A Study Design About the Influence of Spectrum Content in the Perception of Consonant and Dissonant Chords

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Abstract. *This paper tackles the basis for the musical consonance analysis and its relationship with the spectral content of chords present in the tonal system and, based on this, propose an experiment that explores through electroencephalography a relation between the harmonic nature of musical instruments and the brain response to the auditory stimulus.*

1. Introduction

Harmony is the basis of western music history. Consonance X Dissonance is the most important concept of harmony and it is perceived in the structure of tonal music or even in the emancipation of dissonance produced by the 20th century music.

In this study, we propose an experiment based on the idea of psychoacoustic dissonance[Helmholtz, 1954] [Plomp and Levelt, 1965], analysing the degree of dissonance in the spectra synthesized with different waveforms and implement an experiment similar to Pierce's [Pierce, 1966] on the construction of the octatonic spectrum.

During the auditory stimulus, it will be measured the EEG activity of the participants to search for correlations between the consonnant sounds and the brain activity as showed in Park et al. [Park et al., 2011] and Maslennikova et al. [Maslennikova et al., 2013] looking for influence of the number of partials in the consonance perception.

2. Brief theory review

2.1. Sensory or psychoacoustic dissonance

Dissonance is a multidimensional attribute of sound and it can be approached in many ways, for instance by considering its cultural aspects, volunteers' level of musical practice or even the physical properties of the sound. Tenney [Tenney, 1988] divide these approaches to the study of dissonance in five different categories: melodic, polyphonic, functional, counterpointistic and psychoacoustic. In this paper we will see the idea of psychoacoustic dissonance, which then "reduces itself to one scientific, psychophysic aspect, disconnected to cultural and aesthetic factors, for example, which matches to complementary dimensions" [Porres, 2012].

*The authors would like to thank CAPES and the Sonology Research Center at USP.

With the work of Plomp and Levelt [Plomp and Levelt, 1965] we have a review of the Helmholtz theory [Helmholtz, 1954], starting with the concept of critical bandwidth, defined as the smallest band of frequencies that activates the same region of the basilar membrane. With information obtained via an experiment with volunteers without musical training, they checked the degree of consonance between two sinusoidal sounds and realized that the roughness sensation appears only to intervals that are inside the same critical bandwidth, with the highest roughness sensation happening inside a quarter of the critical bandwidths [Sethares, 2005].

Considering that, starting from the decomposition of a spectrum in sinusoidal waves, it is possible to create the dissonance curves of complex tones, adding the dissonance relations between their partials. Figure 1 shows the consonance curve of a complex tone with six harmonic partials, demonstrating the highest consonance on intervals with simple ratios, confirming the practice of the traditional study of western harmony.

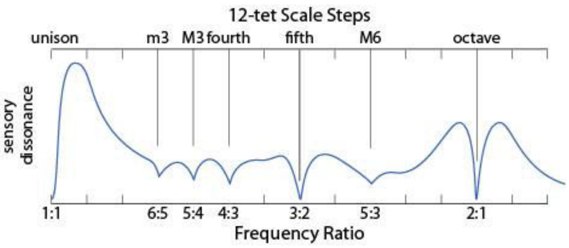

Figure 1: 6-partial sinusoidal dissonance curve

Based on Plomp an Levelt work [Plomp and Levelt, 1965], Pierce [Pierce, 1966] speculated the possibility of synthesis of inharmonic spectrum to obtain consonance on arbitrary scales. Starting with the octatonic scale (a octave divided in eight parts) we have $r = \sqrt[8]{2} = 1.09051$, and according to Sethares [Sethares, 2005],the octatonic spectrum partials are obtained by multiplying a base frequency by : $1, r^{10}, r^{16}, r^{20}, r^{22}$ and r^{24}.

Symmetrically dividing an octave in 4 parts, Sethares makes a comparison between the 12-tone scale and 8-tone scale based on the dissonance curve generated by the octatonic spectrum. We can see in Fig. 2 that there is a coincidence of maximum consonance between the 3th, 6th, 9th and 12th divisions of the 12-tone scale and 2th, 4th, 6th and 8th divisions of the 8-tone scale. So, using this spectrum, the diminished triads sound consonant and the perfect triads sound dissonant.

