MUSICALLY-INDUCED EMOTIONAL PEAKS

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One of the most important properties of music is its ability to induce genuine emotion in listeners. However, much of the empirical research about the relationship between music and emotion has been devoted to listener perception of emotion, rather than the induction of emotion. This thesis presents the results of a study in which 43 participants reported instances of "emotional peaks" – moments in musical works that induce strong emotion. Each peak was musicologically analyzed based on a number of different criteria, and the resultant data was tested to reveal which music-structural features correlated most strongly with the peaks. The variables that achieved statistical significance were a shift in the melody, a change in pulse clarity, a repetition of prior lyrics, a change in dynamics, and an addition of background instruments. It is suggested that musically-induced emotional peaks are ultimately influenced by patterns of tension and release.

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1 INTRODUCTION

Throughout history, the affective power of music has been exercised in every recognized human culture, leading many theorists to consider musical activity an evolutional progression of the human race. Whether or not this assumption is true, however, music serves us today in a variety of ways, most of which can be directly connected to our ability to perceive, convey, and experience emotion. It is a significant aspect of contemporary society that is used in numerous tasks to influence the psyche both consciously and subconsciously, and as such, it plays an integral role in human life, accompanying and setting the foundation for many of our daily interactions.

Since the advent of radio, digital media, and the internet, music has become increasingly accessible to the public. It is now relatively easy to build a collection of music from which to choose a particular piece, album, artist, or genre to listen to. Alternatively, most digital media players offer a randomize feature operating on any of these classifiers in order to automate a playlist within the constraints specified by a listener. In cases like these where an individual oversees his or her own listening session, music is generally thought to operate either as reinforcement of a current emotion or as an attempt to manage one's state of mind – for example, to facilitate a state of relaxation and peacefulness. In this sense, music is often considered a tool for mood regulation.

Mood regulation is typically regarded as a reference to one's own mood (i.e., one does it for himself/herself), but similar principles apply to cases where an individual or group targets music at an external audience. In films, for example, music accompanies video, dialogue, and sound effects to emphasize the plot's vacillating emotional content. Highly emotional scenes may be supplemented with dramatic music, comical scenes with lighthearted music, and so forth. When it is subordinate to other stimuli in this manner, music acts as an affective reinforcement, much like we might use it to reinforce or regulate our own emotions. However, the exact mechanisms that allow music to serve us in this manner remain relatively unclear to researchers and musicians alike.

In the past few decades, there has been an increasing scientific interest in understanding the means by which music arouses our thoughts and feelings. A growing body of empirical research is attempting to formally understand the correlation between music and emotion, which is more than evident in a variety of daily contexts. One recent theme within the subject of music and emotion is the distinction between *perceived emotion* and *induced emotion*. Currently, there is compelling scientific evidence that human beings are considerably adept in the perception and identification of musical emotion as it is intended by composers and performers, but the connection between musical events and induced emotion – emotion actually felt by the listener – is less understood.

Sidney Zink (1960) identifies another two contrasting uses of the word "emotion": *implicit emotion* suggests different states of emotion through the use of descriptors such as "sad" or "unhappy", while *explicit emotion* is a conceptual representation of emotion itself, and can be likened to other neutral terms such as "passion" or "feeling". Bearing this distinction in mind, we can say that research concerning music and perceived emotion generally involves an implicit examination of emotion, probably because most humans are quite familiar with emotion identification. For research purposes, this task involves either listener identification of basic emotion descriptors (see e.g., Juslin & Laukka, 2001) or ratings on a two- or three-dimensional model of emotion (see e.g., Russell, 1980). Though there is some disagreement among researchers and theorists over which approach is more appropriate, both approaches are useful primarily because they lend themselves to quantitative analysis. However, in contrast with perceived emotion, it is problematic for induced emotion to be considered implicit since distinguishing between actually experienced emotions is logistically an ambiguous and difficult task. Therefore, at least in these early stages of research, it seems most pragmatic for induced emotions to be measured explicitly – in terms of the *level* of emotion, passion, or feeling, rather than as a distinction between *particular* emotions, passions or feelings.

This thesis will address the affective reaction to music by investigating the highest level: a so-called "emotional peak". Within a given piece or collection of music, an *emotional peak* will be defined as a moment, or moments, of indefinite length in which the listener's affective reaction is both substantially high and relatively highest. The concept is largely derived from Abraham

Maslow's (1968) conception of "peak experiences", which he described as points in our lives characterized by sudden feelings of ecstasy and well-being. He believed these experiences to be a part of self-actualization – the highest level of his reputable hierarchy of needs. This level describes the personal motivation to reach one's full potential, and Maslow implies that a person's life would be somehow incomplete without peak experiences. However, while these experiences can be thought of as unique psychological events in a person's life, an emotional peak will be considered – for the purpose of this thesis – a music-structural event existent and embedded within a piece of music in such a way that it can be experienced repeatedly.

The primary goal of this thesis is to uncover which conceptual aspects of music are most effective at creating an emotional peak. To do so, a study was conducted by the author in which participants completed a survey about a segment from a freely-chosen recorded musical excerpt that they found to evoke a strong emotional response. A control group of "non-peaks" was created by randomly selecting points in time within the collected pieces that did not fall within the participant-chosen segments. Each of the peaks and non-peaks were then systematically examined for structural changes occurring in the melody, harmony, rhythm, and orchestration. These structural changes were then quantified, statistically analyzed, and compared to uncover which music-structural features were significant indicators of a strong emotional response.

1.1 Thesis Outline

The remainder of this thesis will proceed as follows:

Section 2 discusses prior research on musically-induced emotion. **Section 2.1** is devoted to the scientific distinction between *perceived* and *induced* musical emotion, drawing heavily from the works of Alf Gabrielsson and Klaus Scherer. The end of **Section 2.1** shows how emotional peaks fit in with musically-induced emotion, and provides some justification for targeting peaks in particular. **Section 2.2** covers some of the most common research perspectives pertaining to emotional peaks and peak experiences, including the phenomenological, neurological, biological, and musicological perspectives.

Section 3 begins by stating the three research questions that drove this thesis, and then describes the research project that was conducted to address them. **Section 3.1** provides an overview and justification of the questionnaire that comprised the experiment portion of the project. **Section 3.2** describes the data collection and participants, and also outlines the steps that were taken in order to identify certain participants as outliers. **Section 3.3** details the musicological analysis that was conducted for each of the questionnaire submissions, and **Section 3.4** details the statistical analyses that were performed on this resultant data. Finally, **Section 3.5** presents the results of the analyses.

Section 4 discusses the results of the research project. **Section 4.1** offers a variety of suggestions for future research pertaining to emotional peaks, including ideas for further statistical analyses that can be performed on the gathered data, as well as some ideas for improvement of the current methodology. **Section 4.2** describes some general applications for this project and other research about musically-induced emotion. Finally, **Section 4.3** consists of the author's concluding remarks.

2 PRIOR RESEARCH ON MUSIC AND EMOTION

The following sections provide a summary of the most relevant prior research pertaining to the ideas examined in this thesis. There are two topics of particular interest that are covered here: writings and research about the difference between perceived and induced emotion, and research on musically-induced emotional peaks in particular.

2.1 Perceived and induced emotion

One of the most fundamental distinctions in the subject of music and emotion is that between emotion that has been *perceived* by a listener and emotion that has been *felt* by a listener (i.e., triggered or induced by music). Until recently, however, relatively little research has directly addressed the difference and potential correlations between these two types of emotion. Perhaps the first relevant theoretical analysis was written by Gabrielsson (2002), who proposes and examines four potential relationships between perceived and induced musical emotion. They are as follows:

1. If there is a **positive correlation**, then the induced emotion is the same as the perceived emotion. For example, if the music is sad, then the listener would feel sad.
2. If there is a **negative correlation**, then the induced emotion is the opposite of the perceived emotion. For example, if the music is sad, then the listener would feel happy.
3. If there is **no systematic correlation**, then different circumstances could provoke different reactions to perceived emotion. For example, if the music is sad and the circumstances are appropriate, then the listener will feel sad.
4. There may be **no correlation** at all. In this case, there would be no relationship between the perceived and induced emotion.

