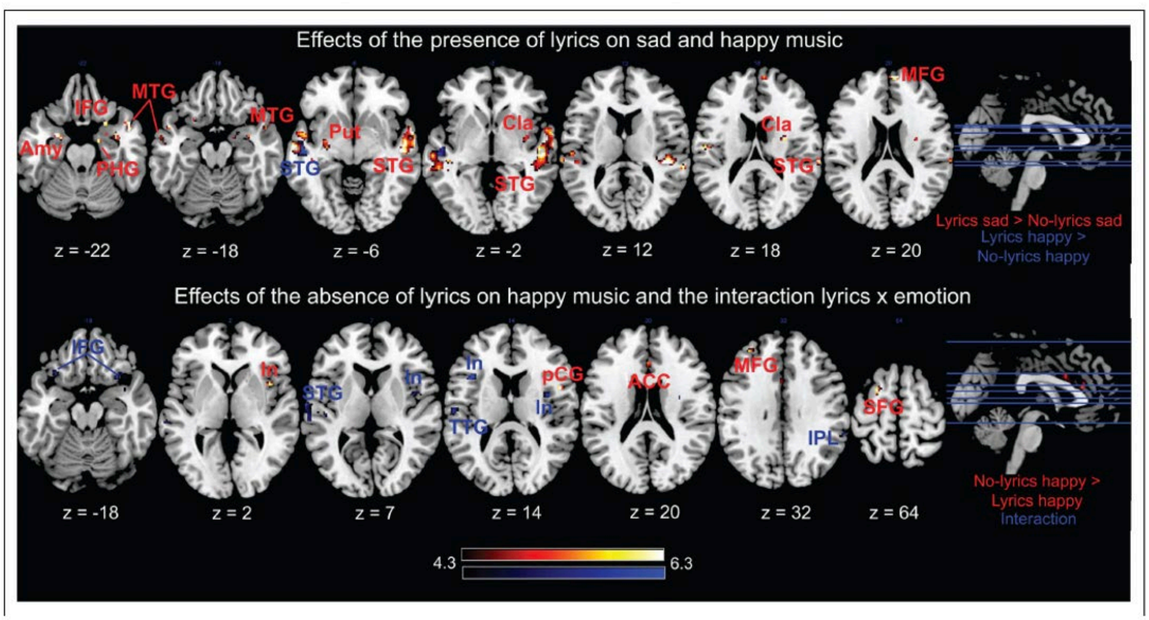
In the first experiment, Ali and Peynircioglu found that overall there was higher intensity rating for music that conveyed positive emotions. They did discover there was a main effect of lyrics on the rating of emotion. They found a small effect that showed that the lyrics detracted from the emotional intensity of the music (Ali & Peynircioglu, 2006).

In the second experiment, they used similar stimuli but switched out the melody-lyric pairs for lyrics that expressed an emotion contrasting with the emotion expressed by the melody. This experiment found no interaction between the intended emotion of the melody and the emotion of the lyrics. They found that melody indicated the emotion that was felt more so than the lyrics, but the lyrics with a different emotion than the melody showed an increase in the intensity of the emotion. They discovered that the intended emotion of the melody could predict the intensity of the specific emotional rating. The happy melodies with sad lyrics were rated as more intensely happy. This was consistent for each melodic and lyrical emotional combination.

Ali and Zehra Peynircioglu's (2006) experiments 3 and 4 were similar to the first two experiments in that the participants listened to melodies with and without lyrics that were expressing certain emotions. This time the participants were also shown a picture meant to elicit an affective emotional response. There were differences in pictures; some matched the emotions in the music, and some differed. The authors found some contradictory evidence in these experiments, where the lyrics did not detract from the positive emotions, but they also did not enhance negative emotions. They argued that the addition of a picture may have further decreased the effect of the lyrics on the listener (Ali & Peynircioglu, 2006).

Elvira Brattico et al. (2011) studied what effect lyrics and emotions in music have on the brain through an MRI study. This study found that music with lyrics activated different areas of the brain than music with no lyrics. They chose specific clips from different genres of pop-rock music that were provided by the subjects themselves, each representing different emotions. 18-second excerpts were then chosen from multiple parts of the songs, highlighting the main themes. In total 64 excerpts were created for testing. Participants rated on a scale of 1-5 for unfamiliar-familiar, sad-happy, feeling-sad-feeling happy, disliked-liked, unpleasant-pleasant, and ugly-beautiful. All of the ratings and listening were completed in a magnetic resonance imaging (MRI) machine to measure blood oxygenation level-dependent (BOLD) contrasts (Brattico et al, 2011).

For the listening ratings of the songs Brattico et al. (2011) found that there was no difference in the emotion recognition of sad and happy songs between lyric and non-lyric examples. The study also showed that happy music without lyrics produced stronger happy ratings than happy music with lyrics. They found no difference in music considered to be sad (Brattico et al, 2011). For the MRI results they found that lyrics were associated with activation in certain parts of the brain. They found that music with lyrics activated the regions of our brains more associated with cognitive functions, while happy instrumental music activated parts of our brain dealing with emotional regulation, and our innate survival functions.



3.1 Effects of the presence or absence of lyrics on emotions and the interaction between lyrics and emotions borrowed from (Brattico et al, 2011).

Sad music, in general, produced activation in the right head of the caudate nucleus (Brattico et al, 2011), which in previous research is also a part of the brain activated during chill-inducing musical pieces (Garbin et al, 2011). They argue that their research and previous research thus points to sad music being more effective in producing the chills effect. They also found different interactions between the effect of lyrics on sad versus happy music. Compared to happy music, lyrics in sad music produced bigger activations in different parts of the brain. These can be seen in Figure 3.1 (Brattico et al, 2011).

Brattico et al. (2011) found that sad music with lyrics is better at activating the limbic system, which suggests more of an emotional induction. The opposite was found for happy music, where instrumental happy music was better at activating the limbic system than happy music with lyrics (Brattico et al, 2011). They argue that their evidence points to the brain processing music with lyrics in a separate area from where it processes music without lyrics. Their data supports a different hypothesis, that lyrics are more important for inducing sad emotions by music, but that instrumental music is better for inducing happy emotions in music (Brattico, 2011).

Ashley Warmbrodt, Renee Timmers, and Rory Kirk (2022), studied what effect emotion trajectory would have on participants when listening to music. They looked at the emotions from a goal-directed point of view. There is strong evidence that people often listen to music for many different reasons; often these are to regulate their emotions, intensify certain emotions, or to stay at a certain emotion (Thoma et al. 2012). Warmbrodt, Timmers, and Kirk (2022) wanted to study the effect that these emotional regulation or trajectory techniques had when listening to music with lyrics or to just instrumental music.

They specifically chose jazz music, as it “significantly affects positive and negative mood management (Cook et al. 2019)”, but also that it often has instrumental and vocal covers of the same songs. Participants were randomly assigned an emotional trajectory, happy-sad or sad-happy. The participants were also connected to sensors to collect physiological responses such as heart rate, respiration rate, and skin conductance.

Warmbrodt et al. (2022) found a significant effect of targeted emotions on the rating of happiness, sadness, arousal, and valence. They also found that targeted emotions had a significant effect on heart rate as well. They did not find an effect of lyrics alone on the self-reported emotions or on any physiological responses. Lyrics did have an effect when interacting with other variables. They found that lyrics had a higher sadness and arousal rating for participant-selected music than in experimenter-selected music. This may point to previous connections with the music and lyrics that evoke a stronger emotional response:

> Interestingly, this study also found an interaction effect that the happy-sad group had a lower HR [Heart Rate] and the sad-happy group had a higher HR, for the lyric group. This supports the concept that music with lyrics is perhaps more personalized, and can strongly evoke sadness, as evidenced by self-reports and HR (higher physiological arousal). However, participants who heard instrumental music rated their sadness significantly higher for experimenter selected than participant selected music. Perhaps instrumental music has a more immediate effect on emotions, with all of its timbres, individual rhythms, pitch contours coming together (Gabrielsson & Lindström, 2010) (Warmbrodt et al., 2022, p. 772).

Hypothesis

Based on previous research and the first study, I expected to continue to find a strong correlation with the difference in felt and perceived anger ratings and ratings of annoyance. I expected lyrics to have a strong effect on the emotional communication of the song. I expected the songs that do not have lyrics to have a lower overall expressed emotional rating than the songs that do have lyrics. This difference was expected to have an overall effect on the annoyance rating. When the listener doesn't have the lyrical cues for the emotions, it was expected that they will be more annoyed by the song.

With songs with mixed emotions between the lyrics and the music, I expected a higher annoyance rating for the version without the lyrics by the same reasoning of a lower overall expressed emotional rating. When heard in the version with lyrics, these songs were expected to have a lower overall annoyance rating. This is based on the previous research that shows correlations between mixed and sad emotions to the enjoyment of music. While annoyance is not the opposite of enjoyment, I predicted that the songs with mixed emotions would lead to a higher annoyance rating.

I expect that number of times listened to would have a slight negative effect on the rating of annoyance, as seen in the previous study. I do not expect training and age to influence the ratings of annoyance, as seen in the previous experiments.

Methodology

This experiment consisted of a self-report completed by participants on their own computers. The participants were asked demographic questions consisting of their gender, age, years of musical training, and their highest degree obtained. They were then asked the emotions that they were feeling at the time by rating levels of happiness, sadness, anger, calm, and annoyed. All emotions were rated on a 7-point Likert scale, where a lower rating means that emotion is not apparent, and a higher rating means that emotion is apparent.

Participants were then instructed to listen to a short 30-second clip of the chorus of a song, then to rate what emotions the song expresses, using happy, sad, angry, and calm/relaxed attributes on the 7-point scale. They were then asked to rate the how the song made them feel, using the first four emotions, with annoyance added on at the end.

Six songs were selected in total, and each participant listened to the songs twice. The first six song clips used for the survey had the vocals removed from the clip using a free vocal remover online.[1] The latter half of the survey used the same six song clips, but with the original vocals included. The latter half also included videos of the songs with the lyrics on the video, so participants would be able to read and understand what the lyrics were saying.

I chose the songs based on the emotions expressed by the lyrics, and if they aligned with emotional cues from the music. Six total songs were used in this experiment, including "I'm Gonna Kick You Down the Stairs" by Captain Vampire, which I classified as Angry lyrics with Angry Music; "Home" by Cavetown, which I classified as sad lyrics with sad music; and "Call Me Maybe" by Carly Rae Jepsen, which I classified as happy lyrics and happy music. Three more songs were selected whose emotions in the song lyrics and the emotional cues in the music did not line up. "Changing of the Season"

[1] https://myedit.online/en/audio-editor/vocal-remover

by Two Door Cinema Club I selected for happy and upbeat music but sad lyrics; “Hard Times” by Paramore I selected for the same reason, as it has very upbeat, fast, music that is in a major key, but with sad lyrics; “Lucky Ones” by Lana del Ray I selected as its music has sad and ethereal aspects, but the lyrics are overall happy. These differences can be seen in Figure 3.2**.**

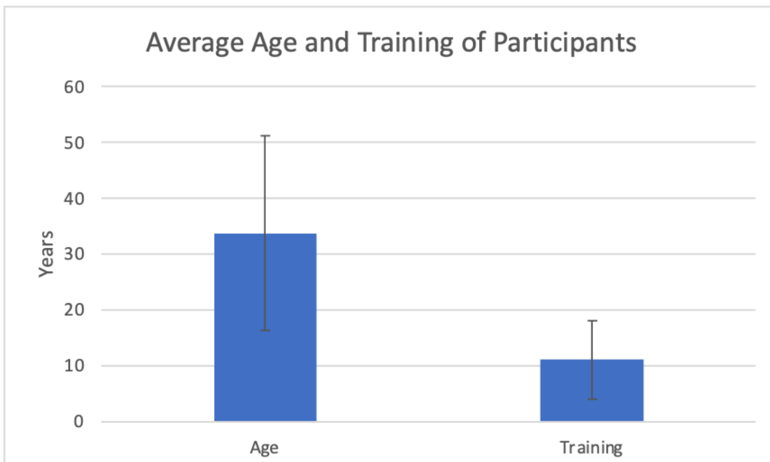
Song	Artist	Emotions Expressed in Lyrics	Emotions Expressed in the Music
“I’m Gonna Kick You Down The Stairs”	Captain Vampire	Anger	Anger
“Home”	Cavetown	Sad	Sad
“Call Me Maybe”	Carly Rae Jepsen	Happy	Happy
“Changing of the Seasons”	2 Door Cinema Club	Sad	Happy
“Hard Times”	Paramore	Sad	Happy
“Lucky Ones”	Lana Del Rey	Happy	Sad

3.2 Songs and the emotions that the lyrics are expressing along with the emotions the music is expressing.

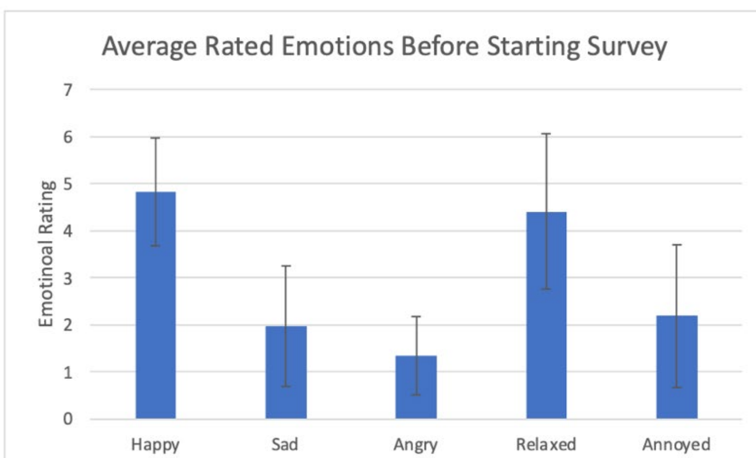
I assigned symbols such as !,@,#, etc. to the clips of the songs to avoid name bias and name recognition bias. I randomized the songs into three separate surveys. The first half of the surveys included examples with vocals removed, while the second half had examples with vocals. I used the website allocate.monster to combine the three surveys into one simple link. This allowed for a single link that, when clicked on, would randomly assign the participant to one of the three surveys.

Results

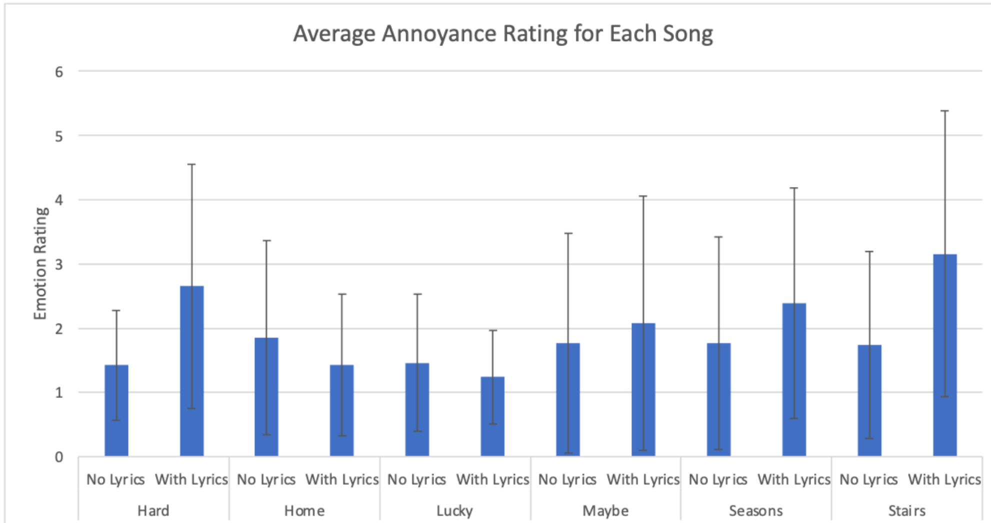
A total of 27 participants completed the survey. 11 were male, 15 were female, and 1 was non-binary. The average age of all the participants was 33.67 years with a standard deviation (SD) of 17.41. The average years of musical training was 11.09 years with a standard deviation of 7.03. This can be seen in Figure 3.3**.** The average happiness for participants before completing the survey was 4.81 (on the 7-point Likert scale) with a SD of 1.14. Sadness was 1.96 with a SD of 1.29. Anger was 1.33, SD of 0.83. Relaxed was 4.41, SD of 1.65. Annoyed was 2.19, SD of 1.52. These results can be seen in Figures 3.3 and 3.4.



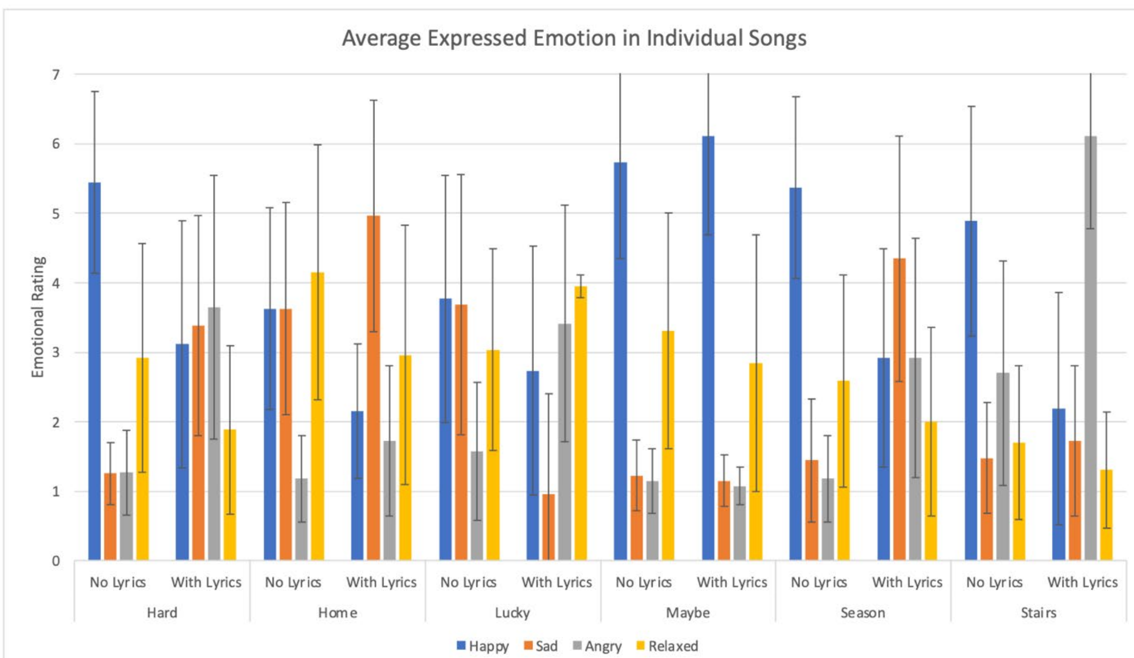
3.3 Average age and training of participants in years.



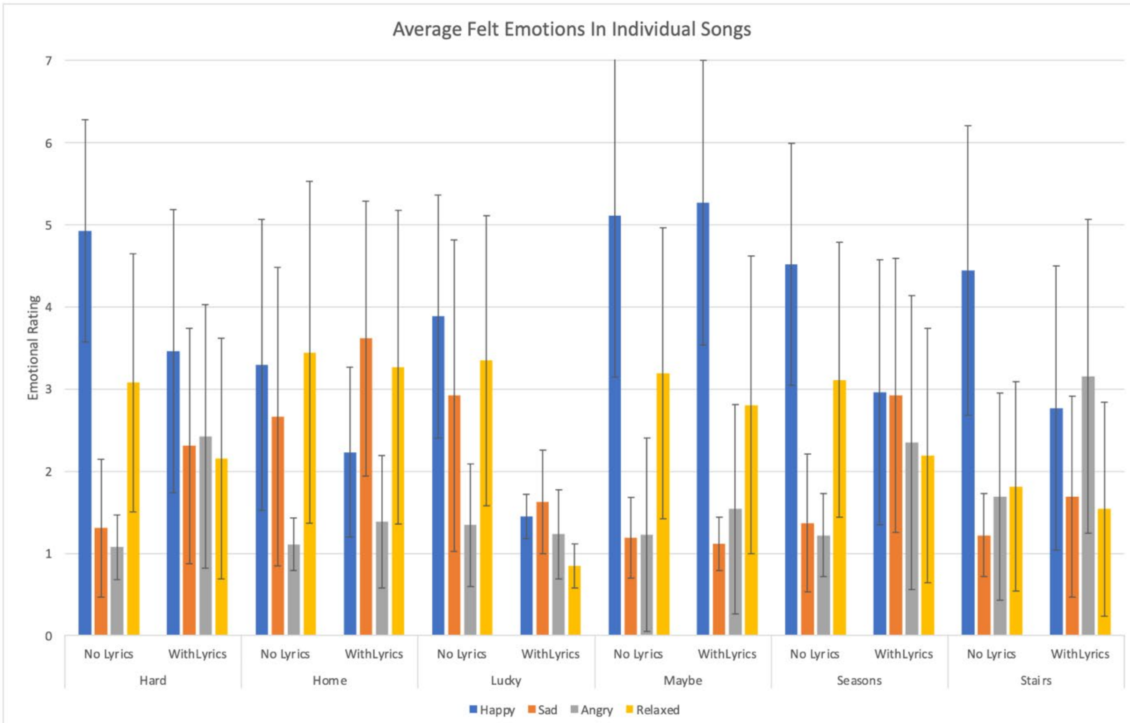
3.4. Average rated emotions (on a 7-point Likert scale) before starting the survey.



