Comenius University in Bratislava
Faculty of Mathematics, Physics and Informatics

Constrained by convention: Emotional effect of microtonality on professional musicians and non-musicians

Diploma thesis

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THESIS ASSIGNMENT

Name and Surname:	Bc. Marek Osrman
Study programme:	Cognitive Science (Single degree study, master II. deg., full time form)
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Title: Constrained by convention: Emotional effect of microtonality on professional musicians and non-musicians

Aim: Review the literature on the aspects of sound, music, microtonality and emotional experiences associated with it. Design and perform an experiment on the emotional aspects of microtonal music. Analyze the data and provide a conclusion with possible further research.

Literature: Juslin P.N. & Sloboda J.A. (2001). Music and emotion: Theory and research. Oxford University Press.
Sethares W.A. (2005). Tuning, Timbre, Spectrum, Scale. Springer Science & Business Media.

Annotation: Various studies have been conducted on the topic of music and emotions. Most of them take into account only the most prevalent tuning system – 12-tone equal temperament. There are infinite possible tuning systems available and some of them might yield emotional responses similar to those in the standard one. In the planned experiment, we expect that the professionality will negatively influence the emotional responses, while non-musicians will process novel systems with more ease. Analysis of the data could provide ground for further research and experiments in the field of non-standard tuning systems and microtonality.

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ZADANIE ZÁVEREČNEJ PRÁCE

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Študijný program: kognitívna veda (Jednoodborové štúdium, magisterský II. st., denná forma)
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Názov: Constrained by convention: Emotional effect of microtonality on professional musicians and non-musicians
Obmedzenie konvenciou: Emocionálny efekt mikrotonality na profesionálnych hudobníkov a nehudobníkov

Cieľ: Urobte prehľad literatúry zameranej na aspekty zvuku, hudby, mikrotonality a ich emocionálnych zážitkov asociovaných s nimi. Navrhnite a realizujte experiment skúmajúceho emocionálne aspekty mikrotonálnej hudby. Analyzujte dáta a urobte závery s potenciálnymi návrhmi pre ďalší výskum.

Literatúra: Juslin P.N. & Sloboda J.A. (2001). Music and emotion: Theory and research. Oxford University Press.
Sethares W.A. (2005). Tuning, Timbre, Spectrum, Scale. Springer Science & Business Media.

Anotácia: Vzťahu hudby a emócii sa venovali mnohé štúdie, avšak väčšina z nich vzala do úvahy len najbežnejší systém ladenia – 12-tónový „equal temperament". Existuje však nekonečne veľa ladiacich systémov a niektoré z nich môžu vyvolať emocionálne zážitky podobné tým v štandartnom ladení. Cieľom experimentu je potvrdiť alebo vyvrátiť odhad, podľa ktorého profesionálne vzdelanie negatívne ovplyvňuje emocionálne vnímanie, zatiaľ čo nehudobníci príjmajú nové systémy s väčšou ľahkosťou. Analýza dát môže ponúknuť zázemie pre budúci výskum a návrhy experimentov v oblasti neštandardných ladiacich systémov a mikrotonality.

Vedúci: doc. PhDr. Ján Rybár, PhD.
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Comenius University in Bratislava
Faculty of Mathematics, Physics and Informatics

Constrained by convention: Emotional effect of microtonality on professional musicians and non-musicians

Diploma thesis

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Abstrakt

Cieľom práce je identifikovať a preskúmať rozdiely vo vnímaní neštandardných (mikrotonálnych) akordov hudobníkmi a nehudobníkmi na emocionálnych škálach GEMS (Geneva Emotional Music Scale). Na teoretickej rovine sa práca zaoberá prehľadom akustiky, psychoakustiky a systémov ladení, ktoré sú mimo štandardného tzv. temperovaného ladenia. Experimentálna časť predstavuje výsledky výskumu s 35 zvukovými stimulmi (akordy založené prevažne na tzv. prirodzenom ladení), ktoré mali participanti za úlohu hodnotiť na 9 emocionálnych škálach (Radosť, Sentiment, Pokoj, Energia, Smútok, Nežnosť, Napätie, Spirituálnosť, Úžas).

Vykonaný experiment na vzorke 13 participantov (6 hudobníkov a 7 nehudobníkov) preukázal štatisticky významné rozdiely vo vnímaní niektorých emócii. Na základe Mann-Whitneyho U Testu sa ukázali rozdiely v emóciach Radosť ($p = 0.18$) a Úžas ($p = 0.21$). V korelačných maticiach emócii pre obe skupiny boli nájdene markantné rozdiely ($\Delta p > 0.5$) u párov Energia x Smútok a Úžas x Smútok, v oboch prípadoch smerujúce ku negatívnej korelácii u hudobníkov. Možné vysvetlenia týchto zistení sú rozvinuté v diskusii.

Kľúčové slová: psychoakustika, emócie, mikrotonalita, xenharmónia

Abstract

The goal of this thesis is to identify and explore the differences in perception of non-standard (microtonal) chords by musicians and non-musicians on GEMS (Geneva Emotional Music Scale). On the theoretical side, the work contains overview of acoustics, psychoacoustics and tuning systems that are beyond the standard equal temperament. Experimental part represents the results of the study with 35 audio stimuli (chords based mainly on Just Intonation tuning) which were evaluated by participants on 9 emotional scales (Joyful Activation, Sentiment, Peacefulness, Power, Sadness, Tenderness, Tension, Transcendence and Wonder).

The experiment conducted on the sample set of 13 participants (6 musicians and 7 non-musicians) indicated statistically significant differences in perceiving certain emotions. Findings from Mann-Whitney U Test showed differences in emotions Joyful Activation ($p = 0.18$) and Wonder ($p = 0.21$). The emotion correlation matrices for both groups yielded major differences ($\Delta p > 0.5$) in pairs of Energy x Sadness and Wonder x Sadness, with both cases leading to negative correlation in musicians. Possible explanations of these findings are elaborated in the discussion.

Keywords: psychoacoustics, emotions, microtonality, xenharmony

Acknowledgments

People in this list helped enormously in the process of making this thesis. There is not enough words to describe my gratitude and respect to them for their patience, honesty and willingness to go above and beyond for the thesis to succeed. In no particular order:

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This thesis is dedicated to Pavol Osrman

Table of Contents

1. FOREWORD

We live in a world of conventions. Grass is green, sugar tastes sweet and the musicians use 12 basic tones per octave to compose and perform music. But the real, physical world is full of sensory stimuli that is continuous in its nature and it is up to our choice to categorize it into smaller, discrete labels. Such labels often arise from physical and biological needs and characteristics, but also as a result of convenience and allow the development of systems that are easier to understand and to use.

C, C#, D, D#, E, F, F#, G, G#, A, A#, B

Figure 1-1. The 12 tones of equal temperament.

Sound is very interesting in this regard. The more the musicians hone their skill of musicality, the more they become accustomed to the standard tuning systems of their culture. For the majority of the world, it is the 12-tone equal temperament that is predominantly taught and used. It is based on natural consonance of tones and convenience of instrument tunings. This might, after a period of exposure, "bound" the musicians to categorize the continuous spectrum of instrument tones to the individual notes, while every tone that does not fall within the categories is rejected as "out-of-tune" and frowned upon. It is, after all, easier to think in terms of individual notes than the whole spectrum. But this spectrum contains infinite number of tones and tone combinations nonetheless.

Our goal is to explore the phenomenon of microtonality (usage of intervals that are beyond the ubiquitous 12-tone equal temperament) and its effect on emotions. The last two decades have brought substantial research on emotions and music, but in general, it only focused on music composed in the equal temperament. We would like to extend this research and provide data showing perceived emotions in non-standard musical intervals. Afterwards, by differentiating two groups based on musicianship, we propose a research question: "Are musicians constrained by the conventional tuning system so they perceive non-standard intervals more emotionally negative than non-musicians?"

2. INTRODUCTION

The first goal of this thesis is to provide the reader with the basic overview of the theory of sound and harmony, the theory of emotions and the relationship between sound and emotions. These topics are covered in order in chapters 3, 4 and 5. The theoretical introduction is highly recommended for readers who are new to the discussion about sound and/or emotions, but can be used as a good refresh before jumping into the experimental section. In the case of very interested and curious reader, a chapter titled "Further Reading" is present at the end of the theoretical section. It contains more detailed overview of a number of publications that are referenced throughout this thesis and can fulfill the desire for knowledge or for leisure reading.

The second goal is to describe our experimental approach to studying the perceived emotions in microtonal chords presented to people with varying degrees of musical experience. The expected behavior is that participants categorized as musicians will perceive the structures that are out of bounds of the standard western tuning as more negative (higher tension, sadness, nostalgia) than non-musicians. The experiment carried out on a sample of 13 participants and the results are statistically analyzed and discussed. The experiment design, results and discussion are found in the chapters 7, 8 and 9 respectively.

The third goal is omnipresent in the whole thesis and it aims to raise awareness of the research in psychoacoustics (the science of sound perception and processing), alternative tunings and microtonality. Due to low number of empirical studies dealing with psychoacoustics found in domestic academic community (Cenkerová, 2017) it is important to continue in this effort and bring more experimental and interdisciplinary research.

3. THEORY OF SOUND

What happens when someone makes a loud clap? What feeling it creates in people that will hear it? When two palms collide with each other, the pressure of the air suddenly rises and, in the form of a ripple, propagates through the space. The energy that the "ripple" carries can either be consumed by materials that it encounters, or, in the scenario that we will focus on, enters the ear canal of a person and vibrates their eardrum. Sound can have many different forms, but it is omnipresent in our world and takes very important place as the stimuli of one of our five senses.

1. Sound characteristics

What makes piano sound different from explosion? How can sound characteristics influence the psychoacoustical experiments and why it matters to choose the appropriate sounds? We will take a look at various physical dimensions of sound – length, frequency, sound pressure level, spectrum and also on subjective equivalents such as pitch, loudness and timbre.

