Research Article ISSN 2693-2490

Journal of Psychology and Neuroscience

EEG Research of Music Impact Tuned on 432 Hz Pitch Vs 440 Hz Effect on Listeners

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Submitted : 15 Jun 2022 ; Published : 10 Jul 2022

Citation: Branislav R. Tanasic. EEG Research of Music Impact Tuned on 432 Hz Pitch Vs 440 Hz Effect on Listeners.J Psychol Neurosci; 2022; 4(3): 1-8.

Abstract
The standard pitch for tuning musical instruments is 440 Hz, and an alternative pitch is 432 Hz, also known as Verdi's A. The famous words of the great Serbian scientist Nikola Tesla, who believes that revealing the secrets of the universe can be grasped through thinking about energy, vibration, and frequency, lead to the conclusion about the importance of the applied frequency standard in music as a universal, planetary language. Numerous experiments through which the authors tried to prove the positive and even healing effect of music trimmed at 432 Hz, were performed using biometric methods, monitoring respiration, heart rate, blood pressure, or skin moisture. This paper is the product of an attempt with the help of an EEG device, to directly measure brain reaction, and compare the effects on music listeners performed on instruments tuned to 432Hz and 440 Hz.

Keywords: Electroencephalograph, musical stimulus, tone pitch, Verdi`s A

Materials and Methods

The experiment was performed in the stable environment with controlled temperature and illumination, respectively all experimental condition was in accordance with Guidelines for the recording and quantitative analysis electroencephalographic activity research contexts. (Pivik et al., 1993). EEG signals were recording using an MITSAR 201 system, through electronic EEG cap. The electrodes on the caps are arranged according to the 10/20 system. The frontal electrode is placed 10% of the total length above the nasion, and the rest of the electrodes are spaced 20% between them. Reference mounting was use, Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2, with a common reference on the ear (A1 & A2). Impendance of electrode is lower than 5 kOhm (Harmon-Jones & Peterson, 2009).

The computer for broadcasting music illustrations is connected to the EEG computer, so that the experimenter can have an accurate insight into the reactions of the respondents during the data analysis, ie. has a recorded brain reaction to a specific musical stimulus. The musical illustrations were made using the following equipments:

- Organ Hammond L100, 1965, connected to Leslie 147, 40W power, 1974.
- Acoustic guitar Eko Ranger VI, 1964, sounded with acoustic guitar pickup Fishman SBT-C.
- Electric guitar Fender Stratocaster, maple neck, big head, 1991.
- Amplifier Marshall JMP 50W, 4x12 Selection speakers, 1968.
- All songs were recorded using 24 channels digital portastudio Tascam 2488 MKII.

All songs are interpreted on the Hammond L100, an electro-mechanical organ with a tonewheels generator, which is the tone pitch changed. With the help of a frequency tone analyzer, the organ is tuned so that the A4 tone is exactly 432 Hz. The same procedure was applied when tuning at 432 Hz as well as returning to the standard 440 Hz of all instruments used.

All participants were warned that must no have neurological disorders and must no be taking mind altering medications or some illegal substances. All of them were required to sign the consent form. The ending, participants in the experiment were asked to fill out a short questionnaire with common questions, gender, age, education, etc. but also a few questions related to music, hearing music, ability to hear in both ears, music education, playing an instrument and the like.

Processing and visualization of EEG signals made by using computer software WinEEG. All statistical calculations and presented tables were done using IBM SPSS 26 software.

Foreward

During the design and organization of this research, there was a growing awareness of how demanding and sensitive this issue is. For decades, music listeners have been exposed to music created according to the official, established model of tuning instruments based on A4 values of 440 Hz. To what extent can this long-term habituation to the official tuning of musical instruments affect the basic idea of the experiment; measuring the impact of music performance on instruments tuned to the A4 at 432 Hz, and compare it to the effect of a standard 440 Hz tone? A very lively discussion can be seen on many websites, musicians and various music theorists evaluate and give arguments for one or another frequency system. The dilemmas over the choice of frequency for instrument calibration date back to the distant past. The references were usually church organs, and their tuning varied considerably from producer to producer, so that the same musical works were performed with considerable differences in pitch. The tuning fork was found in 1711, and before that event there was no standardized way to tune instruments. But, finding a fork didn't help much, and there was still no single, standardized tuning. It was enough to go to another city, and the local musicians used a tuning fork that resonated on a different frequency. Great variety prevailed, depending on the part of the country or the city the orchestra is from. Tuning standards ranging from 400 Hz to as much as 480 Hz were used. It should be understood that until 1830 when Heinrich Hertz proved the existence of electromagnetic waves and explained frequency as a "cycle per second" there was no standard for defining frequency, ie pitch. This is a phenomenon which in physics is defined as the unit of measurement of the number of cycles per second named Hertz – Hz, in honor of the great scientist.