Gabrielsson presents meaningful evidence and examples for each of these possibilities, but this fact alone seems to imply that the correlation between perceived and induced emotion is largely determined by contextual factors, in which case there is no systematic correlation. Unfortunately, this notion reveals little practical information about the nature of the relationship, because although emotion perception probably does exhibit some effect on the induced emotion, it seems likely that other mechanisms have a more substantial correlation.

One systematization of these mechanisms is provided by Scherer (2004), who outlines three main components of a "central route" by which music can induce emotions, including *memory* (an association with emotion-filled memories), *appraisal* (a process of event evaluation based on any number of criteria), and *empathy* (e.g., with another person's suffering, either due to contagion or pity). Of these three components, emotion perception is only directly relevant to the third in the sense that the listener must be aware of and understand the intended emotional content before he or she can empathize with it. Of course, the relevance is only pertinent if the listener actually experiences feelings of empathy for the perceived emotion, and whether or not this happens is dependent on the affective potential of the listener to do so in a given case.

This dependency on the listener is also apparent in the memory component, which arguably lacks any definite variance with the perceived emotion. Through familiar motifs, harmonic progressions, differences in musical styles, or any number of other musical elements, music can trigger memories – both memories of specific past events, and general feelings about the past (i.e., nostalgia). However, since everyone has unique emotion-filled memories, it is difficult to

make specific predictions about the potential of a piece of music to arouse memories without first obtaining prior information about a given music listener.

By contrast, the appraisal component is less dependent on the listener, and more on the music itself as well as the physical and social circumstances under which it is heard. In most cases, the variables related to event evaluation – the basis of appraisal – are more concrete and therefore more practical to quantify than those having to do with human memory and empathy. These variables may include, for example, the location where music is heard, whether music is heard alone or in a group, the type of music heard, or in the case of this thesis, the particular musical events present in a piece. Of course, the process of event evaluation may be unique to an individual or particular group, but trends may still become apparent with appropriately targeted empirical analysis.

Juslin and Västfjäll (2008) expand upon Scherer's ideas by presenting a systematization of six mechanisms (in addition to *appraisal*, which they consider to be the "default" mechanism) for emotion induction through music. These mechanisms are outlined below:

1. **Brain stem reflexes**: emotion results from natural reflexes to acoustic events such as sudden, loud sounds
2. **Evaluative conditioning**: similar to the memory component, discussed above, particularly with regards to the way that music can evoke feelings about the past (i.e., nostalgia), rather than specific memories
3. **Emotional contagion**: similar to the empathy component, discussed above
4. **Visual imagery**: emotion results from evoked imagery, such as weather or landscapes
5. **Episodic memory**: similar to the memory component, discussed above, particularly with regards to the way that music can trigger specific emotionally-loaded memories
6. **Musical expectancy**: emotion results from the violation, delay, or confirmation of the expected musical content

This systematization provides even more evidence that emotion induction is not greatly affected by emotion perception, since only the third mechanism is directly related. Bearing this in mind, care needs to be taken in order to approach emotion induction in such a way that does not revolve around perceived emotions.

Scherer et al (2001) identify three potential research procedures for obtaining meaningful data about musically-induced emotion: (1) the objective measurement of compositional/structural features and performance features, (2) the systematic manipulation of compositional/structural features and performance features, and (3) an analysis of the production of music during purposeful emotional portrayal by the composer or performer. About the first procedure, the following is noted:

> The objective measurement approach requires identifying passages in specific pieces of music that have particularly strong effects (on listener judgment and/or on observable emotional reactions) and determining the respective musical and acoustical parameters (using musical analysis, expert assessment, and acoustic analysis).

This thesis and many other works and research based on musically-induced emotion revolve around the notion that not only is felt emotion something that is measurable in different levels – for example, the intensity of the felt emotion – but also that it is most easily observed when it reaches a peak. It makes sense, therefore, that a substantial portion of the research on musically-induced emotion has, to date, been focused specifically on peaks.

However, there is no reason to limit this assumption to the properties of music only; it is likely that it applies equally to the emotion-dependent properties of the listening experience. In other words, peaks are not only an excellent foundation for understanding the potential that given musical and acoustical parameters have to arouse emotion, but also for understanding how musically-induced emotion relates to other kinds of human emotion, particularly in terms of its various observable effects on the listener. The following section describes some of the various approaches, including the musicological perspective that was described above, to observing and understanding emotional peaks.

2.2 Perspectives on peak-specific research

Emotional peaks are multi-faceted in the sense that they can affect our minds and bodies in various ways, and each of these effects demand appropriate theoretical perspectives and respective methodologies for research. It has become apparent that different aspects of musical emotion must be well understood before they can be codified into a robust working model for the production and effects of strong musical emotion. Since Abraham Maslow's works in the late

1960's and early 1970's (see Maslow, 1968; Maslow, 1971), numerous scholars have conducted unique empirical research on peak experiences and related phenomena. Some of the most common approaches that have been utilized include the phenomenological, neurological, biological, and musicological perspectives. Each of these approaches is outlined below with relevant examples.

2.2.1 The phenomenological perspective

To date, the most familiar approach to peak experiences is that from a phenomenological perspective. This perspective is generally concerned with contextual information about the peaks, such as when and where they occur, or the types of individuals that can experience certain classifications of peaks. One of the earliest studies to utilize this approach was organized by Panzarella (1980), who prompted a total of 103 participants to report an "intense joyous experience" of listening to music or looking at visual art. His data indicates that the phenomenology and occurrence of peak experiences is related to both differences in stimuli (i.e., music vs. visual art) and to personality differences, but not to age, sex, education, approval motive scores, visual art ability, or musical ability. Furthermore, based on his collected responses, he was able to classify three prominent effects of peak experiences: (1) "vivid and continually stimulating memories", (2) "enhanced appreciations", and (3) "permanent 'total' effects involving more positive self feelings as well as improved relationships with others and a boost of optimism". Interestingly, these three effects are rather apparent correlates of Scherer's (2004) three components of musical emotion, which have been discussed in Section 2.1.

Gabrielsson (2001) conducted a similar study based on his *Strong Experiences With Music* (SEM) project, begun in the late 1980's. By 2001, he had gathered over 900 responses to a short questionnaire asking participants to describe "the strongest, most intense experience of music that you have ever had". He categorizes and explains the types of emotions present in the responses as well as the musical and personal factors which influence the types of experiences. He also notes that experiences of strong emotion are not necessarily correlated with high levels of arousal, since many of his respondents reported strong emotion with low levels of arousal (e.g., "peacefulness"). This is interesting because it may coincide with the various arousal

theories (see e.g., Yerkes & Dodson, 1908), which reflect the idea that individuals have an optimal level of arousal at which they function best and enjoy the most.

2.2.2 The neurological and biological perspectives

Relatively little research has been devoted to the correlation between peak experiences and the human brain and body, but a few studies have provided very useful results describing the nature of this relationship. For example, Blood and Zatorre (2001) conducted a study which demonstrates a neurological basis for musically-induced emotional peaks. Their primary goal was to describe the "chills" or "shivers-down-the-spine" that often occur when one listens to music with regard to the brain structures activated during these responses. In the experiment, ten participants were asked to bring their own personally chosen selection of a classical music recording containing an intensely pleasurable emotional peak, and to listen to the piece while the authors utilized positron emission tomography to monitor their neural activity. The authors deduce that the brain structures activated by intensely pleasurable responses to music are the same structures activated by sex, food, abusive drugs, and other euphoria-inducing stimuli. This demonstrates a link between music and "biologically relevant, survival-related stimuli"; especially, as the authors conclude, those involved with human pleasure and reward.

