AFFECTIVE RESPONSES TO MAJOR AND MINOR CHORDS IN HEAVY METAL MUSIC

by

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Dedication

This thesis is dedicated to my partner, Elijah Wiltshire, and his family in recognition of their steadfast support and encouragement throughout my academic journey. Their continued presence and belief in my abilities have been invaluable. I also dedicate this work to my sisters and cousins, whose ongoing support and encouragement have played a significant role in my personal and academic development. Their unwavering presence has been deeply appreciated, particularly during the challenges encountered along this journey.

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ABSTRACT

AFFECTIVE RESPONSESTOMAJOR AND MINOR CHORDS IN HEAVY METAL MUSIC

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Heavy metal music is oftenlabeled as an aggressive or purely negative genre, but listeners frequently experience complex emotional reactions when engaging with it. One understudied aspect of this emotional experience is how the use of major and minor chords can shape affective perception in heavy metal contexts. In Western tonal music, major chords are typically associated with positive emotions such as happiness or brightness, whereas minor chords are often associated with sadness or tension (Pallesen et al., 2003; Lahdelma & Eerola, 2016). However, these emotional associations may change depending on musical context, listener experience, and familiarity with a genre (Parncutt, 2014; Boddington & Herbst, 2023). The present study examined how major and minor chords in heavy metal influence emotional and neural responses. It was hypothesized that minor chords would elicit higher arousal and more negative valence compared to major chords, and that greater familiarity with heavy metal would reduce these differences. In Experiment 1, participants (N = 44) rated valence and arousal using the Self-Assessment Manikin (SAM) and completed the Short Test of Music Preferences

(STOMP). Results showed no significant differences in valence or arousal between chord types. However, higher STOMP scores were associated with increased valence and arousal ratings. In Experiment 2, participants (N = 40) completed the same behavioral measures while neural activity was recorded using electroencephalography (EEG). It was hypothesized that minor chords would produce greater beta activity than major chords. Behavioral results again showed no significant differences between chord types. EEG results revealed no significant differences in beta activity across baseline, major, and minor conditions, and no effects of familiarity.Overall, these findings suggest that harmonic mode alone does not determine emotional or neural responses in heavy metal. Instead, listener experience and genre context appear to play a more important role in shaping how music is perceived.

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CHAPTER I:

INTRODUCTION

Heavy metal music is often misunderstood as a purely aggressive genre;however, it offers rich emotional complexity. One underexplored dimension is how major and minor chords, which have well-established emotional connotations in Western tonal music, operate differently in heavy metal contexts. Traditional models associate major chords with happiness and brightness, and minor chords with sadness and darkness (Pallesen et al., 2003; Lahdelma & Eerola, 2016). However, such associations may be complicated by genre context, cultural learning, and listener experience.

A recent study by Olsen et al. (2023) examined the psychosocial risks and benefits of exposure to heavy metal music with aggressive themes, emphasizing how emotional outcomes depend on listener's prior experiences and engagement with the genre. Their findings show that listeners often experience a range of affective reactions, from heightened arousal to tension or discomfort, depending on how they process the musical and social context of the sound. Heavy metal tonality (major and minor chords) can shape affective perception, with emotional responses emergingfrom the interaction between musical structure and listener experience.

Olsen et al. (2023) also identified a key methodological limitation in the literature: most previous work relied on correlational designs or broad exposure measures rather than controlled manipulations of specific musical features. This calls for more experimental research that isolates variables such as tonality, tempo, and intensity to determine their causal role in emotional experience. The present study directly addresses that gap by systematically varying harmonic modes (chord types), while holding other acoustic factors constant.

Studies show that even single chords evoke consistent emotional reactions. Bakker and Martin (2015) used event-related potentials (ERPs) to show that major and minor triads elicit distinct neural responses within milliseconds of being heard, suggesting rapid, automatic affective processing. Similarly, Lahdelma and Eerola (2016) demonstrated that both trained and untrained listeners perceive major chords as happier than minor ones, though experts exhibit more nuanced discrimination.

Yet the emotional meaning of chords shifts when placed in context. For example, Zhang et al. (2025) found that chord progressions can modulate the perceived emotional valence of a chord, enhancing or diminishing its baseline effect. A major chord in a dark progression may not evoke happiness, while a minor chord in a heroic progression might feel triumphant. This aligns with the synthesis of Parncutt(2014), which argues that emotional responses to tonality arise from a mix of acoustic, perceptual, cultural, and evolutionary factors.

Within heavy metal, the emotional complexity of harmony becomes especially pronounced, often more so than in genres traditionally studied in music research, such as classical or jazz. The genre frequently juxtaposes dissonant, minor-key harmonies with themes of empowerment, resilience, and transcendence, resulting in a paradoxical emotional experience in which listeners may feel uplifted by “dark” sounds. Messick (2020) found that metal fans often ascribe sacred and emotionally resonant qualities to the genre, including feelings of awe, catharsis, and identity. These emotional interpretations suggest that minor chords may not be perceived by metal listeners as inherently negative, but rather as intense, expressive, and affirming.

