Examensarbete

HÖGSKOLAN I SKÖVDE

A = 432: A SUPERIOR TUNING OR JUST A DIFFERENT INTONATION?

How tuning standards affects emotional response, timbre and sound quality in music

A = 432: ETT ÖVERLÄGSET ALTERNATIV TILL STANDARDSTÄMNING?

Hur stämingsstandarder påverkar emotionell respons, timbre och ljudkvalitet i musik

Bachelor Degree Project in
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Simon Palmblad

Supervisor: Markus Berntsson
Examiner: Lars Bröndum

Abstract

The purpose of this study was to explore the ways tuning to A = 432 Hz affects emotional response, timbre, sound quality, character and tone compared to the standard tuning of A = 440 Hz, and whether or not it is humanly possible to discern a difference between these two. This was all done in an effort to evaluate claims that A = 432 Hz is superior to standard tuning in regards the previously mentioned factors. For this to be done, the history and development of tuning standards as well as intonation systems, presented alongside theories on the basic physics of sound, the effect of spectral manipulation on timbre and sound, and finally memory structures for remembering musical pitches. As a musician and composer, exploring new ways of creating emotion and controlling the effects of a composition, and dispelling potential misinformation is always a worthwhile pursuit.

The study was performed by way of surveys where respondents were asked to listen to a composition in two versions, one in A = 440 Hz and the other in A = 432 Hz and then rate the perceived similarity between these two. They were then asked to give their answer regarding preference and associations of character and emotional response to each version.

Results show that the claims of the A = 432 Hz proponents might not be as simple as portrayed, but rather a more complex series of relationships. There is support for the idea that the two tunings are unique enough for the average human to discern a difference between the two, and that some type of unique character is contained in each tuning.

Keywords: Tuning systems, A = 432 Hz, Music, Emotional response, Digital re-tuning, Pitch memory

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1 Introduction

For over 60 years our current standard for tuning musical instruments has remained at A = 440 Hz. Although orchestras, concert halls and performers choose to deviate from the standard for various reasons, the current standard remains the most common. Throughout history, the system has been modified, revolutionized and reversed - shifting greatly from century to century until it reached stability in the middle of the 20th Century.

In recent years, a movement has begun. Many actors, especially online, are claiming that a superior tuning paradigm would be A = 432 Hz for reasons ranging from less strain on singers' voices, greater musical qualities, and the tuning's relationship to magnetic waves in the Earth's atmosphere. The proponents of this idea lack scientific evidence to back up their claims, mainly focusing on argumentation and assuming correlations when the causation is not investigated, making them unreliable. There was an experiment conducted by Bruno Barosi and Norbert Brainin in the late 1980's comparing the qualities of the recordings of a violin first tuned to our current standard and later to the suggested lower one. By analysing the contents of these recordings using a spectral analyser the results Barosi and Brainin hypothesized that a lower tuning contains more overtones and because of this sounds superior to the current standard of A = 440 Hz. Any documentation from the original experiment remains unavailable and the information was found through newspaper reports from New York Times and Executive Intelligence Review – a political American newsmagazine - and therefore its validity is in question. With this in mind, the spectral centroid-theory could explain why lower tuning might be considered more enjoyable. The spectral centroid, which is the point containing the greatest amount of audio information in an audio signal, determines how a sound is perceived and by using a lower tuning the spectral centroid would be shifted, resulting in a slightly different sound which might be preferable.

The purpose of this study is to investigate if there is any truth to the claims of the A = 432 tuning’s superiority when compared to the current standard of A = 440 Hz. First and foremost, whether there is any audible difference between the tunings or not must be investigated, as the difference between these tunings are minute and might not be easily perceived by human ears. Secondarily, what type of emotional qualities and tonal qualities the tunings are perceived to convey. To evaluate this, an approach similar to the one performed by Barosi and Brainin in 1988 was used, but instead of analysing recordings, respondents were tasked to listen to a short composition for solo violin created using a Digital Audio Workstation (DAW) twice - once tuned to A = 440 Hz and once to A = 432 Hz – and grade the perceived differences between the tunings. If any difference was noticed, the respondents would then answer questions relating to emotional response, tonal quality and preference for each tuning.

There is support for this approach in the Levitin Effect, a theory formed by Daniel Levitin in 1994, which states that the human mind is capable of pitch memory – remembering the specific tones of a song and being able to sing them without reference if they are familiar enough with that song. This would mean a long enough exposure to one tuning should create a memory imprint of it, allowing for a difference to be heard between each tuning. A survey design was deemed the most efficient approach, alongside a questionnaire that was quantitatively analysed and the data summarized in order to determine its validity.

2 Background

The background is organized to first cover the basics of sound and its physics to create an understanding for the later subjects and the terminology used in this study. The main part of the background covers the topic of tuning. This includes different tuning systems, the history of tuning from 15th Century leading up to our current standard of A = 440 Hz, and brief reasoning behind historical tuning standards. The pitch standard fluctuated wildly through this period and there are several reasons for the fluctuations: a different sound quality, ease of performance for singers, pure mistakes, as well as health and spirituality.

In the next part, the arguments of 432 Hz proponents are presented in chronological order. This section contains information from parties with different personal agendas, some political, and a critical viewpoint should be maintained when reading these. For example, The Executive Intelligence Review (EIR) was founded by the political activist Lyndon H. LaRouche who was charged and convicted of conspiracy by the USA Government (Aitchison, 2018). The information from these sources is used to showcase the arguments for A = 432 Hz and not as reliable research. This is further discussed in section *3 Problem*.

The final part of the background contains theories related to our perception of pitch, tone colour (the spectral centroid), and ability to memorise pitches (the Levitin effect). These theories provide a possible explanation as to why there might be truth to the claims regarding A = 432 Hz and acts as theoretical foundations for this study.

2.1 The physics of sound

David Miles Huber (2010) goes into great detail describing the physics behind sound and sound waves, explaining that all sound is comprised of air waves expanding and compressing, generally expressed as a cycle. The cycle is most easily explained using a sine curve encompassing 360° where the black areas represent level of amplitude, the intensity of the sounds volume, which increases as it gets closer to either peak (Huber, 2010).

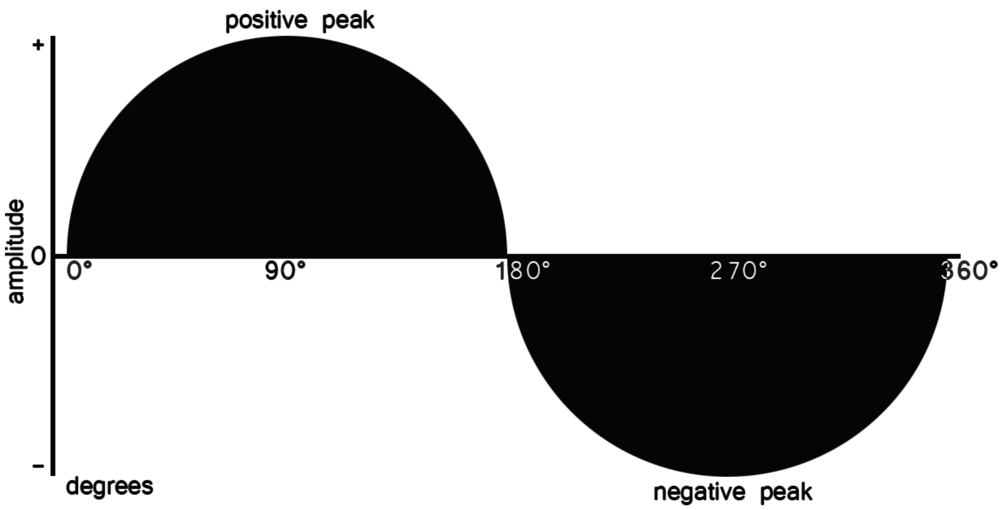

Figure 1 Graph of waveform amplitude and cycle (re-creation of image based on Huber, 2010)

The rate at which a cycle of positive and negative amplitude completes is called frequency, with higher frequencies resulting in a general increase in the pitch of the sound, vice versa for lower frequencies (Huber, 2010). The frequency of the resonating sound is then measured in hertz (here after Hz) which describe how many cycles complete within a second. So, for example, a sound at 440Hz would be perceived as having higher pitch than a sound at 432Hz (Huber, 2010). Not all sound is as simple as portrayed in *Fig. 2*, this model of sound shows a sound wave generated by a single-frequency generator: anything other than a single-frequency generator would not have such a smooth curvature - on the contrary - sound recorded and analysed through the means of a spectrogram reveals its complex form, as shown below in *Fig. 2* (Huber, 2010):

Figure 2 An example of a complex sound wave. (re-creation of image based on Huber, 2010)

2.1.1 Complex waveforms, notes and their relationships

The nature of the complex sound wave can be explained by the prevalence of partials (Huber, 2010). Basically, any note produced also produces several other notes in addition to the fundamental (i.e. the frequency played or sounding) - partials (Huber, 2010). Huber (2010) describes that the partials that are higher in frequency than the fundamental are further divided into harmonics and overtones (or upper partials). Harmonics are any partials that are also a whole-number multiple of the fundamental, overtones are all other partials. Frequencies that are whole doubles of the fundamental are perceived to be related in a special way (this interval[1] is called the musical octave): for the note A at 440 Hz, the ear will interpret 880 Hz as being the next octave of A (Huber, 2010). Any harmonic that is an even multiple in general is perceived as having a pleasant sound, while odd multiples create a harsher, dissonant sound. The partial content of any sound wave (timbre) determine its sound, it is through partial and harmonic content a sound gets its characteristic and is the reason why we can hear a difference between a guitar and a violin (Huber, 2010).