Length

Example: short click vs sustained piano note

If a sound is generated in an anaechoic chamber (sealed room with as small sound reflection as possible), the length of a sound is equal to the duration of the activity of the sound source. But as most materials that surround us do reflect sound, the perceived length of a sound can be longer. A gunshot in a open valley would sound longer than in a small wooden cabin. This is caused by reflection, diffusion and refraction of sound off non-absorbent materials (e.g. rocky mountains). Short sudden bursts of sound (clap, gunshot, playing staccato on a instrument) evoke the sense of urgency, draw attention and are often connected with dangerous situations. Longer sounds such as wind blowing or slow brushes of a bow on the string of a violin carry calmer, less energetic meaning. The length of the sound thus correlates more with arousal of the sound.

Pitch and frequency

Example: low guitar string vs. high guitar string

Pitch and frequency of a sound are loosely related attributes of a sound. Frequency is a physical characteristic of wave oscillations per second (measured in hertz – Hz). Pitch, on the other hand, is a subjective term and is identified either by a measure of "mel" or more commonly by terms from musical system that is used (e.g. cents, semitones). Due to the nature of human hearing system, it is possible to perceive frequencies between 20 and 20 000 Hz, but these numbers are not uniform for all people, nor are they constant throughout the life. The upper limit decreases with age and also by various health issues, such as listening to loud music or working in noisy environment (Patterson, Nimmo-Smith, Weber, & Milroy, 1982).

The ideal frequency range for psychoacoustical stimuli is in the 300 Hz – 3500 Hz range, that is the frequency range of average human voice, where the ear has the highest sensitivity.

Loudness and sound pressure level

Example: whisper vs. shout

When discussing the intensity of the sound, it is important to distinguish two related measures – Sound pressure level (SPL) and Loudness. SPL is measured in decibels where 0dB is the lower limit of audibility (at 1 kHz) and 94 dB equals to pressure of 1 Pa (Pascal). From approximately 80 dB the sound pressure is considered dangerous for human hearing. Normal human conversation occurs at around 40 – 60 dB.
Loudness on the other hand is subjective perception of sound pressure level. Human ears do not have flat response to all frequencies at all levels. The middle frequencies (where the most of natural sounds and speech occur) are perceived as louder than the low and high frequencies. Because of this, when talking about SPL, it is important to note the reference frequency, usually 1 kHz.

For sounds, often the louder the sound is, the higher arousal and attention it creates. This only applies to a certain loudness level, due to discomfort that loud sounds induce. The phenomenon "Loudness war" that peaked around 2007 was based on the idea that loud music is more emotionally engaging than quiet music, thus pushing record companies to produce recordings that are as loud as possible (Deruty & Pachet, 2015).

Timbre and spectrum

Example: sound of guitar vs. sound of piano

The timbre, or often called "color" of the sound is a characteristic of the instrument (or sound generator in general), its construction, shape, material, use, etc. In the physical terms, timbre is identified by the overtones present in the tone, spectral characteristics and the amplitude envelope (the course of amplitude of the sound).
Spectrum is the representation of the amplitudes of each frequency in the sound. It is usually created by Fourier transformation of the sound to simple sine waves and displayed as a spectrum curve where the X axis plots the spectrum and Y axis the amplitude in that particular frequency.

It is very complicated to connect timbre to a valence-arousal spectrum because each instrument can be used in a different setting and produce different response. We will take a closer look at effect of timbre on emotions in the next chapter.

2. Timbre and psychoacoustics

As we have discussed in the last chapter, sound can have different characteristics and attributes that can influence the perceived emotions. For psychoacoustical experiments it is crucial to select sounds that carry no emotional characteristics on their own. If we would use for example a violin sound (timbre) with a slow onset (dynamics) and warm tone (pronounced low end of the spectrum), the participant could get primed into thinking about sad songs, melodies, maybe a movie they once saw which had such musical cues, etc. On the other hand, even the purest clean tones can evoke the sense of sterility and alienate or detach the listener from the experiment. There is a very fine line between familiarity of the tones and choosing the stimuli that has the least amount of unwanted and uncontrollable variables.

Another problem concerning microtonal chords or stimuli that contain multiple tones sounding at the same time is the interference of overtones. Notice how in the Figure 3-1 the combination of overtones at around 225 Hz produces a tone that has higher amplitude that the fundamental frequencies of the original tones. This shows how two tones with the same overtone structure can generate unexpected hidden frequencies that do not correlate with the original intention.

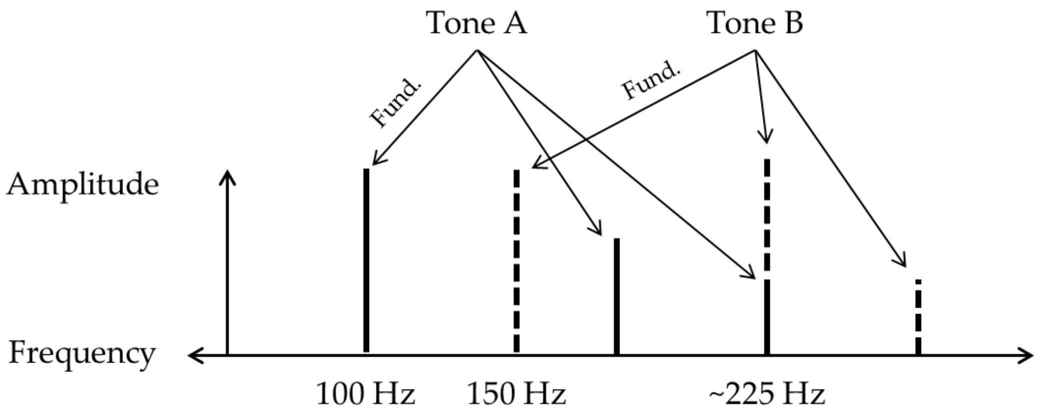


Figure 3-1. Combining of two tones with same harmonic content.

Great deal about this topic has been covered in the book “Tuning, Timbre, Spectrum, Scale” (Sethares, 2005), especially chapter 6 and 7 that cover relationships between spectral structure of tones and tuning.

4. MUSIC SYSTEM

If we had to make music just by using frequencies, mathematical formulas and scientific notation, we would get quickly bored and reproducing the music piece would get tiring not only while writing, but also while playing. Collaboration between multiple artists would be difficult, because everyone could use different frequencies for their instruments and tuning them together might be next to impossible. The listener would be bombarded with musical pieces that are difficult to comprehend and familiarity in music would be non-existent. On the other hand, this world of unrestricted tones could be a magnificent place where everyone is free to express and no one is bound by any rules.

Musical systems were created not to hinder one‘s creativity, but rather the opposite – to provide a common ground on which the artists can build, together. A musical system is a collection of rules that set the notes, scales, intervals and other patterns in the sound spectrum that are important for that particular system.

1. Overview of basic tuning systems

Pythagorean tuning

The legend says that Pythagoras was once listening to smiths using their hammers, smashing them against anvil. Hammers were of different size and produced different clangs. Some of them were harmonically related - they sounded good together, while others were dissonant and produced ear-disturbing sound together. Upon further research, Pythagoras found out that the sizes of the hammers were at certain relations between each other. The "good sounding" pairs had simple whole number/integer ratios of sizes, e.g. one hammer was twice the size of the other (octave) or having a ratio of 3:2 (interval of fifth, second most consonant interval after octave). On the other hand, the dissonant pairs had complicated ratios (e.g. 11:23) (Guthrie & Fideler, 1987).

Most likely this story is a medieval folk tale (Freed, 2008), but it does summarize the basics of interval-based scales.

Pythagorean scale is one of the most basic tunings due to the fact that it incorporates only interval of fifths (3:2). The idea can be encompassed by the following procedure:

1. Take a starting tone, for example D at 288 Hz
2. Multiply the starting tone by 3:2, giving 432Hz – the tone A
3. Divide the starting tone by 3:2 (multiply by 2:3), giving 192Hz – the tone G
4. Repeat steps 2 and 3; in case the calculated tone is outside of an octave from the starting point, adjust it by multiplying/diving it with 2 (octave transposition)
5. The two paths of multiplying and dividing will eventually (after 12 tones) converge to a roughly same tone, but each of them will be just a quarter-tone apart from the other. This difference is called Pythagorean Comma.

The drawbacks of this approach are that there is always one interval (wolf interval) which has to be adjusted by a quarter-tone. Any interval that uses the adjusted note will sound very dissonant. This tuning has been used until the 15^{th} century, even despite its not very flexible nature.

Just Intonation

Just intonation is in a theory similar concept to Pythagorean tuning, because it also uses intervals to lay notes on the scale. The basic idea is to use as simple intervals as possible. Octave is the second most consonant interval (after unison, which happens when two frequencies are equal) and can be represented as "2:1", meaning the second frequency is 2-times higher than the first. The next possible interval is 3:2, which is the third most consonant interval, also called "perfect fifth" (the basic of Pythagorean tuning, see previous chapter). This way we can continue and construct other intervals such as 4:3 (perfect fourth), 5:3 (major sixth), 6:5 (minor third), etc. Just Intonation has sonic advantages due to perfect intervals between tones that resemble resonances found in nature, but carries a similar burden as Pythagorean tuning due to low flexibility when transposing to other keys. An instrument tuned to Just Intonation in C would sound very dissonant if one would play in any other key.

Equal temperament

Another way how to approach musical scale construction is to divide the octave into a number of equally divided intervals. Such approach is called "equal temperament". The most famous and widely used is the 12-tone equal temperament (12-TET or 12ET), which divides the octave into 12 parts (tones) with each part consisting of 100 cents, thus making 1200 cent octave. There are infinite number of possible equal temperaments, each for every possible number.

The major advantage of equal temperament over interval-based tuning systems is that all of the intervals are equally spaced, no matter where the scale starts (compared to interval based tunings, which can have wolf tones and/or problems with transposition). For example a Major Third from C is the same interval as Major Third from F#, that is 400 cents.