Supporting this, Boddington and Herbst (2023) conducted a comprehensive harmonic analysis across five metal subgenres (death, black, doom, metalcore, and power metal) and identified distinctive harmonic features, such as modal mixture, chromaticism, and unconventional chord functions. In power metal specifically, the frequent use of the III chord (relative major) serves to evoke feelings of triumph and heroism, particularly in choruses and climactic sections. Their findings challenge conventional tonal-emotion associations and emphasize the need to account for both musical context and listener identity in studies of musical emotion.

Extending this perspective, it is also important to consider that heavy metal is not a monolithic genre but rather encompasses multiple subgenres. For example, death metal, thrash, symphonic, and melodic metal are each characterized by distinct tempo, timbre, and harmonic structures that elicit different affective responses (Olson et al., 2023). This stylistic diversity underscores the need to account for nuances such as tonal modality, and instrumentation when examining emotional perception in metal music. Even subtle variations in distortion, tempo, and rhythmic complexity can meaningfully shift the listener's affective experience. Therefore, recognizing these genre-specific elements is crucial for accurately interpreting how different forms of metal shape listener's emotional perceptions.

While large-scale studies such as Kolchinsky et al. (2017) found that minor chords are generally associated with more negative emotional valence, based on an analysis of 90,000 songs. Their work focused primarily on mainstream pop and rock, leaving a gap in understanding how harmony functions in more extreme or niche genres like metal. Sharman and Dingle (2015) similarly showed that fans of extreme metal use the genre for emotional regulation, directly challenging stereotypes that equate metal with emotional dysfunction or aggression.

Neuroscientific work by Vuust et al. (2022) and Chen et al. (2022) emphasizes that music engages distributed brain networks, including emotional, auditory, and motor systems, through predictive coding. That is, listeners derive pleasure from musical surprises that violate but ultimately confirm their expectations. This framework can explain why listeners enjoy minor chords in chaotic or dissonant contexts: their brains have adapted to anticipate and find reward in these structures.Most neuroscientific work focused less on the genre of heavy metal music. Much of existing neuroscience and music literature is based on traditional/mainstream genres (classical, pop, etc.), which may not fully reflect the intensity that the metal genre brings. Even existing music studies that include metal music, primarily focus on emotional outcomes rather than underlying neural or psychophysiological mechanisms(Rea et al., 2010).

Together, the literaturehighlights how genre conventions and subcultural listening practices shape affective responses to harmony, and why heavy metal offers a particularly rich context for exploring these dynamics. Moreover, research on chord perception and musical preferences suggests that emotional responses to harmony are shaped by both acoustic features and listener-related factors, including cultural background, affective style, and genre familiarity (Sharman et al., 2015). While major chords are generally associated with pleasantness and minor chords with sadness or tension, these associations are not fixed and can shift depending on musical context and listener identity.

However, most existing research on chord preferences has focused on genres such as classical, jazz, or pop, which tend to uphold conventional tonal-emotional associations. There is a notable lack of research examining how these dynamics operate in genres like heavy metal, which often subvert traditional emotional codes through the use of dissonance, minor modes, and aggressive timbres paired with empowering or cathartic themes. Moreover, it is critical to consider musical preferences when studying emotional perception, as heavy metal culture reflects a unique relationship to emotional expression, regulation, and community. For fans, emotionally intense or “dark” sounds are often experienced not as distressing, but as meaningful, affirming, and even healing. Moreover, the neural underpinnings of these experiences are still not well understood, particularly within the metal genre.

Aims & Hypothesis

Experiment 1

The first aim of Experiment 1 is to examine how harmonic structure (minor chords, major chords) in heavy-metal music influences self-reported affective perception, specifically valence and arousal. This aim focused on determining whether exposure to major and minor chords embedded within metal chord progressions produces differences in perceived valence (Aim 1A) and arousal (Aim 1B). Harmonic mode is commonly linked to emotional interpretation where major is associated with more positive affect and minor with more negative or tense affect. However, these relationships may not function in the same way within heavy metal music. The genre's intensity, distortion, and stylistic conventions may alter or complicate typical tonal–emotion associations. Because much of the existing literature has examined these effects outside of metal contexts, it remains unclear how listeners interpret harmony within this genre.

In this study, lower valence scores indicate more positive or pleasant affect, while higher scores indicate more negative or unpleasant affect. For arousal, lower scores reflect higher physiological activation (e.g., excitement or tension), whereas higher scores indicate lower arousal (e.g., calmness).

It was hypothesized that major chords would be associated with lower valence ratings (i.e., more pleasant affect), whereas minor chords would be associated with higher valence ratings (i.e., more unpleasant affect) (Aim 1A). However, it was also expected that individuals who report greater familiarity or preference for heavy-metal music may show a reduced distinction between chord types. They could potentially be interpreting minor harmonies as expressive or engaging rather than strictly negative.