[1] The distance between two notes is called an interval. The interval system is based on the twelve-tone chromatic scale, and an

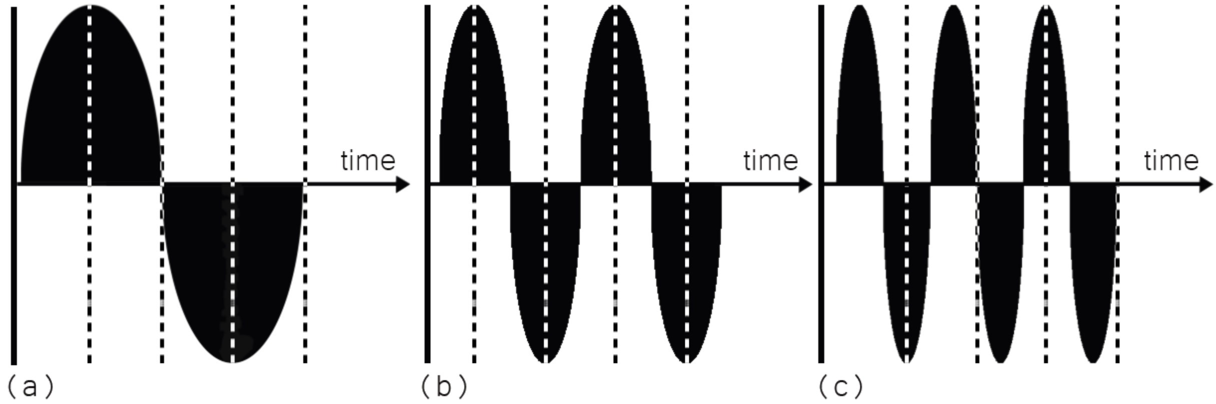

Figure 3 An image representing the (a) funtamental, (b) first octave, and (c) second harmonic. (re-creation of image based on Huber, 2010).

2.2 The history of tuning

Throughout history, our standards for tuning has gone through many transformations regarding the mathematics (tuning system) used to calculate note distance, and the frequency used as reference for tuning (pitch standard) (Barbour, 2004; Cavanaugh, 2009; Haynes, 2004; International Organization for Standardization, 2018; Segerman, 2001). The current tuning standard is according to the International Organization of Standardization (2018) set to A = 440 Hz, and the tuning system most used is in the Western World is Equal Temperament (Scholtz, 1998).

2.2.1 Tuning system

Two major tuning systems will be discussed, The Pythagorean system and Equal Temperament, although there exist several other tuning systems that have been or are being used (Barbour, 2004). The earliest documented tuning system was invented by the ancient Greek philosopher Pythagoras – Pythagorean system (Barbour, 2004). The system relies on the ratio 2:1 for the octave and 2:3 for the fifth – these ratios specify the multiplication used to determine an interval where 2:1 octave denotes that the frequency of octave is double that of the fundamental, as explained in 2.1 The Physics of Sound (Barbour, 2004; Huber, 2010). Using these ratios, any note of the specified scale can be found by tuning in a succession of fifths and octaves (Barbour, 2004). As stated by Barbour (2004), Pythagorean tuning results in some inconsistencies, where certain tones are slightly too high compared to Equal Temperament.

Our modern tuning system, Equal Temperament, is defined by Scholtz (1998) as a system of tuning where each note's distance is exactly equal. It was created in an attempt to combat the inconsistency of the Pythagorean system (Scholtz, 1998). This is done by adjusting the errors that occur through very slight adjustments as lowering the fifth and raising the forth (Scholtz, 1998).

2.2.2 Early history tuning

Segerman denotes a pitch standard as the association of "a note name with a small range of frequencies" (2001, p. 200). Up until the early sixteenth century there was a complete lack of any pitch or note standard, as printed sheet music and tuning devices were not readily available. Instruments were then manufactured in sets for playing certain tunings, each set with their own pitch standards. As musicians and composers started favouring ensemble play the need for a universal pitch standard arose, as to enable instrumentalists of different sets to perform together (Segerman, 2001). Although a universal pitch standard was desired, country-wide differences were still abundant, as well as varying with time.

2.2.3 19th Century tuning

According to Doctor Lynn Cavanagh of University of Regina (2009), standard pitch during the 19th Century was slowly rising higher and higher in frequency. This was a result of three different factors: bigger concert halls and opera houses that could produce higher pitches, allowing orchestras to raise their standard pitch in order to create more intense climaxes; instrument-makers tuning their instruments slightly higher than their competitors' to sell the brightest and most brilliant sounding wares; strings for the stringed instruments improved, allowing for an even higher tuning than possible before (Haynes, 2004). As standard pitch rose, singers were suffering (Cavanagh, 2009). Cavanagh (2009) points out that compositions written with a lower pitch standard in mind might be performed almost a semi tone higher. In 1859, as to combat the higher tuning frequencies, France declared A=435Hz, diapason normal, to be the standard by law, and while other countries and orchestras were not obliged to heed this, the standard was still adopted in Germany and England due to pressure from orchestra conductors and singers (Cavanagh, 2009). The English reaction to the French tuning standard was to eventually attempt to establish A at 440 Hz. According to Haynes (2004) this effort was a complete failure as the Society of Art - responsible for creating the tuning forks used - misunderstood the role of temperature and thus created a fork tuned to about 450 Hz instead of 440 Hz. In 1877, the pitch of Albert Hall in London was measured at A=455, with accounts of Wagner complaining over the inconveniency of having his singers perform at this pitch, and in 1879 famous soprano Adelina Patti refusing to perform until the orchestra tuned down to French pitch (Haynes, 2004).

2.2.4 20th Century tuning

For the first half of the 20th Century, countries, there was still no standardized pitch for tuning (Haynes, 2004). In England, the old mistakenly high pitch was still present in the army and smaller woodwind groups (Haynes, 2004). It was not until 1929 the army officially changed from their high concert pitch standard 440 Hz, and longer for woodwind groups, up to 1950 (Haynes, 2004). France generally still held their diapason normal until around 1957 when 440 Hz was considered as the pitch standard (Haynes, 2004). The German pitch standard is presented below in *Table 1*, showing a constant fluctuation of pitch.

Table 1 Overview of German tuning standards. (Haynes, 2004)

Year	Tuning Standard	Institution
1920	428	Berlin Philharmonic
1924	435	Berlin Philharmonic
1927	435	Amar-Hindemith Trio
1927	448	Berlin Staatsoper
1928	446	Berlin Philharmonic
1928	444	Berlin, Staatskapelle
1932	440	Berlin Philharmonic
1935	445	Berlin Philharmonic
1939	444	Berlin, Staatskapelle
1940	450	Bayeriches Staatsorchester
1941	441	Berlin, Staatskapelle
1943	450	Städtisches Orchester, Berlin

It was not until 1955 a truly universal pitch standard was settled when The International Organisation of Standardization enforced A = 440 Hz as the modern standard for tuning, and enforced once more 20 years later. (ISO, 2018)

2.2.5 Opposition of the pitch standard

Since the standardization of pitch in 1955, several voices have been raised since 1980s claiming that A = 440 Hz is not the optimal tuning (Crotti 2016; EIRMusic 1988a; EIR Music 1988b; Schiller Institute 2018). The Schiller Institute, an organization aimed towards applying the teachings of philosopher Freidrich Schiller on our modern societal and political situation, started a campaign in 1988 to change the pitch standard to - what the Institute refers to as "Verdi tuning"- A = 432Hz (Schiller Institute, 2018; EIRMusic, 1988a). The Schiller Institute and its efforts to change the pitch standard were often reported on by the magazine Executive Intelligence Review (henceforth EIR) (EIRMusic, 1988a; 1988b). As phrased by the EIR (1988a) the Schiller Institute's campaign led to "hundreds of singers, instrumentalists, orchestra directors, and opera lovers have signed the petition circulated internationally by the Schiller Institute for Italy and the entire world to return to the scientific tuning fork of Verdi (C = 256 vibrations, corresponding to an A of 432 vibrations)." As part of the campaign, Bruno Barosi, director of the Physical Acoustics Laboratory at the International Institute for Violin Construction in Cremona, alongside Norbert Brainin, first violinist of the Amadeus Quartet, conducted an experiment comparing the contents of

partials in recordings of Brainin performing Bach's works for solo violin tuned to A = 432 Hz and A = 440 Hz respectively (Abdella, 1989; EIRMusic, 1988b; Goldman, 2013).

As reported by the EIR (1988b, p. 58) the recordings were then analysed and processed using a spectrogram to determine the wealth of overtones present in each recording, where "the sounds in the deep tuning were distinguished by their abundance of overtones, both with regard to the number of such and to the volume". According to the Oxford dictionary of nation biography, Brainin considered the experiment a success in proving that the Verdi tuning held qualities greater than the ISO-standard (Goldman, 2013). Although the Schiller Institute's efforts were largely unsuccessful, as the globally accepted pitch standard still remains at A = 440 Hz (ISO, 2018), several actors and parties in modern media has given Verdi's tuning a new breath of life during the last few years.

This time the claims are based on different arguments than those made 30 years ago: the Schumann resonances. As described by NASA (2018), the Schumann Resonance are created by bursts of lightning which in turn create electromagnetic waves that circle the Earth's atmosphere and, when created at the right wavelength, combine to "create a repeating atmospheric heartbeat known as Schumann resonances" (NASA, 2018). These waves resonate at a rate of 7.83 Hz, causing their length to be precisely equal to the Earth's circle (Rusov et al., 2012). According to a group of scientists at Odessa National Polytechnic University in Ukraine, there is strong evidence that electromagnetic resonant radiations, such as the Schumann resonances, can impact human brain biorhythms such as delta-rhythms and theta-rhythms, although the latter only partially.

In 2016 Enzo Crotti, a proponent of 432, published the book Integral 432 Hz Music. Crotti's main focus is spirituality, meditation and health which is why he seeks to explore tuning to A = 432. This book takes a different approach than the Schiller Institute (2018), instead relating to the Schumann resonances (NASA, 2018). Crotti (2016) claims that A = 432 Hz in Pythagorean or Just Intonation will result in the C at 256 Hz, being five octaves higher than 8Hz, close to the same frequency as the Schumann resonances. According to Crotti (2016) frequencies can alter human behaviour both positively and negatively. Frequencies of 6 Hz can cause depression, while a rate of 10 Hz can lead to aggressiveness (Crotti, 2016). Crotti (2016, p. 36-37) also mentions the works of Ananda Bosman, a researched and musician living in Norway, who researches pineal glands and their effects on the human body. According to her, the pineal gland activates when exposed to vibrations of 8 cycles per second, releasing hormones containing anti-aging properties and positively affecting sleep (Crotti, 2016).