In a similar vein, Rickard (2004) tested "emotional powerful music" (EPM) against contrasting stimuli, including relaxing music, arousing (but not emotionally powerful) music, and emotionally powerful film scenes, in order to target the effect EPM has on the human physiological response. For the experiment, twenty-one participants listened to each of the four types of stimuli (the EPM was participant-selected and the others were pre-selected by Rickard) while their skin conductance, heart rate, skin temperature, EMG, and salivary cortisol levels were monitored. The participants also subjectively reported any instances of physical "chills". It was demonstrated that EPM induces significantly greater skin conductivity and more subjective chills than the three other stimuli. It is suggested that intense emotions related to music are not unlike those emotions provoked by "real world" or non-aesthetic stimuli, which is consistent with Blood and Zatorre's (2001) findings. By contrast, EPM did not produce a statistically significant effect on heart rate, skin temperature, EMG, or salivary cortisol levels. Rickard

speculates that skin conductivity could simply be a better predictor of emotion intensity, and that the other variables may correlate with other aspects of emotion (e.g., valence).

2.2.3 The musicological perspective

This thesis utilizes the musicological perspective to induced emotion, and some description about the appropriate methodology for such research was already provided Section 2.1. In brief, the musicological perspective to musically-induced emotion is concerned with understanding the exact mechanisms by which music arouses our emotion. It seeks to uncover which compositional and performance features are likely to arouse reactions repeatedly in a given listener. There may be some overlap with previously mentioned perspectives, however, especially if there is an interest in distinguishing between types of emotional peaks.

For example, Sloboda (1991) studied the correlation between various biological and physiological human responses – referred to as "thrills" – and structural features found in classical music. He sought to reveal whether any music-structural features could accurately predict the type of physical response to be expected from a given listener. Eighty-three participants completed a questionnaire about specific musical passages that evoked any of twelve pre-determined "thrills", including shivers down the spine, laughter, lump in the throat, tears, goose pimples, racing heart, yawning, pit of stomach sensations, sexual arousal, trembling, flushing/blushing, and sweating. A musicological analysis was performed on each of the passages, and the music-structural features found were tabulated alongside the reported thrills. There were a variety of notable correlations; for example, harmonies descending the circle of fifths to the tonic, melodic appoggiaturas, and melodic and harmonic sequences were all strong indicators that the participant would report experiencing tears or shivers-down-the-spine while listening to the passage. The correlations that were found are especially interesting because they suggest that there may be a very systematic relationship between music-structural features and the resultant human emotional responses.

A more recent study by Lowis and Touchin (2002) carries Sloboda's idea into a slightly different context. In their experiment, both "gentle" and "upbeat" classical music were played in a controlled listening environment, and participants were asked to record any instances of what

they would consider a peak. The musical events occurring during these recorded peaks were then analyzed and reported. The authors describe an alternating high-low emotional response pattern triggered by the gentle music that was not present during the upbeat music, though they admit that it is difficult to make any assumptions about this evidence without further research.

3 RESEARCH PROJECT

The research project that is the primary subject of this thesis was conducted during Fall of 2008 and Spring of 2009. It was designed to provide a new musicological perspective on emotional peaks, particularly about where and how they occur. Initially, the project was influenced by Sloboda's research (described in Section 2.2.3), but focused on strong listener emotion in general rather than on specific biological reactions, and it was not limited to the Western classical genre. In these regards, the project essentially took a "step back" in order to provide a broader view on emotional peaks. The three primary research questions are as follows:

1. In a given piece of music, when is an emotional peak most likely to occur?
2. Can repetition within a piece of music make a significant and systematic contribution to the probability that an emotional peak will occur?
3. Which musical features – melody, harmony, rhythm, and/or orchestration – correlate with emotional peaks?

The project was essentially a four-step process. Firstly, an informal pilot study was conducted in order to devise a questionnaire capable of gathering clear and practical information about emotional peaks. Secondly, the questionnaire was distributed to personal student contacts and through internet mailing lists at the University of Jyväskylä, resulting in forty-three usable textual responses and accompanying musical submissions. Thirdly, a primarily musicological analysis was performed on the responses in order to produce a variety of data about the emotional content of the music. Lastly, a statistical analysis was performed on the data to find patterns and statistically-significant correlations. These steps, along with their results, are outlined in detail in this section.

3.1 The questionnaire

A central element of the research project was a questionnaire that prompted participants to report an instance of an emotional peak in a freely chosen piece of music. The questionnaire itself consisted of only five questions, each of which was finalized after the initial pilot study. Two of the questions required exact responses from the participants and three of the questions were open-ended. Because of the sensitive nature of the strong emotion, the questionnaire was meant to be as concise and open as possible in order to encourage participation, especially since some prior research on musically-induced emotion reported difficulties with gathering sufficient participants. Each of the five questions is described below, and the full questionnaire, along with an introductory letter that was also distributed, is included in the appendix.

The first question prompted the participant to choose a moment or short passage of recorded music that evoked a "peak emotional reaction" within him or her. The participant was then requested to report the composer, the title, and the genre (it was specified that any genre was acceptable) of the piece of music within which the moment or passage occurred. There was no elaboration about what exactly constituted a peak emotional reaction, since the project was meant to reflect explicit emotion, as described in Section 1 (i.e., emotion in general, rather than different emotions), and because a diverse array of responses was desired.

The second question called for the start and end times of the chosen peak emotional reaction in reference to the rest of the piece. These times were requested in minutes and seconds. The participants were also asked to include in the submission of the questionnaire a digital audio recording of the entire chosen piece of music (to which the reported times would reference) in any standard file format.

The third question was open-ended, and asked why the participant chose the particular passage and piece. This question was included to address three particular anticipations: (1) that it would clarify and direct the empirical analysis of the peak, (2) that it would aid in interpreting the final results, and (3) that it would enable outliers to be easily identified (outliers are discussed further in Section 3.2).

The fourth question was also open-ended, and asked the participant to reflect on how the passage made them feel. This question was included primarily to aid in interpreting the final results of the research project.

The fifth and last question was also open-ended, and asked the participant about the lyrics of the piece, if there were any. Specifically, it asked whether or not the lyrics had any particular meaning to the participant. This question was included in order to aid in the identification of outliers (see Section 3.2) and to classify the lyrical significance of the piece into categories (see Section 4.1.4).

The introductory letter was attached to the questionnaire in order to thank the participants, to clarify that their responses and accompanying audio submissions would be kept strictly confidential and would be used for research purposes only, and to remind them that their participation was voluntary.

3.2 Participants and outlier identification

The questionnaire was distributed in two batches. Firstly, in November and December of 2008, it was circulated through internet mailing lists at the University of Jyväskylä. These mailing lists were targeted primarily at foreign students, so the majority of the participants from this batch were not Finnish. There were only fourteen responses from these lists, however, so the questionnaire was administered again in a second batch from December 2008 through March of 2009 on an individual basis to other university-level students.

In total, 49 responses were obtained, though only 43 of the responses were ultimately deemed usable. Outliers were determined on the basis of three factors: (1) if the peak occurred at the very beginning of the piece, (2) if the peak exceeded a maximum length, and (3) if the participant suggested in one of the open response questions that something other than the music triggers the emotional reaction.

Three of the participants reported an emotional peak at the very beginning of the chosen piece. These responses were treated as outliers because a musicological analysis of such a peak would

have been problematic and most likely irrelevant, since the purpose of the analysis (which will be discussed in detail in Section 3.3) was to find the types of repetitions and structural changes in the music that correlate with the occurrence of emotional peaks. This type of analysis, therefore, is concerned with the musical events prior and leading up to emotional peaks just as much as the musical events occurring within the peaks.