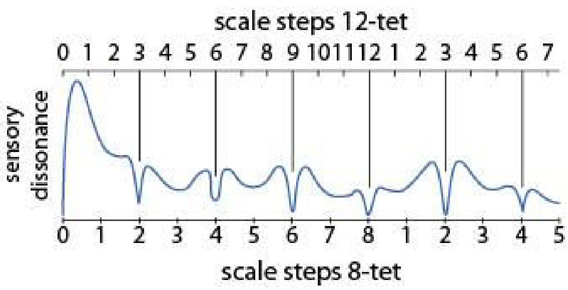

Figure 2: Octatonic spectrum dissonance curve

2.2. Partials and sound synthesis

We were curious about the influence of a different number of partials in the sounds used for the experiments. So we decided to run the same test using different timbres each round. The waveforms used were the classic sinusoidal, triangular, square and sawtooth waves. These waveforms were extensively used in the analog subtractive synthesis context [Dodge and Jerse, 1997]. The waveforms harmonic contents are summarized in Table 1.

Waveform	Partials present	Amplitude decay
Sinusoid	only the fundamental	–
Triangular	fundamental + odd partials	$1/p^2$
Square	fundamental + odd partials	$1/p$
Sawtooth	fundamental + all partials	$1/p$

Table 1: Harmonic content of classic waveforms. p is the partial index

Although just intonation is the more appropriate form to eliminate the roughness on perfect chords and thus achieve the highest level of consonance, in our experiment we apply the tempered system. Some discrepancies between the classical waveforms spectra and the equal temperament do not affect the perception of consonance on major and minor triads. We can see that on dissonances curves on [Porres et al., 2006].

In order to experiment with the octal spectrum, the additive synthesis technique was used to prepare the synthesis model. In this paradigm, each partial of the desired signal is created as an instance of a sinusoidal oscillator with it's own amplitude, frequency and phase parameters [Dodge and Jerse, 1997]. Also, a piano-like sound, the default SuperCollider[1] instrument will be used in the tests.

3. Experiment details

The proposed experiment consists of recording the EEG activity during the auditory stimulus with specific musical excerpts, which will be synthesized with different waveforms containing different spectral content, so we can check the influence of the partials on the consonance. We will test the classic waveforms of table 1, another waveform with the octal spectrum and a piano timbre.

The participants will be divided in 4 groups: popular music inclined musicians, academic trained musicians, music lovers lacking musical education, and people who do not care about music. In such a way we can investigate the influence of musical knowledge in the results, as pointed by [Park et al., 2011] [Maslennikova et al., 2013].

3.1. Musical excerpts

For the construction of musical excerpts we relied on octatonic spectra cited on this paper. Therefore, the chords sequence have only perfect and diminished triads. In Figure 3 we can see the sequence I, IV, V, I and between them their respective diminished dominants, creating a tension and resolution movement.

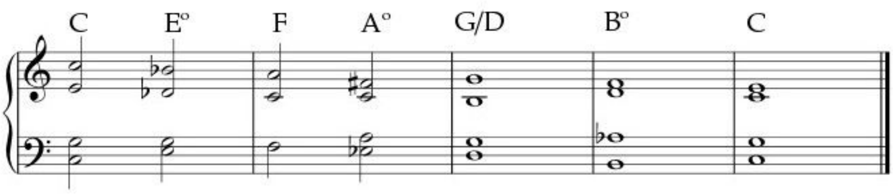

Figure 3: The musical excerpt used in the experiments

We prepared our musical excerpts with SuperCollider, although any language could be used. The SuperCollider code and audio excerpts can be downloaded[2], and we encourage their use and modification.

[1] http://supercollider.sourceforge.net/
[2] http://www.ime.usp.br/~ag/dl/audio-exp.zip

3.2. Analysis parameters and expected results

From the recorded EEG data we will look at both the different frequency bands RMS (Root Mean Squared) power between the chord changes and the ERPs related with the chord changes. This results will be grouped by the spectral content and the subjects musical knowledge. We are expecting three kinds of results:

- confirmation that Gamma activity will increase during the consonant chords and decrease during the dissonant chords as shown in [Park et al., 2011];
- checking if as the spectral content enriches the levels of the Gamma Band record higher values in the consonant parts and lower values in the dissonant parts, in comparison with the tests with less partials;
- check if there is a inversely proportional relation between the number of harmonic partials and the levels registered in the Gamma band for the dissonant parts;

4. Conclusion and ongoing work

Based on what was exposed in this paper we believe to have enough background to proceed with the proposed experiment and achieve significant results.

In order to help us foreseeing possible problems that can cost us time on the session, and also to help improving or tuning our methodology we want to share our ideas with the academic community, as we will have only limited access to a EEG system in a laboratory at our university, and we depend on a lot people that we will ask to contribute to this work as volunteers.

We hope the results obtained with this experiment can be used as basis for other experiments in the future for a deeper investigation of sound cognition and for the development of new EEG based Brain-Computer Interfaces

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