3.5 Average rated annoyance of each song (on a 7-point Likert scale).



3.6 Average rated expressed emotions of each individual song (on a 7-point Likert scale)



3.7 Average rated felt emotions of each individual song (on a 7-point Likert scale).

Number of Participants and How Many Times They Had Heard the Song Before								
		Never/didn't recognize it	0-10	11-20	21-30	31-40	41-50	Over 50
Hard	No Lyrics	16	5	3	2	0	0	0
	With Lyrics	13	8	2	1	1	1	0
Home	No Lyrics	25	1	0	0	0	0	0
	With Lyrics	24	3	0	0	0	0	0
Lucky	No Lyrics	21	3	0	0	0	0	0
	With Lyrics	20	6	0	0	0	0	0
Maybe	No Lyrics	2	2	5	3	4	1	9
	With Lyrics	2	1	5	2	4	1	11
Season	No Lyrics	23	2	0	0	1	0	0
	With Lyrics	20	4	0	0	0	1	1
Stairs	No Lyrics	18	5	2	1	0	0	1
	With Lyrics	22	4	0	0	0	0	0

3.8 Participants and their rating of the questions "To the best of your knowledge how many times have you heard this songs before?

Figure 3.5 shows the average annoyance rating for each song**.** For songs I chose to represent sad emotions, the annoyance rating went down when lyrics were added, whereas for all other songs the annoyance rating went up after the lyrics were added. Of the three songs where the lyrics of the songs matched the style of music being played, the happy and sad only had a slight change, while the angry had a large change. The two songs labeled as having sad lyrics with happy music showed a drastic change in the level of annoyance. The song labeled as having sad music with happy lyrics only showed a small change in the rating of annoyance when lyrics were added.

As you can see in Figures 3.6 and 3.7, lyrics had an impact on how participants rated the expressed and felt emotions of each piece. For the songs “Call Me Maybe” and “Home”, which were chosen because their lyrics matched the emotion of the music, the addition of the lyrics did not drastically affect the perceived emotion when the lyrics were added. If anything, they intensified the emotion that the songs already expressed. There was a slight change in the songs “Home” and “I’m Gonna Kick You Down The Stairs”, where without the lyrics the songs were initially rated happier than they were when lyrics were added back in. For the purposes of the rest of this chapter, “I’m Gonna Kick You Down the Stairs” will be considered a song that expressed mixed emotions.

For the other songs chosen for their mixed emotions, some songs had more of a change than others. The two songs “Changing of The Seasons” and “Hard Times”, which were chosen to have happy music and sad lyrics, showed this change in the averages. The participants initially rated the songs as happier, and after listening again with the lyrics listed them as either sadder or angrier than they did before. “Lucky Ones” by Lana del

Rey did not have a similar effect, where it was initially rated around the same level of happy as it did sad. Once the lyrics were added, it had lower ratings for expressing happy and sad, while having a higher rating for relaxed. It did have a decrease in the rating for sadness.

None of the songs included in this study were recognized by most of the participants, with the exception of “Call Me Maybe”. This can be seen in the chart in Figure 3.8. This were marked by majority of participants as recognized both with and without the lyrics.

To further study the results I ran two stepwise multiple regressions. The first regression looked at the effect of song and the interaction of song and emotional difference on annoyance. The second regression looked at the effect of lyrics on annoyance and the interaction of lyrics and emotional difference. All regressions were completed through Rstudio. To compare the changes in the rating of expressed and felt emotions I took the absolute value of the difference between each rated emotion of the songs and categorized them into the new variables of happy difference (Happydif), sad difference (Saddif), Anger difference (Angerdif) and relaxed difference (Relaxeddif).

In the first regression the interpretation of this categorical variable (song) and its interactions is complicated by the fact that R breaks this into seven binary variables and treats the alphabetically first song as the default value. In this regression that song is “Hard Times” with no lyrics included. To test the significance of song an ANOVA was run on this regression testing compared to a null regression that took out the factor of song. The factor of song had a significant effect on the rating of annoyance with an F=4 and p=2.13e-5, as seen in Figure 3.9b.

Model 1: Annoyed2 ~ Happydif + Saddif + Angerdif + Relaxeddif + Times + Username + Song:Happydif
Model 2: Annoyed2 ~ Song + Happydif + Saddif + Angerdif + Relaxeddif + Times + Username + Song:Happydif

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)	
1	265	499.47					
2	254	425.69	11	73.787	4.0025	2.13E-05	***

3.9b ANOVA of regressions used to determine significance of song factor.

Emotional difference did not prove significant in this regression. Happy difference did show notable changes in the interaction with song. The song “Home”, when lyrics were not present, showed a slight lowering of annoyance rating (-0.86) in the interaction with happy difference. “Call Me Maybe” without lyrics showed a similar change of 0.81; when lyrics were added, this change increased to 0.98. This means that when lyrics were added to the song “Call Me Maybe”, for every 1 point of increase in happy difference the annoyance rating also increased by almost a point. The song “I’m Gonna Kick You Down The Stairs”, when lyrics were added, showed a decrease in the effect of happy difference on annoyance rating of -1.27.

The second regression looked at the effect of lyrics on annoyance, and the interaction of lyrics and differences in emotion ratings. To test the significance of lyrics an ANOVA was run on this regression testing compared to a null regression that took out the factor of lyrics. The factor of lyrics did not have a significant main effect on annoyance rating, as shown in Figure 3.10b.

Difference of emotion ratings were shown to be significant main effects on the rating of annoyance: Happy difference with a coefficient of 0.45 and p=0.001; and Anger

Model 1: Annoyed2 ~ Happydif + Angerdif + NoLyrics + +Times + Username
Model 2: Annoyed2 ~ Lyrics + Happydif + Angerdif + NoLyrics + Times + Username

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	277	571.32				
2	277	571.32	0	-3.411E-13		

3.10b ANOVA of regressions used to determine significance of lyric factor.

difference with a coefficient of 0.28 and a p=0.06. Number of times listened to the song also showed a significant main effect on the rating of annoyance. However, number of times listened had a very small coefficient of 9.6e-5.

In the interaction between lyrics and emotional difference there were only small changes seen in the coefficients. In the interaction of happy difference and lyrics there was a coefficient of -0.01. In the interaction of anger difference and lyrics there was a coefficient of 0.04.

Discussion

Many of the results seen in this survey were similar to the results seen in the first survey. The general results of average emotional ratings for each song proved that lyrics can have an influence on the emotional processing of music.

As seen in Figures 3.6 and 3.7, the songs where the lyrics matched the music showed an increase for that expressed emotion once the lyrics were added back in. The songs that were chosen for their mixed emotions in the music and lyrics show the change in expressed emotions. The song “Hard Times” without lyrics was rated as expressing happiness. Adding lyrics showed a sharp decrease in happiness and an increase in sadness and anger ratings. The same happened with the song “The Changing of the Seasons”. The song “I’m Gonna Kick You Down the Stairs” was the only one that elicited a different effect of lyrics on emotion ratings than expected. Without lyrics it was not seen as angry but was rated as very happy. When lyrics were added it drastically switched and was seen as expressing anger.

There was a main effect of anger difference with a higher annoyance rating. In this survey, however, we also saw a main effect of happy difference to a higher annoyance rating. Both emotions involve high arousal, and there is correlation between a higher rating with the higher arousal of emotions (Rickard & Ritossa 2004). The reason that one observes effects of differences of happiness and anger rating specifically, and not with sadness or relaxation ratings, may be that these are high-arousal emotions.

The happy difference main effect could be due to the same reason suggested in the pilot study: if a song is expressing happiness, but a listener is not feeling the same level of happiness, they are more likely to be annoyed by the song. The listener is frustrated by wanting to feel happy because they know the song is expressing happiness, but they do not feel the same level of happiness. This result was seen in the first survey and the pilot study.

The second regression showed a main effect of difference in anger ratings to a higher annoyance rating. In this study the direction of the change in this finding aligns with previous research showing that anger is often associated with annoyance (Averill, 1983). While this result was not explicitly seen in the first survey, it is consistent across our surveys with the relationship between anger and annoyance.

Surprisingly, in this study there was a main effect of number of times listened to a slightly lower annoyance rating. This is similar to findings in the first survey and to previous research (Margulis, 2014). This could be due to familiarity with the music, or to previous connotations. If a participant is familiar with the music, they can expect the emotions that are being expressed and manage their own better. The participant may also have previous emotional associations with the song that are affecting their responses. This survey did not look at previous emotional associations, but it would warrant future study.

The interaction of the song "I'm Gonna Kick You Down The Stairs" with lyrics and happy difference showed similar results to the angry songs in the first survey. This was the only song in this survey selected for the anger emotion. It showed an interaction of this song and happy difference correlated to lower rating of annoyance. The same was seen for the interaction between the song and the anger difference. This song only had this effect when the lyrics were included. This song did not fully communicate the anger through just its instrumentals. The participants understood that the song was expressing anger and not expressing happiness. However, the song effectively communicated anger and frustration, and could have helped the listener process some anger (Averill, 1983, Doorley, & Kashdan, 2021). This could have led to a lower annoyance rating as well as a higher felt happy, and lower felt anger rating.

Lyrics did not have a significant effect on the rating of annoyance. All differences in annoyance rating are related more to the specific song than to whether they have lyrics or not.

Kazuma Mori and Makoto (2014) showed that when unhappy lyrics were combined with happy music, it predicted pleasant feelings in participants. If the lyrics express a contradictory emotion to the music, it could lead to higher happy felt rating, even if they did not rate the song as expressing happiness. This could lead to a significant happy difference rating, while the contradiction of emotions leads to a higher annoyance rating. This could explain why the happy difference main effect only appears when the songs with lyrics are tested.

One other reason could be that each of the songs with lyrics were at the end of the survey and there may be some ordering bias. This survey was longer than the one that came before it, and the annoyance rating may have increased over the course of the survey.

In these regressions the variable of happy difference was significant when lyrics were studied. It had a significant positive correlation with annoyance rating. This could be because of the higher ratings of emotions when lyrics are involved. Arousal of emotions has been a common and effective predictor in many previous studies (Rickard & Ritossa 2004; Plutchik, 1994; Thayer, 1989). This could also be due to the participant being able to better understand the emotions that are being expressed. This could have led them to a higher happy rating but still to rate the song as annoying.

Overall, the result of familiarity with the song had only small significant effect on the rating of annoyance. In this survey, as you can see in Figure 3.8, only one song was consistently recognized. The lack of recognition of songs caused a low variance in that data which could have led to the small effect on overall annoyance.

When the average ratings of annoying from the first study and this study are compared, they are similar, even when songs in the first survey were more recognizable than the ones in this study. The low ratings could be due to the question itself. When participants are asked to rate how annoying they find a song, they then may expect an annoying song to be coming down the line, causing them to rate everything else slightly lower.

The next two surveys will study different features of the music, and what effect they have on rating of annoyance and emotional communication. The third survey focuses on chord progressions common in popular and rock music. The fourth survey focuses on different levels of metric complexity common in popular music.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song * Happydif + Song * Saddif + Song * Angerdif + Song * Relaxeddif + Age + Training + Times + Username + Happy + Sad + Angry + Relaxed + Annoyed + Lyrics + Recognize, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song + Happydif + Saddif + Angerdif + Relaxeddif + Times + Username + Song:Happydif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-3.6218	-0.6911	-0.1650	0.4288	5.4616

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	0.86	0.54	1.605	0.10964	
SongHardL	0.96	0.52	1.827	0.06883	.
SongHome	-0.13	0.50	-0.253	0.8003	
SongHomeL	0.10	0.48	0.199	0.84264	
SongLucky	0.24	0.52	0.453	0.65092	
SongLuckyL	0.01	0.57	0.021	0.98354	
SongMaybe	-0.23	0.46	-0.503	0.61506	
SongMaybeL	-0.15	0.47	-0.319	0.75025	
SongSeasons	-0.53	0.53	-1	0.31829	
SongSeasonsL	0.81	0.51	1.586	0.11396	
SongStairs	-0.02	0.50	-0.048	0.96201	
SongStairsL	2.29	0.51	4.454	1.26E-05	***
Happydif	0.06	0.33	0.178	0.85882	
Saddif	0.03	0.09	0.346	7.30E-01	
Angerdif	0.11	0.08	1.388	0.16635	
Relaxeddif	-0.05	0.08	-0.659	0.51037	
Times	3.41E-06	4.03E-05	0.085	0.93261	
UsernameAA	0.97	0.54	1.8	0.07298	.
UsernameB	0.66	0.54	1.213	0.22612	
UsernameC	1.05	0.55	1.897	0.05897	.
UsernameD	0.48	0.55	0.874	0.38317	
UsernameE	0.42	0.55	0.768	0.44335	
UsernameF	0.20	0.57	0.355	0.72254	

UsernameG	0.90	0.59	1.533	0.12645	
UsernameH	0.92	0.54	1.689	0.09253	.
UsernameI	0.97	0.55	1.767	0.0784	.
UsernameJ	0.07	0.54	0.132	0.89504	
UsernameK	-0.11	0.55	-0.199	0.84247	
UsernameM	0.84	0.55	1.522	0.12924	
UsernameN	0.90	0.60	1.498	0.13533	
UsernameO	0.44	0.54	0.82	0.41309	
UsernameP	-0.35	0.55	-0.635	0.52568	
UsernameQ	0.02	0.54	0.036	0.97161	
UsernameR	1.81	0.55	3.286	0.00116	**
UsernameS	-0.22	0.54	-0.396	0.69234	
UsernameT	0.70	0.54	1.289	1.99E-01	
UsernameU	0.01	0.55	0.019	0.98488	
UsernameV	-0.60	0.55	-1.092	0.27569	
UsernameW	0.84	0.59	1.442	0.15067	
UsernameX	0.07	0.54	0.133	0.8946	
UsernameY	0.21	0.55	0.379	0.70469	
UsernameZ	2.49	0.55	4.547	8.42E-06	***
SongHardL:Happydif	0.06	0.44	0.135	0.89241	
SongHome:Happydif	0.81	0.46	1.762	0.07934	.
SongHomeL:Happydif	-0.32	0.50	-0.633	0.52705	
SongLucky:Happydif	-0.23	0.42	-0.562	0.57449	
SongLuckyL:Happydif	-0.26	0.50	-0.521	0.60264	
SongMaybe:Happydif	0.77	0.39	1.974	0.04945	*
SongMaybeL:Happydif	0.93	0.42	2.206	0.02827	*
SongSeasons:Happydif	0.82	0.42	1.93	0.05477	.
SongSeasonsL:Happydif	3.80E-03	0.41	0.009	0.99265	
SongStairs:Happydif	0.21	0.43	0.493	0.62238	
SongStairsL:Happydif	-1.22	0.43	-2.842	0.00485	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.295 on 254 degrees of freedom
(7 observations deleted due to missingness)
Multiple R-squared: 0.4842, Adjusted R-squared: 0.3786
F-statistic: 4.585 on 52 and 254 DF, p-value: < 2.2e-16

3.9a Stepwise regression of independent variables effect on annoyance rating and interaction of song and difference in emotions.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Lyrics * Happydif + Lyrics * Saddif + Lyrics * Angerdif + Lyrics * Relaxeddif + Song + Age + Training + Times + Username + Happy + Sad + Angry + Relaxed + Annoyed + Lyrics + Recognize, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Lyrics + Happydif + Angerdif + Song + Times + Username + Lyrics:Happydif + Lyrics:Angerdif, data = data)

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	0.54	0.49	1.093	0.275379	
Lyrics	1.99	0.48	4.106	5.36E-05	***
Happydif	0.43	0.13	3.286	0.001155	**
Angerdif	0.28	0.15	1.841	0.066672	.
SongHardL	-0.45	0.41	-1.107	0.269484	
SongHome	0.46	0.39	1.196	0.232578	
SongHomeL	-1.63	0.45	-3.615	3.60E-04	***
SongLucky	-0.152	0.40	-0.385	0.700711	
SongLuckyL	-1.789	0.46	-3.886	0.000129	***
SongMaybe	0.319	0.38	0.831	0.406496	
SongMaybeL	-1.147	0.46	-2.484	0.013604	*
SongSeasons	0.233	0.39	0.596	0.551662	
SongSeasonsL	-0.691	0.43	-1.606	0.109407	
SongStairs	-5.98E-02	0.42	-0.144	0.885677	
SongStairsL	NA	NA	NA	NA	
Times	9.60E-05	3.50E-05	2.741	0.006551	**
UsernameAA	0.981	0.568	1.727	0.08535	.
UsernameB	0.488	0.565	0.864	0.388565	
UsernameC	0.893	0.580	1.541	0.124572	
UsernameD	0.342	0.57	0.6	0.548798	
UsernameE	0.61	0.57	1.063	0.288639	
UsernameF	-0.02	0.58	-0.042	0.966613	
UsernameG	1.15	0.61	1.893	5.95E-02	.
UsernameH	0.99	0.57	1.736	0.08379	.
UsernameI	0.83	0.59	1.414	0.158441	
UsernameJ	0.12	0.57	0.208	0.835367	

UsernameK	-0.16	0.57	-0.27	0.786999	
UsernameM	0.73	0.57	1.264	0.207199	
UsernameN	0.80	0.59	1.346	0.179348	
UsernameO	0.54	0.57	0.961	0.337377	
UsernameP	-0.29	0.57	-0.507	0.612299	
UsernameQ	-0.06	0.57	-0.108	0.914417	
UsernameR	1.67	0.58	2.888	0.004194	**
UsernameS	-0.16	0.57	-0.28	0.779698	
UsernameT	0.75	0.57	1.33	0.184555	
UsernameU	-0.23	0.58	-0.389	0.697336	
UsernameV	-0.41	0.57	-0.717	0.474157	
Lyrics:Happydif	-0.44	0.18	-2.422	0.016092	*
Lyrics:Angerdif	-0.24	0.18	-1.327	0.185721	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.381 on 265 degrees of freedom
(7 observations deleted due to missingness)
Multiple R-squared: 0.3874, Adjusted R-squared: 0.2927
F-statistic: 4.088 on 41 and 265 DF, p-value: 1.424e-12

3.10a Stepwise regression of independent variables effect on annoyance rating and interaction of lyrics and difference in emotions.

Chapter 4: Harmonic Progressions and Emotions in Western Popular Music

Rock Harmony

Common pop-rock chord progressions often are derived from western norms of harmonic succession. Typically structured around triads, these chords rarely include some seventh chords and even ninth and thirteenth chords or even sus2 or sus4 (sus being an abbreviation of suspended). Pop and rock music consist of similar chord structures and song structures. Because of this the terms pop, rock, and pop-rock are used interchangeably throughout this chapter.

In a corpus compiled from *Rolling Stone's 500 Greatest Songs of All Time*, David Temperley and Trevor deClerq (2011) found that 92.9% of all chords are either major or minor triads. They also found that 76.4% of those triads consist of major triads. Of the remaining 7.1%, 5.3% are seventh chords. They found that sus chords are very rare in rock music but are common in jazz music and blues (Temperley, 2018). The harmonies often limit the use of notes to a single diatonic scale. The song's progression often consists of only three to five different chords, and often these are looped constantly throughout the whole song.

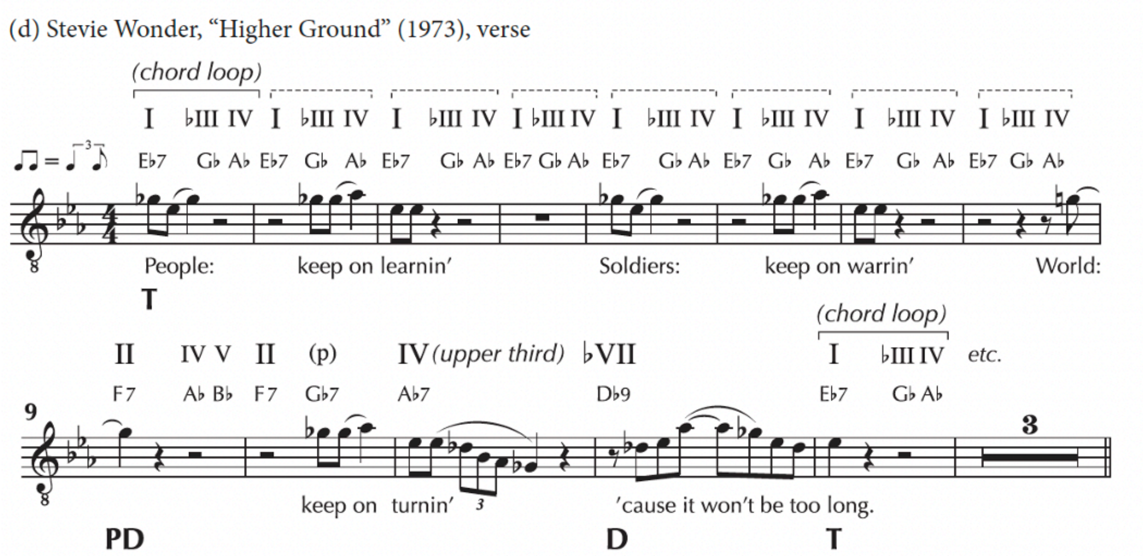
While the harmonic structure of rock and pop music has its basis in Western common practice music these genres often differ in many ways. Chords are typically voiced in root position as the compositional norm. Musicians normally learn songs by ear or rely on lead sheet chords. To play major or minor triads a guitar player can learn a small set of hand patterns and move them up and down the fret board to change the chord. This has given rise to now-common patterns in rock music of using block chords in root position, and patterns of parallel fifths in voice leading and in melodies (Nobile, 2020b). Parallel fifths with no third often played loudly and with distortion became so common in rock and popular music that they have become known as power chords.