2.3 Pitch perception and memory

This section presents two experiments performed in the late 20th Century. The spectral centroid presents a possible explanation to the idea that A = 432 Hz contains different or superior sound qualities since it details how changing the frequency spectrum, the perception of a sound can be drastically modified. The Levitin is related to our ability to memorize pitches and provides theoretical ground as to why A = 432 Hz might be perceived differently from A = 440 Hz.

2.3.1 Spectral centroid

In 1977, an experiment was performed by John M. Grey and John W. Gordon (1978) examining the effects of spectral modification on the timbre of musical notes (Grey & Gordon, 1978). Recordings from 16 musical instruments were used, 8 of these modified in pair, 8 left untouched. The modification consisted of swapping the spectral energy distributions, based on its shape, within each pair of two tones (Grey & Gordon, 1978).

The differences were analysed using both 3-dimensional data matrixes to compare pre-modified positions on the matrix in relation to the new, as well as obtaining a rating from listeners asked to grade the similarity between a randomly selected note pairs on a scale of 1-100 (Grey & Gordon, 1978). Grey and Gordon (1978) found that exchanging the spectral shapes of instruments strongly affect how they were perceived: the modified oboe-clarinet pair caused a reversal in identification; the switch between strings caused the playing technique to be associated with the sample containing its spectral shape rather than the original performing instrument's recording; the spectral exchange between bassoon and French horn led to a bassoon with the explosive attack of a brass instrument and a horn with the soft, round tone of a woodwind instrument. These findings showed that bandwidth (the horizontal distribution of frequencies) was less detrimental to the timbre of a sound than the actual shape of the spectral distribution (Grey & Gordon, 1978). According to Grey and Gordon (1978) the most successful model used to measure spectral shape distribution was the *centroid*, a method which indicates the spectral distribution, acquired through a function in lieu with Zwicker and Scharf's model (1965).

2.3.2 Levitin effect

In 1994, Daniel J. Levitin (1994) was exploring a thesis on absolute pitch (AP) - a rare form of musical memory exists, which is "the ability to perfectly produce or identify specific pitches without reference to an external standard" (Levitin, 1994, p. 414). Levitin (1994) began hypothesizing that perhaps every human, to some extent, possessed AP. Levitin found that non-AP subjects were found to be able to perform better than chance when tasked to identify the pitch of a tone. Subjects with musical training asked to identify a composition's key centre showed similar results (Levitin, 1994). Levitin (1994) states that this ability also seems present in non-musicians as, in an experiment conducted using Shepherd tones - a two-tone set ambiguous as to which note is higher or lower than the other – the subjects were found to, although unable to label pitch, be using AP indirectly.

This led to Levitin (1994, p. 415) forming a hypothesis that AP consisted of two different component abilities: pitch memory or "the ability to maintain stable, long-term representations of specific pitches in memory, and to access them when required"; and pitch labelling or "the ability to attach meaningful labels to these pitches, such as C#, A440, or Do." With this hypothesis as grounds, Levitin (1994) conducted an experiment on the capabilities of the human brain to not only create a memory representation of a song's actual pitches but also be able to recall and sing these pitches without any reference other than memory recollection. As a result of this an experiment with 46 individuals of no or varying musical background whom, after filling out a questionnaire regarding their gender, age and musical background, were seated in a room with 58 CDs and asked to pick one CD that contained a song they knew well (Levitin, 1994). The subjects were then asked to perform the song of the chosen CD as it was digitally recorded and later compared to the original recording in order to determine the subjects' pitch accuracy. The results of these experiments showed that 40% of the subjects could recall the exact pitches in at least one of

the trials, and 12% performed flawlessly (Levitin, 1994). Comparatively, this occurring by chance was estimated to approximate to 17% performing without error on one trial and 0.7% performing perfectly both trials (Levitin, 1994). Through these experiments, Levitin (1994) concluded that there indeed existed evidence supporting his two-component theory on absolute pitch. Subjects were unable to label pitch, which according to Levitin (1994) supports the idea that the two components of his absolute pitch theory are independent of each other.

3 Problem

With the background presented, it becomes clear that pitch standards have changed over time and – most likely – will continue to fluctuate even though a stable standard now exists. A quick Google (Alphabet Inc., 2018) search using the words "432 vs 440" will result in several sources such as videos and blogs heralding these claims without any real scientific backing. These sources focus on the Schumann resonances alongside the tuning's timbre, tone colour and emotional value. Crotti's (2016) writings suggest a number of advantages of tuning to A = 432 Hz, but he too lacks scientific backing in the claims as he mentions variables that have no proven correlation. Previously, the experiment conducted by Barosi and Brainin (EIR, 1988b) claims to have confirmed these qualities through spectral analysis[2], but without readily available data from these experiments the validity of this experiment is questionable. Grey and Gordon (1978) provide evidence that the spectral energy distribution, or spectral centroid, does matter in how music is perceived, and could thus serve as an indication that - if Barosi and Brainin's experiment was as successful as claimed – tuning to A = 432 Hz could change the way music is perceived. The evidence for the sonar qualities of A = 432 Hz is severely lacking, but with the recent resurgence of interest in this subject a scientific investigation is overdue. This is done by a slightly modified version of the experiment conducted by Barosi and Brainin (EIR, 1988b) where, instead of spectral analysis of recordings of a violin performing a piece tuned to A = 440 Hz and A = 432 Hz respectively, the recordings will instead be tested on individuals asked to rate their perceived differences between said recordings. As part of the study, the following research question has been formulated:

"What differences can be found between tuning systems in A = 440 Hz and A = 432 Hz regarding sound quality, timbre and emotional response?"

Since the frequencies of these tunings are very close to each other, it might be impossible for humans to distinguish between them. This is where the Levitin effect (1994) becomes relevant as it provides a theory where we can assume that, given enough time, an individual would form a form memory representation of a composition in one tuning and when played in another tuning notice the differences between these.

3.1 Method

The study is limited to only research the perceived experiences and responses in humans listening to the different tunings. No physiological responses, such as the effects on the biorhythm of our brain, health or stress, are measured. Relationship between the Schumann resonance and musical tunings are not considered or tested in any form.

[2] A tool widely used for analysing sound waves is the spectral analyser, which is used to visually represent an audio signal's frequency contents as well as their amplitude (Huber, 2010). It is generally used as a complement to audio as it provides a second element to hearing – seeing – which allows the observer to immediately see exact frequency contents of an audio signal, their amplitude level and the relationships between them (Huber, 2010). One method of digitally manipulating the audio signal is through spectral modification, or filtering (Huber, 2010). This process can be done using an equalizer, which operates by altering the frequency response of certain frequencies in order to increase or decrease their amplitude and thereby, presence (Huber, 2010).

The study was conducted using a quantitative survey design. The quantitative method is, in the words of Alan Bryman (2010, p. 40-42), generally suited for research with a deductive approach where theory already exists and hypotheses are formulated before any collection of data has occurred, where the aim is testing the validity of the theories and hypotheses through the data, as opposed to an inductive approach which instead generates both theories and hypotheses through empiricism. In this study, both the theories used as grounds for the research question and the hypothesis already exist, thus the main focus lies on testing their validity.

As for the research design, using a survey form serves several functions; more than one case is studied and with greater variety in subjects the odds of variation in any interesting variables observed also increase: data is collected within a specific time frame which means the time or circumstances in which they are collected is less important; quantifiable data is generated which requires a standardized method of evaluation, creating a consistent guideline for the researcher or researchers to follow; only relationships between variables can be studied when using a survey design, disallowing any causality to be observed (Bryman, 2010, p. 64).

In this study, the main advantages of using a quantitative survey design was that a larger sample could be included, which, according to Borg & Westerlund (2013) increases *a.)* the chances of the data being representative of the actual population and *b.)* the possible variables that can be observed. Although no causality can be observed, relationships between the variables can indicate that causality exists, motivating further research of the subject. The gathering of data is made through the means of surveys, which readily allows the coding of any data collected as it is delivered in an already organized format (Bryman, 2010). In using a survey-based method, any possibilities of follow-up questions, as well as helping subjects mid-collection, is forsaken (Bryman, 2010). A qualitative method would enable this, as well as allowing a deeper probing of the subject's perceptions, but would limit the sample size as it is a more time-intensive method. A more thorough understanding is of course desirable, but for the purpose of testing theories, a quantitative approach lends itself perfectly well. Since the main purpose is to identify whether or not there is a distinguishable difference between a composition in A = 440 Hz and in A = 432 Hz, premiering this data is collected as effectively as possible is therefore of utmost importance.

Secondary to this was, if indeed distinguishable, any difference in emotional impact or quality the subjects perceive between each tuning can then be assumed to not have occurred purely by chance. Therefore, the choice of a quantitative approach is the most logical one as it presents the best options for assuring validity (Borg and Westerlund, 2013).

3.2 Sampling

Since the purpose of this study was to evaluate perceived differences between similar tunings, any individual with greater hearing impairment or loss of hearing were excluded in the final results as they may be less capable of hearing these differences. Generally, any individual over the age of 70 will be not selected as the chances of age-related hearing impairment are high (Yang, Schrepfer & Schacht, 2018). No discrimination were made to individuals lacking musical background, as the Levitin effect (Levitin, 1994) supports the idea that pitch memory is present in individuals no matter their musical background. Both

English – and Swedish-speaking people were able to participate since they survey was created with an option for either language.

3.3 Material and considerations

In order to answer the posed research question, 39 seconds of music was composed and created in a Digital Audio Workstation (DAW) with recorded samples of a violin tuned to A = 440 Hz in Equal Temperament tuning and programmed with MIDI notation. The violin samples were then digitally tuned down to A = 432 Hz resulting in two different versions of the same composition: one in A = 440 Hz and the other in A = 432 Hz.