The flexibility, convenience and allowance for complete harmonic freedom made the equal temperament the most popular tuning system for the last 300 years.

	Equal Temperament		Just Intonation		
Note Name	Interval	Cents	Intervals	Cents	Description
C	1.0	0	1:1	0	Unison
C#	1.059	100	16:15	111.7	Minor Second
D	1.122	200	9:8	203.9	Major Second
D#	1.189	300	6:5	315.6	Minor Third
E	1.26	400	5:4	386.3	Major Third
F	1.335	500	4:3	498.0	Perfect Fourth
F#	1.414	600	45:32	582.5	Tritone
G	1.498	700	3:2	702.0	Perfect Fifth
G#	1.587	800	8:5	813.7	Minor Sixth
A	1.682	900	5:3	884.4	Major Sixth
A#	1.782	1000	16:9	996.1	Minor Seventh
B	1.888	1100	15:8	1088.27	Major Seventh
C	2.0	1200	2:1	1200	Octave

Figure 4-1. The overview of 12-tone equal temperament, Just intervals and the approximated note.

2. Consonance and dissonance

It would be easy just to talk about singular tone and its characteristics, but the world is comprised of more than one perfect sine wave. The truth is rather opposite – pure sine waves do not exist naturally and most of the sounds that we hear are combinations of multiple tones, overtones and noise. When two or more waves occur at the same time, the listeners ear has to process not only both of them but also their interaction.
Two sinewaves can interfere each other with either constructive or destructive interference, depending on their phase.

But what if the sinewaves have different frequencies? The phase of the waves changes at the speed of frequency difference. For example if S_1 has a frequency of 220 Hz and S_2 frequency of 221 Hz, the resulting phase interference cycles every second (1 Hz). This is also called a "beat" and it is possible to hear such subtle effect for example when holding two notes on a guitar that are the same pitch, but are just barely out of tune. The more are out of tune, the faster the beat is, until at around ΔS = 10 Hz (difference between the frequencies of the sine waves) it becomes a "rough" attribute of a tone and then the two sinewaves become noticeable (Plomp & Levelt, 1965).

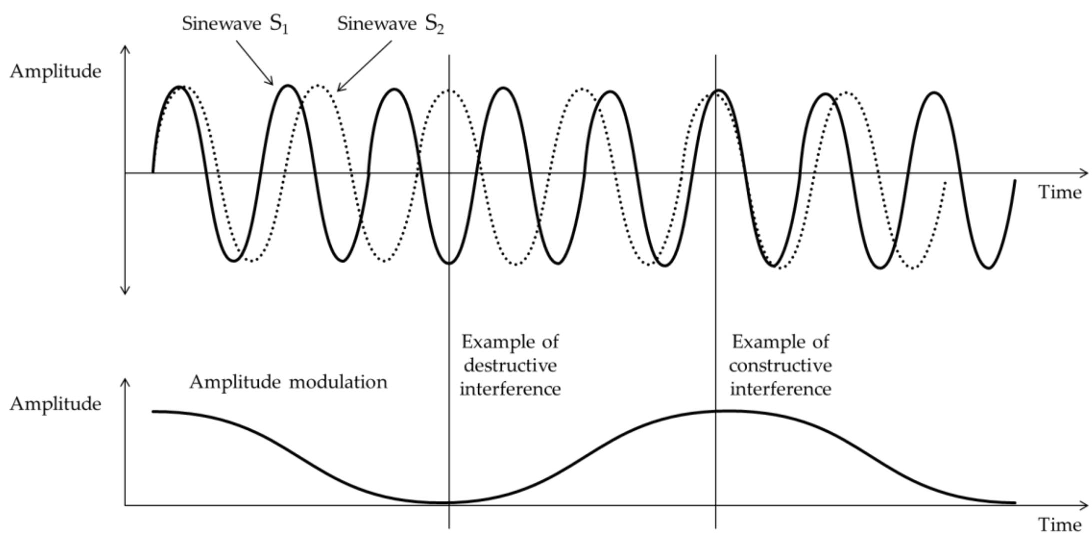


Figure 4-2. Beating phenomenon explained by two detuned sinewaves.

If we continue increasing the frequency difference at some point around ΔS = 50Hz the two sinewaves become two tones, albeit very dissonant ones. The Figure 4-3 shows sensory dissonance for such two tones. Notice the dips (or peaks in consonance) at certain intervals. We have talked about these in the last chapter when building the tuning systems. The idea of most popular tuning systems is to use such intervals and allow for consonant note combinations to be created.

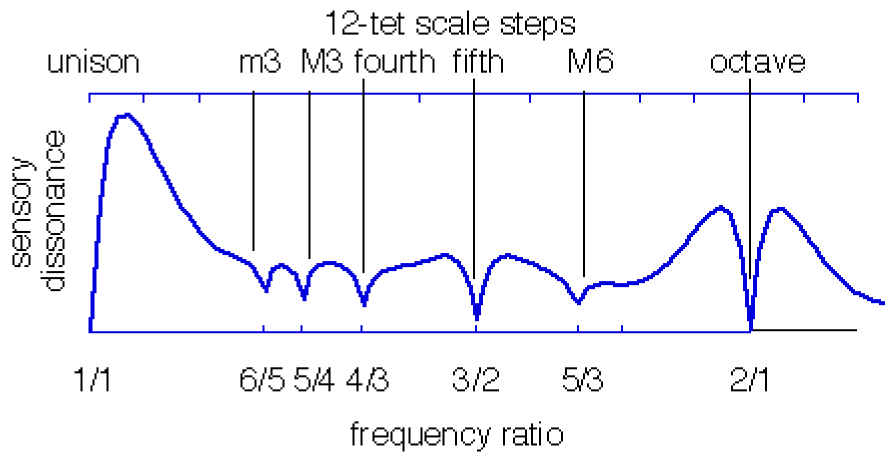


Figure 4-3. The dissonance curve for sinewave (Sethares, 2005)

3. Microtonality

The term "microtonal" refers to intervals that are smaller than semitone (microintervals), but often is used to identify tunings that differ from equal temperament. Other, less common name for this is "xenharmony" (from Greek *xénos* = stranger, foreigner). We decided to use the more prevalent term throughout this thesis.

As we mentioned in the foreword, the world of sound is continuous, thus allowing for infinite combinations and systems to be created and explored. Microtonal tunings challenge every preconception of standard equal temperament and they provide a way how to systematically tap into the sound continuum. Some ways how to approach new tuning systems are for example:

Equal division of the octave

Equal temperament divides the octave into 12 parts, but that number can be different. Popular equal temperaments (also called ET or TET) are 7-TET, 13-TET, 21-TET, 35-TET, but theoretically systems of 1-TET (only octave) or 0-TET (only unison) can exist.

Interval-based systems

Pythagorean tuning or Just Intonation used pure intervals that have as smallest numerator and denominator as possible (e.g. 3:2, 4:3, 5:3). This approach can be generalized by constructing such system where all of the tones can be represented by fractions with denominator that is less or equal to a number. 5-limit and 7-limit tunings are the most common ones, while 9-limit and 11-limit contain much more combinations.

Change the octave

Almost all of the mentioned tunings have two basic elements present – unison (1:1) and octave (2:1). This paradigm can be broken by introducing an octave that has ratio different than 2. Most famous tuning with non-standard octave is Bohlen-Pierce scale (Mathews, Pierce, Reeves, & Roberts, 1988). In this system, the octave is defined as 3:1 and it does not contain any conventional 2:1 octave interval (closest is 49:25, that is 35 flatter than octave).

Culture

The world contains many examples of tuning systems developed through culture and evolution. Some of the most interesting ones have non-equally spaced intervals in a scale – for example Javanese Gamelan system (Brinner, 1995; Sethares, 2005) or use tones that do not have a precise frequency, rather a range in which they are played, such as Indian Raga (Chakraborty, Krishnapriya, Loveleen, & Solanki, 2009).

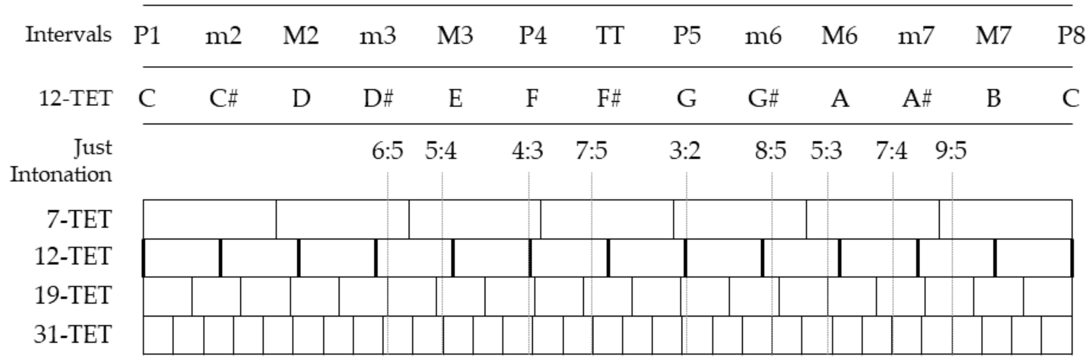


Figure 4-4. Comparison of various equal temperaments and Just intonation intervals.

5. EMOTIONS AND SOUND

Most activities in human lives have either emotional consequences or are done with the goal to elicit emotions. One of such activities is the enjoyment of listening to music. Research shows that people search for and use music for purposes of changing, amplifying or releasing their emotions, for pleasure and feeling of comfort and relieving stress (Behne, 1997; Juslin & Laukka, 2004; Sloboda, O'Neill, & Ivaldi, 2001) .