There are many similarities between rock and classical music, but we don't see as strict constraints in the world of rock and popular music harmonies (Temperley, 2018). Temperley states in his book:

> It is natural to wonder if anything similar or analogous to these principles is present in rock, though as always, we must be careful not to impose common-practice norms on rock beyond what is justified by the facts (Temperley, 2018, p. 42).

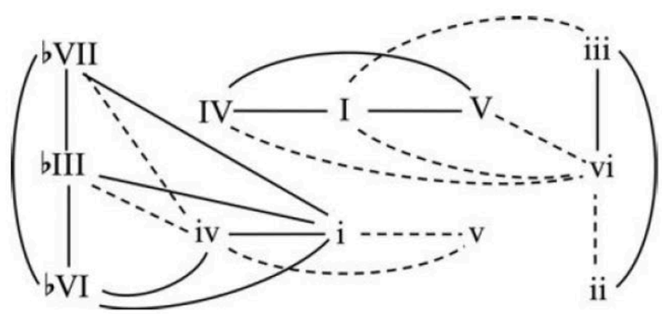
Because of these differences there have been many ways of analyzing chords and progressions in rock music. Drew Nobile (2020b) looks at different ways these can be analyzed in his book *Form and Harmony in Rock Music.* In his book he discusses the chords as three distinct classes, being either a tonic chord (T), a dominant chord (D), or a predominant chord (PD). Nobile (2020b) observes that chord loops in common pop and rock songs usually contain one of each type of chord with a common progression like I-IV-V-I consisting of a T-PD-D-T function. Nobile labels these as dominant and predominant depending on their position in the phrase and not based on their exact chord type. However, in this particular progression the IV is labeled as predominant chord, when most often in rock music the IV chord is placed in a dominant position (Temperley, 2018). This can be seen in common progressions like Green Day's *When I Come Around*, where the IV chord appears at the end of the progression of I-V-vi-IV acting as a dominant resolving to I. In general, the IV chord is the second most common chord, consisting of around 21% of all chords in the Rolling Stone corpus. The most common chord is I at 26% and V is third at 15% (Temperley, 2018).

While Nobile (2020b) discusses the function of the chords on a lower level of chord loops, he also describes the chord loops as serving a higher-level function. He describes the loops as prolongations of larger level tonic, dominant, and predominant chords. He uses the example of Stevie Wonder's *Higher Ground*, which uses three different loops to extend the tonic, predominant, and the dominant chords. The tonic progression consists of I- ♭III-IV; the predominant consists of II-IV-V; and the dominant chord of ♭VII. This can be seen in Figure 4.1. Nobile argues that this prolongation is the reasoning that on a lower-level chords do not have to be in a functional order. The higher-level functions of these prolongations are in a functional order, so the overall structure of the music still makes sense to the listener (Nobile, 2020b).



4.1 Chord Loops in Stevie Wonder's "Higher Ground" borrowed from Nobile (2020b)

Temperley (2018) discusses the line-of-fifths axis. After analyzing the Rolling Stone corpus, he discovered that the line of fifths is a good explanatory model for rock progressions. He examined correlations between the twelve common rock triads. In his chart he showed high correlations (those above 0.4) in solid lines, and moderate correlations (between 0.2 and 0.4) in dotted lines. Out of this emerges two distinct groups consisting of mostly major key area triads, and one of minor key area triads. While the groups are completely separated, they are highly interconnected within the groups. Each group stays consistently connected to its line-of-fifth neighbors in its line-of-fifth area and doesn't stray away (Temperley, 2018). This can be seen in Figure 4.2.



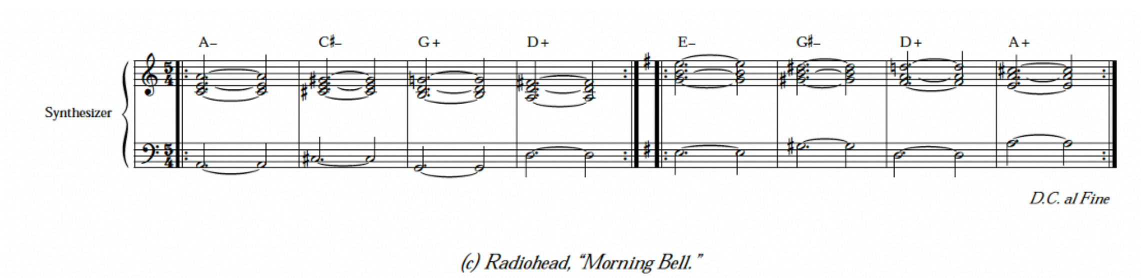
Correlations between triads in the *Rolling Stone* corpus. Solid lines represent correlations above .35; dotted lines represent correlations between .2 and .35.

4.2 Line of Fifths Progressions. Borrowed From Temperley (2018).

Temperley (2018) also discusses different common harmonic schemas that appear in popular music. He discusses the "doo-wop" progressions of I-vi-IV-V, and a variant, I-vi-ii-V, which is derived from common blues progressions. Some of the progressions he argues can also follow common cyclic patterns like descending fifths patterns, but he says that ascending fifths patterns are more distinctive to rock.

While most pop-rock chord progressions can be efficiently analyzed by Roman numeral analysis, as the harmonic language evolved, some of the progressions became more ambiguous, thus requiring different approaches to understand them. Guy Capuzzo (2004) discusses some of these more non-traditional progressions. The Neo-Riemannian approach can help to classify situations in which a song uses modal mixture and chromatic lines, which were common in pop-rock music of the 1990s and the early 2000s (Capuzzo, 2004).

Capuzzo discusses the song *Morning Bell* by Radiohead, which features both modal mixture and a chromatic descending line in the phrase, with a progression of A-, C♯-, G+, D+ showing features of both G major and C# minor. You can see the transformations in Figure 4.3. Here there are chromatic mediant progressions (Neo-Riemannian PL), traditional fifth-progressions (Neo-Riemannian LR), and distant relations having no common tones (Neo-Riemannian RPR and LRL).



4.3 Progressions from Radio Head's song "Morning Bell" borrowed from Cappuzo (2004).

Harmony and Emotions

Many different studies have been conducted on emotional valence based on harmonic properties in music. An initial corpus study completed by David Huron (2008) showed the relation of major and minor melodies to speech prosody. Huron noted that many studies have shown that the ranges of spoken utterances change depending on the emotion being conveyed. Sad utterances have a lower overall pitch range, and happier utterances have a higher range (Williams and Stevens, 1972).

Huron (2008) analyzed 9,788 instrumental themes. He compared the average pitch heights of all the melodies as compared to middle C. He found that the average height for major-key themes was 8.9 semitones, while the average height for minor themes was 7.8 semitones. Huron also measured the pitch ranges for all of the themes and found that the average pitch range for major themes was 13.1 semitones, while for minor key-themes the average pitch range was 13 (Huron, 2008). While he points out that the differences are small and not statistically significant, he reasons that this is because minor keys can be used to express more than just sadness. They can also be used to express anger, fear, and seriousness, and that that the "presumed effect of sadness on pitch has been diluted." While pitch range was not proven significant in his corpus, it has been included in more recent research. including that of Eline Smit et al. (2020).

Smit et al. (2020) studied what effect traditional cadences had on emotional valence and arousal responses in participants. They studied four different cadences: the authentic cadence, plagal cadence, half cadence, and deceptive cadence, both in major and minor keys (Smit et al., 2020). They found that cadences that are more unexpected or go unresolved, like the deceptive and the half cadence, are consistently rated as more emotionally arousing. They also found that if a final chord is minor, it is less arousing than if the final chord is major. As for the valence spectrum, they found that the plagal cadence is lower in valence than the authentic cadence, and that minor cadences overall have a lower valence (Smit, 2020). Overall, between the valence and the arousal results they found consistent results with Huron's (2008) previous research. Lower overall pitch height average correlated with lower arousal and lower valence.

Smit et al.'s (2020) study showed that listeners responded with more emotional arousal when the music moved in a way they were not expecting. Smit et al. base a lot of their results on those of musical expectation. Their results on the valence of the plagal cadence showed a significantly lower rating than those of the deceptive and half cadence. They argue this could be due to the nature of that cadence being more predictable than the others, and due to its stable nature as a cadence. This, however, is not consistent across cultures, as another study by Smit et al. (2022) shows.

In another study Smit et al (2022) studied what effect culture has on our connection of emotions to music. They conducted research in Sydney, Australia as well as in the cloud forest region of Papua New Guinea. They studied many different indigenous groups in Papua New Guinea, each with varying degrees of exposure to Western music styles. They conducted an experiment using different cadences in major and minor, as well as different melodies in major and minor. The researchers found that greater happiness was reported for major cadences over minor cadences in all except the community with the least exposure to Western music. There was only evidence of greater happiness in melodies with higher mean pitch height in only one of the Papua New Guinea groups as well as the Sydney groups (Smit et al, 2022). While they say that this result is significant, they cannot clearly exclude the possibility of universality in the association of major to happy and minor to sad.

In 2019 Eline Smit, Andrew Milne, Rodger Dean, and Gabrielle Weidemann tested how unfamiliar chords were rated by participants, and whether extrinsic or intrinsic factors were more important to the rating of pleasantness. The intrinsic factors they studied were inherent in the music itself, including the roughness, the harmonicity, the spectral entropy, and the average pitch height. The external factors were culture and familiarity with a musical system.

They studied this by using different tuning systems to create different chords that might not be available in a twelve-tone equal temperament system. They used combinations of these different tuning systems to create the intrinsic factors that were studied in this experiment. For example, roughness could be created by notes that may be considered dissonant together. They argue, however, that there is evidence that the addition of different notes in the harmonies does not increase the feeling of dissonance, but that the perception can be changed by training (McLachlan, et al. 2013).

They found in this experiment that there were only subtle changes between the two tuning systems. This led them to conclude that there was less to do with the systems that the participant understands, but more to do with the intrinsic qualities inherent in the music (Smit, et al, 2019). This is significantly different than previous research in this field, which points to extrinsic qualities being more important than the intrinsic qualities.

We can see from previous research that the type of chord, cadence and even culture can influence how harmonies effect our emotional responses. The question that arises is how these different chord progressions and loops affect the emotions of listener. Does any progression specifically arouse annoyance in a listener, or does it have no effect at all?

Hypothesis

The major melodies I expected to be rated as happier than the minor melodies, and the minor melodies I expected to be rated as sadder. However, the open and closed major and minor progressions I expected have bigger difference in felt as compared to expressed emotions and would be rated as a higher level of annoyance. This is in line with evidence found in previous research (Smit et al. 2020).

The chromatic and ambiguous harmonies were more unexpected to the listener and are expected to warrant a higher expressed emotional response, and a higher felt emotional response which is expected to be correlated to a lower annoyance rating.

The harmony of the song “Happy” by Pharrell Williams is expected to not have a significant difference between the felt and the expressed emotion, and it is not expected to have a higher annoyance rating. This is due to a high rating of annoyance in the first experiment, but a strong correlation of annoyance with number of previous hearings.

Methodology

Stimuli

The structure of this study consists of a self-report survey constructed of different chord progressions. Chord progressions were sorted by their features into different categories, one of modality, and that of loop types. The three modalities studied are major, minor, and chromatic. Three loop types were chosen, open, closed, and ambiguous (modal or key mixture). This gave a total of 9 chord progressions to use in the study. The chord progression to the song “Happy” by Pharrell Williams was also included as a tenth example, as it was found to have a high annoyance rating in the first study which warranted further inquiry. The progression of “Bulls on Parade” by Rage Against the Machine, which was found to be annoying in the first study, was also included, but it fit into the category of minor-open progression.

The progressions with an asterisk next to them were created specifically for this study. There were very few closed chord loops that were not classified as a major or minor key area, so closed loops were created for chromatic modality by slightly modifying a previously existing progression. Below you can see a chart of each progression and an analysis of each progression.

Progressions were written out on digital audio workstation Ableton Live 11, using basic midi instruments. The instruments used were a basic drum set, synthesizer bass, electric piano for the harmony, and a gentle pad. The instruments chosen were selected for the most gentle and non-annoying sound, so that the chord progressions themselves could be tested, and not the timbre of the instruments. The rhythmic composition of each sample was kept the same, while only the harmony changed. If the progression consisted of four chords, the chord was changed each measure. If it consisted of three chords, the progression lasted two measures, with the harmony changing on the half note in the first measure and lasting a whole measure for the third chord. If there were five chords in the progression, the last measure changed harmony on the half note.

	Open	Closed	Ambiguous
Major	I-vi-IV-V [C+,A-,F+,G+]	I-♭VII-IV-I [A+,G+,D+,A+]	D+,C+,G
Minor	i-III-i-♭VII-VII [F-,A♭+, F-,E♭+,E+]	i-♭VI-v-i* [C-,Ab+,G-,C-]	B-,D+,F♯-,E+
Chromatic	F+,A-,A♭+,G+	A-,G+,B♭+ A*	A-,C♯-,G+,D+
"Happy":	[D♭+7, C7sus4,F7]**		

4.4 Chord Progressions in their modalities and their loop types.

Major-Open

This is a classic doo-wop progression used in many popular songs in the late 5'0s and early '60s. The tempo of this example was kept at 120 BPM.

Major-Closed

This progression is commonly used in rock and popular music from the late 1950s on and can be found at the end of the song "Hey Jude" by The Beatles. This song was played at a standard tempo of 120 BPM.

Major-Ambiguous

This chord progression was taken from the song "Sweet Home Alabama". While the chord progression may not seem ambiguous, there has been some debate on what the function of each chord is (Nobile, 2020a). This progression was played at the tempo of "Sweet Home Alabama": 85 BPM.

Minor-Open

This progression is from the song “Bulls on Parade”. This was chosen because it received significant results in the first survey and warranted further study. This was played at the original tempo of the song: 83 BPM.

Minor-Closed

This progression is one of the two progressions not derived from an originally existing progression. This was derived through the line-of-fifths progression (Temperley, 2018) and closed off with the same chord that started the progression. This was played at 120 BPM.

Minor-Ambiguous

This progression is from the song “Get Lucky” by Daft Punk and is considered ambiguous, as it could be seen as being in either F-sharp minor or A major. However, it does not include an A chord of any kind, and the F-sharp chord is not preceded by any kind of dominant and happens in the middle of the loop, thus classifying it as ambiguous. The progression starts on a minor chord and contains the F-sharp minor chord, which is a potential tonic, thus making the progression a minor-ambiguous progression.

Chromatic-Open

This progression was originally used in Frank Zappa’s song “Easy Meat”. It is chromatic, as the melody line starts on the third of the chord and descends chromatically before returning to the original note. This was played at the base tempo of 120 BPM.

Chromatic-Closed

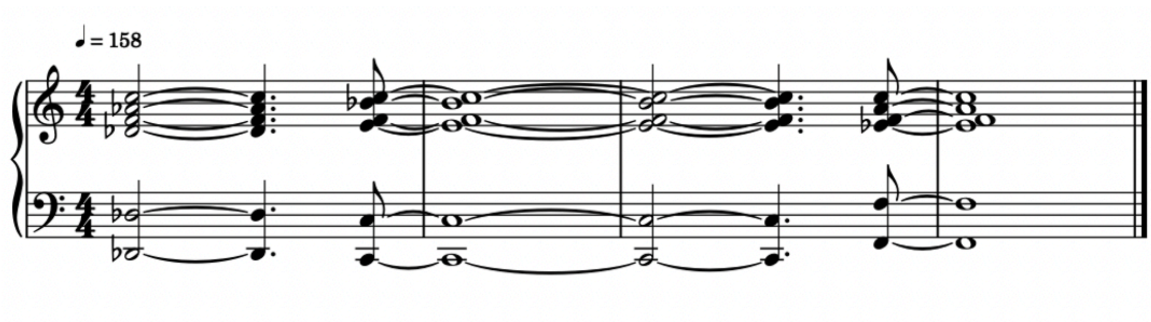
This was the second progression that was not derived from a specific song or a common practice progression in rock music. This was derived by using typical line-of-fifths progressions as laid out by Temperley (2018) to create a closed progression with a chromatic melody line. This example was played at the tempo of 120 BPM.

Chromatic-Ambiguous

This progression is from the song "Morning Bell" by Radiohead. It is considered to be ambiguous for the same reason of the dual-tonic duality (Nobile, 2020a). This was played at the original tempo of the song: 92 BPM.

Happy

This progression is from the song "Happy" by Pharrell Williams. This was included in the study because of the significant results that were seen in the first study. It was not included in any category so that it could be studied on its own. The harmonic rhythm of the progression was kept the same as the song for this example. This can be seen in Figure 4.5 below. This was played at the tempo of the original song: 158 BPM.



4.5 Chord progression in the song "Happy" by Pharrell Williams

Experiment

The experiment was set up as a self-report survey in a similar fashion as the previous two studies. This survey was created using Google forms. The participants were asked demographic questions consisting of their gender, age, years of musical training and their highest degree obtained. They were then asked the emotions that they were feeling at the time, consisting of happiness, sadness, anger, calm, and annoyed. All emotions were rated on a 7-point Likert scale, where a lower rating means that emotion is not apparent, and a higher rating means that emotion is apparent.

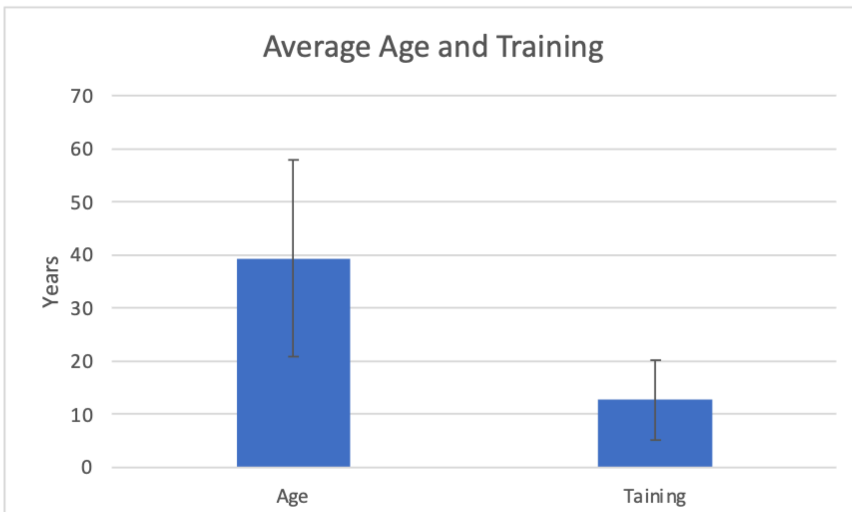
After the basic demographic and emotional levels were taken, the participants answered an example question. This was included so that they could practice the test and would be able to get used to the timbre of the instruments. The previous studies used fully engineered professional tracks of music. This test question was used so that the examples could be viewed as a decrease in the audio quality from the other surveys.

After the test track was played, they were prompted to listen to each track, then rate what emotions the song was expressing, using happy, sad, angry, and calm/relaxed on the 7-point scale. They were then asked to rate the how the song made them feel, using the first four emotions with annoyance added on at the end.

Each recording of the track was looped 4 times before it ended. If the track was derived from a previous song, it was played at the tempo of the song (listed in the analysis). The tracks were then assigned random symbols consisting of !,@,$,#. Three copies of the survey were made, and then the examples were randomized. The participants would access the survey through Allocate.Monster, where they would click one link and then randomly be assigned a survey to complete. Participants would complete the survey on their own computer on their personal time.

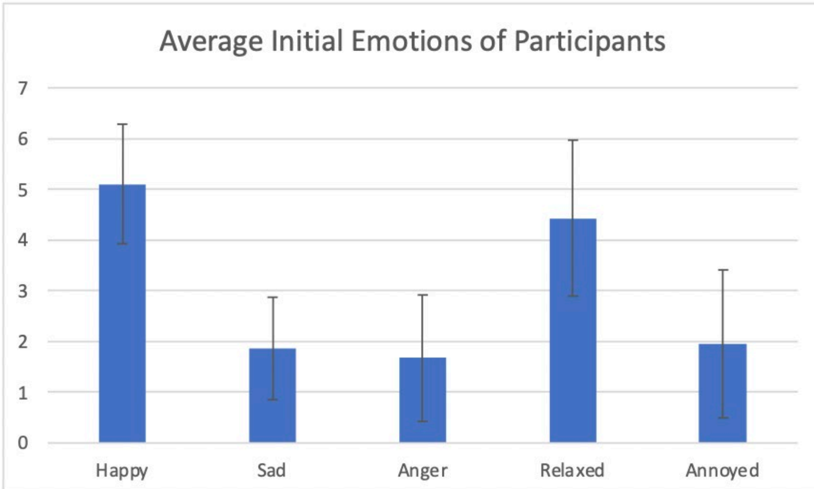
Results

A total of 21 participants completed the survey 7 were male, 13 were female, and one was non-binary. The average age of participants was 39.34 years with a standard deviation (SD) of 18.62. The average amount mount of musical training was 12.62 years with SD of 7.49. This can be seen in Figure 4.6.