A major consideration was using a sample-based digital violin programmed in MIDI versus an actual recording performed by an instrumentalist. The main difference between recording an instrumentalist and using pre-recorded samples lies within the performance, since both methods are based on recordings of real instruments. A disadvantage of using a musician is the chance of human error when playing the piece. Since violins are fretless instruments, the exact pitch of notes can fluctuate depending on the musician's finger position, causing microtonal differences which could in the end contaminate the results if these errors are too great. Using an instrumentalist would also require time for finding a suitable candidate, rehearsing the composition and recording the performance alongside potential editing. Thus, the time factor of finding, hiring and recording an instrumentalist, with the considerations for human error resulted in opting for a digital sample-based approach.

3.4 Problematisation of chosen method

The chosen research design has some limitations. For example, asking follow-up questions, helping respondents with questions or observing behaviours was not possible since the survey was not conducted by on-site participants. Since Bryman (2011) describes observations as a tool for examining behavioural patterns, which is not part of this study, this is irrelevant. The inability to help respondents and ask follow-up questions puts greater pressure on the design and structure of the questionnaire. Therefore, the pilot study was performed with participants answering the questionnaire, followed by a short interview where respondents would raise concerns or questions regarding the questionnaire.

One disadvantage of the chosen method is the inability to use a singular location and providing equipment for musical playback when the respondents listen to the written piece of music. Having a set location gives the ability to control how the listeners experience the music by being able to control room acoustics, speaker types and the distance from the listener to the speakers which would eliminate potential error and contamination of results based on these factors. Room acoustics and distances can be eliminated by having respondents listen using headphones. This does not change the fact that respondents will be listening using different types of headphones, which might have boosted or cut frequencies but this factor was deemed less important than the boon of a greater sample size and ease of distribution provided by using a survey design.

Digital re-tuning a recorded sample does create different results as compared to re-tuning a violin since it uses algorithms to modify the sound wave instead of physically altering the length of the string. This means any potential increase in overtones from tuning down to A = 432 Hz, as claimed by Barosi and Brainin (1988), might be forfeited since the digital re-

tuning will only alter an already recorded sound wave and should not introduce any new information to the recording.

3.5 Designing the survey, data collection and analysis

In designing the survey, two factors were considered: subjects might not be able to maintain a stable memory representation of the compositions for an extended period of time since their exposure to it is limited; and using an efficient method for measuring perceived differences between the composition. The survey was comprised of three elements: listening to the compositions; answering short questions regarding their perception and attitude towards the compositions; and final part of pairing words the respondents felt related to the compositions.

A solution to the first factor would be to allow respondents a second - or several - listening(s) which would increase chances of creating a memory representation of the track (Levitin, 1994). This was rejected since it would change the premise of listening to the music without knowing a difference existed, thus skewing the results. The study is focused on the latent perception of listeners rather than any ability actively determine and perceive pitch differences as this has been exhaustively researched already.

As for the second factor, this boiled down to two things: coding of data; and posing a question that created data corresponding to the perceived differences, and not something else. The question was based around the Likert scale.

> The Likert scale is essentially a multiple-indicator or multiple-item measure of a set of attributes relating to a particular area. The goal of the Likert scale is to measure intensity of feelings about the area in question. In its most common format, it comprises a series of statements (...) that focus on a certain issue or theme. Each respondent is then asked to indicate his or her level of agreement with the statement.
>
> Bryman, 2010, p. 157

This is also what Grey and Gordon (1978) used to measure the response for listeners in their experiment regarding musical timbre, which is similar to the type of research conducted in this study: listeners were asked to rate the similarity of two tones relative to that of all other tones heard previously.

> The similarity rating was made on a scale of 1-30, and this scale was presented to listeners as having three general ranges: (1) 1-10, very dissimilar; (2) 11-20 average level of similarity; and (3) 21-30 very similar, relative to all pairs.
>
> Grey and Gordon, 1978, p. 1495

In accordance with these, respondents were first asked to: "Rate the level of similarity between composition A and composition B on a scale of 1-30 where 1-10 is very dissimilar, 11-20 is average level of similarity, 21-30 is very similar, and 0 is 'I don't know'." The last was added as a measure to enable respondents who perceived no difference in the compositions or didn't understand the question properly a way out that would not skewer the result (Bryman, 2010). After this, respondents would be asked to answer whether they preferred

any of the compositions to the other. If they did, they would answer which one and optionally write a short answer as to why they preferred it. Finally, respondents were asked to pair words they felt corresponded to each composition.

The data was analysed and coded in three different sets, first the similarity scale, second on preference and third by word pairing. The first two sets were already pre-coded (except the optional text responses), which means the data could easily be processed after collection (Bryman, 2010). The word pairing, on the other hand, would have to have a less quantitative approach as it would prove difficult to assign any value to each word. Rather, it would serve as an indication of whether Barosi and Brainin's claims held true regarding the superior warmth and tone quality.

3.6 Procedure

During a two-week period, any eligible potential participants of the study were contacted through the means of email with an inquiry to their potential interest of participating. In this period, any positive response was then catalogued and numbered as they were received in order to create a database of participants. After the two weeks, respondents were then divided into either Group A or Group B, using the following random sequence generated using an online generator at http://www.psychicscience.org/random.aspx (physicscience.org, 2018) and assigning the numbers in sequence generated to each participant, see *Table 2*. Participants in Group A were sent Survey A, vice versa. The order of the compositions was reversed for Group B.

Table 2 Participant number assignment example

Participant	Assigned number
1	11
2	3
3	9
4	18
5	12
6	6
7	7
8	16
9	8
10	1
11	10
12	5
13	20
14	14
15	2
16	4
17	17
18	19
19	13
20	15

Uneven numbers are coloured a light blue for easier visual separation.

The purpose of the study was explained in short terms, making sure not to mention anything regarding abilities to perceive difference between two compositions in different tunings. Of great importance, was that none of the participants had any previous knowledge of the study which would potentially hurt the validity of the results.

Before any listening, basic information regarding gender and age as well as musical background were collected. Participants would then undertake the survey as per description.

3.7 Ethical considerations

Since collecting contact information for the distribution of surveys was part of the research design, it was important that this information was treated carefully and stored only for the researcher to access. This meant avoiding any service which also grants the company access to or ownership of any documents or files stored on it. Respondents were informed of their right for a request to be removed from the list of participants, resulting in their email being permanently deleted from the database. In addition to this, they were also informed that, once the study had been completed, their contact information would be deleted.

Before beginning the questionnaire, participants were in text informed they would remain anonymous throughout the survey, that participation was completely voluntary, their right to discontinue the survey at any time for any reason, and their freedom to not answer certain or

all questions. They were also informed that they at any time could contact the researcher to inform that they did no longer want to participate and their contact information would be deleted immediately.

4 Implementation

This chapter mainly describes the process of creation for the composition, which includes spectral analysis of violin recordings and the digital samples used in the final composition, sketching and writing various compositions and the considerations made when doing this alongside the process of choosing the most suitable sketch and finalizing it through compositional tweaks and MIDI programming. Also described are the results of the pilot study alongside any changes made to the survey and composition based on these results.

4.1 Pilot study

The pilot study consisted of sessions where individuals would first answer the survey online and, then participate in a brief interview based on their answers as well as any problems they might have encountered during the survey such as difficulties understanding certain questions. Two surveys were made in Google Forms (2018): Survey A and B, with the only difference being the order of which the compositions played. One determining factor in choosing Google Forms (2018) over other survey platforms was its ability to embed videos which enabled respondents to listen to the compositions directly in the survey. Since YouTube (2018) displays the name of any embedded videos, the names were made to be almost identical, only differing by one letter so that they could be separated and rearranged more easily in survey B.

After the first session, it became apparent that the last two questions with word association needed clarification to inform respondents that they could choose more than one word, which was then addressed. The survey was then tested again on two respondents, one of which raised similar concerns as the first session: the word association still needed more clarification. The same respondent said they were unsure whether or not they had accidentally listened to the first composition twice since both sections are almost identical. The respondent suggested clarifying this through an added section before playing the second composition, which was subsequently added alongside further clarification for the word association.

Apart from restructuring and adding some sections to some parts of the survey, the results showed that respondents did in fact experience a difference between the two versions, some preferring the 440 Hz version, others the 432 Hz, but all preferring one version to the other. None of the respondents raised any concerns regarding the compositions. The word association did indicate that respondents in fact associated the different versions with different words, although this could be part due to the fact that two respondents only answered one word per composition as they thought that was the restriction. In the interviews, respondents explained why they preferred a certain version other using words such as “profound”, “brightness”, “deeper and more resonant” to describe why they liked a certain piece. This led to the addition of an optional question regarding reasons for preferring one version, which was answered in text.

4.2 Process and progression

The first part of the process of creating the composition was to investigate potential differences between digital re-tuning and analogue, to notice any potential major differences that might affect the results and could affect whether or not a digital or analogue version

would be used. For this purpose, a violin played with open strings in ascending order, tuned to A =440 Hz and A =432 Hz was recorded. After this, the VST[3] instrument to be used was recorded using the same principles but instead tuned using Kontakt 5 (Native Instruments, 1996) native tuning. Each string was recorded four different times with varying bow dynamics, but always using a slow sustained bow attack. The recordings were then analysed using a spectral analysation tool SPAN (Voxengo, 2002) (*Figure 4*) displaying two separate audio signals and their frequency content in comparison to each other to easily identify differences. Images of the graphs were saved and grouped according to three different sets: (1) comparing the recording in 440 Hz to the recording in 432 Hz, (2) comparison of recordings to VST, and (3) comparing the VST in 440 Hz to the VST in 432 Hz. Using Photoshop images of each comparison could easily be stored and access for comparison.

The images were compiled in a table containing information for each comparison.[4] The information gathered was generally inconclusive of any obvious major differences between any groups, but a few interesting. One interesting difference was note between the recordings and the VST:s where the recordings contained a lot of extra information between each peak, whereas the VST had almost no extra information except for its peaks (*Figure 5*). For the data to be conclusive the analysis and experiment would have to be reworked since factors such as varying volume affected by the strength of the bow on the violin, recording technique and recording location would have to be controlled more to reduce the chances of these variables affecting the result. Because of this, the analysis was treated as an indicator of potential results, showing that there indeed were differences between the digitally and analogically re-tuned instruments but the extent of these differences could not be established.

