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Measuring the Ineffable: Perspectives on Tonal Consonance and Dissonance

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Abstract. This paper is a review article that explores the concept of tonal consonance and dissonance, focusing on prominent studies conducted throughout history. The perception of consonance and dissonance in music intervals is a complex phenomenon that has been approached from various perspectives. Early theories, such as Helmholtz's beat theory and Stumpf's tonal fusion, laid the groundwork for understanding the subjective experience of pleasantness and tension in musical intervals. Subsequent studies by Krueger, Malmberg, Guernsey, and others provided further insights into the cognitive and sensory processes underlying consonance and dissonance. Plomp and Levelt's research on the absence of beats and Sethares' exploration of timbre's influence on consonance are significant contributions to the field. The article also discusses the role of neural synchrony and biological frameworks in understanding consonance and dissonance. Overall, the studies reviewed in this article shed light on the multifaceted nature of tonal consonance and dissonance, highlighting the interplay between perception, cognition, timbre, and neural processing.

Keywords: Tonal consonance, Tonal dissonance, Tonal perception

1 Introduction

Spectral analysis of an instrument's timbre reveals spectrum and envelope information that makes up for the perception of timbre for said instrument. Spectral information includes the number of partials present and the fundamental frequency of the timbre. Musical tuning systems are a definition of a set of tones, or pitches constructed from relationship between different frequencies which acts as a basis for musical compositions. The distance between each pitch to the root or first pitch in a set of pitches are musical intervals. Similar to musical intervals, the distance of each partial to the fundamental of a timbre are too intervals, described in ratios. Formalisations of tonal consonance and dissonance relating to timbre and musical intervals are presented in this paper.

© The Author(s) 2023
F. Mustaffa (ed.), *Proceedings of the 3rd International Conference on Creative Multimedia 2023 (ICCM 2023)*,
Advances in Social Science, Education and Humanities Research 786,
https://doi.org/10.2991/978-2-38476-138-8_30

2 Prominent studies on tonal consonance and dissonance

An interval is said to be consonant if it sounds pleasant, with little to no tension or dissonant if it sounds unpleasant, with high tension [1]. The degree of pleasantness (consonance) and unpleasantness (dissonance) are described in Helmholtz's explanation on the phenomenon of beats. High frequency beating occurs if the interval between two pitches is sounded close together due to the interference between the two frequencies. As the interval moves closer, beating frequency lowers and disappears as the two frequencies becomes identical [2]. Plomp and Levelt experimented with consonance by asking participants in their study to rate the degree of pleasantness for different intervals using pairs of pure tones. The result from this experiment is the consonance curve, which shows how consonance levels change as an interval gets larger. High consonance was observed at unison and tapers down to dissonance as the interval gets larger [3]. This paper investigates significant studies, highlighting the different approaches and methods used in the pursuit of understanding consonance and dissonance.

2.1 Helmholtz

Beat theory is one of the earliest observations on tonal consonance and dissonance. Consider two sinusoidal waveforms, one of which with a frequency slightly higher than the frequency of the other waveform. When listened simultaneously, a beating frequency is heard [4]. This beat frequency is the absolute difference between the two frequencies. If the frequency of the waveform with the higher frequency lowered, the observed beating frequency too is lowered. This beat frequency disappears completely as the second frequency is lowered further to match the first. Consonance is observed with the absence of a beat frequency, where consonance is described as pleasantness and stability. While dissonance is observed with the presence of a beat frequency, where dissonance is described as unpleasant and grating.

2.2 Stumpf

Differing from Helmholtz's approach which reduces a tone into its individual components, Stumpf introduced his view on consonance and dissonance which stresses on the idea of verschmelzung (fusion) or more specifically, tonverschmelzung (tonal fusion) [5] which states that several pitches played simultaneously will be perceived as one, thereby losing their individual components [6]. Different combinations of pitch vary in their degree of fusion, and consonance is the degree of which these pitches fuse together [7]. An experiment was conducted by Stumpf in 1890 [5] where musically untrained individuals listened to several intervals and observed that they are either listening to a single tone or two different tones [7, 8].