For arousal (Aim 1B), it was hypothesized that minor chords would produce higher levels of arousal (i.e., lower arousal scores) compared to major chords, reflecting the intensity often attributed to darker harmonic content in metal music. In contrast, major chords were expected to elicit relatively lower arousal levels, particularly among listeners with less exposure to the genre.It was also expected that listeners that are familiar with the genre, may show a reduced difference in arousal as they may be more accustomed to the chords and features found in the genre. Conversely, it is expected that listeners with lower familiarity may higher arousal scores due to the harsh sounding musical components of heavy metal.

Experiment 2

Experiment 2 aims to examine the psychophysiological mechanisms underlying emotional responses to harmonic structure in heavymetal music. This aim is to analyze how neural activity differs in response to major versus minor chords when presented within metal music progressions. Specifically, this experiment seeks to determine whether differences in harmonic structure produce measurable changes in neurophysiological indicators of affective processing. Electroencephalography (EEG) will be used to assess neural correlates of emotional arousal associated with harmonic chord types.

Affective processing is commonly examined through changes in spectral power, particularly within the alpha (8–12 Hz) and beta (13–30 Hz) frequency bands. In the current study, neural activity will be quantified using root mean square (RMS) amplitude, which reflects overall signal power and provides an index of neural activation across time. RMS is commonly used in EEG research to capture changes in neural engagement associated with emotional and cognitive processing.

It has been shown that increases in beta-band activity are associated with heightened arousal, attentional engagement, and emotional intensity. Within heavy-metal music, minor chords are often associated with increased harmonic tension and dissonance, whereas major chords are typically associated with more consonant and stable harmonic structures. However, due to the intensity and stylistic characteristics of heavy metal music, these traditional associations may be altered or amplified.

It was hypothesized that exposure to minor chords within metal-style progressions will elicit greater emotional arousal, by increased beta-band RMS activitycompared to major chords. This increase in beta RMS activity is expected to reflect heightened neural activation and affective engagement in response to more tension-inducing harmonic structures. In contrast, major chords are expected to produce lower levels of beta RMS activity, indicating reduced physiological arousal. This pattern would reflect the heightened intensity and affective engagement typically evoked by harmonically darker and more dissonant passages in heavy-metal music.

CHAPTER II: Methods

Experiment 1: Behavioral Measures

Participants

44 adult listeners, aged 18–45, were recruited from the University of Houston–Clear Lake (UHCL) SONA participant pool. The SONA participant pool is an online platform where researchers can post information about their studies. Students enrolled in classes that need credits can complete those studies through SONA. The target sample size was determined using an a priori power analysis conducted in G*Power (Faul et al., 2007), following recommendations for transparent effect size justification and reporting (Lakens, 2013). Based on prior research demonstrating valence differences between major and minor chords (Kurzom et al., 2023), a moderate within-subjects effect size was assumed ($d = 0.50$). With $N = 46$ and $\alpha = .05$ for a two-tailed paired-samples t-test, the estimated statistical power was .87. The proposed sample size exceeds the conventional .80 threshold and provides adequate sensitivity to detect differences in affective responses to major versus minor harmonic modes. All participantsprovided informed consent prior to participation and received 1 SONA credit upon completion of the online session.

Materials

Short Test of Music Preferences (STOMP)

Participants' musical preferences were assessed using the Short Test of Music Preferences (STOMP; Rentfrow & Gosling, 2003). The STOMP is a 14-item measure designed to identify individual differences in music preference across four broad dimensions: Reflective and Complex, Intense and Rebellious, Upbeat and Conventional, and Energetic and Rhythmic. Participants rate their liking for various music genres (e.g., classical, rock, jazz, heavy metal) on a 7-point Likert scale ranging from 1 (strongly dislike) to 7 (strongly like). Higher scores within the Intense and Rebellious dimension indicated stronger preference for genres such as heavy metal and hard rock.

Major and Minor Chord Stimuli

Musical stimuli consisted of 60 instrumental heavy-metal chord excerpts (30 major and 30 minor) selected from verified YouTube recordings of professional tracks. Excerpts were identified, extracted, and analyzed using Chordify(Chordify, n.d.), which is an online music analysis platform that automatically detects and displays the chord progressions used in songs. It operates by analyzing the harmonic and tonal content of an audio file, such as a songs from YouTube, using automatic chord recognition algorithms. The software identifies individual chords (e.g., major, minor, seventh) in real time and converts them into a visual chord chart, showing when each chord occurs during the song.