The ability of this mysterious concept called "music" to affect emotional state of a person was the focus of philosophers and scholars since ancient Greece (e.g., Budd, 2002; Robinson, 1997). Despite the long history of interest in the connection between music and emotions, there has been sparse research on this topic (compared to other more prominent topics of research in emotions) and the literature that has been published contradicts itself in almost every aspect. To illustrate this aspect and the need for further research, we provide a few examples:

"emotional responses to music do not occur spontaneously, nor 'naturally'," (Becker, 2001)	"this is what emotions are: spontaneous responses that are difficult to disguise." (Peretz, 2001)
"music does not induce basic emotions," (Scherer, 2003)	"remarkable that any medium could so readily evoke all the basic emotions." (Panksepp & Bernatzky, 2002)
"there is a general consensus that music is capable of arousing deep and significant emotions," (Sloboda, 1992)	"instrumental music cannot directly induce genuine emotions in listeners." (Konečni, 2003)

Fortunately, the beginning of the 21st century has seen an upswing in the research on musical emotions and emergence of methodologies and frameworks for studying psychoacoustics (for review, Juslin & Sloboda, 2001; Juslin & Västfjäll, 2008).

1. What are emotions?

What emotions does music create in us? To answer this question, we have to first differentiate between two categories of emotions - felt and perceived (Lewis, Haviland-Jones, & Barrett, 2010; Zentner, Grandjean, & Scherer, 2008).

Felt emotions

Felt emotions consist of our everyday emotional spectrum that sits in the background of short term emotional experiences (e.g. after a angry meeting) and actual environment (e.g. sitting in a calm and pleasant cafe). It might seem trivial and redundant to talk about such emotions, but all of this affects the final emotional value of perceived music.

Apart from "everyday" emotions, there are emotions felt from the currently heard music. What emotions does the song carry? Are there any past experiences attached to it? Does the song "make" us feel emotional?

Perceived Emotions

In contrast to felt emotions, there is the category of perceived emotions. These are emotional descriptors of the music. In (Zentner et al., 2008) the subjects were asked to describe the heard music by emotional identifier, indicators. This task is often carried without personal, subjective (with a caveat) or felt affects. See (Sloboda, 1992) and (Kallinen & Ravaja, 2006) for review.

To better understand this distinction, we can look at genres such as heavy metal. Fans of this genre feel comfortable and experience pleasant emotions, while the music they listen to can be described as aggressive, fear-inducing or evil. If the emotions are "in" the music itself, then everyone should feel oppressed. If the emotions are only projections of our own emotionality, then metal fans should be happy from any kind of music while people labeling metal as arrogant should feel similar emotions from most of the genres.

2. Evaluating emotions

Study " Emotions evoked by the sound of music: characterization, classification, and measurement." (Zentner et al., 2008) contains well laid out comparison of studies related to music and emotions. It is clear that the difference between felt and perceived emotions was often omitted and is one of key critical points in most of research regarding this topic. Another critical area is the vocabulary and labelling of emotions. Too many scholars have tried to either map universal emotional models onto music emotion experiments or, in other case, come up with completely unique and novel categorization. Using universal emotion scales denies the fact that some emotions are more felt than perceived (sadness), while others are more perceived than felt (mystery). This alone skews the results of experiments based on this premise. Constructing novel systems on the other hand, often omits emotions that are rare in one of the felt/perceived categories. Apart from that, more often than not, the words selected are just a subjective selection of an author's vocabulary and their meaning can differ in various settings, cultures and languages.

One of the systems for evaluation of emotions in connection with music is called GEMS - Geneva Emotional Music System. The process of creating this system allowed for enough flexibility and scientific validity to accept it as a worthy alternative to Valence/Arousal model or Differential Emotion Scale (for review see Bisesi & Toiviainen, 2017) Still, we can argue that even this system has its flaws. The language used for the emotional adjectives is English, while the subjects were Italian, French and German speaking. Our subjects are mostly Slovak, thus the need for accurate translation is in place. The music selection used in the paper is time-bound. If the experiment is replicated in the future, the influence of that time period on music can also skew the results. Lastly, the selection of participants could be more diversified and studies with subjects from different cultures and backgrounds should be replicated. Most of these points are discussed in the last chapter of the paper.

3. Biological connection of music and emotions

After birth, until the development of speech, young babies tend to use sounds to express their emotional state. They are also able to recognize melodies that have been transposed in pitch or slowed down / speed up (Trehub, 2003) and prefer consonance to dissonance (Trainor, Tsang, & Cheung, 2002).

Sound in the form of music is widely searched for in the context of relaxation, but can also serve the purpose of mood-changing activity. Music can induce and regulate emotions, change the current emotional state, alter behavior and also cure emotional disorders. Recent studies have also shown that brain regions activated by strong rewards such as sex, food, drugs can also fire in the presence of emotional music (Blood & Zatorre, 2001), (Menon & Levitin, 2005).

4. Basic Emotions

According to P. Ekman, there are 6 basic emotions that are universally recognized in all cultures: anger, fear, disgust, sadness, happiness and surprise (Ekman, 1992). Music induced emotions differ from regular emotions in the sense that we are not confronted with anything in particular. Encounter with a sabertooth tiger is dangerous because there is an actual threat. Encountering an angry boss is an actual threat as well. But listening to an angry heavy metal singer possesses no threat at all. It just evokes the emotion of being threatened (Krumhansl, 1997).

5. Mechanisms of music-induced emotions

The most comprehensive model of mechanisms that describes how the arousal of emotions from listening to music works is the BRECVEM model (Juslin, Liljeström, Västfjäll, & Lundqvist, 2010; Juslin & Västfjäll, 2008). To explain the model in detail, we will first include an excerpt from one of the cited papers that shows each mechanism in a potential real-world scenario. Afterwards, we will briefly explore each of the systems.

Klaus arrived just in time for the concert on Friday evening … He sat down and the music began. A sudden, dissonant chord induced a strong feeling of arousal (i.e., brain stem reflex), causing his heart to beat faster. Then, when the main theme was introduced, he suddenly felt rather happy – for no apparent reason (i.e., evaluative conditioning). In the following section, the music turned more quiet ... The sad tone of a voice-like cello that played a slow, legato, falling melody with a trembling vibrato moved him to experience the same sad emotion as the music expressed (i.e., emotional contagion). He suddenly recognized the melody; it brought back a nostalgic memory from an event in the past where the same melody had occurred (i.e., episodic memory). When the melody was augmented by a predictable harmonic sequence, he started to fantasize about the music, conjuring up visual images – like a beautiful landscape – that were shaped by the music's flowing character (i.e., visual imagery). Next, the musical structure began to build up towards what he expected to be a resolution of the tension of the previous notes when suddenly the harmonics changed unexpectedly to another key, causing his breathing to come to a brief halt (i.e., musical expectancy). He thought, "This piece of music is really a cleverly constructed piece! It actually made me reach my goal to forget my trouble at work." Reaching this goal made him happy (i.e., cognitive appraisal).

Brain stem reflex

When one or more sound characteristics are processed and evaluated by the brain stem as important and requiring the immediate action, emotions can arise very quickly, automatically and without much effort or conscious processing. Such reflexes are usually in response to sudden sounds, unexpected loudness, dissonant tones or rapid, fast features.

Rhythmic entrainment

This process is more is more tied to the tempo and rhythmical structure of the heard music. The emotion is evoked by synchronizing an internal body rhythm, e.g. heart rate or breath rate to the periodicity of the musical piece. By adjusting the frequency of the tempo, the bodily functions might change in periodicity as well, producing increased arousal or calmness.

Evaluative conditioning

Pairing a musical stimulus with a other activity or episode with strong emotional valence repeatedly can condition the person to feel the same or similar emotion when hearing the original music while the activity or episode is not present anymore. This is often used as important tool in film score composing or marketing, when a certain theme or tune can condition the listener to feel similar positive or negative emotions repeatedly, "on-demand" by the composer.

Emotional contagion

This process in the simplest form explains how certain features of music are mirrored in human-like behavior, such as human voice. In a fMRI study (Koelsch, Fritz, v. Cramon, Müller, & Friederici, 2006), listening to expressive music activated brain regions that are associated with premotor representations for the vocal production. Bowed and stringed instruments can mimic the tonality and expressiveness of a human voice, thus may evoke basic emotions in the listener.

Visual imagery

Self-conjured visual images are very individual among listeners and may not be experienced at all in some cases. If present, on the other hand, they are usually crafted from the cues, metaphors and image schemas that are defined by life experience. These visual stimuli can enhance the felt emotion and anchor it also in other parts of the brain, responsible for visual imagery.

Episodic memory

"Darling, they are playing our tune" phenomenon is one of the examples of episodic memory (Davies, 1979) in which an emotion is induced in the listener based on the previous event and its recalled memory. Compared to evaluative conditioning, this effect happens mostly on conscious level.

Musical Expectancy

The listener can have, based on previous experience with music, genre or style, expectations that might or might not get resolved. When the particular piece of music violates, delays or confirms the expectation, it can induce the emotions of anxiety, surprise or thrills. One of the recent theories elaborating on music expectancy is the ITRPA theory of expectation (Huron, 2006) which explains 5 different systems for expectation – Imagination, Tension, Response, Prediction, Appraisal. These can operate across different domains but can be applied also to music.

6. Emotions and Microtonality

How does one feel when encountering an unknown melody? An unknown instrument? An unknown chord structure or combination of frequencies?

Familiarity plays an important role in emotions. Familiar things makes people safe and allow for (otherwise) vulnerable emotions (North & Hargreaves, 1995). On the other hand, unfamiliarity possesses a risk and is often perceived negatively. One of the prime examples in music is the pushback against novel music styles that occurred in the past. Afro-American jazz musicians, the age of Elvis Presley and rock'n'roll, emergence of punk, electronic revolution and who knows what in the future. All of these novel styles were revolutionary at their time and strongly fought against. Labels such as "devils music", "dissonance", "just noise" or "this is not music" were often attached. As we look back, these "unmusical" styles defined a generation and are regarded as important steps in the history of music.