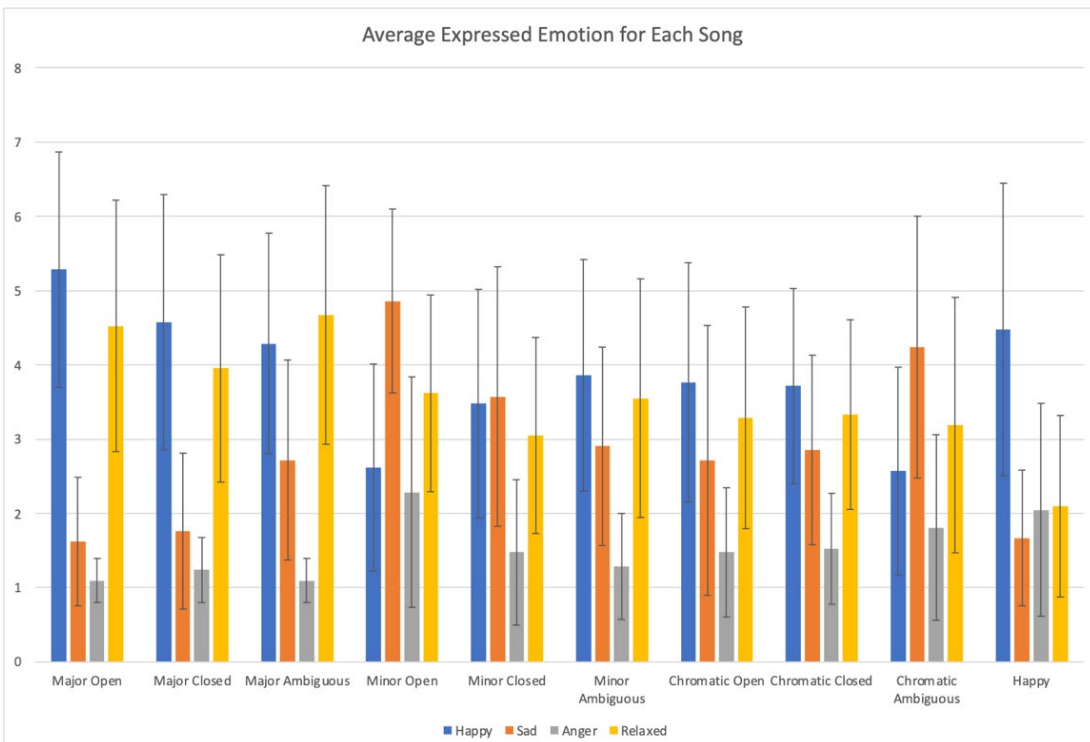


4.6 Average age and training of participants

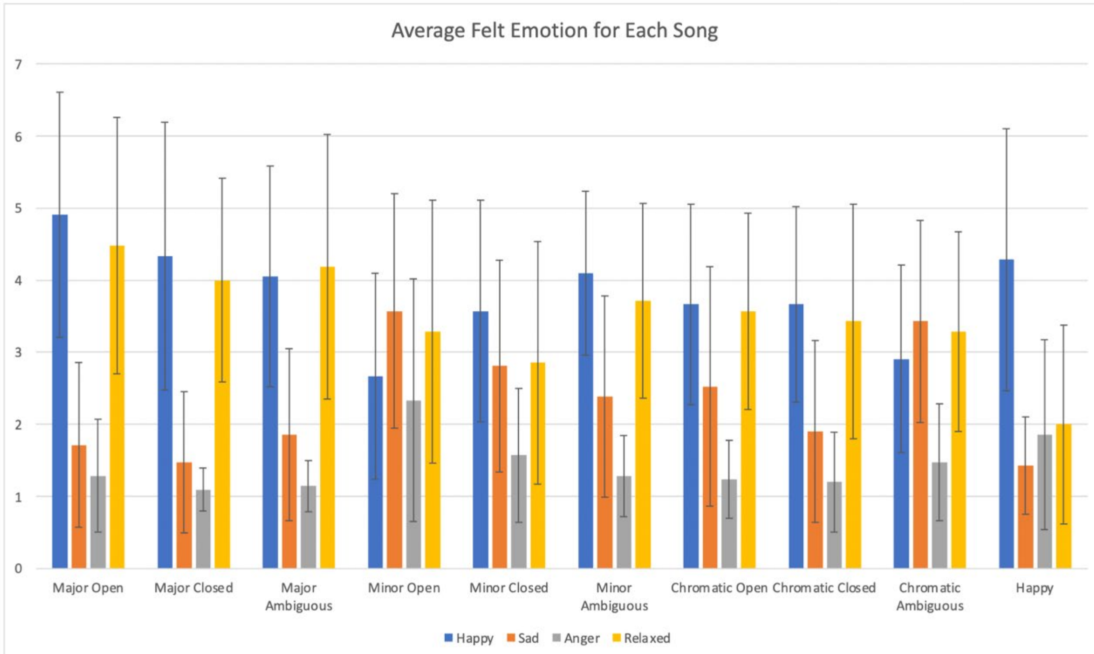
Before taking the survey the participants on average had an average happiness of 5.1 (on a 7-point Likert scale) with a SD of 1.18. Average sadness was 1.85, SD of 1.02; anger was 1.67, SD of 1.24; relaxed was 4.43, SD of 1.54; annoyance was 1.95 SD of 1.46. These can be better seen in Figure 4.7.



4.7 Average emotions at the start of the survey on a 7-point Likert scale



4.8 Average expressed emotions on a 7-point Likert scale.



4.9 Average felt emotions on a 7-point Likert scale.

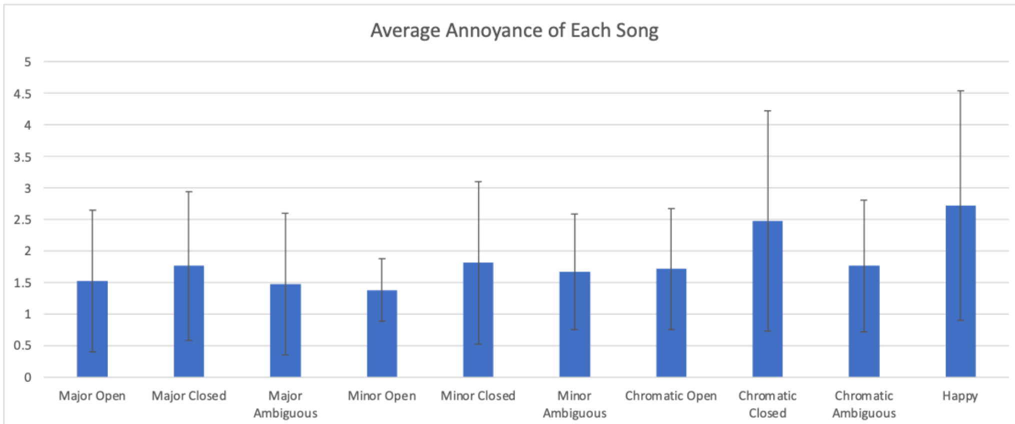
On average, expressed emotion was rated higher than felt emotion. Most stimuli were rated expressing happiness, while three stimuli of "minor open", "minor closed", and "chromatic ambiguous" were rated as expressing more sadness. "Major ambiguous" was the only stimulus to have a high expressed relaxed rating.

While most stimuli had a high rating of happiness, they also had a high rating of relaxed. "Happy" was the only stimulus that had a high rating of happiness and a low rating of relaxation.

There was not much variation in the overall rating of annoyance for each stimulus. The averages can be seen in Figures 4.10 and 4.11. The stimulus "Happy" had the highest rating of annoyance at 2.71, SD of 1.82. The second highest was "chromatic closed", which had an annoyance rate of 2.48, SD of 2.48.

	Major Open	Major Closed	Major Ambiguous	Minor Open	Minor Closed	Minor Ambiguous	Chromatic Open	Chromatic Closed	Chromatic Ambiguous	Happy
Annoyance	1.52	1.76	1.48	1.38	1.81	1.67	1.71	2.48	1.76	2.71

4.10 Average annoyance for individual songs on the 7-point Likert scale



4.11 Average annoyance for individual songs on the 7-point Likert scale

A total of three stepwise multiple regression were ran to study the data. The regressions were all run through the program R. To compare the changes in the rating of expressed and felt emotions, we took the absolute value of the difference between each rated emotion of the songs and categorized into the new variables of happy difference (Happydif), sad difference (Saddif), Anger difference (Angerdif) and relaxed difference (Relaxeddif). The first regression looked at the effect of individual song on annoyance as well as the effect of the interaction between song and difference in emotions. The second regression looked at the interaction between emotion difference and modality, while the third looked at the interaction of emotion difference and loop type.

In the first regression the interpretation of this categorical variable (song) and its interactions is complicated by the fact that R breaks this into seven binary variables and treats the alphabetically first song as the default value. In this regression that song is

“Chromatic Ambiguous.” In an ANOVA of this regression and a null regression, which excluded the factor of song, song was shown to only have a marginal significance with an F=1.79 and p=0.07 (Figure 14.12b).

Model 1: Annoyed2 ~ Saddif + Angerdif + Relaxeddif + Username + Order + Song:Saddif + Song:Relaxeddif
Model 2: Annoyed2 ~ Song + Saddif + Angerdif + Relaxeddif + Username + Order + Song:Saddif + Song:Relaxeddif

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)	
1	159	128.97					
2	150	116.45	9	12.52	1.7919	0.07411	.

4.12b ANOVA of regressions used to determine significance of song factor.

Anger difference was a main factor in this regression with a coefficient of 0.54 and a p<0.0001. However, the interaction of song and anger difference did not prove significant enough to be included in this regression.

The difference between sad expressed ratings and sad felt ratings did not have a significant main effect in this regression, but showed changes in annoyance level in interactions with song. For the song “Happy” sad difference was associated with an increase in the annoyance rating by a factor of 0.21; this means that as the sad difference increased by 1 for the song “Happy” the rating of annoyance went up by 0.21. For the chromatic closed progression, as the sad difference rating went up, the annoyance rating would rise by 0.47. The trend for interactions of song and sad difference was consistently positive. An opposite effect was seen for the chromatic open progression; as the sad difference rating would go up by 1, the annoyance rating would go down by 0.36.

The interaction of song and relaxed difference also reflected mixed effects as in sad difference. There were positive trends seen in in the chromatic open, major ambiguous, major open and minor open progressions. Minor open had the largest change, with an increase of 0.73 in annoyance for every point of change in relaxed difference. Minor closed, major closed, chromatic closed, and the song "Happy" all had a negative trend in the interaction with relaxed difference. The progression of minor closed had the largest decrease of 0.25 in annoyance rating for every 1-point change in relaxed difference.

The second regression looked at the interaction of modality and emotion difference. To test the significance of modality, an ANOVA was run on this regression testing compared to a null regression that took out the factor of modality. Modality did not have a significant main effect on annoyance rating (Figure 4.13b).

Model 1: Annoyed2 ~ Saddif + Angerdif + Username + +Order + Structure
Model 2: Annoyed2 ~ Modality + Saddif + Angerdif + Username + Order + Type

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	176	165.62				
2	174	162.88	2	2.7421	1.4647	0.234

4.13b ANOVA of regressions used to determine significance of modality factor.

In this regression the different modalities are being compared to the chromatic modality. Sad difference showed a marginally significant result in this regression with a coefficient of 0.19 and a p=0.08. Anger difference did not show a significant result in this regression but did show changes between the coefficients.

There were large changes seen in the interaction of anger difference and modality. For major modality, for every change of anger difference by 1 point the annoyance rating increase by 0.88. For minor modality it was slightly lower, at 0.61 increase in annoyance rating for every 1-point change in anger difference.

The third regression looked at the effect of the loop type on ratings of annoyance. To test the significance of loop type, an ANOVA was run on this regression testing compared to a null regression that took out the factor of loop type. Loop type had a significant main effect on annoyance rating with and F=6.722 and a p=0.001544 (Figure 4.14b).

Model 1: Annoyed2 ~ Saddif + Angerdif + Relaxeddif + +Username + Order + Modality
Model 2: Annoyed2 ~ Type + Saddif + Angerdif + Relaxeddif + Username + Order + Modality

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	175	173.38				
2	173	160.88	2	12.502	6.722	0.001544 **

4.14b ANOVA of regressions used to determine significance of loop type factor.

In this regression, the different modalities are being compared to the ambiguous loop type. This regression showed that loop type was a significant factor in the rating of annoyance. No differences between expressed and felt emotions were seen as significant in this regression. However, interaction of emotion differences and loop type showed large changes in the coefficients.

There was an interaction of loop type with sad difference, because sad difference was associated with an increase by a factor of 0.43 in annoyance level for every increase of 1 in the sad difference. While it wasn't a large change, the interaction of open loops and sad difference showed a slight decrease in annoyance rating of 0.02.

There was an interaction of loop type and anger difference, because annoyance increased with anger difference for open and closed loops (by factors of 0.71 and 0.62 respectively) with a smaller effect (0.25) for ambiguous loops. The interaction of relaxed difference and loop types comes from a small effect for open loops (0.31) that does not appear for closed or ambiguous progressions.

Discussion

As seen in the first two studies, difference in anger ratings show significant positive main effects to the annoyance rating. This is consistent with previous research between associations of annoyance with anger (Averill, 1983**).** In the previous studies, the songs that were rated as expressing anger were seen to have the opposite effect on annoyance. If these songs were rated as expressing anger, they were correlated with a lower rating of annoyance. No song was specifically seen as expressing anger in this experiment, so no switch in the annoyance rating was seen in the stimuli.

Modality showed a predicted influence on expressed emotion. All participants in this study were living in North America and can be assumed to be influenced by Western musical culture. As seen in previous research (Smit et al, 2022), the major melodies were consistently rated as happier, and the minor melodies were rated as sadder.

Modality was shown to not have a main effect on annoyance rating, but did interact with emotion differences. Loop type was seen to have a main effect on the annoyance rating. There was a consistent positive trend for annoyance rating in interactions with open loops and emotional differences.

Huron (2006) discusses the nature of tension and anticipation in music. The expectation and then lack of a resolution could be the reasoning for the interaction between anger difference and their correlation with higher annoyance ratings. Most of these progressions are open progressions. The stimuli did not include a final chord. The example ended with the end of the loop not resolving back to the first chord in the loop. This could have potentially frustrated the listener and caused them to have the anger difference and rate it as more annoying. The only confound to this is the inclusion of the "chromatic closed" interaction. The nature of this closed looping being chromatic could make this progression feel like it never resolves, and could lead it to have a more ambiguous nature, thus making the participant more frustrated.

However, ambiguous chords were seen as less annoying overall compared to other examples, but more specifically as compared to the closed examples. Participants seemed more annoyed by the closed examples. This may be due to the repeated chord that happens in these loops. At the end of the phrase the tonic chord lands on a hypermetrically weak beat and can thus make the listener more uncomfortable (Temperley, 2018; Mirka 2021; Huron 2006). The chord is then repeated at the beginning of the loop, causing confusion and frustration for the listener and causing them to rate it as more annoying. Anger difference only had an effect on annoyance for the chromatic closed chord progression.

The song "Bulls on Parade" by Rage Against the Machine, which was studied as the "minor open" stimulus in this experiment, did not show any direct main effect on annoyance. There was, however, a positive association of relaxed difference with annoyance specific to this progression. The participants, while listening to this song, could feel that the song was expressing a relaxing emotion, while it was not making them feel relaxed. It only showed a slight increase in the coefficient of the interaction of sad difference and minor open. This means that the song may have been expressing sadness while not making the participant feel the sadness. While this song in the first study did express anger, it was rated as expressing sadness in this experiment.

The interaction of anger difference could be related to tempo. The slower tempo and longer clip could have been more frustrating to the participant and warranted a higher annoyance rating, and led to a higher annoyance rating. Tempo was not specifically studied in this study. In future studies it might be interesting to study all the different modalities and loop types at the same tempo. With that said, this study can say there is strong evidence that there is something in the musical features of “Bulls on Parade” that can induce a difference in relaxation ratings that correlates to a higher annoyance rating. This survey cannot say for certain whether that is due to the tempo or the harmonic structure of the music.

The harmonic structure of the song “Happy” by Pharrell Williams was seen to have a positive main effect on the rating of annoyance. It was also seen to have a positive interaction with anger difference. On average, this stimulus was seen to be the most annoying by participants who completed this survey. This could be due to multiple reasons. This progression while it only used three chords, it was the only progression in this study that used seventh chords and suspended chords. This level of complexity could have been one of the reasons that it was seen as more annoying. This would agree with previous research in this area (Smit, et al, 2019).

This could also be due to tempo as well. This was by far the fastest example in this experiment at 158 BPM. However, as with “Bulls on Parade”, there is something in the musical features of the song “Happy” by Pharrell Williams that can induce not only annoyance but a difference in the sad ratings that correlates to more felt annoyance. It is not certain whether that is due to the tempo or the harmonic structure of the music.

In the next study I look at the difference in emotions and how they correlate to annoyance when the level of harmonic complexity is changed. This experiment will include many new songs at different levels of complexity, but will also include examples derived from both “Happy” and “Bulls on Parade” to further study what about these songs can induce annoyance.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song * Happydif + Song * Saddif + Song * Angerdif + Song * Relaxeddif + Username + Training + Age + Gender + Order + Tempo + Happy + Sad + Anger + Relaxed + Annoyed + Modality + Type, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song + Saddif + Angerdif + Relaxeddif + Username + Order + Song:Saddif + Song:Relaxeddif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-1.68789	-0.46119	-0.00835	0.45454	2.60603

Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	0.95424	0.498136	1.916	0.05732	.
SongChromClosed	0.419167	0.555603	0.754	0.45177	
SongChromOpen	0.918507	0.530415	1.732	0.08539	.
SongHap	1.36844	0.520831	2.627	0.0095	**
SongMajorAmb	0.259868	0.520331	0.499	0.61821	
SongMajorClosed	0.718445	0.543198	1.323	0.18797	
SongMajorOpen	0.03225	0.556084	0.058	0.95383	
SongMinorAmb	0.836137	0.544422	1.536	0.12669	
SongMinorClosed	-0.107529	0.521572	-0.206	0.83694	
SongMinorOpen	0.707688	0.531745	1.331	0.18525	
Saddif	-0.109018	0.246152	-0.443	0.65849	
Angerdif	0.541336	0.126501	4.279	3.33E-05	***
Relaxeddif	0.002716	0.209069	0.013	0.98965	
UsernameB	0.237065	0.41606	0.57	0.56968	
UsernameC	1.149166	0.428899	2.679	0.0082	**
UsernameD	0.323856	0.430089	0.753	0.45263	
UsernameE	0.151	0.405985	0.372	0.71047	
UsernameF	1.134962	0.420851	2.697	0.0078	**
UsernameG	1.213909	0.426564	2.846	0.00505	**
UsernameH	0.933693	0.424734	2.198	0.02946	*
UsernameI	1.015033	0.447819	2.267	0.02484	*

UsernameJ	0.522775	0.407506	1.283	0.20152	
UsernameK	2.482633	0.424289	5.851	2.95E-08	***
UsernameL	-0.008949	0.409988	-0.022	0.98262	
UsernameM	1.979767	0.40909	4.839	3.20E-06	***
UsernameN	1.138419	0.422992	2.691	7.92E-03	**
UsernameO	0.214149	0.406495	0.527	0.5991	
UsernameP	0.18197	0.402262	0.452	6.52E-01	
UsernameQ	0.100835	0.412391	0.245	0.80717	
UsernameR	0.108152	0.469099	0.231	0.81798	
UsernameS	2.404196	0.411586	5.841	3.10E-08	***
UsernameT	1.169773	0.413217	2.831	0.00528	**
UsernameU	0.166298	0.409966	0.406	0.68559	
OrderFive	-0.432979	0.327964	-1.32	1.89E-01	
OrderFour	-1.102558	0.381972	-2.886	0.00447	**
OrderNine	-0.696576	0.388593	-1.793	0.07506	.
OrderOne	-1.171226	0.425824	-2.75	0.00668	**
OrderSeven	-0.931702	0.355351	-2.622	0.00964	**
OrderSix	-0.683956	0.327031	-2.091	0.03818	*
OrderTen	-0.515299	0.303026	-1.701	0.09111	.
OrderThree	-1.022562	0.360835	-2.834	0.00523	**
OrderTwo	-0.130603	0.357425	-0.365	0.71533	
SongChromClosed:Saddif	0.57862	0.29867	1.937	0.05458	.
SongChromOpen:Saddif	-0.265481	0.291848	-0.91	0.36446	
SongHap:Saddif	0.313905	0.434404	0.723	0.47104	
SongMajorAmb:Saddif	0.115284	0.315569	0.365	0.71539	
SongMajorClosed:Saddif	0.333193	0.453161	0.735	0.46333	
SongMajorOpen:Saddif	0.579305	0.385734	1.502	0.13524	
SongMinorAmb:Saddif	0.140466	0.334839	0.42	0.67545	
SongMinorClosed:Saddif	0.478537	0.317244	1.508	0.13355	
SongMinorOpen:Saddif	0.166007	0.276253	0.601	0.5488	
SongChromClosed:Relaxeddif	-0.097013	0.331555	-0.293	0.77023	
SongChromOpen:Relaxeddif	0.291813	0.371726	0.785	0.43368	
SongHap:Relaxeddif	-0.187732	0.335369	-0.56	0.57647	
SongMajorAmb:Relaxeddif	0.100059	0.308446	0.324	0.74609	
SongMajorClosed:Relaxeddif	-0.257074	0.354072	-0.726	0.46894	
SongMajorOpen:Relaxeddif	0.23782	0.306947	0.775	0.43968	
SongMinorAmb:Relaxeddif	-0.10386	0.257034	-0.404	0.68674	