Two of the participants reported an emotional peak that exceeded a maximum peak length. This limit was created to differentiate "peaks" from "plateaus", so to speak, in the sense that anything over the maximum length would be problematic to consider an actual peak, but instead an entire section. After all of the responses were gathered and reviewed, the maximum peak length was arbitrarily chosen to be one half of the length of the entire piece. The only two reported peaks that exceeded this limit were each over two minutes in length, which seemed far too long to be considered a peak at all.

Finally, one response was considered unsuitable because it was written, performed, and recorded by the participant himself. The lyrical content of the song portrayed actual events in his life, which broke down the composer/performer/listener barrier and presented a variety of complications that fell outside the scope of this project.

3.3 Musicological analysis

An analysis scheme was devised in order to consistently obtain useful data from each of the audio submissions. The scheme was based on the three research questions presented in the beginning of Section 3. The following sections demonstrate how each of the three questions was addressed in the analysis. Section 3.3.1 addresses the first question about peak timing. Section 3.3.2 addresses the second question about repetition, and distinguishes between the repetitions of four musical elements: melody, harmony, rhythm, and lyrics. Lastly, Sections 3.3.3 through 3.3.6 address the third question, which is about structural changes in melody, harmony, rhythm, and orchestration.

3.3.1 Peak timing

The first and simplest task was to notate the timing of the emotional peak. For the majority of the submissions, the start and end times requested in the questionnaire were used. In some cases, however, these reported times were so close (i.e., within a few seconds) to a major structural event in the piece that it was apparent that the reported times had been rounded off or were merely intended as an estimate. In these cases, the start and end times were adjusted to match the structural event exactly.

In a few other cases, the start and end times were adjusted to better reflect the participants' subjective responses to the open-ended questions, particularly when it was mentioned that the reported times included a build-up to the emotional peak. For example, in one response, a participant stated that the peak began at the reported time and increased to the full peak when one of the instruments made an entrance after a long rest. For that submission, the start time of the peak was adjusted to reflect the time at which the instrument entered.

3.3.2 Repetitions

In each of the responses gathered for the pilot study, the reported peak began at some type of transition, whether to a different section, motif, or even simply a different note. It was discovered that many of these transitions culminated in a repetition of a prior theme in the piece.

In order to describe these repetitions, the music occurring at a given emotional peak was separated into four elements: melody, harmony, rhythm, and lyrics. Once the events of an individual element were "memorized", so to speak, the respective piece was then scanned for prior occurrences of the events of that element.

For example, if the melody occurring during the emotional peak consisted of a particular motif, the rest of the piece was scanned for previous instances of that motif. If it turned out that the motif was entirely new and had not occurred previously in the piece, the melody feature for the given response was marked "no repetition." There were four such categories for describing repetition:

1. **No repetition**: reported if the element's events were entirely new

2. **Variation**: reported if the element's events were a variation on a prior theme
3. **Exact repetition**: reported if the element's events were an exact repetition of a prior theme
4. **Not applicable**: a special category created to denote instrumental pieces for the lyrics feature

This process was repeated for each of the four musical elements and for each reported emotional peak.

3.3.3 Melody

One variable was related specifically to melodic structure: the *melodic shift* variable. Each emotional peak was examined to determine whether or not the melody had shifted higher or lower. The leading melodic voice was identified on a case-by-case basis, either as the highest voice, or the loudest and most distinctive voice. There were no cases observed in which the leading melodic voice was ambiguous or difficult to discern, so at least in the case of this project, the identification process was not problematic.

Three categories were created for the melodic shift variable: (1) a shift upwards, (2) a shift downwards, and (3) no melodic shift. In order to constitute a shift, however, the leading melodic voice had to stay shifted for at least an entire phrase, rather than for only a few notes. In other words, neighbor notes and transient melodic jumps did not constitute a melodic shift during the analysis.

3.3.4 Harmony

There were two variables related to tonal harmony: *unprepared harmony* and *harmonic clarity*. An unprepared harmony was noted in cases where, by the rules of Western tonal harmony, the chord progression at the beginning of the emotional peak was unprepared and/or unexpected. For example, in one of the submissions, the reported emotional peak was a final repetition of the chorus that had been directly modulated upwards a whole step. Since the modulation was direct, this peak was noted as featuring an unprepared harmony.

Harmonic clarity was determined on the basis of whether the harmonic content of the emotional peak became more or less comprehensible. Each emotional peak was labeled with either (1) an increase in harmonic clarity, (2) a decrease in harmonic clarity, or (3) no change in harmonic clarity. Two factors contributed to this determination: changes in the "actual" harmonic clarity and changes in the production features of the recording. For example, in one case, there was substantial use of chromaticism that resolved to a mostly diatonic progression at the emotional peak. In another case, the harmony was initially ambiguous due to purposeful distortion of the music by various audio filter effects, but at the peak, these effects were minimized so that the harmony became audibly comprehensible. Both of these cases were labeled as an increase in harmonic clarity.

3.3.5 Rhythm

There were three variables related to rhythm: *pulse clarity*, *tempo change*, and *new rhythm*. The pulse clarity variable was conceptually similar to the harmonic clarity variable; it was determined on the basis of whether the pulse at the emotional peak became more or less comprehensible. Of particular importance were changes in the regularity of the beat and in the clarity of the note onsets. Each peak was labeled as an increase, a decrease, or no change in pulse clarity.

Tempo changes were labeled in the same way: as an increase, a decrease, or as no change in tempo. For the purpose of this project, however, the concept of a tempo change was not limited to the primary Western classical understanding of the term. Instances of rhythmic augmentation and diminution (i.e., when the pulse doubles or halves in speed), both of which are common features in rock and pop music especially, were also treated as increases and decreases in tempo, respectively, even though some music theorists would argue that they do not constitute a true tempo change.

Lastly, the new rhythm variable served to report changes in the subdivision of the beat. The three possible categories were a change from duple to triple meter, from triple to duple meter, and no change in beat subdivision.

3.3.6 Orchestration

Structural changes in orchestration were measured by three variables: *added background instruments*, *added foreground instrument*, and *dynamics.* The added background instruments variable evaluated changes in the number of background instruments. Determination of the background instruments (as opposed to foreground instruments) was performed on a case-by case basis, depending on the loudness and clarity of a given instrument. In cases where an instrument's status was ambiguous and open to interpretation, it was considered a background instrument. Also, in cases where instruments in a group moved in homophony and were difficult to distinguish (e.g., a choir or ensemble of instruments in one family), they were collectively considered one instrument. If there was an increase in the number of added background instruments, the variable was represented by the number that was added. If there were no changes in the number, the variable was assigned a value of 0, and if background instruments were subtracted, it was assigned a value of -1.

The foreground instrument was generally the leading melodic voice, but in some cases, a group of voices was considered one collective foreground instrument, as described above. If a foreground instrument was added at the peak, regardless of whether a different foreground instruments was subtracted at the peak, the variable was assigned a value of 1. If a foreground instrument was neither added nor subtracted at the peak, the variable was assigned a value of 0. If the foreground instrument was subtracted and was not replaced at the peak, the variable was assigned a value of -1.

Each emotional peak was labeled as either an increase, decrease, or no change in dynamics. Dynamics were determined on the basis of a change in volume of the existing instruments, rather than a change in the overall loudness. In such cases where foreground and/or background instruments were added during the emotional peak, resulting in an overall increase in loudness (but no change in the loudness of the existing instruments), the peak was considered to have no change in dynamics, since these instances would be reflected by the other variables related to orchestration.

3.4 Statistical analysis

Once the data from the musicological analyses was gathered, a variety of statistical analyses were performed in order to uncover potential trends and correlations that could address the research questions posed at the beginning of Section 3.