In the current study, Chordify was used to ensure the accurate classification of harmonic mode (major vs. minor) in the instrumental heavy-metal excerpts used as stimuli. Each selected track was uploaded to Chordify, and its chord progression was verified for harmonic consistency before inclusion in the playlists. Using Chordify provided an objective, reproducible method for determining the tonal mode of each musical excerpt, ensuring that the major and minor stimuli were properly categorized prior to experimental presentation.The audio clips were 10 seconds in length and normalized for volume to ensure consistent playback. All excerpts were instrumental to avoid lyrical confounds. Each excerpt was verified to ensure correct classification as either major or minor before inclusion and was converted into an mp4 file.

Self-Assessment Manikin (SAM)

Affective responses to each musical excerpt weremeasured using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). The SAM is a nonverbal pictorial scale that measures two key dimensions of affect: valence (pleasant–unpleasant) and arousal (excited–calm). Each dimension is rated on a 9-point scale represented by schematic figures depicting increasing levels of pleasure and arousal. Participants select one figure per dimension to indicate their immediate emotional reaction after hearing each excerpt.

Headphones and Volume Calibration

Participants were instructed to wear headphones throughout the study to ensure accurate perception of harmonic content and consistent sound quality across sessions. Playback volume was stabilized using YouTube's internal normalization feature, which standardizes audio levels across all excerpts. Because the study wasadministered asynchronously online, participants used their own personal devices (e.g., laptops or desktop computers) in a quiet environment to minimize external distractions and variability in listening conditions.

Procedure

This study was approved by the UHCL Institutional Review Board (IRB#2025-196). Participants were directed to a Qualtrics survey link after logging into the SONA participant pool. The first Qualtrics link contained the informed consent form, which describedthe study's purpose, procedures, potential risks and benefits, and participants' rights to withdraw at any time without penalty. After reading the consent form, participants who chose to continue were automatically redirected to a second Qualtrics survey containing the experimental materials.

In the second survey, participants completed the STOMP assessment and then listened to instrumental heavy-metal music excerpts that were imported from YouTube and verified through Chordify for their harmonic structure (major vs. minor). Musical excerpts were organized into 60 trials, with each trial including a randomized sequence of major (30) and minor (30) chord progressions balanced across conditions. After each excerpt, participants reported their immediate emotional responses using a modified numeric version of the Self-Assessment Manikin (SAM; Bradley & Lang, 1994), which assesses valence (1 = very unpleasant, 9 = very pleasant) and arousal (1 = very calm, 9 = very excited). The entire session lasted approximately 30 minutes, including time for instructions, listening, and rating each excerpt. Upon completion, participants were asked to describe the music they listened to in the survey, ensuring accuracy in self-report measures. Once they completed the study, they received 1 SONA credit for their participation.

Experiment 2: EEG Measures

Participants

The target sample size was determined using an a priori power analysis conducted in G*Power 3.1 (Faul et al., 2007), following recommendations for effect size justification and transparent reporting (Lakens, 2013). Based on prior research demonstrating moderate effects of harmonic structure on affective and cognitive outcomes (e.g., Kurzom et al., 2023), a moderate within-subjects effect size was assumed. For a repeated-measures ANOVA with one within-subjects factor consisting of two levels (major, minor), the analysis was conducted using an effect size of $f = .25$, an alpha level of .05, and desired power of .80. The results indicated that a sample in the mid-30s would be sufficient. A target sample size of 40 participants was selected to ensure adequate statistical power while accounting for potential data loss due to EEG artifacts or participant exclusion.

Experiment 2 included 40 adult listeners (20 male, 20 female), aged 18 to 45, recruited from the University of Houston–Clear Lake (UHCL) SONA participant pool and from local music communities to ensure a diverse range of listening backgrounds and degrees of familiarity with the heavy-metal genre. Participants were screened for eligibility prior to participation and categorized according to their self-reported listening preferences from the STOMPwhich will later be treated as a continuous covariate in EEG data analyses. All participants will provide informed consent before beginning the laboratory session. UHCL students received 2 SONA credits, while community participants volunteered.

Materials

The behavioral measures used in Experiment 2 were identical to those described in Experiment 1. These measures include the STOMP (Rentfrow & Gosling, 2003) to assess musical preferences, the SAM (Bradley & Lang, 1994) to assess valence and arousal, and the excerpts of instrumental heavy-metal songs.Unlike Experiment 1, however, for Experiment 2the audio stimuli were embedded and presented via Labscribe rather than Qualtrics. Additionally, participants wore headphones provided by researchers to maintain consistent sound quality and minimize environmental interference.