SongMinorClosed:Relaxeddif	-0.01738	0.281749	-0.062	0.95089	
SongMinorOpen:Relaxeddif	0.734475	0.301568	2.436	0.01604	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.8811 on 150 degrees of freedom
Multiple R-squared: 0.7064, Adjusted R-squared: 0.5909
F-statistic: 6.117 on 59 and 150 DF, p-value: < 2.2e-16

4.12a Stepwise regression of independent variables effect on annoyance rating and interaction of song and difference in emotions.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Modality * Happydif + Modality * Saddif + Modality * Angerdif + Modality * Relaxeddif + Username + Training + Age + Gender + Order + Tempo + Happy + Sad + Anger + Relaxed + Annoyed + Modality + Type + Song, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Modality + Saddif + Angerdif + Username + Order + Song + Modality:Angerdif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-1.84600	-0.52772	0.03124	0.48011	3.14507

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	0.9785869	0.403316	2.426	0.016316	*
ModalityMajor	0.1663388	0.4129252	0.403	0.687588	
ModalityMinor	1.1962616	0.4199811	2.848	0.004947	**
Saddif	0.1354615	0.0763751	1.774	0.077946	.
Angerdif	0.1946574	0.1857792	1.048	0.29625	
UsernameB	0.019378	0.4080621	0.047	0.962181	
UsernameC	1.0638794	0.4223747	2.519	0.012715	*
UsernameD	0.347634	0.4102978	0.847	0.398056	
UsernameE	0.0135461	0.4046074	0.033	0.973332	
UsernameF	1.0295168	0.4093014	2.515	0.012838	*
UsernameG	1.1508421	0.4157032	2.768	0.006269	**
UsernameH	0.7501339	0.4258787	1.761	0.080004	.
UsernameI	0.8185542	0.4329223	1.891	0.060388	.
UsernameJ	0.4994977	0.4076607	1.225	0.222196	
UsernameK	2.4579254	0.4198826	5.854	2.48E-08	***
UsernameL	-0.0677307	0.4063337	-0.167	0.867818	
UsernameM	1.9001526	0.4128942	4.602	8.24E-06	***
UsernameN	0.9869094	0.4083306	2.417	0.016729	*
UsernameO	0.0812769	0.4071225	0.2	0.842007	
UsernameP	0.1275479	0.4079823	0.313	0.754951	
UsernameQ	-0.0677307	0.4063337	-0.167	0.867818	
UsernameR	-0.094823	0.4080528	-0.232	0.816528	

UsernameS	2.1546401	0.4084645	5.275	4.07E-07	***
UsernameT	1.4977096	0.4166743	3.594	0.000428	***
UsernameU	0.1593616	0.4051837	0.393	0.694594	
OrderFive	-0.5033732	0.3285189	-1.532	0.127353	
OrderFour	-0.9574865	0.388513	-2.464	0.014733	*
OrderNine	-0.7096961	0.4028588	-1.762	0.079958	.
OrderOne	-0.9266741	0.4261625	-2.174	0.031077	*
OrderSeven	-0.8436838	0.368128	-2.292	0.023165	*
OrderSix	-0.6165913	0.3331619	-1.851	0.065975	.
OrderTen	-0.6120396	0.301381	-2.031	0.043863	*
OrderThree	-1.1010913	0.3608374	-3.051	0.00265	**
OrderTwo	0.0003802	0.3615008	0.001	0.999162	
SongChromClosed	0.9761554	0.3312525	2.947	0.003669	**
SongChromOpen	0.6919333	0.4036561	1.714	0.088354	.
SongHap	0.9598553	0.4211076	2.279	0.023911	*
SongMajorAmb	0.1316094	0.4149514	0.317	0.751512	
SongMajorClosed	0.2734064	0.3683003	0.742	0.45892	
SongMajorOpen	NA	NA	NA	NA	
SongMinorAmb	-0.5579471	0.3600359	-1.55	0.123107	
SongMinorClosed	-1.0575343	0.3892632	-2.717	0.007287	**
SongMinorOpen	NA	NA	NA	NA	
ModalityMajor:Angerdif	0.6919736	0.2703511	2.56	0.011368	*
ModalityMinor:Angerdif	0.4264833	0.2452882	1.739	0.08393	.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9046 on 167 degrees of freedom
Multiple R-squared: 0.6555, Adjusted R-squared: 0.5688
F-statistic: 7.565 on 42 and 167 DF, p-value: < 2.2e-16

4.13a Stepwise regression of independent variables effect on annoyance rating and interaction of modality and difference in emotions.

Before Stepwise Procedure:
lm(formula = Annoyed2 ~ Type * Happydif + Type * Saddif +
Type * Angerdif + Type * Relaxeddif + Username +
Training + Age + Gender + Order + Tempo + Happy + Sad + Anger +
Relaxed + Annoyed + Modality + Type + Song, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Type + Saddif + Angerdif + Relaxeddif +Username + Order +
Song + Type:Saddif + Type:Angerdif + Type:Relaxeddif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-1.92526	-0.44759	-0.05217	0.47518	2.80869

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	1.16E+00	4.30E-01	2.69E+00	0.00781	**
StructureClosed	-0.242644	4.30E-01	-5.64E-01	0.57343	
StructureOpen	8.99E-01	4.55E-01	1.98E+00	0.04967	*
Saddif	0.002322	1.34E-01	1.70E-02	0.98619	
Angerdif	2.49E-01	2.05E-01	1.21E+00	0.22663	
Relaxeddif	-0.025946	1.15E-01	-2.26E-01	0.82182	
UsernameB	0.122327	4.03E-01	3.04E-01	0.76187	
UsernameC	0.978816	4.20E-01	2.328	0.02112	*
UsernameD	0.223515	4.12E-01	0.543	0.58805	
UsernameE	-0.066311	0.397953	-0.167	0.86787	
UsernameF	0.879646	0.411244	2.139	0.03393	*
UsernameG	1.04786	0.418553	2.504	0.01329	*
UsernameH	0.739797	0.420226	1.76	0.08021	.
UsernameI	0.685575	0.427908	1.602	0.11107	
UsernameJ	0.38582	0.40122	0.962	0.33768	
UsernameK	2.313185	0.418396	5.529	1.27E-07	***
UsernameL	-0.075846	0.398789	-0.19	0.8494	
UsernameM	1.891356	0.410801	4.604	8.33E-06	***
UsernameN	0.964413	0.409117	2.357	0.0196	*
UsernameO	0.09457	0.405054	0.233	0.81569	
UsernameP	0.128565	0.400422	0.321	0.74857	
UsernameQ	0.010844	0.406072	0.027	0.97873	
UsernameR	-0.104012	0.427889	-0.243	0.80825	

UsernameS	2.18087	0.405894	5.373	2.65E-07	***
UsernameT	1.23559	0.411703	3.001	0.00312	**
UsernameU	0.101201	0.399083	0.254	0.80014	
OrderFive	-0.440351	0.323846	-1.36	0.1758	
OrderFour	-0.95192	0.381739	-2.494	0.01365	*
OrderNine	-0.703387	0.39151	-1.797	0.07426	.
OrderOne	-0.92694	0.418086	-2.217	0.02801	*
OrderSeven	-0.873087	0.361553	-2.415	0.01686	*
OrderSix	-0.693496	0.325459	-2.131	0.03461	*
OrderTen	-0.512751	0.298342	-1.719	0.08758	.
OrderThree	-1.036421	0.353632	-2.931	0.00387	**
OrderTwo	-0.041114	0.35506	-0.116	0.90796	
SongChromClosed	0.536075	0.30188	1.776	0.07764	.
SongChromOpen	-0.488157	0.357659	-1.365	0.17419	
SongHap	0.057554	0.355848	0.162	0.87171	
SongMajorAmb	0.331845	0.33245	0.998	0.31968	
SongMajorClosed	0.552527	0.361579	1.528	0.12844	
SongMajorOpen	-0.917012	0.354684	-2.585	0.01061	*
SongMinorAmb	0.686004	0.40775	1.682	0.09441	.
SongMinorClosed	NA	NA	NA	NA	
SongMinorOpen	NA	NA	NA	NA	
StructureClosed:Saddif	0.4333	0.185605	2.335	0.0208	*
StructureOpen:Saddif	-0.022747	0.170882	-0.133	0.89427	
StructureClosed:Angerdif	0.38293	0.296082	1.293	0.19774	
StructureOpen:Angerdif	0.473782	0.241642	1.961	0.05163	.
StructureClosed:Relaxeddif	-0.025557	0.172692	-0.148	0.88253	
StructureOpen:Relaxeddif	0.338342	0.164447	2.057	0.04125	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.8856 on 162 degrees of freedom
Multiple R-squared: 0.6797, Adjusted R-squared: 0.5867
F-statistic: 7.314 on 47 and 162 DF, p-value: < 2.2e-16

4.14a Stepwise regression of independent variables effect on annoyance rating and interaction of structure and difference in emotions.

Chapter 5: Metric Complexity, Emotions, and Annoyance

Meter and Rhythm in Rock

Meter in music is a structure built out of sounds happening in consistent and predictable patterns (Lerdahl and Jackendoff 1983; Hasty, 1997). Christopher Hasty considers meter to be predictive experience. That is, when a listener hears a sound and then hears another sound a certain space of time after it, they will then predict that a third sound will happen in the same length of time that separated the first two (Hasty, 1997).

The expectation of this experience involves accented notes and unaccented notes. The pattern of accented note to unaccented note back to accented note is considered a duple pattern. A pattern that involves two unaccented notes in between the accented notes would be triple (Hasty, 1997). This expectation of pattern continuation is what creates meter.

Hasty also argues that this expectation of pattern continuation can happen on different metrical levels. The most obvious one to a player would be the level of a "beat" or tactus. This is often marked in music, and in most popular music, as a tempo in beats per minute (BPM). There can also be metrical patterns below the beat, usually only consisting of a duple and triple division (Lerdahl and Jackendoff, 1983). When this metrical pattern happens higher than the level of tactus, it is referred to as hypermeter (Hasty, 1997; Temperley, 2018).

David Temperley describes how this predication of time and meter is produced in modern rock and popular music.

> By Convention, the bass (or "Kick") drum marks beats 1 and 3 of a 4/4 measure (by far the most common meter in rock) and the snare drum marks beats 2 and 4…. For this reason, cases of metrical confusion or ambiguity—where meter is unclear—very rarely occur in rock (Temperley, 2018 p. 67).

Temperley discusses how listeners tend to consider beats as accented depending on certain cues in the music. Long notes, loud notes, stressed syllables, and harmonic change are viewed as more accented, and can be called "phenomenal accents" (Temperley, 2018). Anticipatory syncopation happens when a musician purposefully puts one of these phenomenal accents on a weak beat in the established meter. They are usually displaced by an eight note or less, which can be seen as a metric dissonance in the music. This is a common practice in rock, blues, and jazz. These, however, are not heard as destabilizing. Temperley argues that we associate them with the beat that follows them. He states that these syncopations also provide a type of rhythmic flexibility that allows a better fit for the pacing of the lyrics (Temperley, 2018).

David Geary uses these different predictive models of meter, and with a simple quadruple meter introduces the theory of interpretive flexibility. In this he states that at a BPM between 100–120 there can be multiple levels of perceptible tactus that a listener can choose to listen to and follow. He states that songs that have a high level of interpretive flexibility in their beat pattern will cause a listener to have a preferred pulse layer that they are listening to. This preference is based on different factors that could include their familiarity with the music, level of training, and the strength of the reference structures in the music.

Geary (2022) states that one of the most important reference structures in music is that of the drum pattern layer, and that this pattern can strongly influence a listener's sense of meter in the song. The reference is also heavily influenced by tempo in the music. He discusses how in the Panic! At the Disco's song "I Write Sins Not Tragedies," there could be two levels of a preferred tactus: one the tempo the drums imply of 170 BPM, while a tactus of 85 PBM would be preferred based on absolute tempo (Geary, 2022).

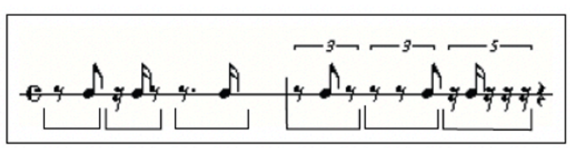
Nicole Biamonte (2014) discusses how different metrical dissonances in popular music can have formal functions. She states that metric dissonances that cause only small disruptions (two or three bars) usually serve one of three functions. They can signal the beginning of a phrase or section, a cadential hemiola, or a truncated link at the end of a formal section that accelerates it into the next section. One example of this is in David Bowie's "Changes", where in the chorus, the 4/4 meter is displaced by half a bar and then becomes a triple meter lasting four bars. She argues that this metric dissonance helps to lead into the cadence at the end of this section (Biamonte, 2014).

Large form dissonance, or a disruption of the form, can be used to define the role of chorus and verse on a larger scale. A chorus may contain a more regular metric structure and rhythm, while the verse may be more irregular. "A shift from changing or asymmetrical meter to regular meter between the verse and chorus can serve as an additional parameter reinforcing the roles of the chords as culmination and resolution" (Biamonte, 2014, sec. 7.7).

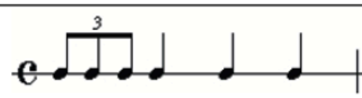
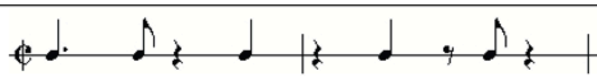
There are many ways to look at how dissonance can be interpreted in music, how it can function formally in music, and how it could be measured quantitatively. Francisco

Gomez, Godfried Toussaint, et al. discussed different mathematical ways to measure levels of rhythmic syncopation in music. They created a method called weighted note-to-beat distance measure (WNBD). This uses a mathematical formula from which one can derive a fraction that represents the level of syncopation in the music. They define it as follows:

> Firstly, notes are supposed to end where the next note starts. Let e_i; $e_i + 1$ be two consecutive strong beats in the meter. By strong beats we just mean pulses. Also, let x denote a note that starts after or on the strong beat ei but before the strong beat ei+1; we first define T(*x*) = min{d(*x*; e_i); d(*x*; e_i + 1)}, where d denotes the distance between notes in terms of duration. Here the distance between two adjacent strong beats is taken as the unit and, therefore, the distance d is always a fraction. For example, quarter notes in 4/4 time are the strong beats, and, if the notes in Figure [5.1] are referred to the nearest strong beat, then the distances T(*x*) are, respectively, 1/2, 1/4, 1/4, 1/3, 1/3, 1/5.
>
> The WNBD measure D(*x*) of a note *x* is then defined as follows: 0, if $x = e_{\mathrm{i}}$; $\frac{1}{\mathrm{T}(x)}$ if note ends before or at $e_{\mathrm{i}} + 1$; $\frac{2}{\mathrm{T}(x)}$ if note x $\neq e_{\mathrm{i}}$ ends after $e_{\mathrm{i}} + 1$ but before or at $e_{\mathrm{i}} + 2$; and $\frac{1}{\mathrm{T}(x)}$, if note $x \neq e_{\mathrm{i}}$ ends after $e_{\mathrm{i}} + 2$. Let *n* denote the number of notes of a rhythm. Then, the WNBD measure of a rhythm is the sum of all D(*x*), for all notes *x* in the rhythm, divided by n. The table in Figure [5.2] lists the WNBD values for various rhythms (Gomez, 2020 sec. 3.4).



5.1 Measuring syncopation with the WNBD measure. Borrowed from Gomez (2020)

Rhythm	Musical Scores	WNBD
Hesitation		1/2
Anticipation		1/2
Syncopation		1.2
Triplet		0.857
Bembé		3
Bossa-Nova		4
Irregular		5

5.2 Example of the WNBD measure. Borrowed from Gomez (2020)

When this is applied to a rhythm, different measures of syncopation are obtained that can be further compared and studied. While this method is useful, it does have drawbacks. It does not consider rests and their impact on the level of rhythmic dissonance. This method also only analyses rhythmic dissonance and not a disruption of the meter. While it relies on a strict tactus to compare the rhythms to, it does not consider other levels of the metric hierarchy.

Rhythm, Meter, Tempo, and Emotions in Music

There is evidence that beat induction is an inherent ability that is present in adult humans as well as newborn infants (Honing, et al., 2009). Honing, et al (2009) studied beat induction by having adult participants listen to differently constructed patterns, which consisted of a basic drum pattern with certain beats omitted. The participants completed this while connected to an EEG machine. An EEG machine measures the electrical patterns in the brain, and changes in those patterns can be studied on a continuous time spectrum. Syncopated patterns were created by omitting attacks on beats one and three of the pattern. Participants were then instructed to press a button when they noticed a deviant pattern. In a second study the participants in one group were asked to press a button when the intensity in a continuous sound stream changed, while another group was told to ignore all sounds and watch a muted movie with subtitles. (Honing, et al., 2009).

They found that in adults there was a trend towards a faster reaction time for removal of strong beats rather than removal of weak beats in a pattern, which supported their hypothesis that subjects were sensitive to the meter (Honing, et al., 2009).

In another study involving newborns, they used the same pattern from the first study, but only used the syncopation with the first attack omitted. Here they took similar brain pattern responses from EEG monitors. They found similar brain responses in the newborns as in the adults, which led them to conclude that this beat induction is already functional at birth (Honing, et al., 2009).

Metrical and rhythmic dissonance has been found to have a significant effect on how emotions in music are perceived by a listener. Musical entertainment of musical rhythms can be linked to pleasantness. Wiebke Trost, et al. (2014) showed that the basal ganglia region of the brain is involved in processing both emotions and rhythms in music, and further showed that it contributes significantly to the entrainment of rhythm by our brain**.** They played 10 different pieces of piano music, each in duple meter. While the participants listened to the excerpts, they also had to detect when a target would appear on the screen and respond as fast as they could. The visual target would appear at two different positions in the music, either on the first beat of the meter or on the second beat. All these tests were completed in an MRI machine (Trost, et al. 2014).

They found that the effect of meter was stronger in music that was deemed harmonically dissonant by the listener, while in music that was consonant, the meter did not have as strong an effect.

> Rhythmic entrainment in basal ganglia circuits represents a powerful and automatic process, which is engendered even by dissonant/unpleasant music, and more broadly deployed when music is perceived as pleasant. We propose that consonant music may establish a sustained pleasant emotional state, in which attention is globally broadened and readiness to react is heightened, whereas dissonant music makes attention more focused on rhythmic musical features. (Trost, et. al, 2014, p.63).

Jessica Sommer, Kimberly Simmon, and Daphne Tan (2021) studied what effects metric dissonance would have on emotional responses through Robert Schumann's piece *Carnaval.* They chose 10 metrically constant excerpts from this piece and 10 metrically dissonant re-compositions of those excerpts. The participants consisted of graduate piano students as well as non-musicians. After listening to the excerpts, they were asked to choose from different clusters of words that describe the mood of the music. For example, cluster A contained the words bright, cheerful, happy, and joyous. They were then asked on a sliding scale how strongly they felt the music expressed that cluster.

Sommer et al. (2021) found significant differences in the perceptions of emotion between the excerpts. While both the consonant and dissonant versions had cluster B (humorous, light, lyrical, playful), they had large differences in the second choice of cluster. For consonant excerpts they chose cluster A (bright, cheerful, happy, joyous) as the second choice. While for the dissonant excerpts the most common second choice was cluster F (dramatic, passionate, exciting, triumphant). They concluded that while metric consonance and dissonance showed some change, larger effects must be in play, such as mode and tempo.

However, Sommer et al. (2021) did find in the study that musical training had an effect on the choice of clusters, stating that musicians and non-musicians use different vocabulary for their descriptions of music. They also found that non-musicians were more likely to change their top choice clusters between consonant and dissonant pairs (Sommer et al., 2021). They conclude overall that the emotional response may depend more on what the listener is listening to in the music itself. This can be very individual and can be influenced by many other factors (Sommer et al., 2021).

Tempo can also impact the way emotions are perceived in a piece of music. Some preliminary findings from Guangyuan Liu (2021) show that faster tempo music increased neural activity, which showed an increase in the intensity of the emotional experience.