Initially, descriptive statistics were calculated on the raw collected data, but these statistics only provided basic information about the collected emotional peaks themselves, rather than what may have caused them. Therefore, a control group of "non-peaks" was created to offer a statistically significant element of comparability to the overall analysis by providing a reference point for the evaluation of the emotional peaks. The creation of this control group, along with the subsequent analyses, is described in detail below.

3.4.1 The control group

The purpose of the control group was to provide a context within which to understand emotional peaks. By comparing the features of the emotional peaks with the features of the control group (i.e., the non-peaks), it was possible to say with a measurable degree of statistical significance what is different about emotional peaks, and therefore which musical features actually correlate with emotional peaks.

The control group was created through a random selection of points in time in the participant-submitted musical pieces. Firstly, a sub-group of twenty pieces was randomly chosen out of the forty-five usable submissions. Then, a point in time was randomly chosen for each piece to mark the beginning of a non-peak. In order to ensure that a structural event actually occurred at the chosen point, it was adjusted – generally no more than a few seconds – to reflect the beginning of the nearest measure. If the resultant point in time fell within the time segment that was reported as an emotional peak for the submission of that piece, different points were randomly chosen until one fell outside the boundaries of reported segment; this point would serve as the non-peak. Once twenty of such non-peaks were secured, a musicological analysis was performed on each of them almost exactly as noted in Section 3.3, in order to produce control data; the only difference was that there were no end times chosen for the non-peaks.

3.4.2 Significance tests

Once all of the data for the control group was gathered, two types of statistical significance tests were performed on most of the variables: Fisher's exact test (Fisher, 1922) and the Freeman-Halton variation of Fisher's exact test (Freeman & Halton, 1951). In both cases, the control data (i.e., the data calculated from the non-peaks) was used to produce the expected values for each variable, while the emotional peak data was used to produce the observed values for each variable.

Fisher's exact test is a practical choice when the expected and observed values of a given variable are relatively low, as was the case in this project. However, many of the variables defined in this project (see Section 3.3) consisted of three distinct categories, and it is only possible to use Fisher's exact test in its original form with 2-by-2 contingency tables (i.e., tables with two conditions by two categories). For the variables with three categories, the Freeman-Halton variation of Fisher's exact was used instead because it was designed to work with an arbitrary number of conditions and categories, therefore making a direct analysis of all three categories possible.

Under ideal circumstances, the chi-square goodness-of-fit test would probably have been a more appropriate choice to demonstrate statistical significance. For most variables, however, Fisher's exact test or the Freeman-Halton variation was the only option. The main difficulty encountered when using the chi-square test was that it is only considered useful for experiments which feature large sample sizes. In particular, the validity of the test breaks down when a given variable's categories have an expected value below five, and since this was often the case, the chi-square test was considered unsuitable.

3.5 Results

A variety of statistics were calculated as described in the previous section. The results of these analyses are provided below, divided into three sections which individually address the questions presented at the beginning of Section 3.

3.5.1 Peak timing

The start times and lengths of the emotional peaks were considered in two ways: as absolute times and as normalized times. The absolute peak time reflects a peak's location in minutes and seconds into the respective piece, while the normalized time reflects a peak's location as a fraction of the overall length of the piece. Similarly, the absolute peak length reflects the peak's duration in minutes and seconds, while the normalized peak length reflects the peak's duration as a fraction of the overall length of the piece.

For example, if a four minute piece of music had an emotional peak at two minutes that lasted for one minute in duration, the absolute start time of the peak would be two minutes, the normalized start time of the peak would be 0.5, the absolute peak length would be one minute, and the normalized peak length would be 0.25.

A summary of descriptive statistics for each of the variables related to peak timing is provided in Table 1. The mean length of the submitted musical pieces was found to be 5:30, and the mean absolute start time was 3:39, with a standard deviation of 2:10. The mean normalized start time was 0.641, with a standard deviation of 0.221. Since the standard deviation of the normalized start time was relatively smaller than that of the absolute start time, the normalized start time was more indicative of the temporal location of the emotional peaks in the collected responses.

TABLE 1. Summary of descriptive statistics related to emotional peak timing

	Lowest value	Median value	Highest value	Mean value	Standard deviation
Absolute start time (mm:ss)	00:12	03:05	09:10	03:39	02:10
Absolute peak length (mm:ss)	00:08	00:21	01:30	00:27	00:17
Normalized start time	0.112	0.685	0.929	0.641	0.221
Normalized peak length	0.014	0.081	0.258	0.093	0.06
Total length of piece (mm:ss)	01:20	04:58	10:13	05:30	02:14

This is further demonstrated in Figures 1 and 2, in which histograms are provided that show the start times' frequencies of occurrence in terms of absolute and normalized time, respectively. Each histogram is divided into twenty bins. The largest bin for absolute start time, with seven occurrences, is from 2:15 – 2:30. The largest bins for normalized start time, with seven occurrences each, are from 0.65 – 0.7 and from 0.8 to 0.85. The negative distribution of the second figure appears to be slightly more evident than the positive distribution of the first figure, which again suggests that the normalized start times were more indicative of the temporal location of the emotional peaks.

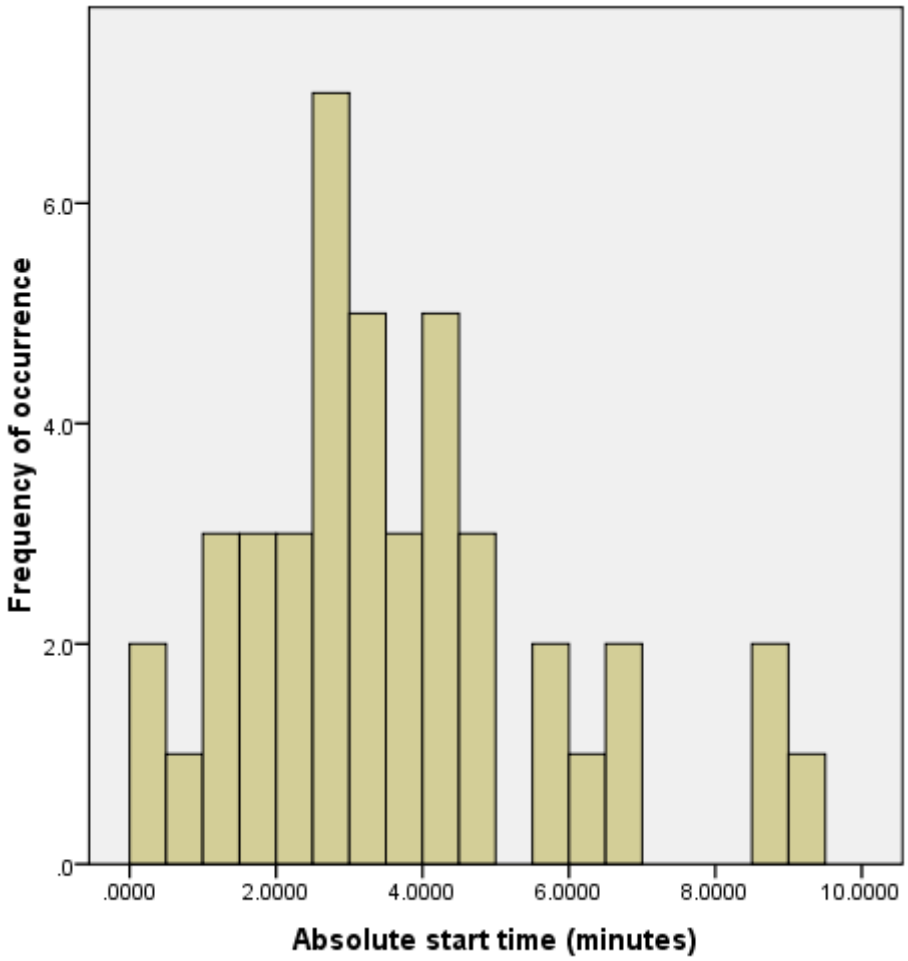

FIGURE 1. Histogram showing the absolute start time of the emotional peaks, in seconds, versus their frequency of occurrence