It is interesting to note some devices that preceded the sonic fork. The Savart wheel is an acoustic device, named after the French physicist Felix Savart, it is actually an improved construction of the idea of Robert Hooke. The device works simply, the card attached to the side touches the rotating toothed wheel and thus produces a certain tone. The pitch depends on the speed of rotation of the wheel. Savart used an 820 mm diameter wheel with 720 teeth and could generate a tone of up to 24,000 Hz or 24KHz, which is beyond the range of hearing of the human ear. It was the first device capable of producing tones in the ultrasonic area (Graff, 2012). German Johann Scheibler 1834 presents an acoustic instrument called a *tonometer*. It is a series of 56 sonic forks, each representing a specific tone as an instrument for accurately measuring pitch by counting beating using a metronome. (Beyer, 1999). Basically, the whole device represents a wooden board in which sound forks are planted. The sound was produced with a small wooden mallet with which the forks are to be struck and a good metronome, constitute Scheibler's tuning apparatus (Loehr & Wehrhan, 1853). The Frenchman Gustave Trouve in 1889, introduced to the world his electric keyboards capable of producing 88 tones, allowing harmonic chords and dynamics. The same principle is used in modern-day electromechanical organs, such as the Hammond organ, that make use of tonewheels sound generator (Desmond, 2015). The basic component sound of a Hammond organ comes from a tonewheel. Each one rotates in front of an electromagnetic pickup. The variation in the magnetic field induces a small alternating current at a particular frequency which represents a signal similar to a sine wave. When a key is pressed on the organ, it completes a circuit of nine electrical switches, which are linked to the drawbars. The position of the drawbars, combined with the switches selected by the key pressed, determines which tonewheels are allowed to sound (Campbell, Greated & Myers, 2004).

The first step in the attempt to regulate this area was made by France, so in 1859 passed a law and define the standard for A4 at 435 Hz on the whole territory. In the context of this research it is interesting to note that Italian composer Giuseppe Verdi had proposed a slight lowering of the French tuning system, it's the famous Verdi's A, and Schiller Institute's recommended tuning for A of 432 Hz. In the UK, this standard is defined at 439 Hz, probably only to differ from the French norm, although the French pitch has been widely accepted in much of Europe. Two and a half decades later, in 1885 Italy legally regulates this area, Music Kommission of the Italian Government is defined A4 at 440 Hz, but some parts of the country have defined A4 at 450Hz. In 1917, in the United States, American Federation of Musician, setting the cammer tone A at 440 Hz. Finally, at the international conference held in London in 1939, the standard for A_4 at 440 Hz was recommended. Without going into a consideration of the influence of the Nazis and the reasons for their insistence, that the 440 Hz frequency be official. This standard was accepted, especially supported by the BBC's intervention and their recommendation that all orchestras adhere to tuning instruments according to this model. Truth be told, some practical aspects of standardization need to be emphasized. After the adoption of the international standard for instrument tuning, opportunities for international trade in instruments have been created, and guest orchestras no longer have a problem tuning instruments, regardless of their continent. The 440 Hz standard is globally accepted.

Regardless of the generally accepted standard, many modern symphony orchestras use different standards for tuning their instruments. So, Abdella said, The New York Philharmonic, under Zubin Mehta, tunes to an A at 442 hertz, as does the Chicago under Georg Solti and the Boston Symphony under Seiji Ozawa. In Berlin, orchestras tune to an A around 448 hertz. In Moscow, the symphony's pitch is even higher, near 450 hertz (Abdella, 1989).

Notwithstanding this diversity in the application of instrument tuning standards, this research is based on an attempt to determine the extent to which the effect of music on listeners differs on instruments tuned to two basic tuning systems A4=440 vs 432 Hz.