The effect of tempo has also been found when people listen to music while completing another task. Matthew Moreno (2020) showed that faster tempos of music would negatively impact a participant's ability to complete a cognitive task. This specific study tested the effects tempo had on a reading comprehension exam. He suggests that the reasoning for the decrease is because "as the tempo of background music increases, cognitive load increases, resulting in less working memory resources that the listener can muster to deal with the cognitive processing demands of the task." (Moreno, 2020, p. 71)

Moreno (2020) also found associations with increased ratings of high arousal emotions with faster tempos, which he explains helps take up some of the cognitive processing abilities of the brain. He also argues that appraisal, or the ability of the mind to make judgments regarding psychological circumstances, is a factor. The unconscious appraisal of someone listening to music can be distracting to while completing a task. This can cause disruptions to our cognitive capabilities when high arousal emotions are involved. In this study fear, excitement, and anxiety were the most significant (Moreno, 2020).

Hypothesis

Based on the previous surveys and previous research, I expected to find that there will still be a correlation between anger difference and annoyance after participants listen to the examples.

Rhythmic complexity is expected to have little to no effect on annoyance rating by participants. The more complex music is expected to be rated as less annoying because there is more to listen to, and the participants chose a preferred tactus (Geary, 2022) and thus will enjoy the song more. The less complex music will not allow for that and therefore may lead to more annoyance.

I expected to find a correlation between happy difference and a higher rating of annoyance as in study 1 and 2. The same is expected for anger difference. If a song is perceived to be expressing anger by the participant, these results are expected to result in a lower annoyance score. There is no song in this experiment expected to be only perceived as angry.

Based on Moreno's (2020) research I expect higher felt emotional ratings for the songs with faster tempos. The faster songs are expected not to have a high difference in felt versus expressed emotions because of the higher ratings for felt emotions. Annoyance was not expected be directly influenced by tempo.

Overall, I did not expect rhythmic complexity to be as important as other factors in the music such as modality, tempo, and pervious emotional associations. I did not expect to see large significant results directly related to the complexity of the music.

Methodology

Stimuli

Stimuli in this survey were selected through an analysis of the rhythmic complexity of popular music in the past 70 years. The rhythmic complexity was measured using the weighted note-to-beat distance measure, (WNBD), defined above (Gomez, 2020). Separate measures were taken of the musical layers of the melody, the harmonic instruments, the bass, and the drums. The separate measures were then averaged to organize the songs into four different levels of complexity, designated as levels. Level 1 is low complexity and level 4 is high complexity. I will consider overall complexity, as well as the different complexities of each layer of the songs. These can be seen in Figure 5.3**.**

Each example was taken from the chorus of the song and consisted of a four-measure loop. There were three levels of tempos studied, fast (130+), medium (110–129), and slow (below 110).

Song	Drums	Bass	Harmony	Melody
Toxic	12/38	22/14	14/17	6/16
Happy	24/40	30/21	0/4	24/18
Ain't No Mountain High Enough	54/57	32/28	16/8	16/15
Man! I Feel Like a Woman!	108/68	0/16	96/48	42/19
Call Me Maybe	32/56	18/19	18/10	52/20
Bulls on Parade	60/50	96/38	96/38	70/27
Like a Prayer	106/74	68/25	108/32	32/23
1000 miles	180/76	80/24	80/24	56/16
Whatever Whenever	294/135	80/24	112/24	70/25

5.3 a.

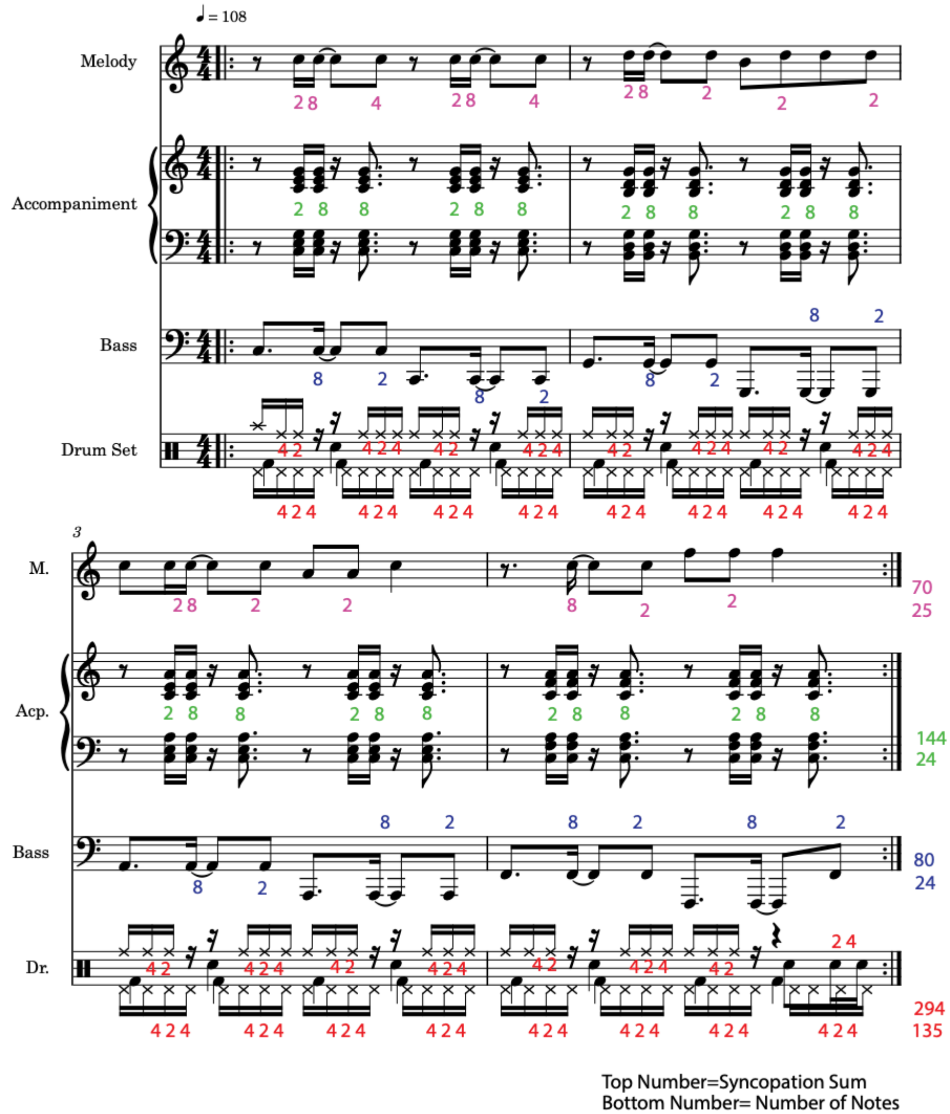
Song	Tempo in BPM	Drums	Bass	Harmony	Melody	Average	Level of Complexity
Toxic	148	0.32	1.57	0.82	0.38	0.77	1
Happy	158	0.60	1.43	0.00	1.33	0.84	1
Ain't No Mountain High Enough	130	0.95	1.14	2.00	1.07	1.29	2
Man! I Feel Like a Woman!	126	1.59	0.00	2.00	2.21	1.45	2
Call Me Maybe	120	0.57	0.95	1.80	2.60	1.48	2
Bulls on Parade	85	1.20	2.53	2.53	2.59	2.21	3
Like a Prayer	114	1.43	2.72	3.38	1.39	2.23	3
1000 miles	95	2.37	3.33	3.33	3.50	3.13	4
Whatever Whenever	108	2.18	3.33	6.00	2.80	3.58	4
Avg		1.36	1.93	2.43	2.19		

5.3 b.

5.3 WNBD measure of stimuli used in the study. a. original fractions from the analysis b. numerical average from the analysis with averages calculated.

I made the stimuli with Ableton Live 11. They consisted of a standard chord progression of I-V-vi-IV in the key of C major, with rhythms taken from each song. Four rhythmic layers were taken from each song: one for the drums, one for the bass, one for the harmony, and one for the melody. The chord progression was standardized to avoid the conflict of modality in this study. The melody is chosen by starting on a single note and moving stepwise in the same motion as the melody in the original song. An example of an analysis of the rhythms from the song "Whenever, Wherever" by Shakira, analyzed using Gomez et al.'s (2005) WMBD method, can be seen in Figure 5.4 The rest of the analysis can be seen in Appendix A, Figures 1–9. Each example was played at the tempo of the song from which the rhythms were derived at the original tempo and is labeled in Figure 5.3**.**

Extracted Rhythms from "Whenever, Wherever"



5.4 Analysis of the extracted rhythms from "Whenever, Wherever" by Shakira. Numbers are the measures of syncopation from Gomez (2020).

Experiment

The experiment was set up as a self-report survey in a similar fashion to the previous three studies. This survey was created using Google forms. The participants were asked demographic questions consisting of their gender, age, years of musical training, and their highest degree obtained. They were then asked the emotions that they were feeling at the time, consisting of happiness, sadness, anger, calm, and annoyed. All emotions were rated on a 7-point Likert scale, where a lower rating means that emotion is not apparent, and a higher rating means that emotion is apparent.

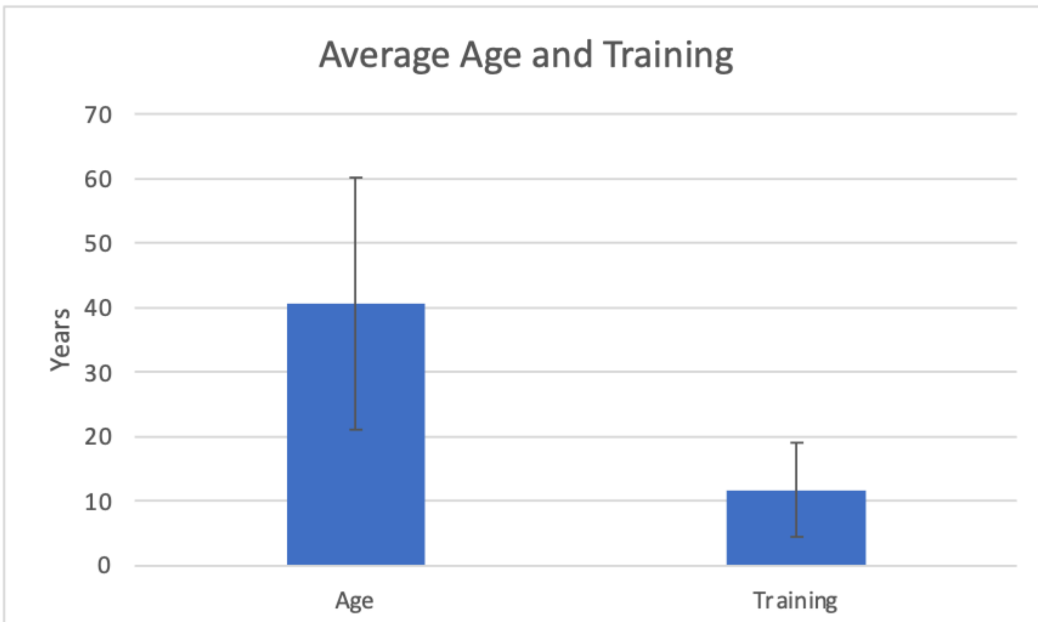
After the basic demographic and emotional levels were taken, the participants answered a test question. This was included so that they could practice the test and would be able to get used to the timbre of the instruments. Experiments 1 and 2 used fully engineered professional tracks of music.

The participants were then prompted to listen to each track, then rate emotions expressed by the example using happy, sad, angry, and calm/relaxed on the 7-point scale. They were then asked to rate how the song made them feel, using the first four emotions with annoyance added.

Each recording of the track was looped 4 times before it ended. The tracks were then assigned random symbols consisting of !,@,$,#. Three copies of the survey were made with order randomized. The participants accessed the survey through Allocate.Monster, where they clicked one link and randomly assigned them a survey to complete. Participants would complete the survey on their own computer in their personal time.

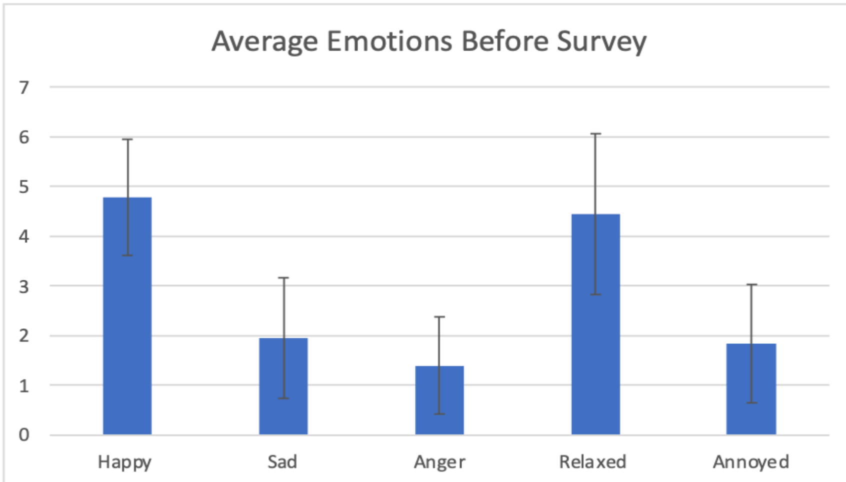
Results

18 participants completed this survey. 7 of the participants were male, and 11 participants were female. The average age of the participants was 40.5 years, with a standard deviation (SD) of 19.57 years. The average musical training was 11.69 years, with a SD of 7.24. These can be seen in Figure 5.5.



5.5 Average age and musical training of participants in years

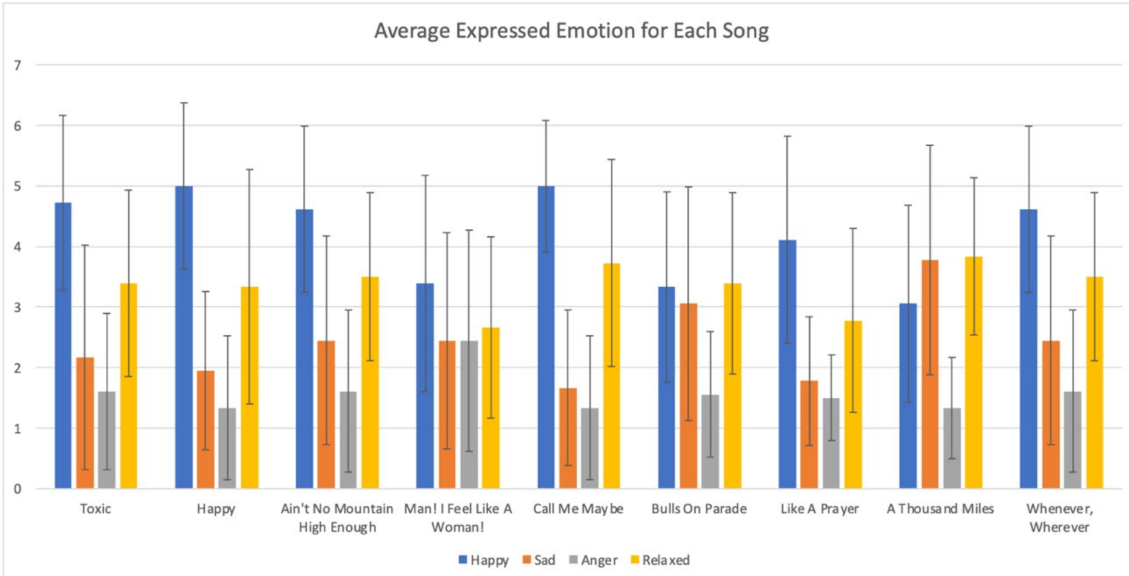
Average happiness before completing the survey was 4.78, SD of 1.17; sadness was 1.94, SD of 1.21; anger was 1.38, SD of 0.98; relaxed was 1.83, SD of 1.2; and annoyance was 1.83, SD of 1.2. These can be seen in Figure 5.6.



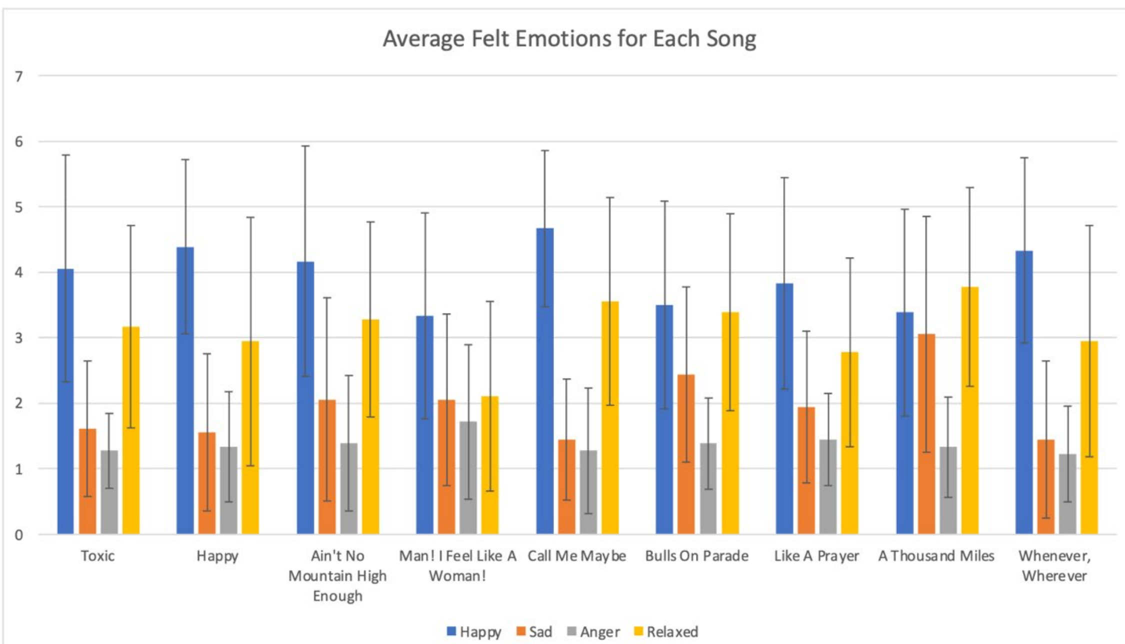
5.6 Average initial emotions of participant before takin the survey on a 7-point Likert scale

All songs had a high rating of expressed happiness, except for the songs "A Thousand Miles" and "Bulls on Parade". "A Thousand Miles" showed a high rating for expressed sadness. "Bulls on Parade" showed an almost even amount of expressed happiness (3.33), and expressed relaxed (3.38), with relaxed being just slightly higher. These two songs and "Man! I Feel Like a Woman!" all showed an overall lower level of expressed happiness than the other songs included in this survey. These results can be seen in Figure 5.7.

All songs had a high rating of felt happiness, except for the song "A Thousand Miles", which had a higher rating for felt relaxed. The sad felt rating was significantly lower than the sad expressed rating, and a felt happy rating that was much higher than the expressed happy rating. The song "Bulls on Parade" expressed to having a slightly higher felt happiness. However, the difference is small and unlikely to be significant. These results are laid out in Figure 5.8.

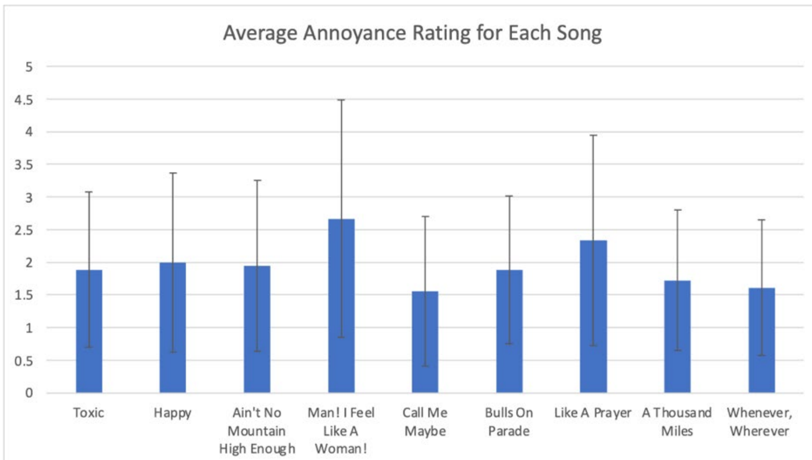


5.7 Average expressed emotions for each song on a 7-point Likert scale.



5.8 Average Felt emotions for each song on a 7-point Likert scale.

The song "Man! I Feel Like a Woman!" had the highest average annoyance rating, with "Like a Prayer" having the second highest rating. All the other annoyance levels were similar, hovering somewhere between 1.5 and 2 on the 7-point Likert scale.



5.9 Average annoyance for each song on a 7-point Likert scale.

I ran three stepwise multiple regressions using the statistics software R. These were completed in a similar fashion to the regressions in the previous three studies. The first regression studied the effect of individual song and emotion difference on the annoyance rating. For the song factor, R treats the alphabetically first song ("Bulls On Parade") as the default value. The results of this regression can be seen in Figure 5.10. To test the significance of song, an ANOVA was run on this regression testing compared to a

Model 1: Annoyed2 ~ Happydif + Saddif + Angerdif + Username + Song:Happydif
Model 2: Annoyed2 ~ Song + Happydif + Saddif + Angerdif + Username + Song:Happydif

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	133	1.13E+02				
2	1.25E+02	1.06E+02	8	6.6733	0.9832	0.4523

5.10b ANOVA of regressions used to determine significance of song factor.

null regression that took out the factor of song. The factor of song did not have a significant main effect on annoyance rating Figure 5.10b.