2.3 Krueger

Kruger argues that because Helmholtz's beat theory relies heavily on overtones, it does not explain consonance with tones without or with few overtones. While for Stumpf's tonal fusion experiment, Kruger opined that it suffers some discrepancies with subject's experience, and it was premature of Stumpf to arrive to a physiological hypothesis. Krueger conducted an experiment with a large number of intervals with independent subjects having no prior knowledge of the objective. Difference tones was observed to be of fundamental importance to the perception of consonance and dissonance. Perfect consonances such as unison and octave contain no difference tones while the number of difference tones increases with complexity of the interval frequency ratios [9]. Krueger's difference tones theory was criticised by Stumpf in which he argued consonance and dissonance are perceived even when the two tones are presented separately, one to each ear, which excludes the possibility of difference tones [10].

2.4 Malmberg

Malmberg's 1918 compilation of prior studies on consonance and dissonance dates back from the 12th century up to 1911. These studies rank intervals from consonance to dissonance using various methods including theoretical, mathematical, and analytical [10]. Simple intervals such as the octave, fifth and fourth are largely agreed to be the most consonance out of all twelve tones. As the interval ratio increases in complexity, disagreement in ranking order between the different studies are more pronounced. This leads to the idea that fundamental reasons for the divergence in ranking consonance and dissonance was due to the lack of common ground definition of consonance. Malmberg suggested that the perception of consonance is a cognitive process involving the factors of blending, smoothness, and purity, effectively taking both Helmholtz's and Stumpf's perspective into consideration. To support his definition of consonance and dissonance, Malmberg conducted studies with trained observers to identify interval ranking. These studies were repeated with the piano and tuning fork as the tone source. From these studies, it was observed that the order of interval ranking varies for different tone qualities [10].

2.5 Guernsey

Guernsey derived a list of criteria for the definition of consonance from previous studies which are sensory fusion, smoothness, feeling and affection, and habit and familiarity. Addressing these criteria, Guernsey conducted experiments on three groups of subjects - musically untrained, with moderate musical training and very advanced musical performers. Contrary to Malmberg's method of prior knowledge, Guernsey strictly employed method of ignorance wherever possible. For example, subjects were not given a definition of the term smoothness and were allowed to interpret the terms in their own manner. The study concluded that consonance cannot be defined in terms of either fusion or smoothness, tonal fusion is sensorial and distinct from aesthetic or affective experience of consonance, judgement of tonal smoothness is dependent on the musical experience of the listener and of the criteria listed, feeling and affection seem most legitimately applied to consonance. Guernsey concludes that the differences in the perception of consonant intervals is dependent on the criteria of judgement and the musical training of the individual rather than the quality or intensity of tones. While fusion and smoothness are conditioned by tone quality, intensity, and duration among other factors [11].

2.6 Guthrie and Morrill

The results of Guthrie & Morrill's experiment shares resemblance to an earlier experiment by Brues albeit achieved using a drastically different method. Both Guthrie & Morrill and Brues were studying fusion of non-musical intervals where non-musical intervals are defined as intervals beyond the 12 tone intervals used in western music [12, 13]. Brues experimented with four observers by having them listen to two notes and recording the degree of fusion from 1 (no fusion) to 5 (perfect fusion) [12]. The first note was a constant pitch throughout the observation and the second note are varied to include 24 quarter tone intervals from unison to octave. In Guthrie & Morrill's experiment, 44 simple tone intervals were explored with multiple groups of approximately 50 observers per group, bringing a total of approximately 380 observers [13]. Observers records each tone combination given at random as either pleasant or unpleasant. The same series of tone combination are then given to the same group of observers for them to judge each combination as consonant or dissonant. The study concluded that consonance or pleasantness does not coincide with intervals of simple ratio or with musical intervals of the 12-tone equal tempered scale commonly used in western music, and for the average individual the notion of consonance and pleasantness are closely identical [13].