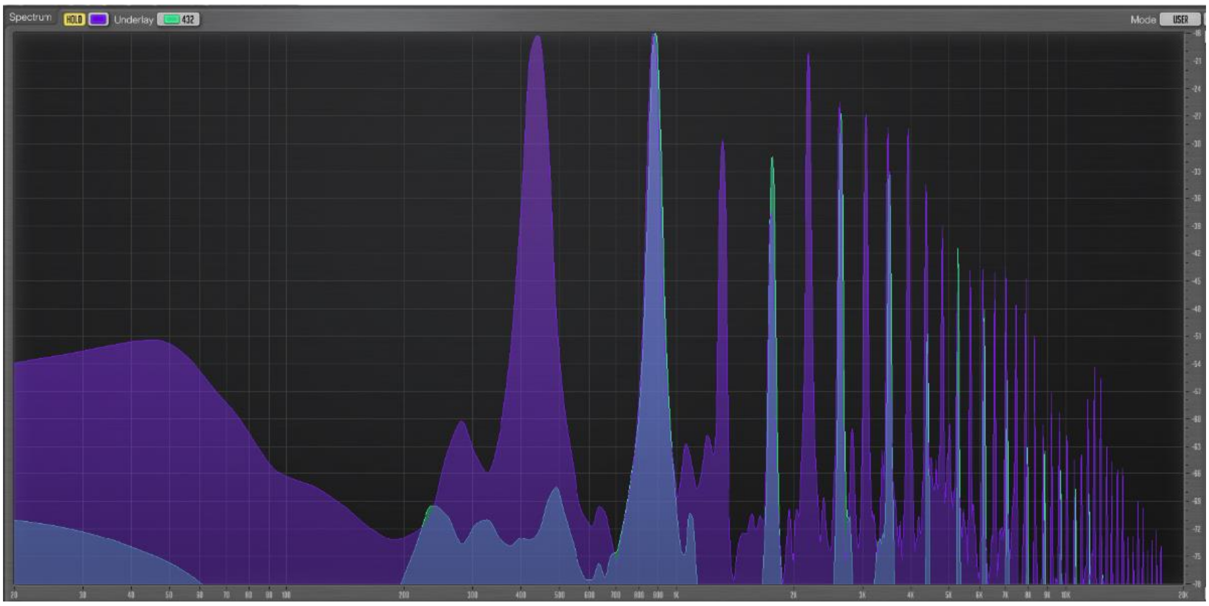

Figure 4 Comparison of recording and VST. Purple represents recording, green VST, and dark blue any overlapping frequencies.

[3] Virtual Studio Technology. A plugin-format created by Steinberg where all functions of the plugin or instrument can be controlled directly and automated in the chosen DAW (Huber, 2010).

[4] See Appendix for the full tables of comparison.

4.2.1 Sketching and selection process

After completing the spectral analysis, the next part of the process was to start writing sketches that would eventually lead to a singular, final composition. An early idea that was soon abandoned was to utilize already existing compositions, such as classical music works, and reprogram them in MIDI. The idea stemmed from the fact that respondents could be more likely to notice any differences between versions of a - for example - well know classical piece. This also would serve as a way to partly emulate both the experiment by Barosi and Brainin in 1988 as well as that by Levitin in 1998. The idea was not pursued for one specific reason: any previous experience with the composition might affect the listeners' responses, since a memory representation of the composition in its original tune might already be present and might prime respondents to be abnormally likely to notice differences as opposed to comparing versions of an original piece.

Because of this reason, the composition was decided to be an original. One specific goal was set when writing the composition: to create an interesting, memorable, yet simple melody in order to engage listeners and ensure the greatest possible chance of creating a memory representation of its pitch (Levitin, 1994). Creating this composition was split in two main processes: writing various sketches and judging them based on this goal; finalizing the chosen sketch through MIDI programming and compositional tweaks. The sketching process consisted of creation of various musical ideas and melodies by playing a MIDI-keyboard controlling a violin VST in Reaper (2018) until several different melodies approximately 30 seconds in length were ready. In writing and judging the sketches a strong theme[5] was one of the main criteria. As a tool for this, inspiration for themes was taken by analysing and listening to music from Lord of the Rings (Shore, 2001) The Legend of Zelda: Ocarina of Time (Kondo, 1998) and classical pieces such as Für Elise by Beethoven (1810). Five sketches were created and then played to peers at the University of Skövde in order to determine the best candidate. Once the process of elimination was complete, the next step was to finalize the chosen sketch by tweaking the composition and fine-tuning the MIDI programming and automation.

4.2.2 Finalizing the composition

As for the composition, only minor changes were made to the piece. These included adding an anacrusis at the beginning and modifying the tonal content at the end to create a more interesting and complete ending. The finished composition is written in the key of D minor harmonic, 9 bars total and in a tempo of 63 beats per minute. Although primarily written in D minor harmonic, the composition uses modal mixture[6] by borrowing from the D Phrygian scale occasionally and modulating from the D minor harmonic to D Phrygian completely in the last three bars. The mixture of the minor harmonic and Phrygian scale enabled melodically more interesting music through the chromatic line formed from the subdominant to the supertonic. As for the compositions structure, the theme of the heavily relies on the repetition of motives, a fundamental building block in music, described by Shoenberg et al. (1999, p. 8) as: "intervals and rhythms, combined to produce a memorable

[5] "[Musical] passages that sound as a cohesive unit (...)" (Richards, 2016, p. 1).

[6] The technique of using a chord or note borrowed from a different scale than the composition's native.

shape or contour which usually implies an inherent harmony”. The motives used can be seen in *Figure 5*:

Figure 5 *Motive a* and *b*. The main motives of the composition.

These motives are repeated in all bars except 4 and 9, in either modified form or as exact repetitions. The first motive *(a)* utilizes modified repetitions where the first note is changed to a different pitch, and the second motive (*b)* uses both exact and modified form. How the motives were used to form a theme is exemplified below (*Figure 7)*.

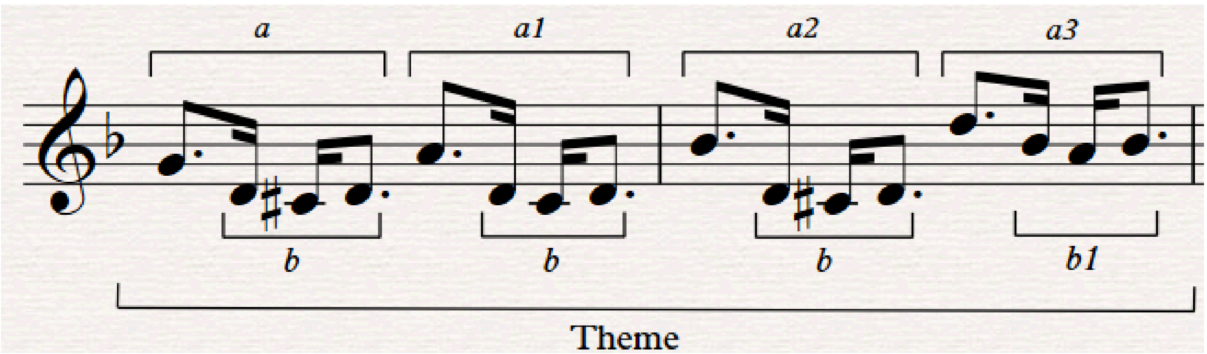

Figure 6 The use of motives in the composition. The numbers after motive letters represent their alterations. The main theme is also presented.

Apart from motives and themes, Russo, Ainis and Stevenson (2012) write that a good melody should have an upper curve as well as lower one. By this, they refer to the melodic line and the tonal height of each note. The upper curve is more important than the lower and the upper curve’s peak is at the highest tone and the curves should preferable occur gradually (Russo et al., 2012). The theme does this by shifting the first note of motive *a* upwards gradually, until it’s lowered once again in bar 5 where the same process is repeated until the high point is reached in the second part of bar 8 (*Figure 7)*.

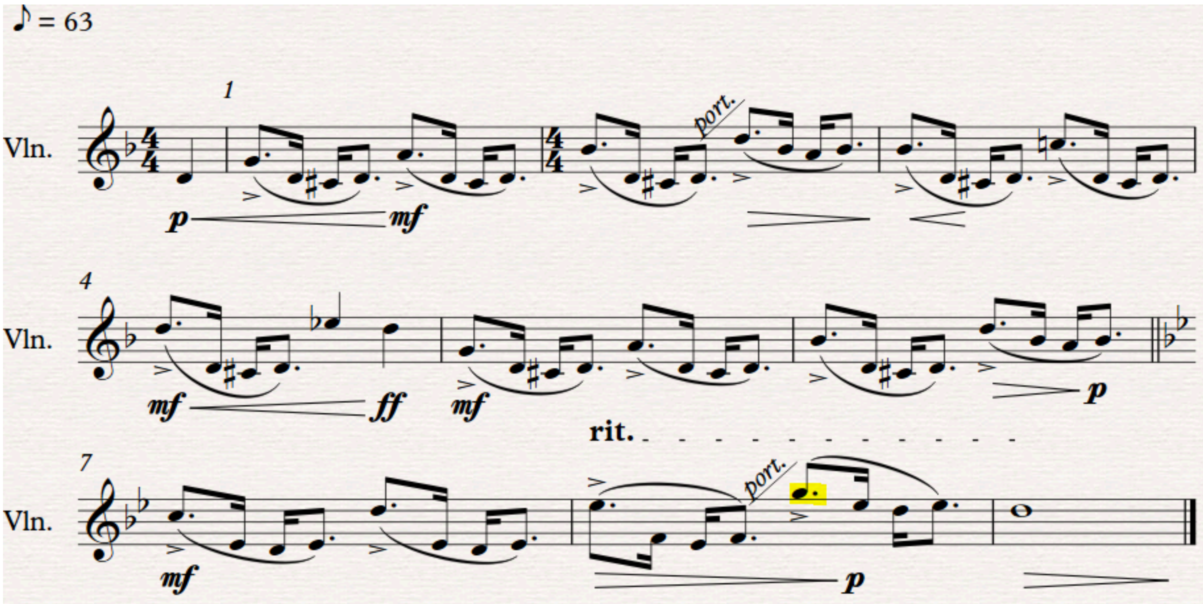

Figure 7 Full composition. With tempo, articulation and dynamic markings. High point is highlighted in yellow.