Electroencephalography (EEG) iWorx ROAM headband

A non-invasiveiWorx Roam Wireless EEG headband was used to continuously record electrophysiological brain activity throughout the experiment. This lightweight, wireless system allows for naturalistic listening and minimizes participant discomfort during data collection. Participants were fitted with the EEG device prior to the start of the task, and electrode contact was checked to ensure optimal signal quality. The EEG system will focus on changes in beta (13–30 Hz) frequency bands, which are known to be associated with emotional arousal, attentional engagement, and affective processing. A frontal electrode configuration was used with Ag/AgCI electrodes positioned at FP1, FP2, F7 and F8 according to the 10/20 international system. The headband was placed across the middle of the forehead to capture activity in prefrontal regions of the brain. During the experiment, EEG data was time-locked using programmed markers to distinguish between task phases. The EEG data was segmented accordingly to isolate neural beta activity during the music-listening periods (14 seconds) from the response-related activity (12 seconds; 6secondsvalence, 6seconds arousal). EEG data was collected in real time using Labscribe as the recording software. All data wase secured in UHCL's psychology lab, password protected computers. For analyses, EEG was divided into epochs corresponding to the stimulus presentation windows, and the Root Mean Square (RMS) of beta values were computed to quantify overall signal amplitude within the epoch where music was played. RMS beta activity was extracted during the segments where minor and major chords were being presented. RMS beta activity is often linked to emotional arousal, which is typically associated with increased attentional engagement or affective processing.

Procedure

This study was approved by the UHCL Institutional Review Board (IRB#2025-196).The study took place in a sound-attenuated, controlled laboratory environment to minimize distractions and control for external variables. Participants first completed an informed consent form, and then a musical preference questionnaire (STOMP).After they completed the questionnaire, participants were then fitted with the EEG headband to record neural activity throughout the task. Participants thenremain still for a duration of five minutes while baseline data was recorded. Following the baseline, participants were instructed to sit comfortably while listening to a randomized sequence of songs through high-quality headphones; the same audio stimuli used inExperiment 1. Each trial consisted of musical excerpts featuring either a major or minor chord video (60 total trials; 30 each), presented within a full heavy metal progression. As in Experiment 1, after each audioexcerpt, participants completed a brief self-report assessment (modified SAM scale) evaluating valence (positive–negative emotional response), and arousal (level of emotional intensity). The audio clips were 14 seconds long, and participants had

6 seconds to enter in a score for valence and 6 seconds for arousal. The entire session lasted approximately 60 minutes. At the end of the experiment, participants were debriefed and given the opportunity to ask questions about the study's purpose and procedures. Participants were offered 2 SONA? credits for Experiment 2.

CHAPTER III:

RESULTS

Experiment 1 Results

Aim 1 Results

Paired-samples t-tests were conducted to examine differences in valence and arousal ratings between major and minor chord conditions. Descriptive statistics indicated that mean valence ratings were similar across conditions, whereas arousal ratings differed more substantially.For valence, there was no significant difference between minor (M = 4.93, SD = 1.94) and major (M = 4.84, SD = 1.83) chords, $t(43)$ = 1.16, p = .253, d = 0.17.For arousal, there was no significant difference between major (M = 4.64, SD = 1.53) and minor (M = 4.60, SD = 1.53) chords, $t(43)$ = 0.49, p = .629, d = 0.07.

Evaluation of the means suggests that harmonic mode (minor vs. major chords) did not substantially influence either valence or arousal. Valence ratings were slightly higher for minor chords compared to major chords, but this difference was small and not statistically meaningful. Similarly, arousal ratings were nearly identical across conditions, indicating that both chord types elicited comparable levels of responses. Variability in responses was also similar across conditions, as reflected by comparable standard deviations. Overall, these findings do not support the hypothesis, as no significant differences were observed between major and minor chords for either valence or arousal.

A Generalized Linear Model (GLM) was conducted to examine STOMP scores as a covariate on the effects of chord type (major, minor) on arousal and valence. The overall model was significant, $F(2, 85) = 19.07$, $p < .001$, $R^2 = .310$.There was a significant main effect for STOMP, $F(1, 85) = 38.07$, $p < .001$, indicating that higher music preference was associated with increased valence ratings. In contrast, there was no significant main effect of chord type, $F(1, 85) = 0.063$, $p = .802$, suggesting that valence ratings did not differ between major and minor chords.

A general linear model (GLM) was also used to examine the effects of chord type (major vs. minor) and music preference (STOMP) on arousal ratings. The overall model was significant, $F(2, 85) = 8.95$, $p < .001$, $R^2 = .174$.There was a significant main effect of STOMP, $F(1, 85) = 17.89$, $p < .001$, which indicated that higher music preference was associated with increased arousal ratings. There was no significant main effect of chord type, $F(1, 85) = 0.015$, $p = .902$, suggesting that arousal ratings did not differ between major and minor chords.