2.7 Plomp and Levelt

In a study by Kaestner, pairs of intervals of both simple and complex tones are presented to observers to indicate which interval was more pleasant. Findings from this study showed peaks signifying high indication of pleasantness for simple frequency ratios in the case of the complex tone. While in the case of the simple tone, simple frequency ratios did not show prominent peaks, rather, it suggests frequency distance as the decisive parameter. Based on this study coupled with findings from Guthrie & Morrill's experiment, Plompt & Levelt observed that Helmholtz's beat theory supported the results of these two experiments well. Additionally, for the case of simple tones, there are no peaks for simple frequency ratios, suggesting that interval recognition is the result of musical training. In regard to complex tones, the absence of beats or difference tones is not clear as without beats or difference tones, it could be simply the case of a single partial belonging to either one of the two complex tones. Plompt & Levelt seeks to investigate more thoroughly the hypothesis that tonal consonance is due to the absence of beats [3]. Kaestner conducted his study using the frequencies 256Hz and 320Hz as the fundamental to construct the interval ratios while Guthrie & Morrill used 395Hz, hence these studies does not provide information on how the evaluation of intervals might be influenced by frequency. Plomp & Levelt conducted an experiment with 5 groups, each group consisting between 11 to 22 subjects and was assigned to judge 12 to 14 intervals constructed with a fundamental in various range of frequencies. This study revealed results with similarities to the results from Kaestner's and Guthrie & Morrill's study. It also revealed that Helmholtz's view on roughness or dissonance is caused with two frequencies with a difference between 30Hz to 40Hz only holds true for intervals constructed with fundamental frequency ranging between 500Hz to 1000Hz. Higher fundamental frequencies show a wider frequency difference to cause dissonance or beating. Plompt & Levelt concluded that a modification of Helmholtz's view is necessary and states that instead of a constant frequency difference, the difference is proportional to the critical bandwidth [3]. Maximal tonal dissonance is produced by intervals subtending 25% of the critical bandwidth and maximal tonal consonance is produced at 100% of the critical bandwidth. In the case of complex tones, consonance no longer depend only on the distance between two fundamental frequencies, but also between the partials. Plomp & Levelt assumed that dissonance may be added. For an interval of a complex tone, the total dissonance is equal to the sum of the dissonances of each pair of neighbouring partials. Total dissonance for a lower complex tone with a fundamental frequency of 250Hz and a varying fundamental for a higher complex tone, with both tones containing 6 harmonics are calculated and plotted. The plot reveals peaks which signifies consonance at frequency ratios containing numbers 1 to 6. The use of a complex tonecontaining 8 harmonics would yield peaks at ratios containing numbers 1 to 8, which shows that for complex tones, consonance is related to simple frequency ratios.

2.8 Sethares

Citing Carlos, who observed that the timbre of an instrument strongly affects what tuning and scale sound best on said instrument, Sethares interprets the term "timbre" to refer to the spectral components and the term "sounds best" to refer to Plomp & Levelt's theory on tonal consonance. Sethares seeks to establish a relationship between the timbre of a sound and a set of intervals in which the timbre will sound most consonant [14]. Sethares proposed two computational techniques, first to find consonant scales given a specified timbre and second to find consonant timbres given a specified scale. These techniques are based on the concept of local consonance. Local consonance is based on the dissonance curve which in turn is based on Plompt & Levelt's consonance curve [3] that is flipped to highlight dissonance instead of consonance. Given a timbre, if sounded at various intervals, the dissonance curve for said timbre can be calculated by adding up all the dissonances between each pair of partials as proposed by Plomp & Levelt [14].