Researsh – Results and discussion

A total of 74 respondents were EEG scanned, of which 33 females and 41 males. Respondents were primarily asked to complete a questionnaire that in addition to the usual socio-demographic data, contains a set of questions formulated in such a way that the answers give a basic idea of the participants in the music-related research.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Up to 20 yrs	11	14.9	14.9	14.9
	20 – 30 yrs	23	31.1	31.1	45.9
	30 – 40 yrs	11	14.9	14.9	60.8
	40 – 50 yrs	10	13.5	13.5	74.3
	50 + plus	19	25.7	25.7	100.0
	Total	74	100.0	100.0	

Table 1 : Age

The participants of the experiment voluntarily responded to the call to help this research, and a special contribution was given by current and former students of the local music school. Respondents ranged in age from less than 20 to over 50 years, (Table 1), all right-handed, with different occupations and levels of education (table no. 2&3).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High school	40	54.1	54.1	54.1
	College	28	37.8	37.8	91.9
	Master	6	8.1	8.1	100.0
	Total	74	100.0	100.0	

Table 2: Education

All participants were selected as right-handed because of differences that occur in brain lateralization. Using functional magnetic resonance imaging, a team of scientists found that when right-handers were asked to silently generate words, 4% of them showed activation of both halves of their brain. Meanwhile, when studying left-handers, only 10% of them showed right hemisphere activity for this task, (Jarry, 2021). About 30% of people with a predominant left arm have oppositely located cerebral hemispheres, which may lead to errors in reading EEG findings (Bryder, 1982). Of the respondents, 44 stated that they had never played instruments, 29 that they were amateurs and only one professional musician. As many as 29 respondents own a musical instrument, most have a piano -11, then 8 respondents own a violin, 7 have acoustic guitars, 2 of them have flutes, and one reported a saxophone. Interestingly, none of the respondents reported having an absolute hearing, while 36 of them were familiar with the basic tone A4 and knew the value in Hertz exactly.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No music education	42	56.8	56.8	56.8
	Elementary music school	26	35.1	35.1	91.9
	High music school	5	6.8	6.8	98.6
	Music academy	1	1.4	1.4	100.0
	Total	74	100.0	100.0	

Table 3: Music education

Speaking of absolute hearing or perfect pitch, it can be said that this is a very rare ability with the frequency in the general population, according to some estimates, is only 1 in 10,000 people. A 2019 survey indicates a prevalence of at least 4% among music students (Carden & Cline, 2019). Levitin absolute pitch explains as: “ability to perfectly produce or identify specific pitches without reference to an external standard” (Levitin, 1994). Given these exceptional abilities of people who possess absolute hearing, they should be in a special category and are probably not suitable for the research conducted. Because these people are able to recognize every tone or remember and sing a melody without reference, for each musical illustration they would know to which frequency band it belongs and that would be a disruptive factor in this experiment.

The first analysis was a review of the relationship between the measuring scale elements with the aim of determining internal consistency. Table no. 4, shows the reliability, ie the internal consistency of the measurement scale, Cronbach’s alpha coefficient.

The acceptable value of the alpha coefficient is 0.7 (Streiner, 2003). Considering the obtained result, alpha 0.852, it can be said that the internal agreement of the scale is very good, so the selected 15 items of the scale have a high degree of reliability measuring the basic research construct.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.852	.867	15

Table 4: Reliability Statistics

A correlation was made between the variable education and knowledge of the concept of reference tone A_4. Pearson's correlation coefficient r = 0.817, positive, p < 0,005, and the bond strength is estimated to be large according to Cohen's guidelines (Cohen, 1988). This means that higher education implies a greater possibility of knowing the official reference tone A_4 440 Hz. The same procedure was applied when calculating the correlation between respondents who own a musical instrument and knowledge of tone A_4. Pearson's correlation coefficient r = 0.867, positive, p < 0,005, and the bond strength is estimated to be large. Correlation between music education and knowledge of referent tone A_4 (table 5). This means that higher music education implies a greater possibility of knowing the reference tone A_4.

		Music education	Ref. tone A_4
Referent tone A_4	Pearson Correlation	1	.901**
	Sig. (2-tailed)		.000
	N	74	74
Having some music. Instrum.	Pearson Correlation	.901**	1
	Sig. (2-tailed)	.000	
	N	74	74

Table 5: Correlations

The presentation of the general educational structure and music education of the respondents illustrates the colorful composition of the participants in the experiment. It was based on the assumption that music-educated respondents have been listening to music for years and playing instruments tuned to the A_4 = 440 Hz standard. In contrast, people without music education do not have that perceptual filter. After this analysis, an interesting idea emerged to investigate and analyze the difference in the influence of 440 vs 432 Hz on these two groups.