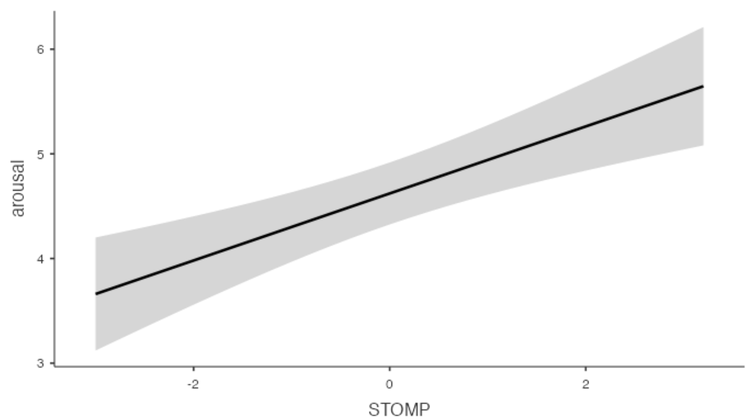

Figure 1. Linear relationship between music preference (STOMP) and predicted arousal ratings, collapsed across major and minor chords(p < .001).

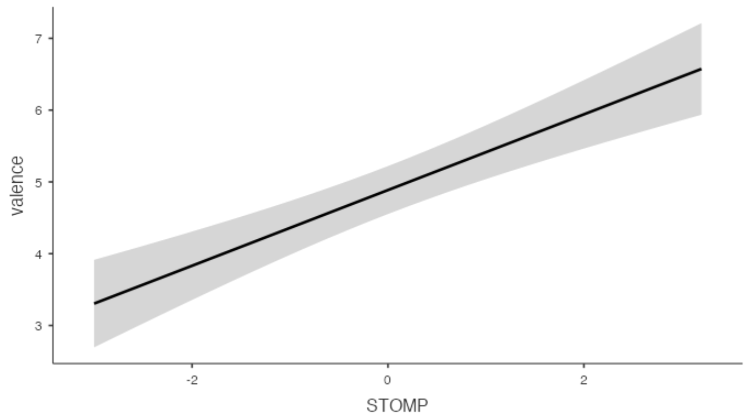

Figure 2. Linear relationship between music preference (STOMP) and predicted valence ratings, collapsed across major and minor chords (p > .05)

Experiment 2 Results

Aim 2 Results

Behavioral

First, the behavioral data was analyzed similar to those analyses for Experiment 1. To examine subjective emotional responses, paired-samples t tests were conducted on Self-Assessment Manikin (SAM) ratings of arousal and valence. There was no significant difference in arousal between the major (M = 5.16, SD = 1.46) and minor (M = 5.35, SD = 1.31) conditions, $t(39) = -1.60$, p = .118, $d = -0.25$. Similarly, there was no significant difference in valence between the major (M = 5.75, SD = 1.34) and minor (M = 5.83, SD = 1.48) conditions, $t(39) = -0.54$, p = .592, $d = -0.09$. These findings indicate that chord type did not significantly influence self-reported emotional valence or arousal.

Additionally, A GLM was conducted to examine STOMP scores as a covariate on the effects of chord type (major, minor) on arousal and valence. The overall model was significant, $F(2, 77) = 14.30$, $p < .001$, $R^2 = .271$. There was a significant main effect of STOMP, $F(1, 77) = 28.60$, $p < .001$, indicating that higher music preference was associated with higher valence ratings. There was no significant main effect of chord type, $F(1, 77) = 0.000$, $p = .995$, indicating that valence ratings did not differ between major and minor chord conditions. For arousal, a general linear model (GLM) was conducted to examine the effects of chord type (major vs. minor) and music preference (STOMP). The overall model was not significant, $F(2, 77) = 0.28$, $p = .755$, $R^2 = .007$.

There was no significant main effect of STOMP, $F(1, 77) = 0.18$, $p = .670$, indicating that music preference did not significantly predict arousal ratings. Additionally, there was no significant main effect of chord type, $F(1, 77) = 0.38$, $p = .539$, suggesting that arousal ratings did not differ between major and minor chord conditions.