4.2.3 MIDI Programming

The finalized version was heavily inspired by the playing technique of professional concert violinists and, in an attempt to mimic these, observation and analysis of solo violin performances laid the grounds for the final sound. The sound was achieved by controlling parameters such as dynamics, articulation and vibrato and through automating CC values, key-switches and tempo. MIDI CC values were used to control of dynamics and vibrato by drawing curves in Reaper's CC message interface (see *Figure 8*), and key-switches to change the instrument's articulation and to create crescendos and diminuendos for individual notes. This phase worked through a very iterative process, since any changes to a part would also affect how well it transitioned to the next. The iteration consisted of programming MIDI for a certain bar or motive until its sound was satisfactory, then listening to the changes in context of the whole composition which most of the time would require additional tweaking. This type of workflow was used for all MIDI programming, alternating between working on smaller excerpts and working on the composition as a whole.

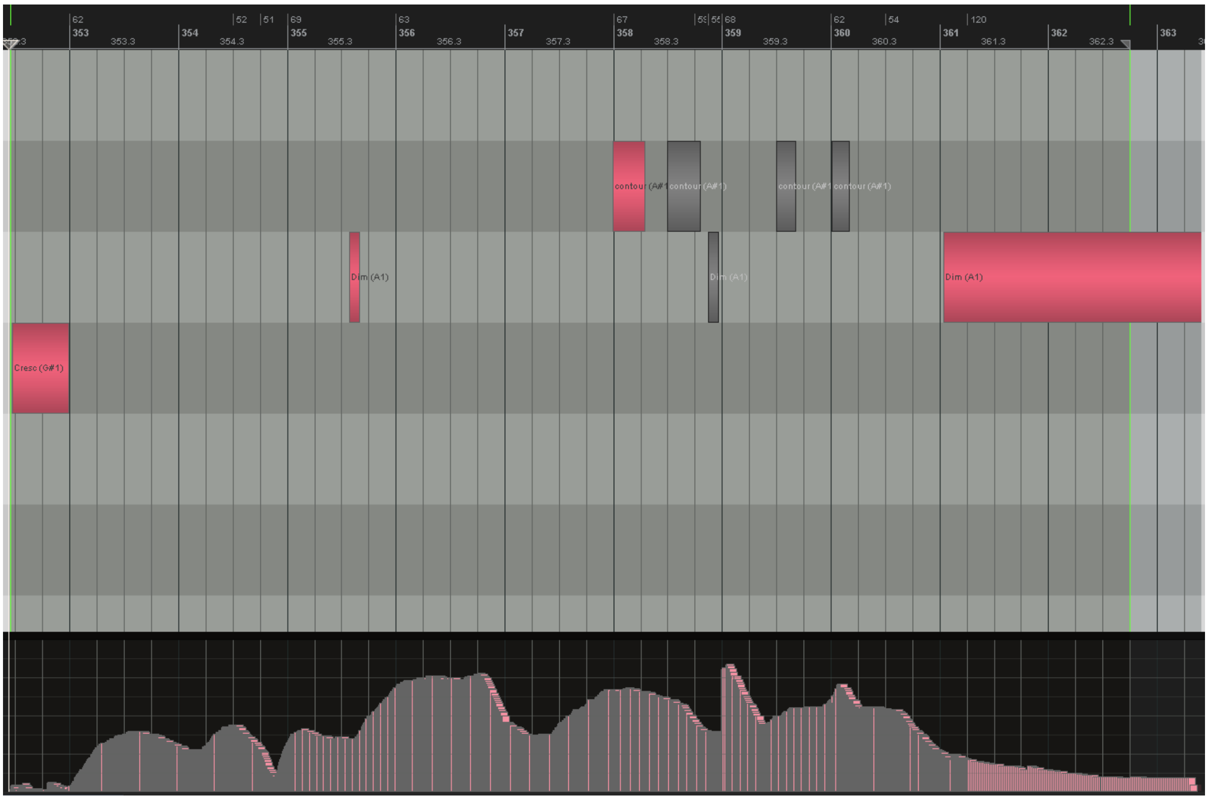

Figure 8 MIDI, CC and tempo automation data used to control the performance of the VST violin. Bar numbers are displayed incorrectly.

Once the iterative process was complete and the composition sounded natural, a compressor was applied to the track in order to even out any volume irregularities as a result of varied dynamics and bow attacks. The composition was then rendered twice: first in A = 440 Hz tuning, and then again in A = 432 Hz. By rendering the MIDI twice instead of changing tuning of the already rendered audio file, the variants had a higher chance of being less similar since they may contain slight differences as a result of round robins in the VST. The two versions were then saved in both.wav and .mov format, the .mov versions uploaded privately to YouTube for use in the pilot survey.

5 Evaluation

This chapter covers the study iterated through the previous pilot study. All the data gathered an analysed as part of the study will not be presented within this chapter, favouring visual clarity and avoiding unnecessary clutter. All tables not presented in text are included in Appendices B-E except for the table on preferential reasoning which has not been translated to English and is therefore excluded. The survey contained two language alternatives, both English and Swedish, but as all participants were native Swedish citizens, no one chose the English version.

5.1 The Study

All surveys were answered within the span of a week and results saved in Google Forms for later analysis. The study was performed on 30 people with a majority of respondents in ages 19-30, where each person had been organized in a table in no particular order and then assigned a random number from a 30 number sequence (as shown in chapter 3.6 Procedure). For even numbers, respondents were sent Survey A, for uneven Survey B. They were then asked to send a confirmation that they had either completed the survey or chosen not to participate, and their name would then be checked off in the table until all respondents were checked. All respondents chose to participate in the study. Out of the 30 respondents, 8 had some form of previous formal musical education, 3 suffered from tinnitus or similar hearing damage and a stunning 8 claimed to possess absolute pitch, of which 2 had a musical background. That all of these respondents would in actuality possess perfect pitch is not impossible but incredibly unlikely as Sacks, O (1995, p. 621-622) reports that approximately 1 in 10 000 has this ability, although it is also mentioned to be more prevalent in professional musicians. Most likely this is an error in understanding terminology, and more importantly an error in the design of the survey by not explaining the term and instead assuming it was common knowledge. It is also possible these respondents confused absolute pitch with the term relative pitch.

5.2 Analysis

After all surveys had been completed, the data was then transferred to two separate Google Sheets files in preparation for analysis. Using these sheets, the analysis document was then created which contained the data for both Survey A and B separate, as well as summarized together. Firstly, any respondents not using headphones, possessing absolute pitch, or with any type of hearing impairment were filtered through color-coding for ease of recognition later. Data from the two separate documents was transferred to various tables for the purpose of identifying potential correlations. This effort began with the variables that were deemed most important such as similarity rating, tuning preference and word associations. The type of data generated for these were either quota/interval variables or nominal variables which are easily analysed in either correlation or frequency tables (Bryman, 2010). As these tables were completed and patterns emerged, additional variables and potential correlations became interesting: musical background and it's relation to tuning preference and similarity rating; musical background in relation to similarity rating; shared and unique characteristics (word association) in the different tunings. Lastly, any potential relationship between similarity rating and tuning preference was studied as this might contain additional

information as to why someone might prefer a specific tuning. The data's statistical significance and correlation coefficients were not calculated.

The open question regarding why respondents preferred a specific tuning were coded differently as it contained longer text and all responses were gathered in a table and then analysed for categories. Answers containing two separate categories were split into different cells and once this process was complete the data was into four different categories for analysation: emotion, tonality, playing technique, and characteristics.

Absolute pitch-positives were generally discarded as false positives after their data was scrutinized for deviations from the norm. Out of the 8 total, the 2 with musical background were considered more carefully as their data had deviations, of which one gave an extremely low similarity rating and is treated as an outlier for all analysis.

5.2.1 Similarity rating

The majority of respondents found both versions to be very similar, a few rated them as being of average similarity and the outlier gave the versions a very low rating. The statistics are presented below in *Fig. 9*.

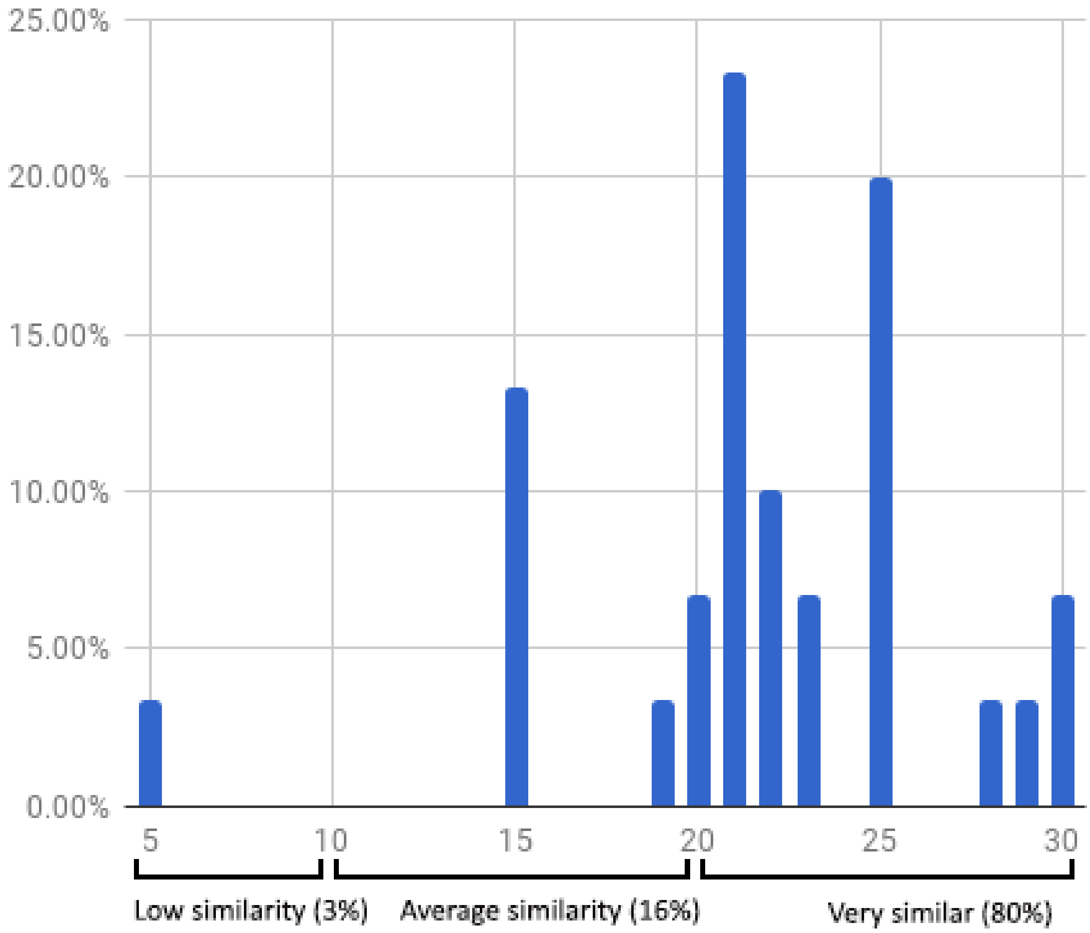

Figure 9 Total similarity rating. X represent grade of similarity, Y percentage of answers (Appendix B).