2.9 Lots et al.

Lots et al. explores the theory of synchronisation properties of ensembles of coupled neural oscillators to demonstrate why they are important for auditory perception [15]. In an earlier experimental study, it was observed that patients with cerebral cortex lesions lack the ability to evaluate consonance compared to normal patients [16]. This study leads to the question, whether the source of musical perception occurs in the inner ear or if specific neural pathways devoted to consonance and dissonance computation exists. In another study, electroencephalography (EEG) responses of subjects exposed to pairs of pure tones show that consonance is determined by neural processing in the auditory cortex, not just solely on the absence of perceived roughness [17]. Lots et al. concludes that there may be more than one neural source that contributes to the perception of consonance and dissonance. Additionally, neural synchrony had been postulated as an important mechanism in auditory perception, supporting Lots et al.'s observation that preference for simple frequency ratios in pure tones may be a natural consequence of neural synchronisation.

2.10 Bowling and Purves

Bowling & Purves highlighted a biological framework for understanding consonance and dissonance. It was argued that natural sounds, such as streams of water and wind contains little to no periodicity. Periodic sounds, however, can be found in nature, in sound signals produced by animals for social communication. As an example, for the human species, briefly hearing human vocalisation is sufficient to form an impression on the source's sex, age, emotional state, and identity. Just as most musical tones, vocalisations are harmonic. The presence of the harmonic series is then a characteristic that defines human social life. In respect to music, Bowling & Purves suggests that our attraction to harmonic tones is possibly biological in part, due to the similarity and our familiarity with vocalisations [18].

3 Tonal consonance across western music periods

This chapter illustrates how the perception of consonance and dissonance has shifted over different historical periods, reflecting changes in compositional practices, aesthetic values, and the cultural context of the time. It's important to note that these shifts are general trends, and individual composers and musical styles within each period may have had their own unique approaches to consonance and dissonance.

3.1 Medieval Music

During the medieval period (9th to 14th centuries), the perception of consonance and dissonance was influenced by the practices of Gregorian chant and early polyphony. Consonance was primarily associated with perfect intervals, such as the perfect fourth and perfect fifth, while imperfect intervals, such as the major and minor thirds, were considered dissonant. Dissonances, including the tritone, were generally avoided or resolved quickly.

3.2 Renaissance Music

In the Renaissance period (14th to 16th centuries), there was a shift in the perception of dissonance. Composers such as Josquin des Prez and Giovanni Pierluigi da Palestrina introduced controlled and carefully prepared dissonances. Dissonant intervals, such as the major and minor seconds, were used to create tension and were resolved by stepwise motion to consonant intervals. The concept of consonance expanded to include certain dissonant sonorities treated within the rules of counterpoint.

3.3 Baroque Music

In the Baroque period (17th to early 18th centuries), composers like Johann Sebastian Bach and Antonio Vivaldi further expanded the use of dissonance and the perception of tension. Dissonant intervals, including suspensions and passing tones, were skillfully employed to create expressive and dramatic effects. Composers began to explore chromaticism and the use of dissonant harmonies, leading to more complex harmonic language.

3.4 20th Century and Avant-Garde Music

In the 20th century, the perception of consonance and dissonance underwent significant changes with the advent of experimental and avant-garde movements. Composers such as Arnold Schoenberg, Igor Stravinsky, and Béla Bartók explored atonality, dissonant harmonies, and unconventional tonal systems. The concept of dissonance expanded to include extended techniques, dissonant clusters, and microtonal intervals. These new approaches challenged traditional notions of consonance and dissonance.

4 Tonal consonance across different musical cultures

The concepts of tonal consonance and dissonance provide a framework for understanding and analyzing the emotional impact and tension in music. Consonance refers to a sense of stability and agreement between musical tones. Consonant intervals and chords sound pleasant and stable to our ears. Dissonance, on the other hand, refers to a sense of tension and instability in musical tones. Dissonant intervals and chords sound harsh or unresolved. It's important to note that the perception of consonance and dissonance can vary across different musical cultures and historical periods. Prominent studies in this area are mostly focused on western musical traditions. However, what is considered consonant or dissonant may be influenced by cultural, historical, and personal factors. In this chapter we will present examples where perception of tonal consonance and dissonance varies across different musical cultures.