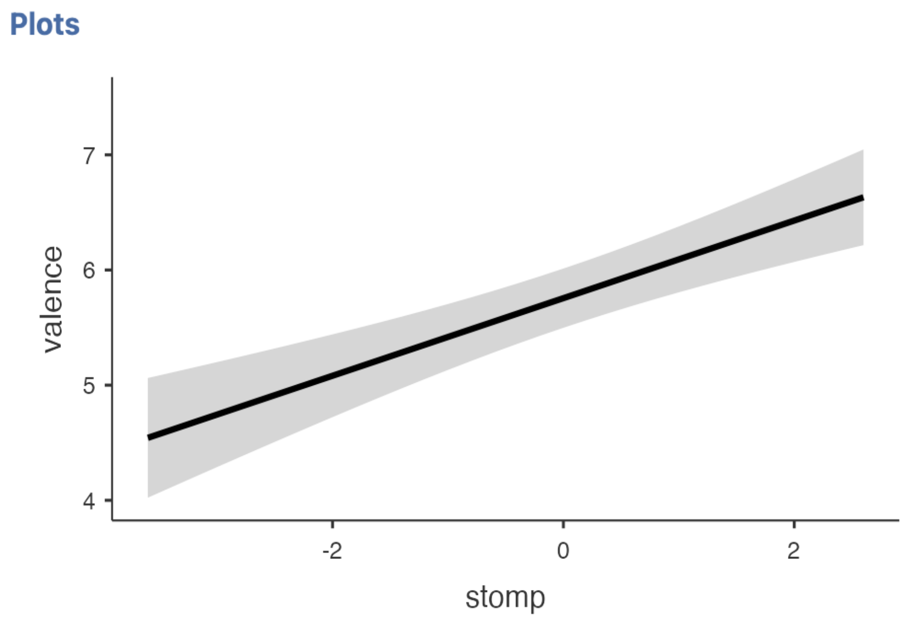

Figure 3. Linear relationship between music preference (STOMP) and predicted arousal ratings, collapsed across major and minor chords for Experiment 2 (p < .001).

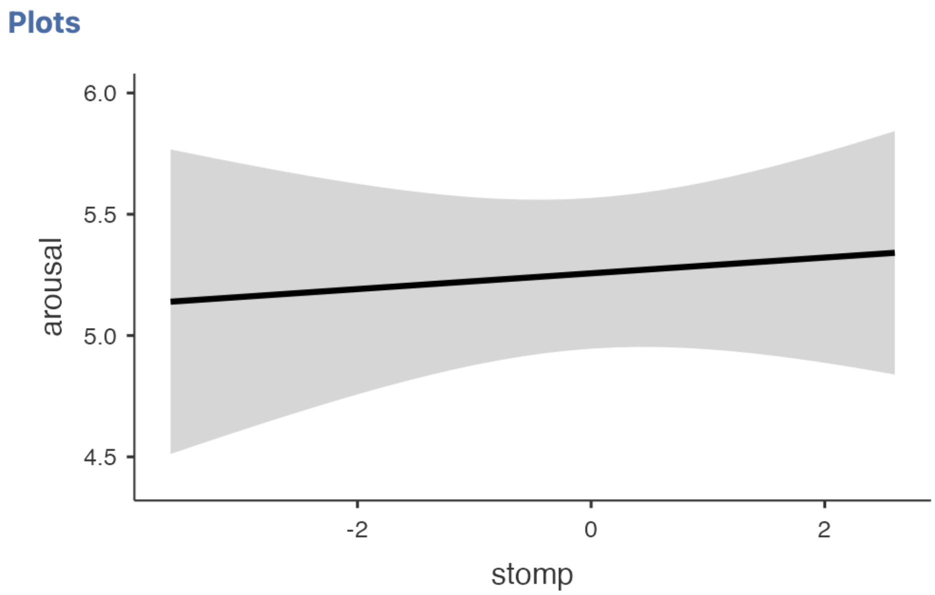

Figure4. Linear relationship between music preference (STOMP) and predicted valence ratings, collapsed across major and minor chords for Experiment 2 (p > .05)

Neural

A repeated measures analysis of variance (ANOVA) was conducted to examine the effects of chord type (baseline, major, minor) on log-transformed beta RMS values, with STOMP scores included as a covariate to account for individual differences in familiarity with heavy metal music. When the assumption of sphericity was violated, Greenhouse–Geisser corrections were applied.

There was no significant main effect of chord type, $F(1.54, 58.41) = 0.013$, $p = .970$, $\eta p^2 = .000$, indicating that beta activity did not significantly differ across baseline, major, and minor conditions. There was also no significant interaction between chord type and STOMP, $F(1.54, 58.41) = 0.293$, $p = .689$, $\eta p^2 = .003$, suggesting that familiarity with heavy metal did not moderate neural responses across conditions. Additionally, there was no significant main effect of STOMP, $F(1, 38) = 0.001$, $p = .978$, $\eta p^2 = .000$.

Discussion

The goal of this study was to examine how harmonic structure, specifically major and minor chords, influences emotional perception and neural activity within the context of heavy metal music. Overall, the findings suggest that traditional assumptions about major and minor emotional meaning do not fully apply in this genre. While previous research has consistently linked major chords with positive affect and minor chords with negative affect (Pallesen et al., 2003; Lahdelma & Eerola, 2016), the results of the present study showed a more nuanced pattern that depended on context and individual differences.

For Experiment 1, it was expected that major chords would be perceived as more pleasant and minor chords as more unpleasant. However, this hypothesis was not supported, as there were no significant differences in valence between conditions. This aligns with research suggesting that emotional responses to harmony are not fixed, but instead shaped by musical context (Parncutt, 2014; Zhang et al., 2025). Heavy metal often incorporates distortion, intensity, and complex harmonic structures that may override or blur typical tonal–emotion associations. For example, a minor chord embedded in a powerful or "heroic" metal progression may not be perceived as negative, which helps explain the lack of valence differences observed in this study.