Microtonality takes this concept a step further by introducing constructs that are novel to the casual listeners' ears in many more ways than the "novel" music of the past. The easiest (on the ears) is to use common song-writing techniques and genres, use well known instruments tuned to microtonal scales and have the microtonality be the only attribute that is novel.

There have been studies dealing with emotions and music (Bisesi & Toiviainen, 2017; Juslin & Sloboda, 2001; Zentner et al., 2008), microtonality alone (Ferrer Flores, 2007), expectation (Steinbeis et al., 2006). However, none of them measured the emotional response of the participants to sounds from the microtonal world.

6. MUSICIANSHIP

This chapter is dedicated to explaining how musicians acquire their knowledge of the tones and sense of pitch correctness.

1. Music education

In most European countries, music education is part of the primary school curriculum. It is safe to say that music education is more prominent than dance or rhetorics (amongst fine arts). Usually, the goal of such education is to have a "good ear". This term is an abstract concept that in professional jargon means to spot mistakes in a piece, evaluate musicality and have a taste in music in general. It is often associated with "absolute/perfect pitch", i.e. to be able to name any note just by ear. One can be born with talent for such skill, but in any case, it has to be honed by experience (Profita, Bidder, Optiz, & Reynolds, 1988). In cognitive terms, it means to associate and identify certain frequencies and categorizing them to notes of a scale.

The training of "perfect pitch" brings along some drawbacks, one of which is the sensitivity to badly tuned instruments and tones that do not fall into preconceived categories of notes on a scale (out-of-tune). This concept is a stepping stone of this thesis, with the goal to evaluate whether the trained ear of a professional is susceptible to tones out of standard tunings in an emotional way and whether non-trained person is free of this preconception.

2. Absolute pitch and Relative pitch

The term *absolute pitch*, or more commonly referred to as *perfect pitch* is defined as the ability to identify and/or recreate the pitch of a tone without the presence of a reference tone. In contrast to absolute pitch, the term *relative pitch* is similiar to absolute pitch, but with the difference of the reference tone being present to the listener.

Interesting research on the topic of absolute pitch and non-standard tunigs was done by Miyazaki (1993; 1995). The results of his experiments showed that people with the ability to identify absolute pitch had slower response times and significantly lower accuracy in evaluating pitch intervals when the root note changed from the regular C (approx. 262Hz) to detuned C (slight deviations of +16, +30 and +50 cents) or, in the case of the second experiment, to slightly flatter E (quarter tone lower than standard E) and in-tune F#. In both cases, the control groups consisting of participants who did not exhibit the ability to identify absolute pitch, had comparable results across the different tasks. This effect might be due to the difference between absolute and relative pitch identification, especially when we take into account that people with absolute pitch show signs that their relative pitch identification is usually shadowed by the absolute pitch skill, which often takes the role of identifying separate pitches and analyzing their interval, rather than assessing the relative pitch in the first place.

We speculate that similar effect occurs in chord evaluation when there are intervals that do not fall into familiar territory of equal temperament. This new sensation should be easy to notice by musicians who expect standard intervals, but can slip by unnoticed by non-musicians who do not have any deep knowledge of intervals and take the structure as-is.

3. Evaluation of professionality

What qualifies a professional musician? Is it the number of successful concerts? Is it the amount of hours that is dedicated to the particular instrument? Is it the ability to improvise and reinterpret musical pieces? Because of this ambiguity, we have to classify a certain criteria for a musician to properly categorize the participants.

Our professional is based on following criteria:

1. Experience with playing an instrument for at least 5 years and active performing for at least 2 years.
2. No active experience with microtonal music. Artist should not play or work with microtonal systems. The most acceptable level of influence of microtonality is from

lectures at school. Indifference to microtonality or lack of knowledge about it is preferable. This is required in order to minimize pre-experiment bias towards microtonal music and influencing emotions studied.

The expected stereotype is that professional musicians who do not experiment with non-standard tunings and/or microtonality, work in the same system every day, thus adjusting their perception of sound specifically to the common frequencies and intervals found in their system. The convention that allows them to "simplify" the sound spectrum is then influencing their perception of sounds and / or notes that are outside of this convention. This is what we will call "temperament bias".

In contrast, non-musicians who are just casual listeners of music should have this bias in lesser extent. Although they mostly listen to music in the equal temperament (convention), they are not forced to analyze and assess the tuning of individual notes as critically as professional musicians have to. Temperament bias would be virtually non-existent in a person who has never listened to any music in any system.

In the next chapter, we are proposing an experimental design aimed to search for differences of perceived emotions in microtonal chords for musicians and non-musician.

7. EXPERIMENT

In the theoretical section we have overviewed the basic concepts of music, emotions and their connection from various perspectives. Also, we have delved into the mysterious world of microtonal tunings and how they differ from standard, western twelve tone equal temperament. Our goal is to cross these two areas and explore the connection between microtonality and emotions. This is an area that has seen very little interest, maybe due to the disputes in emotionality/music research or maybe due to the even lower focus on microtonality in research.

1. Goals

The goal if this study is to show that musicians perceive microtonal structures (chords) as more emotionally negative compared to non-musicians. This premise is based on the presumption that musicians are more in close contact with equal temperament and have to train their ears to distinguish any violations of this tuning. Thus, their automatic response for anything that goes beyond the standard tuning is evaluated as "wrong" or "bad". Non-musicians do not train their ear, so they should be more "open" to novel tunings and have less negative response.

Recent research suggests that this might be true, by showing that musicianship plays a role in learning novel microtonal tunings (Leung, 2017). In an experiment, non-musicians were able to indirectly detect violations of a non-standard tuning, while musicians and even musicians with experience in microtonality did not exhibit this trait.

The experiment will follow two major hypothesis:

1. Musicians and non-musicians differ in the emotional response to the microtonal stimuli.
2. Musicians perceive microtonal stimuli on a more negative scale – lower score on emotions Joyful Activation and Peacefulness and higher score on emotions Tension and Sadness

2. Design

The structure of the experiment consists of 35 trials with different chord structures that the participant has to evaluate on all of the 9 emotional scales in a PsychoPy environment, the post-test questionnaire to categorize the participant into musician / non-musician groups and the informal feedback session. Each part is explained in detail in the following subchapters.

3. Participants

Total number of participants that agreed to take part in the study was 13 with the mean age average of 32.4, age range of 24-63 and gender distribution of 5 females and 8 males. Taking into account musical education, active experience of playing on an instrument (at least 5 years) and experience with composing, we have categorized each participant into either musician group (1) or non-musician group (0).

N.	School	Performing	Composing	Music	Musicianship
1	0	0	0	Various	0
2	1	Piano (9+)	0	Classical	1
3	0	Piano (4)	0	Indie	0
4	0	Various (3)	0	Rock	0
5	0	Guitar (9+)	1	Metal	1
6	0	Piano (9+)	1	Electronica	1
7	0	Piano (9+)	1	Classical	1
8	0	Piano (1)	0	Pop	0
9	0	Piano (9+)	1	Hip-hop	1
10	0	0	0	Rock	0
11	1	Various (9+)	1	Rock	1
12	0	No	0	Electronica	0
13	0	No	0	Electronica	0

Table 7-1 List of participants. Value of zero indicates response that does not influences group membership.

4. Trials

For the trials, participants were seated in front of a computer running PsychoPy environment with the experiment script. We have chosen this software because it has been proven useful in previous research on emotions and music (for example Bisesi & Toiviainen, 2017; Peirce, 2007, 2009). The participants were asked to sit comfortably, put on the provided headphones and follow the instructions on the screen. It guided them to relax, sit calm and politely asked them to turn off any signaling on their cellphones. The controls for advancing to the next parts of the application were clearly marked on the screen ("Press spacebar to continue").
The next screen instructed the participants to fit the headphones so they sit firmly, but comfortably on the head and a test tone in the background allowed them to set the volume level accordingly. Afterwards a testing trial of the experiment was conducted to make sure the participants understood the instructions.
Until the live experiment, the researcher was near the tested subject, so that any case of misunderstanding or questions can be resolved. Throughout the experiment itself, the supervisor was at hand, but did not interfered or talked to the participant going through the trials. Also, we tried to eliminate any emotion-influencing background stimuli (e.g. background music, movement in the room, loud talk).

Each of the 35 trials consisted of sound stimuli and presented emotional scales. The task was to listen to the stimuli, select value on each of the 9 scales and confirm the selection with a button underneath each scale. After all 9 scales were submitted, the application advanced to the next trial. The trials were ordered the same way for all of the participants. After all of the trials have been successfully submitted, a screen informing the end of the experiment was shown.

Average time for the experiment for one participant was estimated at 45 minutes (30 minutes of the trials + 15 minutes questionnaire and feedback).

5. Stimuli

Each of the stimuli is an audio wave file (.wav) that is 5 seconds long. The chord that the participant had to evaluate is built tone by tone by first introducing the root note (C with fundamental frequency of 261.63), then after 0.5 seconds the second note (labeled "II" in the table), then finally after another 0.5 seconds the third note ("III") is introduced. Afterwards, the chord is held for approx. 2.3 seconds after which it stops for a 1.7 second silence. The whole file was looped endlessly so the participant had time to select all of the emotion scores.

The sound was synthesized on the E-MU Proteus 2000 digital synthesizer with the help of Scala for creating and working with microtonal tunings. The base tone is based on a four stacked sinewaves (digital samples). One sinewave is tuned to the fundamental frequency of the tone and the other three are tuned relatively in octaves (two, three and four respectively). This mitigates the problem of colliding overtones that might create microtonal artefacts that would change the tonal characteristic of the chord. For review on the topic of constructing suitable tones in microtonality, see (Sethares, 2005).

We have decided to base all of the chords on the root C, otherwise the effect of harmonic expectancy on emotions (e.g., Gabrielsson & Lindström, 2010; Steinbeis et al., 2006) could influence the results. The heuristic for choosing the chords consist of a mix of various types of structures that we wanted to introduce and were suggested by people interested in xenharmony ('The Xenharmonic Alliance', 2018).