The average similarity rating was a 22.5, which is the lower end of the Very similar category. This indicates that, in general, listeners were able to distinguish between the tunings and that tuning to A = 432 Hz does change the timbre and spectral content sufficiently enough to create a perceptible difference for the average human. The effect of a musical background – or lack thereof – appears to be negligible in regards to perceived similarity, as the difference between both mean and average values of these groups were <0.5 units (22.36 for no education and 21.86 for musical education(Appendix B)). Out of all responses, two respondents perceived the versions as being completely identical at a similarity rating of 30. Interestingly enough, one of the respondents, although rating a 30, did prefer the 440 version which might indicate that to them, a rating of 30 was not equivalent of total similarity but instead as being incredibly similar.

5.2.2 Tuning preference

Since respondents seemed able to separate the versions sufficiently, this should allow for them also favouring either version. The final results show that one of the version indeed was favoured, the current standard tuning at A = 440 Hz. The majority of respondents preferred standard tuning over the alternative, A = 432 Hz, the second most popular choice - by a 1 answer margin. Below are the exact statistics for tuning preference, as presented in *Table 3*:

Table 3 Tuning preference

Tuning preference	Nr. of answers	Per cent
440	13	43.33%
432	9	30.00%
None	8	26.67%
TOTAL	30	

The 'None' option is a neutral option, and only indicates that either the respondent perceived both tunings as very similar or had no preference to any of the tunings, although perceiving them as different. As it is a neutral option, it neither supports nor dispels the claims of the 432 proponents. Because of this, it becomes less attractive to rank it with the other alternatives and as such, the data is adjusted to compare those with a preference, where, out of the 22 respondents with a preference, $^3/_5$ preferred A = 440 Hz, still a marginal difference.

As it stands clear that the majority preferred A = 440 Hz, how does musical background reflect on preference? For respondents with a formal musical education, there was a significantly greater preference for standard tuning, whereas the group with no education is evenly split between all options (*Table 4*).

Table 4 Tuning preference in relation to musical background (Appendix D)

Preference based on background				
	Musical education		*No musical education*	
Preference	No. of answers	Per cent	No. of answers	Per cent
440	5	62.50%	8	36.36%
432	2	25.00%	7	31.82%
None	1	12.50%	7	31.82%
TOTAL	8		22	

For tuning preference in relation to similarity rating, no significant patterns were recognized in ranges 0-22. In the higher ranges (23-30), the frequency of no preference increased and seven out of the total eight 'None'-responses were in this range, representing 58,3 % of all answers in this range. Outside of no preference, all but one respondent with a preference preferred the higher 440 Hz. These results point towards the fact that a higher perceived similarity has a negative correlation to the prevalence of preference. (Appendix D)

Out of Group A and B, enjoyed standard tuning the most: over 50% preferred 440, while Group B was completely equal between all three alternatives (Appendix E). With musical education having a higher tendency of preferring standard tuning, one would assume Group A would be the most prevalent in individuals with musical background, but out of the 15 participants in this group only 2 had a musical background.

5.2.3 Characteristics and associations

As for unique characteristics, associations and emotional response in both tunings results did not support the idea that either A = 440 Hz or A = 432 Hz might affect these factors differently (Appendix C). The variables analysed for these factors were word association and motivation for a certain preference. Both tunings shared very similar answer frequency in the word associations with the most common associations being warm, dark and soft. Generally, both tunings shared most associations, although A = 432 Hz was considered slightly darker. As for unique associations, A = 440 Hz was perceived as being both sharp and light, whereas sharp was its second most common association – twice as frequent as for 432.

In regards to affect related to A = 440 Hz, respondents both reason that the tuning sounded happier, sadder, more gentle and more dramatic. For A = 432 Hz respondents mentioned emotionality and vulnerability, that the composition was "conveying a solemn feeling", being more soothing and not as dark, and that it was even more energetic. For A = 432 Hz, two completely contradictory responses were present, as one respondent said they "thought it (432) was better in a minor key", while another "felt (that 432 was) more nuanced and not as minor compared to A (440)." No real patterns towards unique emotional qualities or characteristics were found in either tuning – on the opposite – both seemed to convey a wide variety of emotions and characteristics, often times contradictory within the same tuning.

Interesting to note is that only A = 440 Hz had responses in the category 'playing technique' and one respondent mentioned a "softer bow and the sound was not as sharp. It felt as if someone had practiced a month longer between the two compositions."

5.2.4 The absolute pitch problem

According to the results, one in every four respondent possessed absolute pitch, which is not only an absurd amount, but most likely the result of confusing terminology. One of the musically educated respondents reporting the possessed absolute pitch rated a 5 on the similarity scale, a very extreme answer compared to the rest which suggest this person indeed perceived the versions as totally different. This person preferred 432 instead of the 440 tuning, which was otherwise the usual preference for respondents with musical background. The other respondent voted a 15, preferred standard tuning and mentioned they preferred the standard tuning because it sounded more "clear" and "because of the similarity of the compositions, I thought Composition B was played in a lower key."

5.3 Conclusions

In general, the individuals were able to discern differences between both versions and on average deemed them to contain sufficient uniqueness to more often than not have a preference towards one of the versions with as many as $^3/_4$ respondents. From these results, it is possible to see that tuning to A = 432 Hz moved the spectral centroid enough to affect both the tone of the composition and to be discernible by human ear when compared to standard tuning. Whether or not this change is significant enough on its own is impossible to tell from the results of this study.

The study does not support the claim that A = 432 Hz is superior to A = 440 Hz. In contradiction to these claims, tuning to A = 432 Hz might in actuality lessen a composition's quality, as the majority of respondents preferred the version in standard tuning. With this said, some effects were found when altering tuning: lowering to A = 432 Hz does create a slightly darker tone, as it was more often considered dark compared to its counter-part but not sadder or more solemn. It appears that for emotional response and unique characteristics, these factors are most likely tied to the personal interpretations of the listener, their own associations and mental constructs rather than an innate attribute of any tuning. For both versions, a spectrum of similar emotional responses was found- even contradictory within the same tuning – and therefore, any claims that a greater emotional response is evoked when tuning to A = 432 Hz appears unlikely. Same as A = 432 Hz was considered slightly darker, A = 440 Hz was considered both significantly sharper and somewhat lighter than its counter-part. Also, unsurprisingly, listeners who found the versions to be very similar were less likely to have a preference towards either.

For anyone with a formal musical education, there might be a connection between preferring standard tuning over the lower alternative. This is could be due to the nature of musical education which generally revolves around standard tuning and training students to relate their pitch classes to this tuning, creating a subconscious - or conscious - preference towards it.

It is possible that the order in which compositions were presented did affect preferential patterns: Group A (listening to 440 first) had an almost overwhelming preference towards it at 75 % of total answers, whereas Group B (listening to 432 first) was evenly split between

preferring 440, 432 and having no preference. This could just as well be a factor of sample size, as both groups are relatively small and might therefore be purely coincidental.

Finally, it is suggested that music and its relation to emotional response and preference is not as simple as being tied solely to one factor: it is a series of inter-tied relationships between not only the composition and the performer but also the listener's own mental devices, previous experiences, current mood, and associations which are accumulated and curated over a life-time of musical exposure. Therefore, tuning and its effect on emotion could just as well be a construct of these factors rather than some innate quality of the unique frequencies produced by a specific tuning. It is also possible that the emotional created response is tied to the character of a composition or an instrument rather than tuning.

6 Concluding Remarks

Presented in this chapter is a summary of the study, discussion on the results, chosen methods and research design and a concluding section on the possibility of future research and what such work might include.

6.1 Summary

The purpose of this study was to evaluate differences between two tuning systems in A = 440 Hz and A = 432 Hz in regards to emotional response, timbre, character and sound quality with a starting point in the opinions of a various proponents of A = 432 Hz who claim this tuning to be superior. Throughout this thesis, a theoretical background on previous tuning systems and - standards, historically as well as current were presented, alongside the basic physics of sound and theories related to pitch memory and the effects of spectral manipulation on the perception of sound.

A survey was constructed to investigate to what extent the claims of the A = 432 Hz proponents were true, using data gathered from 30 respondents. For these respondents, the most popular tuning was A = 440 Hz, in contradiction to the investigated claims. The results suggest that effects of tuning on tonal character and emotional response is not as simple as one tuning possessing inherent qualities different or superior to another. Other factors, such as the listener's emotional state and personal preference might affects how they perceive, and subsequently organize their preferences. The instrument itself and the composition's nature could also be a factor in what type of emotional response is evoked in the listener.

A lower tuning can be used to create a slightly different listening experience as A = 432 Hz was perceived as being darker than A = 440 Hz, which on the other hand was reported to be both sharper and lighter in character. As a composer or musician, one should always be aware of these potential effects when creating music but should not expect to completely alter the emotional evoked by deviating from the standard tuning. It is also possible that, tuning to A = 432 Hz has a negative effect on how well a composition is received by its listeners, although it should be noted that the difference between the two tunings is marginal.