4.1 Traditional African Music

In Western classical music, intervals such as the major and minor thirds are considered consonant and are extensively used. However, in certain traditional African musical cultures, these intervals may be perceived as dissonant. African music often employs intricate polyrhythms and melodic patterns that prioritize other intervals, such as the perfect fourth or the major sixth, which may be perceived as consonant in those contexts.

4.2 Indian Classical Music

Indian classical music has its own system of melodic structures called ragas. The perception of consonance and dissonance in Indian classical music is based on different principles than those in Western music. The concept of "shruti" plays a crucial role, which refers to the microtonal variations between the twelve notes of the Western chromatic scale. Certain intervals that might be considered dissonant in Western music, such as the minor second or tritone, can be employed and perceived as consonant within specific ragas in Indian classical music.

4.3 Indonesian Gamelan Music

Gamelan music, indigenous to Indonesia, features ensembles of tuned percussion instruments. The tuning systems used in gamelan music may incorporate intervals that are not traditionally found in Western music. Some gamelan scales include intervals known as "slendro" and "pelog." These scales may contain intervals that sound dissonant in a Western context but are perceived as consonant and aesthetically pleasing within the gamelan tradition.

4.4 Middle Eastern Maqam System

The maqam system, used in Middle Eastern music, encompasses a set of melodic modes. It incorporates microtonal intervals and scales that differ from the equal-tempered intervals of Western music. Some intervals that might be perceived as dissonant in Western music, such as quartertones or smaller microtones, can be utilized and considered consonant within specific maqam contexts.

4.5 Japanese Traditional Music

In Japanese traditional music, particularly in the context of gagaku (ancient court music), the concept of consonance and dissonance is unique. Gagaku often employs intervals which are microtonal pitch bends between notes. These pitch bends can create subtle dissonances that are intentionally used and appreciated within the aesthetic framework of Japanese traditional music.

4.6 Indigenous American Music

Various indigenous American tribes have their own musical traditions that feature distinct tonal systems. For example, the music of the Inuit people incorporates vocal techniques such as throat singing and the use of harmonies that differ from Western harmony. The perception of consonance and dissonance in these traditions can vary from Western conventions and reflect the specific cultural context and musical aesthetics of such communities.

5 An observation of tonal consonance and dissonance in popular music

Popular music, including genres like rock, can incorporate dissonance intentionally and creatively. Dissonant elements, such as distortion, are often embraced as part of the genre's aesthetic, and the perception of consonance and dissonance can evolve over time as musical tastes change. The emotional impact and expressiveness of the music play a crucial role in how dissonance is perceived and appreciated in popular music.

5.1 Distortion as an Aesthetic

Commonly used in rock music, introduces harmonic dissonance by intentionally distorting the sound waveforms of electric guitars or other instruments. This effect adds overtones and creates a more aggressive, gritty, and powerful sound. While distortion introduces dissonance in terms of added harmonics, it is often perceived as an essential part of the genre and can contribute to the overall aesthetic and emotional impact of the music.

5.2 Evolution of Musical Taste

Over time, musical tastes and perceptions change. What may have been considered noisy or dissonant in the past can gradually become widely accepted and even celebrated in popular music. As listeners become exposed to new sounds and styles, their perception of what is consonant or dissonant can shift. Certain genres and musical techniques, once considered avant-garde or unconventional, can find acceptance and appreciation as musical tastes evolve.

5.3 Emotional Impact and Expressiveness

In popular music, dissonance can be intentionally used to convey emotional intensity, rebellion, or edginess. The dissonant elements can create a sense of tension, adding excitement and energy to the music. The perception of dissonance in this context is often associated with the emotional impact and expression rather than strict adherence to traditional harmonic rules.