Type	Chords	Description
C Major	1, 35	Basic chord structures with variations on just intonation intervals that are near the III
C Minor	2	
C Augmented	3,4	
C Diminished	5,6	
7-limit	7-24	All combinations of intervals that have denominator less than 7 except when similar to the first 6 chords
Suggested	25-31	Various special cases and interesting intervals suggested by the Xenharmonic community
Bohlen-Pierce	32-34	Three special cases of Bohlen-Pierce scale suggested by Xenharmonic community

Table 7-2 Chord groups presented in the stimuli order.

No.	Name of the file	Just Intonation			Cents		Nearest 12-tone	
		I	II	III	II	III	II	III
1	01-C-E-G (4-5-6).wav	1	5/4	3/2	386.3	702.0	E	G
2	02-C-Eb-G (10-12-15).wav	1	6/5	3/2	315.6	702.0	D#	G
3	03-C-E-Ab1 (1-3_2-11_7).wav	1	3/2	11/7	386.3	782.5	E	G#
4	04-C-E-Ab2 (1-3_2-8_5).wav	1	3/2	8/5	386.3	813.7	E	G#
5	05-C-Eb-Gb1 (1-6_5-10_7).wav	1	6/5	10/7	315.6	617.5	D#	F#
6	06-C-Eb-Gb2 (1-6_5-7_5).wav	1	6/5	7/5	315.6	582.5	D#	F#
7	07-1-4_3-5_3.wav	1	4/3	5/3	498.0	884.4	F	A
8	08-1-5_4-7_4.wav	1	5/4	7/4	386.3	968.8	E	A#
9	09-1-3_2-7_4.wav	1	3/2	7/4	702.0	968.8	G	A#
10	10-1-6_5-8_5.wav	1	6/5	8/5	315.6	813.7	D#	G#
11	11-1-7_5-8_5.wav	1	7/5	8/5	582.5	813.7	F#	G#
12	12-1-6_5-9_5.wav	1	6/5	9/5	315.6	1017.6	D#	A#
13	13-1-7_5-9_5.wav	1	7/5	9/5	582.5	1017.6	F#	A#
14	14-1-8_5-9_5.wav	1	8/5	9/5	813.7	1017.6	G#	A#
15	15-1-7_6-4_3.wav	1	7/6	4/3	266.9	498.0	D#	F
16	16-1-7_6-3_2.wav	1	7/6	3/2	266.9	702.0	D#	G
17	17-1-4_3-3_2.wav	1	4/3	3/2	498.0	702.0	F	G
18	18-1-7_6-5_3.wav	1	7/6	5/3	266.9	884.4	D#	A
19	19-1-3_2-5_3.wav	1	3/2	5/3	702.0	884.4	G	A
20	20-1-7_6-11_6.wav	1	7/6	11/6	266.9	1049.4	D#	A#
21	21-1-3_2-11_6.wav	1	3/2	11/6	702.0	1049.4	G	A#
22	22-1-5_3-11_6.wav	1	5/3	11/6	884.4	1049.4	A	A#
23	23-1-9_7-11_7.wav	1	9/7	11/7	435.1	782.5	E	G#
24	24-1-9_7-12_7.wav	1	9/7	12/7	435.1	933.1	E	A
25	25-1-11_9-13_9.wav	1	11/9	13/9	347.4	636.6	D#	F#
26	26-1-13_10-8_5.wav	1	13/10	8/5	454.2	813.7	F	G#
27	27-1-19_16-3_2.wav	1	19/16	3/2	297.5	702.0	D#	G
28	28-1-4_3-16_9.wav	1	4/3	16/9	498.0	996.1	F	A#
29	29-1-11_8-13_8.wav	1	11/8	13/8	551.3	840.5	F#	G#
30	30-1-13_10-3_2.wav	1	13/10	3/2	454.2	702.0	F	G
31	31-1-5_4-19_12.wav	1	5/4	19/12	386.3	795.6	E	G#
32	32-bp_1-9_7-75_49.wav	1	9/7	75/49	435.1	736.9	E	G
33	33-bp_1-27_25-75_49.wav	1	27/25	75/49	133.2	736.9	C#	G
34	34-bp_1-75_49-49_25.wav	1	75/49	49/25	736.9	1165.0	G	C
35	01-C-E-G (4-5-6).wav	1	5/4	3/2	386.3	702.0	E	G

Table 7-3 List of stimuli that were used for the experiment. Name of the files represent files as found on the included CD.

6. Emotional scales

For the emotion scales, we have chosen the first order factors from the Geneva Emotional Music Scale (Zentner et al., 2008).

Due to the nationality of the participants, we had to translate the labels into Slovak language. The nuances of the language, cultural differences and the difficulty to find exact translations are crucial when evaluating the results that had the emotional labels in different languages. That is why we opted to include only participants that are native Slovak speakers and do not mix different languages.

Each emotion can be rated on a discrete scale from 1 to 10 where 1 means that the emotion is not perceived at all and 10 means that the emotion is perceived very strongly, or that the stimuli "defines" the particular emotion.

English label	**Slovak label**
Joyful Activation	Radosť
Nostalgia	Sentiment
Peacefulness	Pokoj
Power	Energia
Sadness	Smútok
Tenderness	Nežnosť
Tension	Napätie
Transcendence	Spirituálnosť
Wonder	Úžas

Figure 7-1 – English-Slovak translation of the emotional scales

7. Questionnaire

The goal of the questionnaire was to evaluate the level of musical knowledge in the participants. Apart from demographic information (age, sex), we asked the participants whether they attended school that specialize in music (including high schools – conservatories), what instruments they actively play (for how long), if they compose music, what genres of music they prefer, what genres of music they are exposed to on a daily basis (this can be different in case of working environments where the person has no choice over the played music) and their preferences towards music that has tendencies to cross the boundaries of equal tunings (jazz, experimental, world music).

The questionnaire was given to each participant either in oral or written form using online-based survey service. The questionnaire was taken after the trials so that the idea of non-standard tunings was not brought up before the experiment and could not influence the decision making process.

8. RESULTS

Out of 13 participants, all of them submitted the emotional score for all of the stimuli, thus producing 455 cases (210 for musicians and 245 for non-musicians). The data was analyzed by various statistical procedures and the results are found below. This chapter contains only the results found, while the chapter “Discussion” goes into analyzing the findings and providing potential explanations of the phenomenon occurring in the data.

1. Means

First statistical analysis is the calculation of means for each emotion scale and each musicianship group. This gives us a rough overview of the responses and differences between the groups. Most notable differences are in Wonder (0.50 in favor of musicians), Joyful Activation (0.48 in favor of non-musicians) and Tension (0.39 in favor of musicians). We will try to focus on these emotions more in the following statistical tests.

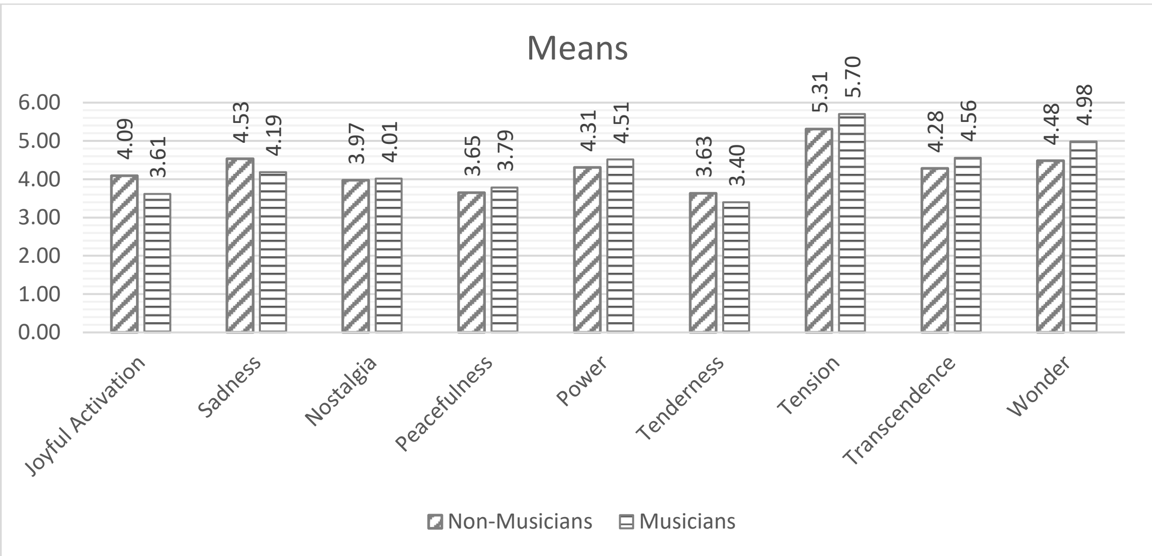


Figure 8-1 Visual comparison of mean values for non-musicians and musicians across the emotional scales

Emotion	Musician	Mean	Std. Deviation	Median
Joyful Activation	0	4.09	2.370	4.00
	1	3.61	2.339	3.00
	Diff	-0.48		
	Total	3.87	2.366	3.00
Sadness	0	4.53	2.464	4.00
	1	4.19	2.455	4.00
	Diff	-0.34		
	Total	4.37	2.463	4.00
Nostalgia	0	3.97	2.443	3.00
	1	4.01	2.411	4.00
	Diff	+0.04		
	Total	3.99	2.426	3.00
Peacefulness	0	3.65	2.171	3.00
	1	3.79	2.503	3.00
	Diff	+0.14		
	Total	3.71	2.328	3.00
Power	0	4.31	2.262	4.00
	1	4.51	1.959	4.00
	Diff	+0.20		
	Total	4.40	2.128	4.00
Tenderness	0	3.63	2.304	3.00
	1	3.40	2.043	3.00
	Diff	-0.23		
	Total	3.52	2.188	3.00
Tension	0	5.31	2.568	5.00
	1	5.70	2.502	6.00
	Diff	+0.39		
	Total	5.49	2.542	6.00
Transcendence	0	4.28	2.288	4.00
	1	4.56	2.298	4.00
	Diff	+0.28		
	Total	4.41	2.294	4.00
Wonder	0	4.48	2.439	4.00
	1	4.98	2.317	5.00
	Diff	+0.50		
	Total	4.71	2.394	4.00

Table 8-1: The Mean, Standard Deviation and Median for each emotion scale. Musician=1 means musician participants and Musician=0 the non-musicians. Diff is the difference between musicians and non-musicians where positive numbers mean higher mean value for musicians and vice-versa. Totals are calculated throughout the whole dataset.