There is a significant main effect of anger difference on annoyance with a coefficient of 0.31 and a p=0.006. There is no main effect of happy difference, but there were effects seen in the interaction of happy difference and song. There was an effect of the interaction of song and happy difference with the song “Happy”, with an increase at a rate of 0.52 in annoyance. That means for “Happy”, when happy difference increases by 2, the rating of annoyance increases by 1. Overall, the trend was not consistent, and the coefficients around +/- 0.5 are not likely to meet a significance threshold. The model includes an interaction because of the difference between a negative and positive trend in certain songs. A positive trend in the coefficients was seen for the songs “Happy,” “Ain’t No Mountain High Enough,” “Toxic,” and “Man! I Feel Like A Woman!”, with the last having the highest coefficient of 0.69. The songs “Wherever, Whenever,” “A Thousand Miles,” “Like a Prayer,” and “Call Me Maybe” all had the opposite effect in the interaction with happy difference. The largest was seen in the song “Wherever, Whenever”, which had an effect of -0.71 in annoyance rating for every change of 1 in the happy difference rating.

The second regression looked at the effect of complexity on annoyance. When breaking down the categorical variables in this regression, R is using the complexity level of “Four” as the default value. To test the significance of complexity, an ANOVA was run on this regression testing compared to a null regression that took out the factor of complexity. The factor of complexity did not have a significant main effect on annoyance rating, as shown in Figure 5.11b.

Model 1: Annoyed2 ~ Happydif + Saddif + Angerdif + +Username + Tempo
Model 2: Annoyed2 ~ Complexity + Happydif + Saddif + Angerdif + Username + Tempo

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	139	133.82				
2	136	130.32	3	4. 3.4929	1.215	0.3067

5.11b ANOVA of regressions used to determine significance of complexity factor.

Anger difference was significant in this regression, with a coefficient of 0.27 and p=0.01. Happy difference also was marginally significant, with a coefficient of -0.46. and a p=0.07. Sad difference also showed a marginally significant effect, with a coefficient of 0.17 and a p=0.07.

There was a strong interaction between happy difference and complexity. For the first level of complexity, there was a change of 0.38 in the annoyance rating. This means that for every 3 points of change in happy difference rating there was a 1-point increase in anger. For the second level of complexity, there was 0.2 increase in annoyance rating for every change of 1 in happy difference rating. At level three, the interaction switches to a lowering of annoyance rating by -0.4.

The third regression looked at the effect of tempo on the rating of annoyance and the interaction of tempo and happy difference. The break of the tempo variables by the program R has set the “Fast” tempo as a default. To test the significance of tempo, an ANOVA was run on this regression testing compared to a null regression that took out the factor of tempo. The factor of tempo did not have a significant main effect on annoyance rating, as shown in Figure 5.12b. There is a confound in the design of the

Model 1: Annoyed2 ~ Happydif + Saddif + Angerdif + +Username + Complexity
Model 2: Annoyed2 ~ Tempo + Happydif + Saddif + Angerdif + Username + Complexity

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	138	131.61				
2	136	130.32	2	1.2864	0.6712	0.5128

5.12b ANOVA of regressions used to determine significance of tempo factor.

experiment, as the tempos are not varied consistently across the complexity. Therefore, we cannot say for certain whether the pattern seen is due exactly to complexity or due to the tempo.

Happy difference showed a positive main effect in this regression of 0.34 with a p=0.04. Anger difference also showed a positive main effect of 0.26 with a p=0.02. Sad difference showed a slightly significant effect of 0.18 with a p=0.06. This is consistent with the results found in the other two regressions.

In the interaction of happy difference and tempo, there were large changes in the coefficients between tempos. For slow tempos there was a decrease in annoyance rating by 0.35 for every one-point increase in happy difference. For medium tempo the change was -0.13 for every one-point increase in happy difference. Again, I cannot be sure of the explanation for this, due to the confound mentioned earlier.

Discussion

A positive effect of anger difference on annoyance has been seen in each of the four studies. As seen in previous research (Averill, 1983, Doorley, & Kashdan, 2021**),** this relationship of anger and annoyance is very close. This effect of anger difference on the annoyance can reverse if the song is expressing anger. When a song is expressing a lot of anger, a participant can use that to regulate their own anger (Warmbrodt et al. 2022**),** which in turn makes the participant feel happier and rate the song as less annoying. However, this experiment did not have any song that was rated as specifically expressing anger, and this result was not seen.

The interaction of song and happy difference is interesting. For the song “Man! I Feel Like a Woman!”, there was a higher positive coefficient than for the other songs. This means that the participants felt the song was expressing happiness, but if it made them less happy, the participant also found the song annoying. There are previous studies that discuss the relationship of tempo with difficulty completing a task (Moreno, 2020). There may also be a similar connection between tempo and annoyance. This points to a possible future area of study on happy difference, and its effect on annoyance or enjoyment of music.

Complexity proved to not be a significant factor in the communication of emotions and their correlation to the rating of annoyance. The metric complexity was only significant in the interaction with happy difference. This was predicted by the hypothesis based on Geary’s (2022) theory on interpretation of different metrical levels in songs. The more metrically complex songs could create the difference in happy rating because the participants were able to latch onto the level they wanted, and they would then rate it as less annoying. This could have led them rate the song as not expressing happiness, but because they felt comfortable listening at their chosen metric level, they rated as feeling happier.

Tempo also proved not to have a significant effect on annoyance. However, I cannot say for sure due to the confound mentioned earlier. In the interaction of happy difference and tempo, interesting changes were seen in the coefficients. At the slower tempos a difference in felt and perceived happiness was more likely to predict a lower annoyance rating, while at higher tempos the happy difference was more likely to predict a higher annoyance rating. It would be interesting to further study the effect of how tempo changes arousal and can affect likability or annoyance in music. Previous research has shown the likability of music to be directly related to emotional arousal in music (Salimpoor et al, 2009). With the understanding of how tempo can affect anxiety control in the brain (Elliott, Polman, R., & McGregor, R. 2011), a new line of study could see how levels of arousal as compared to tempo could affect likability in music.

The song “Ain’t no Mountain High Enough” showed an association of happy difference and annoyance not shared by other songs, leading to the observed interaction. This could be for multiple reasons. The song was rated on the second level of complexity with a fast tempo. The average expressed happy rating (4.6) of this song was drastically higher than the felt happiness (1.38) of this song. This means that that the song was expressing happiness but not making the listener feel that happiness. This is similar to results seen in the first three surveys, where if the song is expressing a high valence emotion but doesn’t make the listener feel that emotion, it is rated as more annoying.

For the song “Wherever, Whenever” there was a prediction of a decrease in the annoyance rating for larger happy difference. The expressed happiness rating of this song (4.6) was also drastically higher than the felt rating of (1.37). While the differences in the emotional ratings for “Wherever, Whenever,” and “Ain’t No Mountain High Enough” were almost identical, they produced different effects on annoyance. These two songs were on two completely different levels of complexity; thus the complexity could have more to do with the annoyance rating in these results. This agrees with the evidence found in the second regression in this survey, where the more complex a song, the lower the annoyance rating.

The song “Man! I Feel Like a Woman!” had the highest annoyance ratings out of all the songs used in this survey. This song was on the second level of complexity and was considered to have a medium range tempo. This was the only song to have a high coefficient for the interaction with happy difference, meaning that this song was seen as expressing happiness but did not make the participant happy, and adding on a low complexity thus, making them feel more annoyed.

The reasoning for the annoyance level of “Man! I Feel Like a Woman!” could be because of a specific feature of the metric complexity of the piece. This is the only song where the harmony and bass are constantly playing repeated notes that do not change pattern as the loop progresses. This level of repetition may have led to the higher annoyance rating, as it did not prove to have overall significance or any interaction with the difference in emotions and annoyance rating.

The factor of song is not significant in this regression. “Bulls on Parade” did show large changes in the coefficient in the interaction of happy difference and annoyance in this survey, which is similar to an interaction found in the first two surveys. Happy difference had a negative effect on annoyance for this song, meaning that the song was viewed as not expressing happiness, but made the listener feel happy and rate it as less annoying. This differed from the first two surveys, however, in that anger difference showed a positive correlation. In this survey this song was not expected to express anger, as the song was in a major modality and played on standard instruments without distortion.

In the interaction of song and happy difference, the song “Happy” by Pharrell Williams showed similar results to those in the first survey. In this interaction the song was a positive effect with annoyance rating. The overall expressed happy rating for “Happy” (5.00) was higher than the overall felt happy rating (4.38). Like in the first survey, the listeners know the song is expressing happiness, but it is not fully translating and causing annoyance.

This song again was the fastest song included in the survey, and the faster tempos were usually rated as more annoying than the slower tempos. As in the third survey, there is evidence that something in the metric structure or tempo of the song “Happy” leads to a disconnect in its effectiveness to communicate emotions, which can lead it to be rated as more annoying.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song * Happydif + Song * Saddif + Song * Angerdif + Song * Relaxedif + Complexity + Tempo + Age + Training + Username + Order + Happy + Sad + Anger + Relaxed + Annoyed + Recognize, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Song + Happydif + Saddif + Angerdif + Username + Song:Happydif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-2.31145	-0.40123	-0.05223	0.36978	2.89446

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	1.68058	0.40962	4.103	7.31E-05	***
SongHappy	-0.4919	0.40045	-1.228	0.22162	
SongMaybe	-0.34821	0.39358	-0.885	0.37801	
SongMountain	-0.29675	0.44286	-0.67	0.50404	
SongPrayer	0.42496	0.40085	1.06	0.29112	
SongThousand	-0.26775	0.40361	-0.663	0.5083	
SongToxic	-0.40357	0.42789	-0.943	0.34742	
SongWhenever	0.04533	0.43471	0.104	0.91711	
SongWoman	-0.01343	0.42706	-0.031	0.97496	
Happydif	-0.46455	0.31704	-1.465	0.14535	
Saddif	0.13907	0.09648	1.441	0.15195	
Angerdif	0.31042	0.11208	2.77	0.00647	**
UsernameB	0.30429	0.4544	0.67	0.50432	
UsernameC	1.03357	0.4519	2.287	0.02387	*
UsernameD	0.93594	0.44577	2.1	0.03777	*
UsernameE	-0.45834	0.49958	-0.917	0.36067	
UsernameF	0.14548	0.44302	0.328	0.74318	
UsernameG	-0.44136	0.44121	-1	0.31908	
UsernameH	-0.44145	0.44707	-0.987	0.32534	
UsernameI	1.98944	0.46257	4.301	3.40E-05	***
UsernameJ	1.4369	0.47118	3.05	0.0028	**
UsernameK	-0.56594	0.4458	-1.27	0.20662	

UsernameL	-0.29467	0.43988	-0.67	0.50417	
UsernameM	0.2462	0.45234	0.544	0.58722	
UsernameN	-0.64586	0.45296	-1.426	0.1564	
UsernameO	-0.55041	0.44767	-1.23	0.22119	
UsernameP	-0.65914	0.44067	-1.496	0.13724	
UsernameQ	1.20591	0.45968	2.623	0.00979	**
UsernameR	0.73929	0.44435	1.664	0.09867	.
SongHappy:Happydif	0.98375	0.37278	2.639	0.00937	**
SongMaybe:Happydif	0.29819	0.42527	0.701	0.48449	
SongMountain:Happydif	0.69651	0.49424	1.409	0.16124	
SongPrayer:Happydif	0.12833	0.46277	0.277	0.782	
SongThousand:Happydif	0.20082	0.45291	0.443	0.65825	
SongToxic:Happydif	0.5711	0.40247	1.419	0.1584	
SongWhenever:Happydif	-0.25079	0.45901	-0.546	0.58578	
SongWoman:Happydif	1.15654	0.47537	2.433	0.01639	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9211 on 125 degrees of freedom
Multiple R-squared: 0.6275, Adjusted R-squared: 0.5202
F-statistic: 5.849 on 36 and 125 DF, p-value: 6.077e-14

5.10a Stepwise regression of independent variables effect on annoyance rating and interaction of song and difference in emotions.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Complexity * Happydif + Complexity * Saddif + Complexity * Angerdif + Complexity * Relaxedif + Complexity + Tempo + Age + Training + Username + Order + Happy + Sad + Anger + Relaxed + Annoyed + Recognize + Song, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Complexity + Happydif + Saddif + Angerdif + Username + Song + Complexity:Happydif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-2.31557	-0.45279	-0.01572	0.39755	2.88521

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	1.50801	0.42464	3.551	0.000535	***
ComplexityOne	-0.50282	0.38667	-1.3	0.19576	
ComplexityThree	0.10069	0.3821	0.264	0.792568	
ComplexityTwo	0.43439	0.37777	1.15	0.252308	
Happydif	-0.45933	0.25289	-1.816	0.071626	.
Saddif	0.17157	0.09542	1.798	0.074483	.
Angerdif	0.27446	0.10814	2.538	0.012325	*
UsernameB	0.27368	0.44286	0.618	0.537668	
UsernameC	1.19636	0.44191	2.707	0.007696	**
UsernameD	1.02218	0.44272	2.309	0.022529	*
UsernameE	-0.57276	0.49356	-1.16	0.247982	
UsernameF	0.14574	0.43925	0.332	0.74058	
UsernameG	-0.37701	0.43734	-0.862	0.390248	
UsernameH	-0.39826	0.44585	-0.893	0.373369	
UsernameI	2.03224	0.46181	4.401	2.23E-05	***
UsernameJ	1.38913	0.46739	2.972	0.003525	**
UsernameK	-0.61246	0.44296	-1.383	0.169141	
UsernameL	-0.2507	0.4391	-0.571	0.569016	
UsernameM	0.20692	0.44186	0.468	0.640363	
UsernameN	-0.5149	0.44815	-1.149	0.25268	
UsernameO	-0.46347	0.44618	-1.039	0.300846	
UsernameP	-0.54887	0.43827	-1.252	0.212683	

UsernameQ	1.20077	0.45371	2.647	0.009136	**
UsernameR	0.73604	0.44493	1.654	0.10048	
SongHappy	0.27856	0.31198	0.893	0.373579	
SongMaybe	-0.85087	0.31721	-2.682	0.008259	**
SongMountain	-0.57647	0.31258	-1.844	0.067426	.
SongPrayer	0.50609	0.31101	1.627	0.106107	
SongThousand	-0.03217	0.31284	-0.103	0.918264	
SongToxic	NA	NA	NA	NA	
SongWhenever	NA	NA	NA	NA	
SongWoman	NA	NA	NA	NA	
ComplexityOne:Happydif	0.83135	0.29939	2.777	0.006301	**
ComplexityThree:Happydif	0.05342	0.34051	0.157	0.875571	
ComplexityTwo:Happydif	0.6491	0.31706	2.047	0.042649	*

Residual standard error: 0.9236 on 130 degrees of freedom
Multiple R-squared: 0.6105, Adjusted R-squared: 0.5176
F-statistic: 6.573 on 31 and 130 DF, p-value: 6.333e-15

5.11a Stepwise regression of independent variables effect on annoyance rating and interaction of complexity and difference in emotions.

Before Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Tempo * Happydif + Tempo * Saddif + Tempo * Angerdif + Tempo * Relaxedif + Complexity + Tempo + Age + Training + Username + Order + Happy + Sad + Anger + Relaxed + Annoyed + Recognize + Song, data = data)

After Stepwise Procedure:
Call:
lm(formula = Annoyed2 ~ Tempo + Happydif + Saddif + Angerdif + Username + Song + Tempo:Happydif, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-2.23086	-0.45509	0.00046	0.35462	3.06490

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	0.97881	0.40356	2.425	0.01665	*
TempoMedium	1.11947	0.35814	3.126	0.00218	**
TempoSlow	0.54885	0.36816	1.491	0.13842	
Happydif	0.34843	0.16435	2.12	0.03589	*
Saddif	0.18085	0.09499	1.904	0.05913	.
Angerdif	0.25516	0.10942	2.332	0.02123	*
UsernameB	0.34716	0.44634	0.778	0.4381	
UsernameC	1.32337	0.44793	2.954	0.00372	**
UsernameD	1.08512	0.44497	2.439	0.01608	*
UsernameE	-0.61173	0.49756	-1.229	0.2211	
UsernameF	0.25022	0.44545	0.562	0.57526	
UsernameG	-0.35581	0.4421	-0.805	0.42238	
UsernameH	-0.3694	0.44421	-0.832	0.40715	
UsernameI	2.02594	0.46194	4.386	2.35E-05	***
UsernameJ	1.47928	0.47284	3.129	0.00217	**
UsernameK	-0.53999	0.44391	-1.216	0.226	
UsernameL	-0.19949	0.44474	-0.449	0.65448	
UsernameM	0.28903	0.4455	0.649	0.51761	
UsernameN	-0.44824	0.45006	-0.996	0.32111	
UsernameO	-0.37401	0.44745	-0.836	0.40475	
UsernameP	-0.51331	0.44225	-1.161	0.24788	
UsernameQ	1.29576	0.46049	2.814	0.00565	**

UsernameR	0.67749	0.44974	1.506	0.13437	
SongHappy	0.27759	0.31575	0.879	0.38092	
SongMaybe	-0.87836	0.32111	-2.735	0.00709	**
SongMountain	0.22808	0.3156	0.723	0.47115	
SongPrayer	-0.16318	0.31759	-0.514	0.60824	
SongThousand	-0.16377	0.31292	-0.523	0.6016	
SongToxic	NA	NA	NA	NA	
SongWhenever	-0.87063	0.31672	-2.749	0.00682	**
SongWoman	NA	NA	NA	NA	
TempoMedium:Happydif	-0.48679	0.22783	-2.137	0.03449	*
TempoSlow:Happydif	-0.70011	0.2758	-2.538	0.0123	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9354 on 131 degrees of freedom
Multiple R-squared: 0.5974, Adjusted R-squared: 0.5052
F-statistic: 6.48 on 30 and 131 DF, p-value: 1.541e-14

5.12a Stepwise regression of independent variables effect on annoyance rating and interaction of tempo and difference in emotions.

Chapter 6: Final Discussions and Conclusion

Emotions and Difference in Emotions

This thesis found that emotional communication plays a role in a participant's decision to rate a song as annoying. The most consistent and significant results found were relating to the difference between felt anger rating and expressed anger rating. Across all four studies, anger difference was consistently correlated with annoyance. Happy difference, while not as consistent across the studies, showed variations in the changes of the coefficients in the interaction of happy difference and song. This means that the relationship of happy difference to annoyance depends on the song that is being studied.

Preliminary evidence was found in chapter 2 that points to the effect of direction and the valence of the emotion on annoyance. Direction means whether the expressed rating was higher or lower than the felt rating. If a high valence emotion, like happy, is expressed more than it is felt, the participant is more likely to rate a song as annoying. If there is more felt happy than expressed happy emotions the rating of annoyance will go down. This effect is flipped for low valanced emotions.

	Higher Expressed Emotion	**Higher Felt Emotion**
High Valence Emotion	Increase in Annoyance	Decrease in Annoyance
Low Valence Emotion	Decrease in Annoyance	Increase in Annoyance

Figure 6.1 Potential Effects of Valence and difference in expressed versus felt emotions in songs.

This thesis did not directly study direction of the change in emotions, but this could be looked at in this data with more time and different tests. If the studies in this thesis are repeated or studied further, it would be important to study the direction of the change in emotions.

Difference Between Felt and Expressed Anger Ratings

Anger difference rating showed significant positive results in every experiment except in chapter 2, and like initial annoyance ratings, requires more context to predict its effect on annoyance rating. In the regressions of chapters 3, 4, and 5, anger difference showed a positive main effect. In chapter 2 it did not show a main effect, but did show changes in the coefficients in the interaction with song.

Consistently, anger difference showed a positive correlation with annoyance rating. This means that if there is a difference in the expressed anger rating as compared to the felt anger rating, a listener is more likely to rate the song as annoying. My analyses used the absolute values of the differences in emotion and did not consider in which direction the differences happen.

However, this connection between anger difference can be flipped. In songs that were expressing a lot of anger, the correlation could be negative. If the song was expressing anger and the listener didn’t feel as much anger, they might rate the song as less annoying. Using this evidence, we can speculate that if a song elicits a higher felt anger rating than the expressed rating, it is more likely to be rated as more annoying, and if the song is expressing a lot of anger and the listener does not feel the same amount of anger, it is more likely to be rated as less annoying.

Future studies might be inclined to complete this research with a more directional approach, where the direction between expressed and felt can be measured and compared more easily. It would also warrant a look at what the emotional trajectory of the listener is, and what their emotional goals are when they are listening to music.

Difference Between Felt and Expressed Happy Ratings

Happiness was not consistently correlated with annoyance in the surveys. It did, however, show prominent changes in interaction with song. If the song is expressing a lot of happiness but does not make the participant feel the same happiness, it will be rated as more annoying. However, if a song does not express a lot of happiness ("Bulls On Parade") but makes the listener feel happy, it will have a lower annoyance rating.