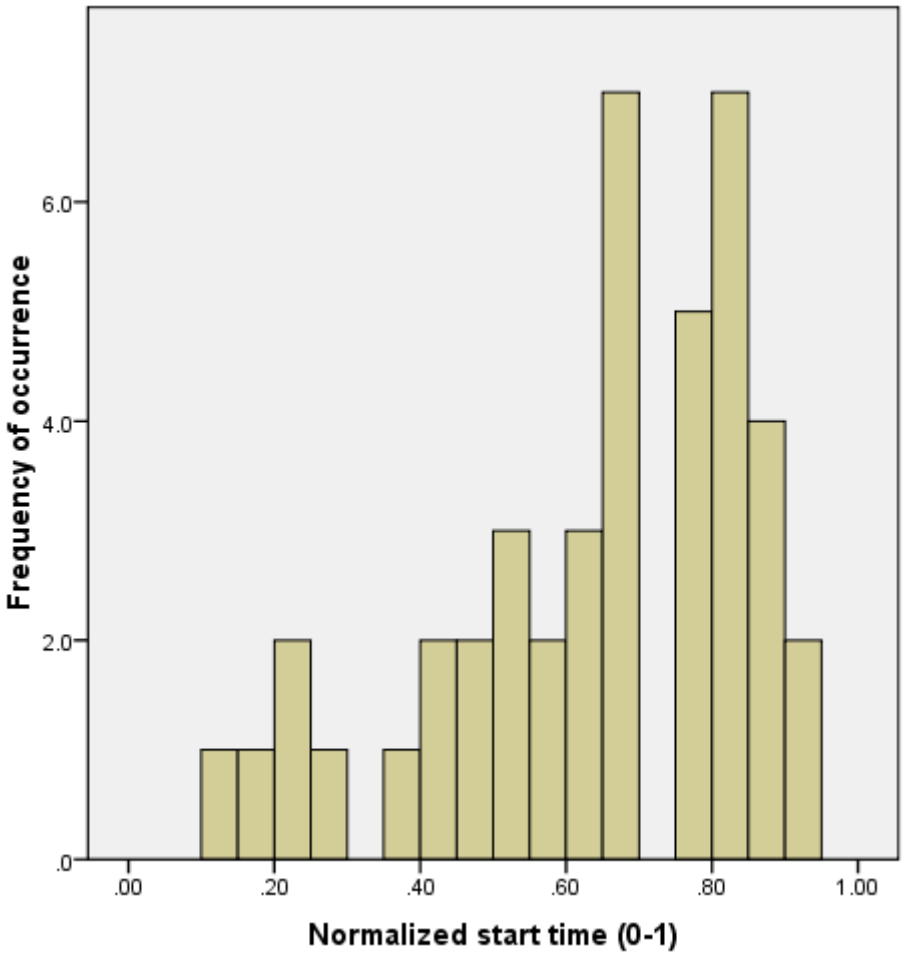

FIGURE 2. Histogram showing the normalized start time of the emotional peaks, as a fraction of the total piece length, versus their frequency of occurrence

3.5.2 Repetitions

A general summary of the observed values (the emotional peak data) and expected values (the non-peak data) for each of the three categories of repetition is provided for each musical feature in Table 2. As a whole, the "exact repetition" category appears to correlate most strongly with the emotional peaks, since the emotional peak data contains well over twice as many exact repetitions as the non-peak data.

TABLE 2. Summary of observed (peak) and expected (non-peak) frequencies for each of the four repetition variables

	No repetition	Variation	Exact repetition
MELODY REPETITION			
Emotional peaks	18	7	18
Non-peaks	11	5	4
HARMONY REPETITION			
Emotional peaks	10	2	31
Non-peaks	7	1	12
RHYTHM REPETITION			
Emotional peaks	14	4	25
Non-peaks	8	1	11
LYRICAL REPETITION			
Emotional peaks	19	3	11
Non-peaks	18	1	1

The data in Table 2 was used to perform three kinds of tests: two cases of Fisher's exact test, and the Freeman-Halton extension of Fisher's exact test. In the first case of Fisher's exact test, which only allows two categories for each variable, the *no repetition* category was combined with the *variation* category and measured against the *exact repetition* category. In the second case of Fisher's exact test, the *no repetition* category was measured against a combination of the *variation* and *exact repetition* categories. This allowed the observation of any differences between when variations are forced into the *no repetition* category and into the *exact repetition* category, both of which may be useful to consider. The Freeman-Halton extension of Fisher's exact test was also performed on each variable because it allows the three categories to be tested without the need for any category combination.

The p-values of significance for each of the three tests are provided in Table 3. Interestingly, the lyrical repetition variable was the only one to demonstrate significant p-values, and it did so in all three tests. The next most significant variable was the melody repetition variable, followed by the harmony repetition variable, and lastly, the rhythm repetition variable.

TABLE 3. P-values for the two cases of Fisher's exact test and for the Freeman-Halton extension; significant p-values are indicated with an asterisk

	Fisher's exact test – "no repetition" combined with "variation"	Fisher's exact test – "variation" combined with "exact repetition"	Fisher-Freeman-Halton test
Melody repetition	0.16	0.42	0.24
Harmony repetition	0.39	0.37	0.57
Rhythm repetition	1.0	0.58	0.85
Lyrical repetition	0.02*	0.02*	0.03*

3.5.3 Structural events

The variables related to music structural features that exhibited a significant correlation with emotional peaks include *melodic shift*, *pulse clarity*, *dynamics*, and *added background instruments*. These and the rest of the variables related to the music structure appear in detail in Table 4. Each are broken down into their respective categories and are displayed alongside their counts for both the emotional peak and non-peak conditions. The associated p-value, calculated either using Fisher's exact test or the Freeman-Halton extension, depending on the number of categories, is also shown for each variable.

TABLE 4. Observed and expected values for each category of each variable related to music-structural events; significant p-values are indicated with an asterisk

Musical feature	Variable/category	Emotional peaks	Non-peaks	P-value
MELODY	Melodic shift upwards	24	2	< 0.01*
	No melodic shift	18	15	
	Melodic shift downwards	1	3	
HARMONY	Prepared harmony	41	19	1.0
	Unprepared harmony	2	1	
	Harm. clarity increase	6	0	0.16
	Harm. clarity no shift	37	20	
	Harm. clarity decrease	0	0	
RHYTHM	Tempo increase	5	0	0.32
	No tempo change	35	19	
	Tempo decrease	3	1	
	No new rhythm	38	20	0.45, 0.17 w/rhythms combined
	Triple to duple	3	0	
	Duple to triple	2	0	
	Pulse clarity increase	14	0	< 0.01*
	No change in pulse clarity	29	17	
	Pulse clarity decrease	0	3	
ORCHESTRATION	Dynamics increase	16	1	< 0.01*
	No change in dynamics	26	14	
	Dynamics decrease	1	5	
	Foreground inst. added	15	3	0.15
	Foreground inst. no change	27	15	
	Foreground inst. subtracted	1	2	
	Background inst. added	25	3	< 0.01
	Background inst. no change	16	13	
	Background inst subtracted	2	4	

4 CONCLUSIONS

Based on the analyses related to peak timing, it can be concluded by examining the standard deviation of the absolute peak start time (particularly in relation to the mean length of the pieces, which was 05:30), 02:10, and the standard deviation of the normalized peak start time, 0.22, that the absolute start time is less indicative of a peak than the normalized start time. In other words, the extent to which a piece of music is complete is probably more important than the actual listening duration when predicting the occurrence and position of an emotional peak, of which the most likely location is approximately 64% of a piece's duration. Both the absolute and the normalized time should be taken into consideration when considering peak timing, however, because in practice, it is likely that the two are related. For example, it may be that normalized time is only more important in musical pieces of a "typical" duration, and that pieces which exceed this duration generally contain peaks with a lower normalized start time. In other words, the length of the musical piece may indicate whether normalized or absolute time is more important in predicting the occurrence of an emotional peak.