2. Mann-Whitney U Test

After comparing the mean values, we ran a Mann-Whitney U Test (also called Wilcoxon-Mann-Whitney Test) to determine if there are differences between the group of musicians and the group of non-musicians on the emotion score for each of the emotions. The null-hypothesis is that the distribution of score for the two groups is the same. The results are summarized in Table 8-2. Using the statistical significance (Asymptotic Sig. in the table) we can decide to keep or dismiss the null-hypothesis for that particular emotion. Only two cases showed values below *0.05* – Joyful activation and Wonder. This means that the two groups had statistically significant differences and we can dismiss the null hypothesis for them. In case of Joyful Activation, the engagement score for musicians (*mean rank* = *212.38*) was lower than for non-musicians (*mean rank* = *241.39*), $U = 22\ 445.5$, $z = -2.371$, $p = .018$. In case of Wonder, there was opposite trend with engagement scores for musicians (*mean rank* = *243.20*) higher than for non-musicians (*mean rank* = *214.97*), $U = 28\ 917.0$, $z = 2.300$, $p = .021$.

Emotion	Mean Rank Non-Musicians	Mean Rank Musicians	Mann-Whitney U	Standardized Test Statistic (z)	Asymptotic Sig. (2-sided test)
Joyful Activ.	241.39	212.38	22 445.5	-2.371	**.018**
Sadness	237.42	217.01	23 417.5	-1.664	.096
Nostalgia	226.61	229.62	26 065.0	.245	.806
Peacefulness	228.04	227.95	25 714.0	-.008	.994
Power	218.84	238.69	27 965.5	1.623	.105
Tenderness	231.88	223.48	24 775.0	-.689	.491
Tension	219.15	238.33	27 893.5	1.561	.119
Transcendence	220.80	236.40	27 490.0	1.272	.203
Wonder	214.97	243.20	28 917.0	2.300	**.021**

Table 8-2 Results of the Mann-Whitney U Test

3. Correlations between emotions

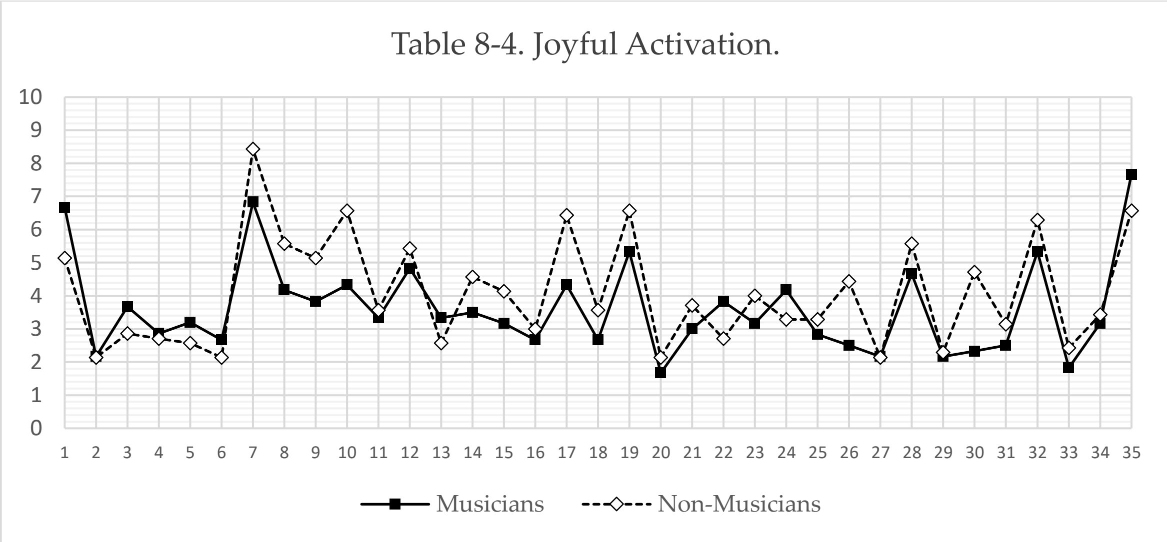
Next, we wanted to see if the correlations between the emotion scores (that is, if one emotion correlates with any of the other ones) is different across the two groups. If the two groups have similar approach to scoring the stimuli, we would find no major changes. For this, we have used the Spearman's rank order correlation.

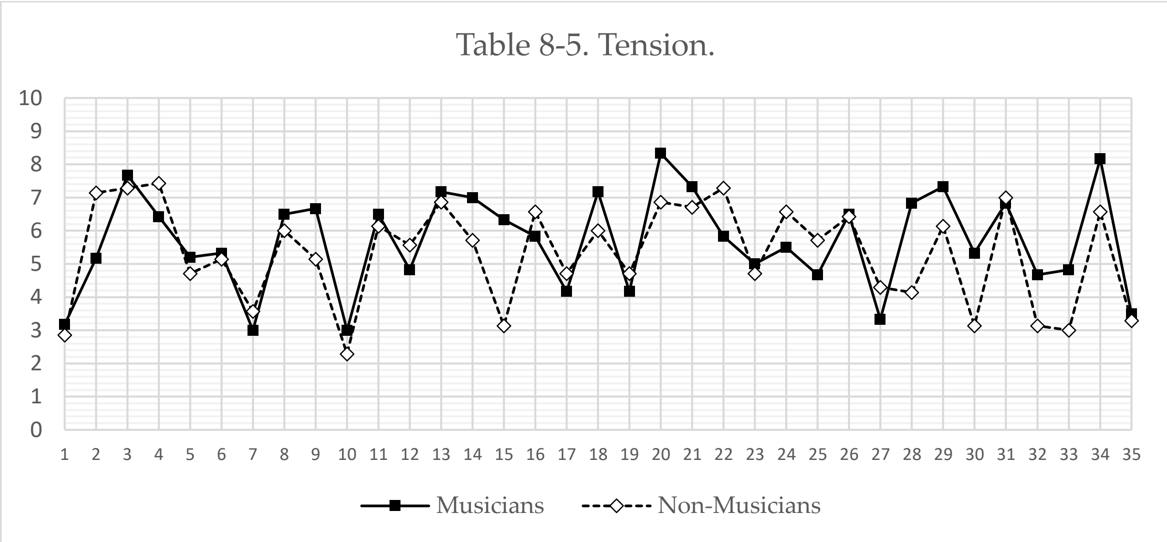
In the Table 8-3 we chose to list only those differences, where the absolute value of delta between the correlations was higher than *0.250*. The case of Joyful Activation and Wonder shows a minor rising trend from almost non-existing correlation at $r_s = 0.116$ for non-musicians to $r_s = 0.378$ for musicians, which can be classified as moderate correlation. Other interesting cases are Power – Sadness and Wonder – Sadness, which both showed $abs(\Delta r_s) > 0.400$. In both occasions, the correlation between these emotions was positive for non-musicians (at $r_s = 0.247$ and $r_s = 0.234$ respectively) and negative for musicians ($r_s = -0.216$ and $r_s = -0.289$) signifying a change in the direction of the correlation.

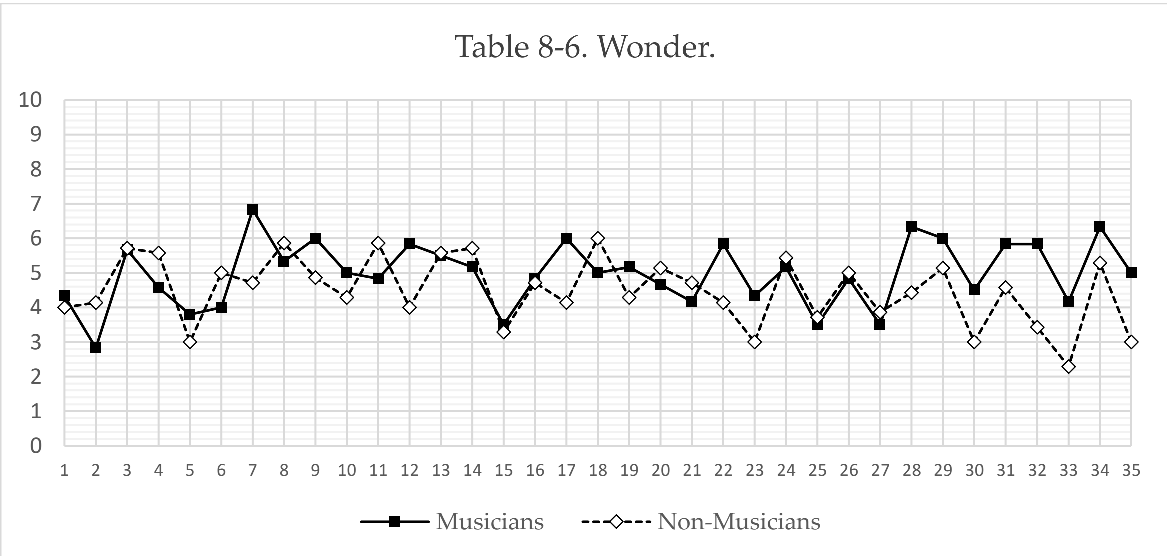
Emotion – Emotion		Non-musicians	Musicians	Delta
Joyful Activ. – Wonder	Spearman	0.116	0.378	0.262
	Sig. (2-tailed)	0.070	< .0005	
Power – Nostalgia	Spearman	0.044	-0.240	-0.284
	Sig. (2-tailed)	0.489	< .0005	
Peacefulness – Tension	Spearman	-0.089	-0.334	-0.245
	Sig. (2-tailed)	0.166	< .0005	
Power – Sadness	Spearman	0.247	-0.216	-0.463
	Sig. (2-tailed)	< .0005	0.002	
Wonder – Sadness	Spearman	0.234	-0.289	-0.523
	Sig. (2-tailed)	< .0005	< .0005	

Table 8-3 List of correlations between emotions where the delta of coefficients is higher than 0.300.
Delta = Difference of correlation for two emotions for non-musicians and correlation for the same two emotions for musicians.
Delta > 0 means the correlation is stronger for musicians.
Delta < 0 means the correlation is stronger for non-musicians.