Other Emotional Difference Rating

The case for the differences in the other emotions studied is not as strong, but sometimes there are observable effects. Overall, happy difference, sad difference, and relaxed difference did not show consistent direct correlations to annoyance ratings in the four surveys. When they did have a direct influence, the higher valence emotions like happiness showed a negative effect on annoyance rating. This would mean that either a song is not expressing happiness, but it made the listener feel happy, so they rated it as less annoying. Once again, this thesis did not study the direction of these differences.

Sad difference saw similar effects to anger difference, where if it had a significant main effect alone, as in chapter 5, it would correlate to a higher annoyance rating. When it did show as an interaction, the effect on annoyance was reversed. Interestingly, when sad difference was seen to interact with other factors such as complexity and tempo, the effect was not reversed but did lessen. As stated in chapter 5, there is a confound between tempo and complexity, so we cannot say for sure whether if it was due to the tempo or the complexity.

Some significant features in this study may warrant further study. The direction of the change should be investigated in future surveys. Emotional trajectory would be important to factor in, either to consciously effect that change in the participant, or to ask them if they have an emotional goal while listening to music.

Relaxed difference would warrant more specific study. This thesis included only two songs, in chapter 2, that were expected to be perceived as relaxed or calm. There were not major results found for that emotion. Relaxed difference would be interesting to study. If a song is trying to express a relaxed mood but does not make the listener relaxed, it could have an effect on annoyance rating. If such a song exists or can be created, it would prove interesting to study further the effects that it would have on a listener.

Lyrics and Other Musical Aspects

Lyrics

The effect of lyrics can be seen in chapter 3 but can also be seen when comparing some results from chapters 4 and 5 to the results of chapter 2. Overall, in chapter 3 the effect of lyrics on emotional communication proved significant. Songs with that were chosen with mixed emotions between the music and lyrics showed a switch in expressed emotions by participants. Participants got most of their cues for the expression from the lyrics. This was predicted, and supports other evidence found about emotional communication and lyrics (Ali & Peynircioglu, 2006).

When the average results from the first two studies are generally compared to the results from the last two studies (which didn't include lyrics), there is a higher average rating for expressed emotions in songs with lyrics than in songs without lyrics. Lyrics did not prove to have a main effect on the rating of annoyance. So this average higher rating may be due to the fact that all the other expressed ratings were higher for the songs with lyrics, resulting in slightly higher average ratings for songs with lyrics.

The increase in annoyance for songs with lyrics was an unexpected result. I predicted that when a song included the lyrics it would better communicate the emotion and warrant a lower annoyance rating. However, this result could be due to the difference between levels of expression. When comparing songs with lyrics versus those without, emotional ratings were higher in songs with lyrics, meaning that the participants could have thought that the songs with lyrics expressed the given emotion more strongly. This bigger difference in the expressed and felt emotions could have led to a higher annoyance rating, resulting in the difference seen in chapter 3.

Further study into lyrics could look at how understanding of the words relates to annoyance. A study of songs where singers are reported to mumble and mix up words would be interesting to study. Does ability to understand the lyrics effect annoyance; does it make it more enjoyable? It would be interesting also to study the effect lyrics have on the ability to work with music. This was looked at partially by Moreno (2020) but could be looked at in more detail. How does the processing of emotion in lyrics in the music change as our levels of active listening change?

Modality

Modality showed predicted results around emotional expression. The major progressions were consistently rated as expressing happy emotions, while the minor progressions were rated as sad. The minor ambiguous chord progression was rated as expressing happiness and not overall sadness, and the chromatic progressions were mixed in what they were rated as expressing.

For overall annoyance there was no significant effect of modality. The interactions with happy difference for each modality were similar to the songs seen as expressing happiness that were included in the first two experiments. When there was an interaction with happy difference, it was more likely to be rated as less annoying. For anger difference the trend was consistently positive. This goes against previous research that showed modality had influence on the likability of music (Hauashihara & Oda, M. 2009)

In future studies it would be interesting to look at if there were anything relating to modality that would trigger anger in a listener, and thus have more potential to trigger annoyance. None of these examples had surprising or unexpected chord progressions. All the chord progressions were derived from popular songs and might have been familiar to the listeners. It might be pertinent to include more atonal loops that do not consist of loops heard in popular music, to see if there is any different effect of modality.

Loop Types

Loop types had a significant effect on annoyance. Open loops were seen as slightly more annoying. This result initially seemed contradictory, because open loops make up a large percentage of popular music. Open loops were not seen as expressing a lot of anger but sometimes made the listeners feel anger. As my analyses of this data did not distinguish between direction of differences between felt and expressed emotion, we cannot say for certain if the result was consistently in one direction or the other, but it could warrant further study.

This consistently high correlation of annoyance with the open progressions could be due to the way the experiment was run. In this experiment the open loop does not resolve at the end of the clip. The loop is left open, which may lead to a lack of resolution that leaves the listener frustrated and causes them to rate it as more annoying. This is one theory, but it would be interesting to study the effect of resolution on liking of music, and the effect it has on annoyance.

Closed progressions received on average the highest ratings of annoyance in this experiment. However, they did see large changes in the interaction of anger difference and chord progressions. The reasoning behind this could be that these progressions resolve, but don't resolve where a listener might expect. Normally the open progressions would resolve at the end of the loop, adding an extra measure at the end of a piece. Closed loops resolve on the last measure of the loop, and thus end more abruptly than the rest of the loops studied in chapter 4.

This line of thinking would also partially explain the positive results seen for the open loops. It is possible that the participant would answer the questions on the survey while listening to the clip. There were no instructions saying to explicitly listen to the clip and then answer the questions, and since it was a self-report survey it was not possible to control if the participants followed those instructions. If they listened to the open loop and enjoyed it until it didn't resolve and frustrated them, there would have been a bigger difference in the expressed and felt anger ratings. Whereas, if they listened to the closed loop, they could have heard the frustrating resolution and thought that maybe the progression lack of resolution was expressing anger, and thus had a lower difference and a lower correlation to annoyance rating.

Surprisingly, the ambiguous examples were the least annoying to the participants. This could be due to the same reasoning as why the others were so annoying. The major ambiguous example, being one of the lowest rated examples, could also have been due to it being the shortest clip used in the survey. Each loop was played four times, and this was only a two-measure loop, thus leading it to be an overall shorter clip.

The ambiguous loops might be the lowest rated because of comfort with uncertainty. This could lead participants to enjoy the music more and not let any lack of a resolution effect their annoyance ratings. It would be interesting to look more deeply into ways in which the structure of the music can affect a listener's annoyance of the piece.

Metric Complexity

Metric complexity overall did not have a significant main effect on the rating of annoyance by listeners, but did show significant change in the effect in the interaction with happy difference. As the music got more complex, the interaction with happy difference switched from a positive effect on annoyance to a negative effect. When the songs were lower in metric complexity, the pieces were expressing happiness but not making the listener feel as happy and were leading them to rate them as annoying. At higher metric complexity, greater happy difference was associated with lower annoyance ratings.

The two songs with the highest metric complexity were found to be some of the lowest rated on average annoyance. This could be due to the theory of interpretive flexibility **(**Geary**,** 2022) where, as the music gets more complex, the listener can discern between the levels of metric complexity and listen at the level that is most comfortable to them. This agrees with other research found about the processing of metric complexity (Davies, et al. 2013).

This study only looked at the regular patterns of complexity that repeat in loops over time. It would be interesting to look further into how different levels and types of complexity affect our level of annoyance, but also the variations in that complexity. Does the complexity stay consistent? Does the complexity change as the example progresses? Does the complexity form to create a regular beat, or is it random (the difference between a metrically complex pop song, and an Elliot Carter piece)?

Tempo

Tempo had a significant effect on annoyance in chapter 5. Tempo was not studied in chapters 2, 3, and 4. In chapter 5, the medium tempo had the highest average annoyance ratings, while slow tempos had the lowest. In the interaction with happy difference and tempo, the slower tempos annoyance level decreased. There is evidence that faster tempos can create more stress and distract listeners from their work (Moreno, 2020). It makes sense that slower examples were rated as less annoying: if a tempo is faster than a listener wants, it can cause them more stress and then rate it as more annoying.

As for the interaction of tempo and happy difference, the slower tempo songs could have been rated as not expressing as much happiness as the listener felt. This could have led to the lower annoyance rating. This study did not find a main effect of relaxed difference, but the slower songs could have also seemed calmer in comparison to faster songs and led to the overall lower annoyance rating.

Individual Songs

"Bulls On Parade"

"Bulls On Parade" by Rage Against the Machine was included as an example in chapters 2, 4, and 5. While it did show not distinct changes in the coefficients in chapter 5, results for this song proved interesting in chapters 2 and 4.

In experiment 1, "Bulls On Parade" was rated as highly annoying. The song expresses a lot of anger and had loud guitars, and the lead vocalist speak-sings the melody. Interestingly however, in the interaction of song and difference between felt and expressed anger, the effect on annoyance changed for this song. When a listener understood that the song was expressing anger, they could separate that and not let the anger in the song directly affect them and would rate it as less annoying.

In chapter 4 this song was not seen to have a direct effect on the rating of annoyance, but did have a significant change in the interaction of song and relaxed difference. The participants thought the song was trying to express relaxation, or that the music felt relaxed, but it did not make them feel relaxed. When the relaxed difference increased there were higher ratings of annoyance for this song. When you listen to this song the harmonies do feel slightly laid back; it is also at a slower tempo. This song was at a slower tempo than most of the other songs included in that survey, which could have led to that result.

Overall, there may be something significant in the harmony, and potentially the rhythms used in this song that prove to be annoying to listeners. If the annoyance was intentional by the band (my guess is that it was), they did a great job of using that effect in different aspects of the music. Future studies may want to look at this song in more detail and study the change in the direction of the emotions.

"Happy" by Pharrell Williams

"Happy" by Pharrell Williams was studied in chapters 2, 4, and 5. It showed interesting results in each chapter that it was studied in. Looking at the overall ratings for the song, it often induced a high annoyance.

This song was seen in chapter 2 to have distinct rating changes in the interaction of song with both happy difference and anger difference. This means that listeners understood that the song was trying to express happiness but was not feeling that happiness, and that the song was not expressing anger, but that it made them feel anger. This led them to rate the song as more annoying.

In chapter 4 this song was seen as having a positive change in the interaction of song with sad difference. “Happy” showed that for around every 3 points increase in sad difference, there was a 1-point increase in the annoyance rating. In this experiment, the song was seen as not expressing sadness, but made the listener feel sadness, correlating to a higher annoyance rating.

Chapter 5 saw similar results as were seen in chapter 2. The song "Happy” did show a significant change in the interaction of song with happy difference. As in the other experiments, the listeners knew that this song was trying to express happiness but did not feel the same happiness, which led them to rate it as more annoying.

Overall, this song did have the fastest tempo (158 BPM) of any song used in this thesis. This fast tempo could have had a significant effect on rating of annoyance. When all other examples are at a slower tempo that a listener gets used to, and suddenly a fast tempo is introduced, it could cause a higher rating of annoyance. All examples of this song were played at the original tempo of the song. Any further research into this song might want to fully separate the different aspects of the song for study.

This thesis found evidence that there is potentially something inherent in the structure or tempo of the song “Happy” by Pharrell Williams that causes annoyance to the listener. This survey cannot directly point to which exact structure it is, but it provides room for further study on this subject and this song. Further study on this song may want to separate out different elements and see which has a specific effect on the listener, and if it is a result of one aspect or a combination of the aspects.

Final concluding remarks

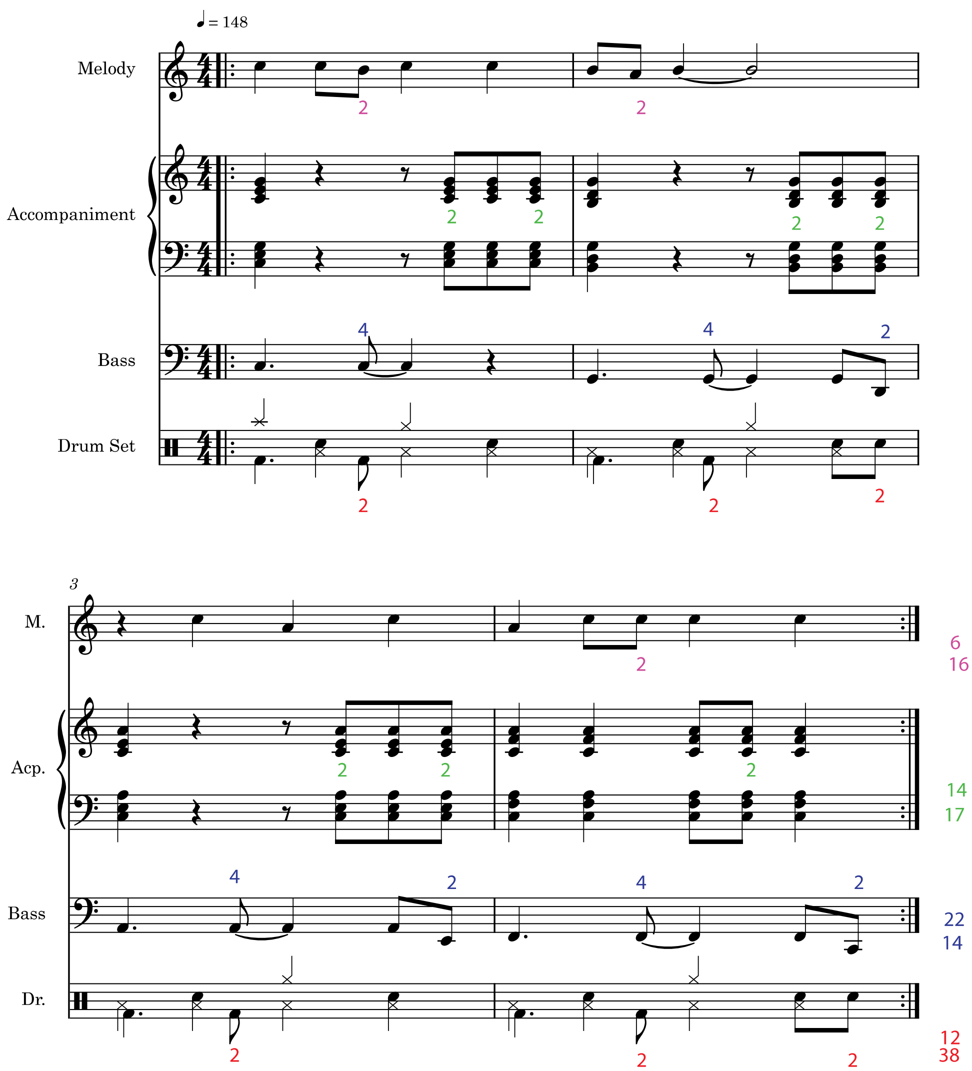
There is significant evidence found in these surveys that difference in the expressed versus felt emotions in music can correlate with annoyance levels. There is strong evidence that difference between felt anger and perceived anger plays an important role in annoyance. There is partial evidence that shows that the direction of change may determine if the rating of annoyance increases or decreases. There is also partial evidence that the valence of the emotions matters as well and can determine whether the rating of annoyance rises or falls.

The theory of the effect of valence and direction presented in Figure 6.1 is based on preliminary evidence found in this thesis and warrants further research. Future studies on this aspect would want to look at the direction of the change from expressed to felt emotions and to look closer at the valence of specific emotions. It would be interesting to see if these effects switch at all for liking of songs.

Appendix A

Chapter 5 Analyses

Extracted Rhythms from "Toxic"



A.1. Analysis of the extracted rhythms from "Toxic" by Britney Spears. Numbers are the measures of syncopation from Gomez (2020).

A.2. Analysis of the extracted rhythms from "Happy" by Pharrell Williams. Numbers are the measures of syncopation from Gomez (2020).

Extracted Rhythms from "Ain't No Mounatin High Enough"

Top Number=Syncopation Sum
Bottom Number= Number of Notes

A.3. Analysis of the extracted rhythms from "Ain't No Mountain High Enough" by Marvin Gaye and Tammi Terrell. Numbers are the measures of syncopation from Gomez (2020).

Extracted Rhythms from "Man! I Feel Like A Woman!"

A.4. Analysis of the extracted rhythms from "Man! I Feel Like a Woman!" by Shania Twain. Numbers are the measures of syncopation from Gomez (2020).

Extracted Rhythms from "Call Me Maybe"

Top Number=Syncopation Sum
Bottom Number= Number of Notes

A.5. Analysis of the extracted rhythms from "Call Me Maybe" by Carley Rae Jepsen. Numbers are the measures of syncopation from Gomez (2020).

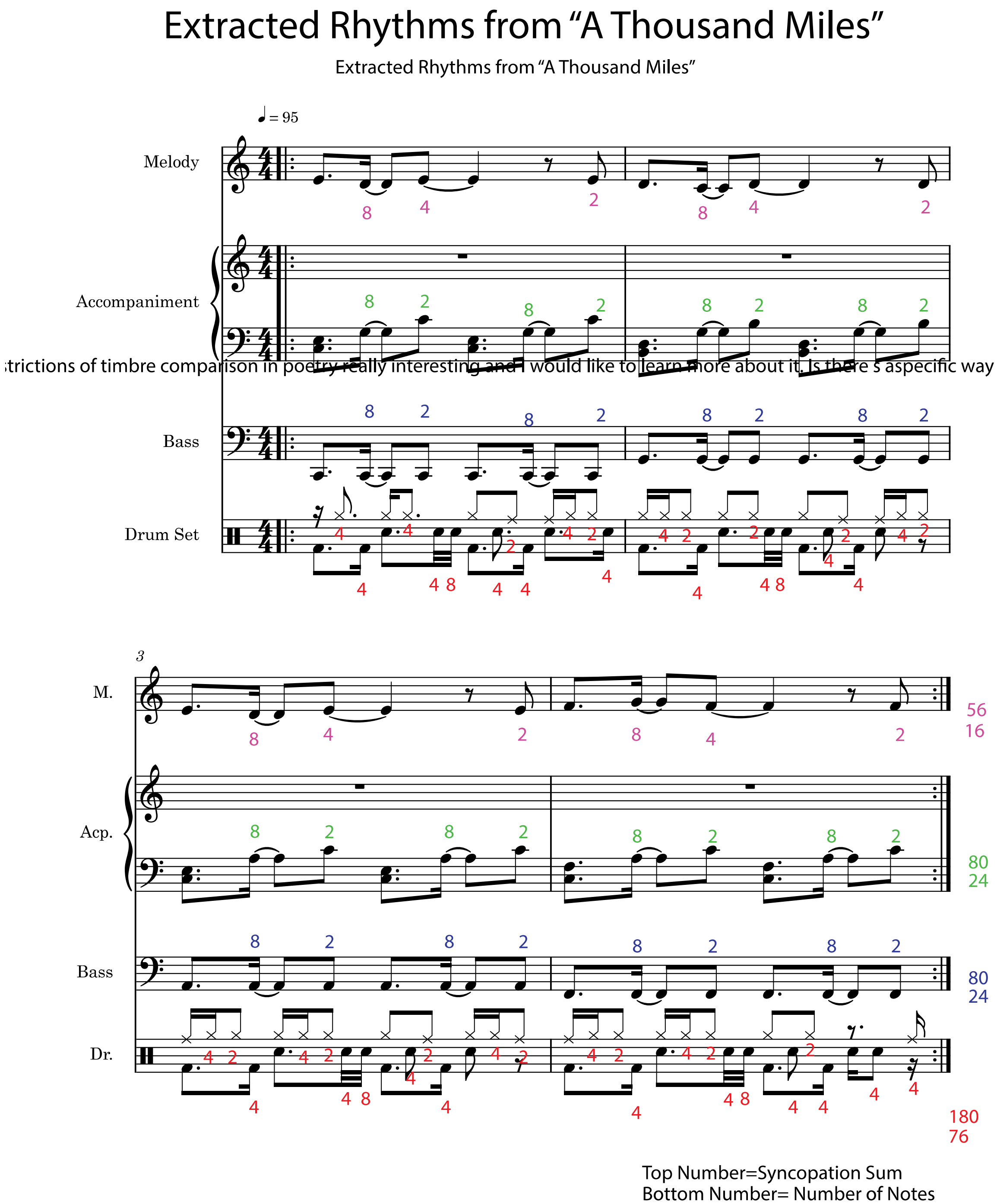
Extracted Rhythms from “Bulls on Parade”

A.6. Analysis of the extracted rhythms from “Bulls on Parade” by Rage Against the Machine. Numbers are the measures of syncopation from Gomez (2020).

Extracted Rhythms from "Like a Prayer"

Top Number=Syncopation Sum
Bottom Number= Number of Notes

A.7. Analysis of the extracted rhythms from "Like a Prayer" by Madonna. Numbers are the measures of syncopation from Gomez (2020).



A.8. Analysis of the extracted rhythms from “A Thousand Miles” by Vanessa Carleton. Numbers are the measures of syncopation from Gomez (2020).

Extracted Rhythms from “Whenever, Wherever”

Top Number=Syncopation Sum
Bottom Number= Number of Notes

A.9. Analysis of the extracted rhythms from “Whatever, Whenever” by Shakira. Numbers are the measures of syncopation from Gomez (2020).

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