Some further conclusions can be drawn from the analyses related to repetition and structural events. The variables achieving statistically significant (i.e., $p < 0.05$) correlations with emotional peaks were *lyrical repetition*, *melodic shift*, *pulse clarity*, *dynamics*, and *added background instruments*. Since the sample size of this experiment was relatively small, however, variables with higher p-values should be considered as relevant possibilities as well, since they may have achieved statistical significance given greater sample sizes. The variables with a p-value below an arbitrary value of 0.2 (not including the significant ones noted above) are *melody repetition*, *harmonic clarity*, *new rhythm*, and *added foreground instrument*.

One of the most fundamental concepts related to Western music is that of "tension and release", which is the idea that we enjoy the buildup and release of musical tension. This vacillating level of tension is generally regarded as responsible for maintaining listener interest throughout a given piece of music. Two of the variables stated above, *pulse clarity* and *harmonic clarity*, are directly related to tension and release because a decrease in either variable creates ambiguity and therefore tension, while an increase in either releases the ambiguity into coherency. Of the 43

submitted emotional peaks, 16 featured an increase in one or both of these variables, while none of them featured a decrease in either. This is consistent with the idea that we enjoy the release of tension, but since only 16 of the responses directly reflected that, it is necessary to consider additional factors to account for the remaining 27 responses.

Most of the peaks featured a positive value (i.e., an exact repetition or an increase) in at least one of the significant or near-significant variables; in fact, very few of the peaks featured "negative" values at all. Interestingly, for many of the variables, a positive value also equates to an increase in mental or physical effort. Some examples that demonstrate this are outlined below:

1. A **melodic shift** upwards generally requires an increase in mental and/or physical effort, since higher notes tend to be more difficult to reach for the voice and most instruments.
2. An increase in **dynamics** – either a crescendo or an immediate rise in volume (i.e., terraced dynamics) – generally requires an increase in physical effort to achieve for the voice and most instruments.
3. **Added background instruments** and/or an **added foreground instrument** results in a larger collective effort, since more instruments are required to play.
4. A **new rhythm** generally requires increased mental effort, since they can be technically difficult to achieve, especially in an ensemble.

Higher levels of required mental or physical effort are likely to create tension due to the increased resultant activity, so the concept of tension and release applies to these variables as well, even if only indirectly. Therefore, it seems that patterns of tension and release are important not only for maintaining listener interest, but also for influencing the emotional reaction.

A summary of the p-values for each of the repetition and structural variables organized by their respective musical elements is provided in Table 5.

TABLE 5. P-value summary for each of the repetition and structural variables

	MELODY	HARMONY	RHYTHM	LYRICS	ORCHESTRATION
$p < 0.5$	melodic shift		pulse clarity	lyric repetition	dynamics, added background instruments
$0.5 \leq p < 0.2$	melody repetition	harmonic clarity	new rhythm		added foreground instrument
$p \geq 0.2$		unprepared harmony	tempo change		

At this time, little can be said to empirically distinguish the prominence of each of these musical elements, but by glancing at Table 5, it appears that melody, lyrics, and orchestration are likely more conducive to strong emotion than harmony and rhythm. The factuality of this statement is problematic, though, because simply weighing the number of variables in each category offers little insight on their actual significance. Moreover, different combinations of these variables may have had special (i.e., non-linear) effects that were not perceptible by the statistical analyses used in this project. Further research and analysis may be able to reveal more about the potential contribution of each musical element to listener emotion, however.

4.1 Suggestions for future research

There are a variety of ways that subsequent research can be improved without drastically changing the theoretical design and methodology of this project. Some suggestions are outlined in the following four subsections.

4.1.1 More responses

One of the greatest difficulties in this project was obtaining enough responses to produce robust and statistically significant results. It would have been ideal to use the chi-square test instead of Fisher's exact test and the Freeman-Halton extension, but relatively low expected values (i.e., less than five) calculated from the control group made this virtually impossible. A greater-sized control group would not only have enabled the use of the chi-square test, but it – as well as more

responses in general – would likely also have produced lower p-values, at least for some of the variables.

Many participants reported via personal communications that they were intimidated by the great deal of time it would take to browse their music collection and consider the "perfect" submission, and that the open-endedness of the questions made it difficult to pinpoint the exact reasons that that piece affected them so greatly. For these reasons, data collection was a relatively slow process, and due to time constraints, it was necessary for the questionnaire administration to be cut short before the initially desired number of responses (one-hundred) was reached. Given ideal circumstances, future research should either focus a great deal of effort on obtaining sufficient responses, or alternatively consider utilizing less open-ended types of questions.

4.1.2 Clarifications and different types of peaks

One potentially misleading element of the questionnaire was asking for a peak end time, which may have led some of the participants to submit an entire passage (a "plateau", so to speak) rather than one particular moment. The end times were not used for any statistical analysis in this project – other than to identify a few outliers – and requesting them may have only drawn the participants away from considering actual peaks. Therefore, future research on emotional peaks should consider the potential advantages of only requesting a start time.

Moreover, future research may benefit from distinguishing between different types of emotional peaks. Though doing so would introduce an entirely new dimension of data and probably a variety of complications for statistical analysis, it might also provide further insight into the nature of musical emotion. Perhaps different types of peaks (if there truly are different types) are aroused by different mechanisms; if this is the case, then gathering further information about the type of aroused emotion would be very useful.

4.1.3 The control group

As discussed in Section 3.4.1, the control group was determined by a random selection of points in time from twenty of the submitted pieces. This was the quickest and easiest way to create the

group, but it bears one oversight: it is likely that there are different levels of emotional peaks (and listener emotional response in general), and a random selection of points does not guarantee the avoidance of some of the "smaller" peaks, so to speak. With the random selection method, the only distinction is that between the submitted emotional peaks and any other moment in time – possibly even other emotional moments – not necessarily a distinction between the submitted emotional peaks and moments characterized by low levels of emotion.

An alternative to the random selection method for the control group is to ask participants directly in the questionnaire to report one or a few moments in their submitted piece which they find to *not* arouse any particular emotion. This would allow a distinction between the musical features that arouse high and low levels of emotion. However, it is uncertain how accurate and reliable such a distinction would be, since the participant would likely find the entirety of the submitted piece to arouse at least some emotion. Requesting a moment of low emotional response may therefore be counter-intuitive.

A second alternative to the random selection method for the control group is to use a continuous response interface in order to monitor emotional response level. For this method, participants would be given a slider to manually adjust that would reflect their emotional response in one or more dimensions. For example, in (Luck et al, 2008), a listening experiment was conducted in which participants used a slider on a computer interface to continuously rate music therapy improvisations in three dimensions (not simultaneously): activity, pleasantness, and strength. If this methodology was used with only one dimension (i.e., the listener's overall emotional response), then the points in time during which the slider was at its lowest could be used to create the control group of non-peaks, while the points in time during which the slider was at its highest could be used to identify the peaks.

It is speculated that the random selection method for creating the control group was effective, since it allowed the highest peak of each submitted piece to be distinguished from another moment. Because the focus of this project was on moments of the highest emotional reaction rather than on different levels of emotional reaction, this should have been sufficient, especially

since some statistically significant results were obtained. However, future research pertaining to musical emotion may want to consider the methods suggested above as well.

4.1.4 More advanced correlations

Data was gathered for three extra variables that were not directly related to the submitted emotional peaks, including the genre of the piece, the lyrical theme of the piece, and the lyrical significance for the piece. These variables would be beneficial for future research because they would provide information about whether or not particular musical features arouse strong emotional reactions given a specific genre, lyrical theme, or degree of lyrical significance.