4. Overview of selected emotions







9. DISCUSSION

In the previous chapter, we have presented the results of several statistical analyses and overviews of the important parts of the data from the experiment. In order to answer our research question, we have to take a closer look at the results and connect them from a broader perspective. We propose several possible explanations with references to the data provided in the Results section.

1. Hypothesis

Hypothesis 1: Musicians and non-musicians differ in the emotional response to the experimental stimuli.

By calculating means and standard deviations for all of the emotions, we found out that three out of nine emotions differed by a coefficient bigger than *0.35*. These emotions are: Joyful Activation, Tension and Wonder. Later, we have conducted a Mann-Whitney U Test which showed that some of the differences are statistically significant. Two out of three emotions yielded statistically significant difference in their mean ranks – Joyful Activation and Wonder ($p < .050$). We concluded that it is important to focus on these three emotions in the further evaluations.

Result 1: The musician and non-musician group differs in responses to emotions on at least two occasions (Joyful Activation and Wonder). This has been confirmed statistically by comparing the mean value and concluding Mann-Whitney U Test.

Hypothesis 2: Musicians perceive microtonal stimuli on a more negative scale – lower score on emotions Joyful Activation and Peacefulness and higher score on emotions Tension and Sadness

We have concluded that musicians and non-musicians differ, but how and why? Assessing from the means overview and visual representation of the emotions Joyful Activation and Tension, a slight trend is present. Musicians have lower mean score in the Joyful Activation (*3.61* compared to *4.09* in non-musicians) and the graph plots their average responses for this emotion lower than for non-musicians in almost all of the experimental cases. With Tension, the trend is inverted – mean value of *5.70* (compared to *5.31*) and higher response score than non-musicians in more than half of the cases (but to a lesser extent than in Joyful Activation).

We did not find the responses to Wonder very insightful, although it must be noted that the response to the stimuli 28 – 35 were much higher for musicians than the rest of the trials. This could be due to change in the stimuli structure. From the stimuli number 27 onwards, the structure of generating stimuli was violated and later the chords from the Bohlen-Pierce scale were introduced. This finding could be further studied by randomizing the sample order.

We did not found any substantial evidence of lower response for Peacefulness (mean value *0.14* points higher for musicians). For Sadness, the score was somewhat lower for musicians (difference of *-0.34*) which narrowly misses our threshold (*0.35*).

Result 2: Musicians value the stimuli lower on the scale of Joyful Activation and higher on the scale of Tension. The difference in Joyful Activation is statistically supported in the Result 1, while the difference in Tension is based only on the mean value and visual evaluation and needs further research. Peacefulness did not exhibit any substantial difference and Sadness showed expected difference but not on a statistically significant level.

Hypothesis 3: Musicians and Non-musicians have different approach to evaluating emotions.

Comparing the correlation matrix Emotion x Emotion for both groups, we have listed 3 minor ($abs(\Delta r) > 0.25$) and 2 major ($abs(\Delta r) > 0.45$) differences between pairs of emotions as rated by the two subject groups. While the musicians had minor increase in Joyful Activation – Wonder positive correlation, the other pairs showed increase in negative correlation. All of the remaining 4 pairs are combinations of a positive valence/arousal (Power, Wonder, Peacefulness) with negative valence/arousal (Nostalgia, Sadness, Tension).

We think that explanation for this lies within the musicians ability to better distinguish emotions when it comes to musical cues and better interpreting of such emotions and their relationships. On the other hand, for a non-musician, the task of identifying emotions from a pure chord structures could lead to confusion and not having any strong emotional perception.

Result 3: Musicians and non-musicians employ a different set of evaluating criteria for perceiving emotions in the experimental stimuli. This is shown by finding differences between pair-wise correlations of emotion scales for the groups.

2. Limitations

Sample size

The low number of participants introduces additional variables such as background, individual differences, relationship with the researcher or simply random deviations occurring from subject to subject. The research has to be repeated on a much larger sample set with more broader distribution of age, background, gender and qualification.

Language

All research based around emotions is influenced by language preferences of its subjects. For example, in our case, the labels used to scale emotions can have slight variations in the context of Slovak language than in English. The GEMS scale system was based on German-Italian-English word set. Due to the fact that Slavic languages (e.g. Slovak) differ substantially to Germanic and Latin languages (used in GEMS) this factor might influence the understanding of the emotional labels.

Further research with emotion scales could be in place where language specificity is not a variable. Some existing methodologies are using pictographic labels, photos of faces with emotional affect, comparisons between music stimuli or measuring arousal by means of brain imaging or skin conductivity (omitting lexical information at all).

Cultural variety

Because the exposure to different tonalities is culturally bound, it is of utter importance to also include listeners from cultures different to Western European / American culture which use equal temperament. The best case scenario would be to include members of each continent, race, gender, age, or, replicate studies in different parts of world and combine them in a meta-analysis.

Stimuli generation and propagation

For some participants, the sound of four stacked sinewaves strongly reminded them of a pipe organ and church setting. This might evoke the memories of spirituality and skew the results in the scale of Spirituality, Tenderness, Wonder and related.

Moreover, we think that the sound generation could be improved for it to be more error-proof. Because the synthesizer is a digital generator, its sounds are produced out of digital

„samples“ which have certain sampling frequency. With the advancements and availability of analog sound sources, it would be beneficial to implement similar experiment on analog, pure sinewave sources. Currently, there are synthesizer modules that provide such functionality and can also utilize Scala scales for quantization (tuning). To propagate small, subtle nuances in sine wave relationships (for example the beat phenomenon), the finer and accurate the sound source is, the better. For the interested reader, the world of modular synthesizers provides such tools with high precision oscillators allowing to setup small, psychoacoustic laboratory. Another factor that can improve the research methodology, comfort of subjects and error-proofing the results is standardization of listening equipment. Although we have used headphones that are isolated and are primarily used for studio monitoring (thus have moderately flat frequency response and low harmonic distortion), there are not ideal by any means. Headphones with improved comfort (some subjects reported discomfort due to oddly shaped headband) and better performance characteristics (e.g. planar magnetic headphones with flat response curve) could mitigate potential errors. Moreover, having subjects in the same environment would further rule out differences created by factors such as effects of environment on mood, lighting, or ambient sound levels, but on the other hand provide skewed results by inducing emotions usually connected with laboratory setting.

3. Possibilities for future improvement

We believe that this research could lead to raised interest in psychoacoustics and microtonality. Below, we propose a few improvements that could help when replicating the study or conducting a new study in this field.

Change the order of the stimuli either with randomization or by reversing the order. In the latter design, participants would first hear samples of unknown tunings to which they accommodate. Afterwards, encountering standard tuning could sound out of tune, in comparison to their current state.

Comparing instead of evaluating. When presented with two (or more) choices, participants would be able to listen to different stimuli (e.g. slightly detuned version of one another) and choose the one that best describes an emotion. Question on the screen could look for example: "Choose stimuli that best describes the word – Joyfulness".

More interactive elements could allow participants to change characteristics and variables of the given tuning. Akin to a sandbox, they would be able to change the number of equal divisions, intervals, basic rules. This needs a good goal-based, maybe game-like system where participants are motivated to play with the scales.

Third group of xenharmonists which are people interested in alternative tunings. The strong online community can provide good amount of participants with varied experience with tunings. Such group could be positively inclined towards unusual sounds and could pose a contrast to professional musicians using just equal temperament.

10. CONCLUSION

In the first chapter of this paper, we have explored the theory behind sound, how it is produced, what qualities does it have and from what perspective we can study it. The second chapter was dedicated to using the sound for musical purposes. We have looked into the art of tunings and scales, theorize on how scales are made and uncovered the secrets of microtonality. The third chapter was emotional, or rather we talked about emotions and music. Why we listen to music? Why it moves us? Those were only a few questions that rose from that chapter. Following that was a brief overview of professionality in music, how are musicians made and what is the state of music education.

After the theory, in the second part of this paper, we have proposed an experiment design, which we then carried out and concluded. The result section contained valuable data from the psychoacoustical experiment conducted on 6 musicians and 7 non-musicians. Each of them submitted 9 emotional scores for each of the 35 microtonal stimuli. This data we have then analyzed in the discussion. We have managed to show that musicians and non-musicians differ in the emotional response to microtonal stimuli and that musicians have a statistically lower score in Joyful Activation, moderately higher score in Tension and higher score in Wonder than non-musicians. Also, we have showed that both groups vary in terms of emotional correlations, most notably for Power x Sadness and Wonder x Sadness. Lastly, we evaluate the limitations of the experiment and possible improvements for the future.

So, are musicians constrained by convention? Our research shows that they differ from non-musicians and are less joyful and more tense when encountering microtonal chords. But does that mean they are constrained? While conducting our experiment, we have came to a surprising conclusion that the opposite might be true. To wield and flexibly use equal temperament allows musicians to explore infinite combinations within it, which is liberating in itself. And if xenharmony causes any discomfort to the listener, it is good to remind oneself that we live in a world of continuous sensory stimuli after all.

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