6 Conclusions

In conclusion, the studies reviewed in this article provide valuable insights into the perception of tonal consonance and dissonance. While there are differing theories and approaches, it is evident that consonance and dissonance are complex phenomena influenced by multiple factors, including frequency ratios, tonal fusion, difference tones, sensory fusion, smoothness, familiarity, and neural processing. The studies demonstrate that there is no single universal definition of consonance and dissonance, and their perception is subjective and context dependent. The findings also highlight the importance of considering timbre and the spectral components of sound in understanding tonal consonance and dissonance. The relationship between timbre and interval perception suggests that the perception of consonance is not solely determined by frequency ratios, but also by the spectral characteristics of the sound. Furthermore, the studies indicate that the perception of consonance and dissonance involves cognitive processes, neural synchrony, and the interaction between different parts of the auditory system. This multidimensional nature of consonance and dissonance necessitates a holistic approach that takes into account both perceptual and physiological aspects.

Overall, this article provides an overview of prominent studies on tonal consonance and dissonance, shedding light on the complexities of this phenomenon and laying the foundation for further research in the field. Understanding the perception of consonance and dissonance is crucial not only for the field of music theory and composition but also for fields such as psychology, neuroscience, and auditory perception. Further research is needed to explore the interplay between different factors and to develop a more comprehensive understanding of the mechanisms underlying the perception of tonal consonance and dissonance.

References

1. Terhardt, E. (1984). The concept of musical consonance: A link between music and psychoacoustics.
2. Helmholtz, H. (2013). On the sensations of tone. Courier Corporation.
3. Plomp, R., & Levelt, W. J. M. (1965). Tonal Consonance and Critical Bandwidth. The Journal of the Acoustical Society of America, 38(4), 548–560. doi: 10.1121/1.1909741
4. Rasch, R. A. (1984). Theory of helmholtz-beat frequencies. Music Perception: An Interdisciplinary Journal, 1(3), 308-22.
5. Schneider, A. (2005). Music, Gestalt, and Computing, Studies in Cognitive and SystematicMusicology. , 115–143. doi: 10.1007/bfb0034111
6. Martinelli, R. (2013). Themes from Brentano: Brentano and Stumpf on Tonal Fusion.
7. Dewitt, L. A., & Crowder, R. G. (1987, 1). Tonal fusion of consonant musical intervals: The oomph in Stumpf. Perception & Psychophysics, 41(1), 73–84. doi: 10.3758/BF03208216
8. Apel, W. (2003). The harvard dictionary of music. Harvard University Press.
9. Krueger, F. (1913). Consonance and Dissonance. The Journal of Philosophy, Psychology and Scientific Methods, 10(6), 158. doi: 10.2307/2012516
10. Malmberg, C. F. (1918). The Perception of Consonance and Dissonance. Psychological Monographs, 25(2), 93–133. doi: 10.1037/h009311
11. Guernsey, M. (1928). The Role of Consonance and Dissonance in Music. The American Journal of Psychology, 40(2), 173. doi: 10.2307/1414484
12. Brues, A. M. (1927). The Fusion of Non-Musical Intervals. The American Journal of Psychology, 38(4), 624. doi: 10.2307/1414398
13. Guthrie, E. R., & Morrill, H. (1928). The Fusion of Non-Musical Intervals. The American Journal of Psychology, 40(4), 624. doi: 10.2307/1414344
14. Sethares, W. A. (1993). Local consonance and the relationship between timbre and scale. The Journal of the Acoustical Society of America, 94(3), 1218–1228. doi: 10.1121/1.408175
15. Inbal Shapira Lots, L. S. (2008). Perception of musical consonance and dissonance: an outcome of neural synchronization. Journal of the Royal Society, Interface, 5(29), 1429-34.
16. Peretz, I., Blood, A. J., Penhune, V., & Zatorre, R. (2001, 05). Cortical deafness to dissonance. Brain, 124(5), 928-940. Retrieved from https://doi.org/10.1093/brain/124.5.928 doi: 10.1093/brain/124.5.928
17. Itoh, K., Suwazono, S., & Nakada, T. (2003). Cortical processing of musical consonance: an evoked potential study. Neuroreport, 14(18), 2303–2306.

18. Bowling, D. L., & Purves, D. (2015). A biological rationale for musical consonance. Proceedings of the National Academy of Sciences, 112(36), 11155–11160. doi: 10.1073/pnas.1505768112

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