6.2 Discussion

As a result of the study's nature, the possible conclusions are limited, due to various factors: the use of a singular instrument for the composition, the choice of digital re-tuning in favour of analogue, and the use of an original composition instead of an existing. These factors limit any data to the effects of digitally re-tuning a solo violin VST specifically and conclusions to the general nature of tuning systems should be further investigated with different factors.

By limiting instrumental usage, it is not possible to guarantee that, in reproduction of this study, results will be the same. This choice was made deliberately to mimic the experiment performed by Barosi and Brainin in 1988 who used a solo violin as played by Norbert Brainin. By choosing this approach instead of using several, or a pool of different instruments, variables such as the unique effect of an instrument's timbre affecting tuning and the interaction between instruments were a non-factor. Since the main purpose was to evaluate the claims to a A = 432 Hz superiority, the choice of solo violin becomes more

obvious. Regrettably, many other factors around the experiment by Barosi and Brainin are not fully disclosed and a complete reproduction of the experiment was therefore impossible.

Some design choices in the survey turned out to be slightly problematic: by using a similarity scale it is possible for respondents to value each individual step as different, meaning that one respondent's 25 might be equivalent to another's 22. This is a problem that is always present for this type of questions, but it could possibly be mitigated by further explaining each similarity category and the scale steps within. The choice to not explain the term absolute pitch did somewhat contaminate the results, where each positive had to be treated as a potential false, and a degree of scepticism had to be maintained. This did affect the true reason behind including this question: to be able to instantly discern any individual with AP, which was now made more difficult.

Since the composition was created through the use VST:s, there is an added element of chance as a result of round robins, in which both versions most likely triggered different samples and these samples might work better or worse together. Therefore, it is possible one of the compositions 'won the sample lottery' resulting in an overall 'better' or superior version. There is always the chance version A had more coherent sample content, resulting in it being favoured because of this, instead of as a factor of tuning preference. Although it is healthy practice to consider this, an approach using live instruments is not bereft of these types of problems. There is always the possibility of human error and variations between each recording would still exist if this approach was chosen. Alongside this, it is possible there might be some slight differences as a result of different sample triggers, but it is most likely not the solely determining factor.

The data generated by this study can be used by musicians and composers alike for a more critical approach when contemplating using A = 432 Hz as their tuning system, rather than assuming the claims of its proponents to be true. With awareness comes the ability to choose more deliberately and knowledge is the prevention of false assumptions. Of course, music is created by humans with individual preferences and, if one prefers a certain tuning, this should not be discouraged. Although no significant evidence for A = 432 Hz being superior to A = 440 Hz was found, there are other potential reasons to choose the tuning, such as lessening the strain on signer's voices as they reach for higher notes or to mimic a certain era's or artist's sound.

Whether or not the use of Levitin's theory was successful is ultimately unanswered. It is possible that by trying to create a more memorable composition, respondents had an easier time recognizing differences between the two versions, but for it to be tested completely different study would have to be constructed, focused on the time it might take the human mind to form these memory representations.

6.2.1 Social aspects

As we live in an age of information, and with, perhaps, an over-saturation of information it's easy to accept facts and claims at first glance, not always critically judging the source or validity of said fact or claim due to the sheer volume of information readily available. This study has been an attempt to give a more nuanced picture of the 440 vs 432 debate by examining the claims given by the 432-proponents. Since a lot of the claims are ungrounded, a better understanding is needed. Hopefully this study can serve as a gate-way for further examination of the subject and light the spark for a more critical debate.

6.2.2 Ethical aspects

The whole purpose of the study is to explore the rather unethical practice of claiming facts to be true based on association and arbitrary statements, with an argumentation driven by emotion rather than evidence. By using a pseudo-scientific approach, people might assume the claims to be true rather than speculative, as it is presented in a factual way. On the other hand, one might suggest that this approach did cause the claims to garner enough traction to be investigated and discussed both in online and real-life context. Although this could also be achieved by a more critical approach, instantly opening up to a discussion of the proposed potential uses for A = 432 Hz rather than the current discourse. The critical approach is a more morally sound way of presenting alternatives, indeed, but perhaps not as easily marketed and sold as presenting the hypothesis as the end-all-be-all of tunings. Some of the proponents do have a rather large following of people convinced of the benefits of their practices and the superiority of A = 432 Hz. A whole market for selling books and music exists in which its authors and creators benefit by the continued belief that A = 432 Hz is better even if it has no proven benefits as of yet. One might want to consider the ethical implications of this type of practices.

As for the exclusion of individuals with damaged or impaired hearing, it was done in the purpose of acquiring data with higher validity and to avoid introducing other potentially hidden variables. Respondents with minor hearing impairment were still included in the study, although this data was recorded for the sake of tracking outliers. I would consider this approach ethnically defensible as no respondent were asked to relay this information beforehand, but instead had their answers recorded anonymously and then evaluated in the analysis based on grade of disability.

6.3 Future Work

As for future research, there are numerous areas within the realm of tuning systems that are yet unexplored and this study is an attempt to scrape the surface of it. The next logical step would be to reproduce the study using analogue instruments to test the effects of these in the tuning of A = 432 Hz. To completely dispel the claims of the 432 proponents, an analogue approach should be considered, since re-tuning this way does alter the sound wave in differently than its digital counter-part. If the results of those efforts point in a different direction, there is opening for yet another interesting field: the difference between digital and analogue re-tuning.

Apart from this, the effect of different tunings on a composition comprised of more than one instrument could prove to contain information very valuable to composers and musicians. Although not supported by the research, it is possible that certain constellations or instrument pairings affects how these are perceived based on their tuning.

Furthermore, as this study was demarcated to the comparison of A = 440 Hz and A = 432 Hz, it does create an interesting opening for a larger span of tuning variations to be compared, and even different intonation systems. Additionally, testing with well-known compositions can provide additional insight into the nature of how tuning systems might impact the character and tone of a musical piece.

In conclusion, the research gathered shows a more complex picture of the nature of music and the effects of tuning systems than the one presented by the 432 proponents. There is already an incredible amount of research available regarding emotional response in music, but this is an attempt to scrape the surface of a complex relationship between the individual and sound, and will hopefully inspire further investigation into this specific area.

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Appendix A - Spectral analysis of recordings and VST

440 recording vs 432 recording	
String	**Notes (16 comparisons)**
E	Very similar harmonic content. 432 contained more information inbetween peaks in ranges 0-7k but peaks extremely similar.
A	Very similar harmonic content. 440 contained more information inbetween peaks in ranges 0-7k but peaks extremely similar.
D	Inconclusive. Waveforms extremely similar.
G	Some slight differences. 432 version contained slightly more harmonic content.

Recordings vs VST:s
Notes(16 comparisons)
Peak missing in VST at around 400. VST contains almost no extra information inbetween peaks, as compared to the recorded which has information between each peak, at a level of around -70 to -63 dB. Recordings contained more peaks and audio information in general.

440 VST vs 432 VST
Notes (8 comparisons)
Two first comparisons showed more audio information in the 432 Hz version, especially in the 20-3k frequencies. 432 also peaked higher (approximately 5 dB difference). Both waveforms contained almost identical peaks apart from their volume difference. All other comparision showed two almost identical graphs.

Appendix B - Data analysis

Preference based on background				
	Musical education		*No education*	
Preference	No. of answers	Per cent	No. of answers	Per cent
440	5	62.50%	8	36.36%
432	2	25.00%	7	31.82%
none	1	12.50%	7	31.82%
TOTAL	8		22	

Mean similarity rating			
		Background	
Type	Musical	Non-musical	Total
Median	21	22	22
Average	21.86	22.36	22.5

Similarity rating (combined)		
Similarity	No. of answers	Per cent
5	1	3.33%
15	4	13.33%
19	1	3.33%
20	2	6.67%
21	7	23.33%
22	3	10.00%
23	2	6.67%
25	6	20.00%
28	1	3.33%
29	1	3.33%
30	2	6.67%
TOTAL	30	

Appendix C - Word associations

	440	432
Answer	Percent	Percent
Soft	40%	43,3%
Warm	30%	30%
Loud	10%	13,3%

440		
Word	Amount	Percent
Dark	15	50%
Sharp	14	46,7%
Soft	12	40%

432		
Word	Amount	Percent
Dark	17	56,7%
Soft	13	43,3%
Warm	9	30%

Greatest difference		440	432
Answer	Percent unit diff.	Percent	Percent
Sharp	23,3%	46,7%	26,7%
Light	10%	33,3%	23,3%

Appendix D - Similarity rating and preference

Similarity rating and preference correlation			
Nr	Score	Pref	Musical education
	(5)	432	☑
	15	440	☑
3	15	432	☐
4	15	432	☐
5	15	dont know	☐
	19	440	☑
7	20	440	☐
8	20	440	☐
	21	440	☑
10	21	440	☐
11	21	440	☐
	21	432	☑
13	21	432	☐
14	21	432	☐
15	21	432	☐
16	22	440	☐
17	22	440	☐
18	22	432	☐
19	23	neither	☐
	23	440	☑
21	25	440	☐
	25	don't know	☑
23	25	don't know	☐
24	25	432	☐
25	25	dont know	☐
26	25	dont know	☐
27	28	neither	☐
	29	440	☑
29	30	neither	☐
30	30	440	☐

Appendix E - Separate group data

Group A preferences		
Preference	No. of answers	Per cent
440	8	53.33%
432	4	26.67%
None	3	20.00%
TOTAL	15	

Survey A		
Similarity	No. of answers	Per cent
15	2	13.33%
21	6	40.00%
20	1	6.67%
22	2	13.33%
23	1	6.67%
25	3	20.00%
TOTAL	15	

Group B preferences		
Preference	No. of answers	Per cent
432	5	33.33%
440	5	33.33%
None	5	33.33%
TOTAL	15	

Survey B		
Similarity	No. of answers	Per cent
5	1	6.67%
15	2	13.33%
19	1	6.67%
20	1	6.67%
21	1	6.67%
22	1	6.67%
23	1	6.67%
25	3	20.00%
28	1	6.67%
29	1	6.67%
30	2	13.33%
TOTAL	15	