For example, it may be that features related to harmony carry a greater potential for emotion arousal in classical music than in rock music. Similarly, perhaps features related to melody are more important when the listener relates to the lyrics than when he/she does not. In the end, however, these variables were ignored in this study because more responses were needed in order to establish each of their different categories comprehensively.

4.2 Applications of musically-induced emotion research

Research on musically-induced emotion has a number of practical outlets. Two examples are demonstrated below: applications for composition and automatic music generation, and music therapy.

4.2.1 Composition and automatic music generation

Composers – especially algorithmic composers – may benefit from a more empirical understanding of the musical features that contribute to induced emotion. The school of composition is largely based on heuristics, and relevant research may supplement this in such a way that either reinforces the current “rules of thumb” or challenges composers to search for new methods to arouse listener emotion. Automatic music generation (e.g., generative music, algorithmic music, or interactive/adaptive music) in particular can utilize such research in order to create more emotionally practical environments for whatever the application is, whether it is music simply for the sake of listening to or music as a supplement to some other stimulus like a film, computer game, or website.

Having empirical data about the specific indicators of emotional peaks allows music generators to incorporate more efficient and practical algorithms for emotion induction. For example, since an upward change in dynamics was earlier shown to be statistically indicative of a peak, then it would likely be appropriate to call for a crescendo when an increased emotional response is desired. In the case of music as a supplement to a narrative, this type of response may be desired during climactic moments that are meant to deeply affect the viewer.

4.2.2 Music therapy

Music therapy, in the broadest sense of the term, involves the guided listening or production of music between a therapist and client for the purpose of building and/or maintaining health. It offers a variety of applications pertaining to both physical and mental health of particular clients, as well as to general fields like physical therapy and psychology. One example in which research on musically-induced emotions can benefit the field of music therapy is by aiding the analysis of music therapy improvisations. Improvisation is a common tool used in music therapy that encourages clients to express themselves in ways that they might not otherwise be able to. These improvisations can be recorded and analyzed in order to learn more about the client (see e.g., Luck et al, 2006), and incorporating empirical knowledge about musically-induced emotion may allow therapists to identify when their clients are attempting to convey different levels of emotion.

4.3 Concluding remarks

There have been oral and written accounts of music inducing real human emotions for millennia, yet until recently, very few empirical accounts of this phenomenon have surfaced. Composition, performance, and even the study of music in general, are largely founded on tried-and-true methods for emotion induction – rules of thumb, so to speak. Researchers are only just beginning to quantitatively document the effects of specific music-structural features on the emotional reactions of listeners. This thesis furthers such research by focusing on peaks in listener emotional reaction and by using statistical analyses to show which music-structural features correspond most closely. A few specific trends were demonstrated quite clearly, and it is likely that further trends will become apparent with continued research. Some alternative

methodologies were suggested for this continued research, which in time may be able to contribute to a more well-rounded understanding of musically-induced emotion, a critical aspect of the field of music cognition.

REFERENCES

Blood, A.J. & Zatorre, R.J. (2001) Intensely pleasurable responses to music correlate with activity in brain regions implicated with reward and emotion. *Proceedings of the National Academy of Sciences*, 98, 11818-11823.

Fisher, R. A. (1922). On the interpretation of chi-square from contingency tables, and the calculation of P. *Journal of the Royal Statistical Society*, 85(1), 87-94.

Freeman, G.H. & Halton, J.H. (1951). Note on exact treatment of contingency, goodness of fit and other problems of significance. *Biometrika*, 38, 141-149.

Gabrielsson, A. (2001). Emotions in strong experiences with music. In P. N. Juslin and J. A. Sloboda (eds.), *Music and emotion: Theory and research* (pp. 431-449). New York: Oxford University Press.

Gabrielsson, A. (2002). Emotion perceived and emotion felt: same or different? *Musicae Scientiae*, Special Issue 2001-2002, 123-147.

Juslin, P. N. & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: Different channels, same code? *Psychological Bulletin, 129*, 770-714.

Juslin, P. N. & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences*, 31, 559-621.

Lowis, M. J. & Touchin, C. (2002). An analysis of the properties of music found to trigger peak emotional experiences. *British Journal of Music Therapy*, 16(1), 35-45.

Luck, G., Riikkilä, K., Lartillot, O., Erkkilä, J., Toiviainen, P., Mäkelä, A., Pyhäluoto, K., Raine, H., Varkila, L. & Värri, J. (2006). Exploring Relationships between level of Mental Retardation and Features of Music Therapy Improvisations: A Computational Approach. *Nordic Journal of Music Therapy*, 15(1), 30-48.

Luck, G., Toiviainen, P., Erkkilä, J., Lartillot, O., Riikkilä, K., Mäkelä, A., Pyhäluoto, K., Raine, H., Varkila, L. & Värri, J. (2008). Modelling the relationships between emotional responses to, and musical content of, music therapy improvisations. *Psychology of Music*, 36(1), 25-46.

Maslow, A. (1968). *Toward a psychology of being* (2nd ed.). New York: Van Nostrand Reinhold.

Maslow, A. (1971). Peak experiences in education and art. *Theory into Practice*, 10(3), 149-153.

Panzarella, R. (1980). The Phenomenology of Aesthetic Peak Experiences. *Journal of Humanistic Psychology*, 20(1), 69-85.

Rickard, N. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. *Psychology of Music*, 32(4), 371-388.

Russel, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39, 1161-1178.

Scherer, K. R. (2004). What Emotions Can be Induced by Music? What Are the Underlying Mechanisms? And How Can We Measure Them? *Journal of New Music Research*, 33(3), 239-251.

Scherer, K. R. & Zentner, M. R. (2001). Emotional effects of music: Production rules. In P. N. Juslin and J. A. Sloboda (eds), *Music and emotion: Theory and research* (pp. 361-392). New York: Oxford University Press.

Scherer, K. R., Zentner, M. R., & Schacht, A. (2001). Emotional states generated by music: an exploratory study of music experts. *Musicae Scientiae*, Special Issue 2001-2002, 149-171.

Sloboda, J. A. (1991). Music Structure and Emotional Response: Some Empirical Findings. *Psychology of Music*, 19, 110-120.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, 18, 459-482.

Zink, S. (1960). Is the Music Really Sad? *Journal of Aesthetics and Art Criticism*, 19(2), 197-207.

APPENDIX: Questionnaire

Dear fellow students,

I would be most grateful if you took a moment of your time to fill out the short survey below and returned it by replying to me at aprechtl@gmail.com. It is part of an experiment for my master's thesis in the Music, Mind, and Technology program at the University of Jyväskylä. I will ask a few questions about a piece of music that arouses your emotion, and then I kindly ask you to attach an audio file (in any format) of your chosen piece of music. Please note that your response and attached audio file will be kept strictly confidential, and will be used for research purposes only. Of course, participation in this survey is entirely voluntary.

Thank you so much for your time,
Anthony Prechtl

SURVEY ON MUSICAL EMOTION

Please search your digital music collection for a piece of music within any genre that has a particular moment or short passage which evokes a peak emotional reaction within you, and indicate the artist's name and the title of the piece, as well as the genre, below:

---> (composer) – (title) – (genre)

At roughly what time does the emotional "peak" begin, and at roughly what time does it end?

---> from this beginning time: (min:sec) to this ending time:(min:sec)

Why did you choose this passage and piece? Please write as freely as you like.

--->

Please describe how this passage makes you feel.

--->

Lastly, if the piece of music has words (which is not necessary), do they mean anything to you?

--->

Please attach the audio file (any format, under 20 megabytes) in your response to aprechtl@gmail.com. If you need further assistance, are unable to attach files, or your file is over 20 megabytes, please e-mail me for help. My supervisor for this thesis is Suvi Saarikallio (Suvi.Saarikallio@campus.jyu.fi). Thank you so much!