Neuromarketing results

Electroencephalographic scanning provides an extremely large amount of information. Depending on the set goal, the researcher opts for a certain type of data that he processes, compares, and based on the obtained results, confirms or refutes the set hypotheses. This research aims to use EEG research to determine the levels of musical impact set at 432 Hz in relation to the 440 Hz effect on listeners. Attention in the analysis of EEG records focuses on the emotional response, the degree of liking, or rejection of promotional content. For this purpose, brain reactions of beta rhythm, alpha levels of the frontal cortex, then theta waves that are closely related to emotional reactions of the limbic sector, represented in the orbitofrontal cortex, will be monitored (Aftanas & Pavlov, 2005: 85-94). Prefrontal cortex activity in theta rhythm may represent fear, anxiety, rejection (Coan & Allen, 2004). The amygdala is also affected in emotional processes, but since it is located in the central part of the brain, its activity cannot be monitored directly by EEG scanning, amygdala involvement is reflected through the cortico-stratio-thalamo-cortical loop to the dorsolateral prefrontal cortex (DLPFC). Important for this experiment is the distinction between the cortical activity of the left and right hemispheres of the brain (alpha asymmetry). According to Davidson's model, the alpha rhythm of the left hemisphere represents a positive emotional response, while the right cerebral hemisphere response is interpreted as negative (Davidson, 1992). Alpha rhythm in the occipital cortex is associated with impaired attention and processing of what is seen, idling rhythms, (Feige, et al., 2005), so such an EEG finding that shows disinterest can also be interpreted as a negative reaction to stimuli.

Through neurophysiological research conducted using EEG, research raw data need to be processed prior to the analysis, correction of EEG artifacts. The signals usually acquired during EEG are generally contaminated with different noise sources, power line interference 50Hz, and severe biological signals. WinEEG offers methods of digital EEG filtering. The list a set of parameters were used: speed 30 mm/sec, gain/absolute peak-to-peak threshold/200 mV, low cut 0.1 sec (1.6 Hz), high cut 30 Hz, and notch filter to suppress AC line, 45-55 Hz, (Europian AC frequency standard is 50 Hz). Eyeblink artifacts separation was performed using an Independent Component Analysis (ICA) method. Throughout different statistical analyzes EEG findings, and discussion will present data and evidence to suggest the impact and effects of these frequencies on listeners.

Cortical signal analysis was initiated by the observed asymmetry of alpha signals in the area of the prefrontal cortex. The T-test of paired samples was performed by comparing the average results of the frontal electrodes of the left hemisphere (Fp1, F3 and F7), during the emission of musical stimuli at 432 Hz and 440 Hz (table 6).

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Alpha	Left hemisphere 432 vs 440 Hz	.39189	1.13255	.13166	.12950	.65428	2.977	73	.004

Table 6:T-test comparison of alpha prefrontal cortex, left hemisphere (electrodes- Fp1, F3. F7)

During the broadcast of music at 432 Hz, stronger activity of the left prefrontal cortex of the alpha wave was recorded, which indicates an increased level of liking of the broadcast content (Davidson, et al., 1990; Davidson, 1992; Davidson & Irvin, 1999). The truth should be noted that the level of significance is expressed through Sig. 2 tailed, (p= 0.04), almost at the limit of the value that indicates a significant difference in the influence of measured musical stimuli on the respondents (values of p <0.05 indicates a significant difference in the obtained values). So, from the presented values of alpha in the prefrontal cortex, it can be concluded that with a slight difference, the musical stimulus at 432 Hz is better accepted. Also according to the HERA model (*Hemispheric Encoding Retrieval Asymmetry*), the left prefrontal cortex is responsible for processing information into long-term memory (Tulving, et al., 1994; Habid, Nyberg & Tulving, 2003), and a prerequisite is that the content is the focus of attention, that is be accepted. This is fully in line with Davidson's model of responsibility of the left prefrontal cortex (LPFC), for accepting-liking content that is stored as such for a long-time memory.

The identical procedure was repeated for the right hemisphere. The T-test of paired samples was performed by comparing the average results of the frontal electrodes of the right hemisphere (Fp2, F4 and F8), during the emission of musical stimuli in both frequency ranges (table 7).