For arousal, the results differed across experiments. In Experiment 1, minor chords were associated with higher arousal ratings, partially supporting the hypothesis that darker harmonic structures in metal are perceived as more intense. However, this effect did not replicate in Experiment 2, where no significant differences in arousal were observed. This inconsistency suggests that subjective reports of arousal may not always align with other measures, or that the context of listening may influence how participants interpret and report their emotional states.

The EEG findings from Experiment 2 further support this lack of differentiation between chord types. There were no significant differences in beta RMS activity across baseline, major, and minor conditions, and familiarity with heavy metal (STOMP) did not significantly influence neural responses. These results do not support the hypothesis that minor chords would elicit greater neural arousal compared to major chords. One possible explanation is that RMS, as a general measure of signal amplitude, may not capture the specific neural processes associated with emotional arousal. Research on music and the brain suggests that emotional responses involve distributed networks and predictive processing mechanisms (Vuust et al., 2022; Chen et al., 2022), which may not be fully reflected in overall signal amplitude alone.

Despite the lack of significant neural effects, the behavioral findings highlight the importance of listener-related factors. In both experiments, chord type did not significantly influence valence or arousal ratings. However, STOMP scores were positively associated with valence ratings, indicating that individuals with stronger music preferences tended to perceive the stimuli more positively overall. This supports the idea that emotional responses to music are shaped not only by acoustic features, but also by listener experience and familiarity with the genre (Sharman & Dingle, 2015; Olson et al., 2023).

Within heavy metal specifically, this interpretation is further supported by prior research. Metal listeners often experience the genre as emotionally meaningful, and even positive, despite its dark qualities (Messick, 2020). Rather than interpreting minor chords as negative, these listeners may perceive them as expressive or empowering. Additionally, harmonic analyses of metal music show that the genre frequently uses unconventional chord structures and modal mixtures that challenge traditional tonal expectations (Boddington & Herbst, 2023). This may explain why no overall differences were found between major and minor conditions, as emotional interpretation likely depends more on listener experience than on chord type alone.

There are several limitations that should be considered when interpreting the findings of this study. For Experiment 1, one major limitation is the lack of control over the listening environment. Because the study was conducted online, participants used their own personal devices and headphones, which may have introduced variability in sound quality. Participants may have also adjusted the volume of the music, which could have influenced their emotional responses, particularly for arousal. In addition, self-report measures such as the SAM rely on participants accurately assessing and reporting their own emotional states, which may not always reflect their true experiences. The study was not conducted in a controlled setting, meaning that distractions or environmental factors could have impacted participants' attention and responses. Technical issues related to personal devices, such as buffering or differences in audio playback, may have further contributed to variability in the data. Additionally, although the stimuli were controlled for harmonic structure, heavy metal music contains many other features, such as tempo, distortion, and rhythm, that may have influenced emotional perception. As noted in previous research, even subtle differences in musical features can significantly alter affective experience (Olson et al., 2023). These limitations may help explain why the hypothesis for valence was not supported, as we failed to reject the null hypothesis and found no significant differences between major and minor conditions. However, the hypothesis for arousal in Experiment 1 was partially supported, as we were able to reject the null hypothesis and found that minor chords were associated with higher arousal ratings.

For Experiment 2, there were also several limitations related to EEG data collection. EEG recordings are highly sensitive to movement and environmental interference, and artifacts in the data may have affected the accuracy of the RMS measurements. The use of RMS as the primary EEG measure may have limited the ability to detect differences in emotional processing, as it reflects overall signal power rather than frequency-specific activity. Future studies could examine frequency-specific activity, such as alpha or beta power, to better capture arousal-related neural responses. Similar to Experiment 1, the use of self-report measures alongside EEG introduces potential inconsistencies between subjective and physiological responses. Additionally, some participants reported hearing background noise, such as construction drilling near the UHCL lab, which may have interfered with both their concentration and neural recordings. These external factors could have reduced the sensitivity of the EEG measures and contributed to the lack of significant findings. Furthermore, the sample included participants with varying levels of familiarity with heavy metal, which may have contributed to variability in both neural and self-reported responses. As a result, the hypothesis for Experiment 2 was not supported, as we failed to reject the null hypothesis and found no significant differences in RMS beta activity between major and minor chord conditions.

Future Directions

Future research should continue to explore how musical context and listener characteristics interact to shape emotional perception. Examining different subgenres of metal, or directly comparing metal to other genres, could provide further insight into how harmonic meaning shifts across contexts. It would also be useful to incorporate more sensitive physiological measures or combine EEG with other methods, such as skin conductance or heart rate, to better capture emotional arousal.

Conclusion

In conclusion, this study highlights that emotional responses to music cannot be fully explained by harmonic structure alone. Instead, they emerge from a complex interaction between the music itself, the listener, and the broader cultural context. These findings reinforce the idea that heavy metal offers a unique framework for studying emotional perception, as it challenges traditional assumptions and emphasizes the importance of experience, identity, and context in shaping how music is felt and understood.

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