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Alpha	Left hemisphere 432 vs 440 Hz	.58108	1.61336	.18755	.20730	.95487	3.098	73	.003

Table 7: T-test comparison of alpha prefrontal cortex, right hemisphere (electrodes- Fp2, F4. F8)

Subjects who reported higher values in the left prefrontal cortex had higher values in the right PFC. Researchers in this field point to the great importance of the right frontal cortex in coding (Ohme, Reykowska & al. 2010: 785-793), and the memorization of visual content (Astolfi, et al., 2008). It should be noted that the right prefrontal cortex plays an important role in accessing data from LTM, long-term memory (Kelly et al., 2005), which may indicate a reaction that the broadcast musical illustration is recognized or has some similarities which is associated with an already heard melody. It is thus an individual perception, an individual experience of a musical stimulus.

The next step is to compare the theta signals of the frontal electrodes of the left hemisphere (Fp1. F3, F7). Beta asymmetry will be omitted because the asymmetric EEG finding usually indicates a pathological change, as Marcuse Laura argues: "Perhaps the most important finding when analyzing beta activity is interhemispheric asymmetry. In particular, the side of reduced amplitude usually points to the pathological hemisphere (Marcuse, 2015). Therefore, attention will be focused on the theta asymmetry. First, the values recorded during the broadcast of a musical stimulus at 432 Hz will be compared (table 8).

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
432 Hz	Theta Left hemisphere Right hemisphere	1.35135	3.54011	.41153	.53117	2.17153	3.284	73	.002

Table 8: T-test comparison of prefrontal cortex reactions, left hemisphere (electrode - Fp1, F3, F7 vs Fp2, F4, F8)

The significance of theta rhythm asymmetry in the prefrontal cortex, according to Davidson's model of frontal asymmetry, is confirmed by the findings of Aftanas and Pavlov, who investigated the connection between theta range and emotional and memorizing positive, acceptable content (Aftanas & Pavlov, 2005). And the MAC model of hemispheric asymmetry, an acronym for *Memory Affect Cognition*, a model developed by Ambler and Burne, emphasizes the importance of the role of emotions in memory. Increased activity of the left prefrontal cortex alpha and theta rhythm is interpreted as a reaction to likable content and which are remembered as such (Ambler & Burne, 1999). An identical procedure compares the values recorded during the broadcast of a musical stimulus at 440 Hz (table 9).

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
440 Hz	Theta Left hemisphere Right hemisphere	.39189	1.13255	.13166	.12950	.65428	2.977	73	.004

Table 9: T-test comparison of prefrontal cortex reactions, left hemisphere (electrode - Fp1, F3, F7 vs Fp2, F4, F8)

From the value of the presence of theta waves (table 8 &9), it is clear that the difference is on the border of significance, and that in the statistical, quantitative expression of the influence of the frequency of 432 Hz, nuances prevailed.

The next step investigates the relationship between EEG slow (theta) and fast (beta) waves, (theta / beta ratio, table 10), which is related to the phenomena of emotional regulation and levels of attention to a given stimulus (Morillas-Romero, Tortella -Felici & Putman, 2015).

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Theta	432 Hz All electrodes 440 Hz All electrodes	.81081	2.21870	.25792	.29678	1.32484	3.144	73	.002
Beta	432 Hz All electrodes 440 Hz All electrodes	.78378	2.34240	.27230	.24109	1.32647	2.878	73	.004

Table 10: Theta / Beta Ratio

The relationship between theta and beta rhythm is calculated based on the results collected from all electrodes from the subject`s scalp. From the presented values, it can be concluded that the increased attention and emotional involvement of the respondents to the musical stimulus 432 Hz, so that this content is in the focus of attention.

Conclusion

Numerous experiments through which the authors tried to prove the positive and even healing effect of music trimmed at 432 Hz, were performed using biometric methods, monitoring respiration, heart rate, blood pressure, or skin moisture. Namely, increased arousal recorded through an increased heart rate, rapid breathing, caused by a recognized melody to which the subject is bound by certain memories, an event of special significance that triggers strong emotions. In an attempt to avoid this possibility, authentic musical illustrations, author's works of the organizers of the experiment were recorded. Some of the productions were inspired by classical music, but it was kept in mind, that there are respondents who do not know classical music, or do not even like it. They may have a repulsive attitude towards musical illustration, no matter the frequency setting. The big question is how to distinguish the respondent`s reaction to the melody from the reaction to the frequency at which the instruments are tuned, whether positive or not. The findings of this study are that respondents give a slight preference to musical illustrations performed on instruments tuned to 432 Hz. In the end, it can be concluded that it is an individual reaction, a personal experience, a unique perception of an individual, after all, if it were not so, would there be art at all?

Acknowledgement

This manuscript is dedicated to my Late Mother Ljuba.

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