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Acoustic Characterization of Sound Stimuli from Tibetan Singing Bowls

Caracterización Acústica de Estímulos Sonoros de Cuencos Tibetanos

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ABSTRACT

The document describes the methodology used to obtain the polar pattern of 3 Tibetan bowls. Physical measurements were taken for each bowl, including diameters of 9.7 cm for the "small" bowl, 11 cm for the "medium" bowl, and 12.6 cm for the "medium-large" bowl. Then, measurements were made using the Svan 977 sound level meter for data collection and analysis. The subject playing the bowl was placed in the middle of a circle, with points spaced at 45-degree intervals in a range of 0° to 360°. The sound level meter was located at approximately 1.20 meters from the ground, with the source 80 cm from the microphone capsule. Specific settings were used on the sound level meter, including a 94.00 dB calibration, one-third octave band, and Slow filters and Z-weighting. During the measurements, participants tapped and rubbed the bowls as directed, applying a duration of 20 seconds to each measurement, which was considered adequate to obtain the necessary data. The subsequent analysis of the data was carried out using a code in MATLAB, allowing the visualization of the polar pattern of the sound stimuli generated by each one of the bowls.

RESUMEN

El documento describe la metodología utilizada para obtener el patrón polar de 3 cuencos tibetanos. Se toman las medidas físicas para cada cuenco, incluidos diámetros de 9,7 cm para el cuenco "pequeño", 11 cm para el cuenco "mediano" y 12,6 cm para el cuenco "mediano-grande". Luego, se realizan mediciones utilizando

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el sonómetro Svan 977 para la recolección y análisis de datos. El sujeto intérprete del cuenco tibetano se coloca en medio de un círculo, con puntos espaciados a intervalos de 45 grados en un rango de 0° a 360°. El sonómetro se ubica aproximadamente a una altura de 1,20 metros del suelo, con la fuente a 80 cm de la cápsula del micrófono. Se utilizaron configuraciones específicas en el medidor de nivel de sonido, incluida una calibración de 94dB, bandas de un tercio de octava, filtros lentos y ponderación Z. Durante las mediciones, los participantes golpean y frotan los cuencos según las instrucciones, con una duración de 20 segundos para cada medición, considerándose adecuada para obtener los datos necesarios. El posterior análisis de los datos se realizó mediante un código en MATLAB, que permitió visualizar el patrón polar de los estímulos sonoros generados por cada uno de los cuencos.

1. Introduction

A singing bowl is a metal instrument that produces a bell-like sound when struck with a mallet or drumstick. It is made from an alloy of 7 different metals (usually gold, silver, tin, lead, mercury, copper, and iron) and has great meditative and relaxing properties. According to Tibetan tradition, it was established around 480 BC. A craft popularized in this culture by the Dalai Lama and the monks and brought to the West about forty years ago. This project aims to deepen the knowledge of Tibetan bowls, a musical instrument known for its ability to induce a state of relaxation and meditation in those who use them. To do this, the characterization of the sound stimuli generated by these bowls will be carried out, as well as the characterization of the bowl itself as a sound source. Through the analysis of different acoustic properties, we will seek to identify what characteristics make Tibetan bowls such an effective tool for meditation and relaxation.

2. State-of-the-art

2.1. Structural dynamical analysis of a musical instrument: Tibetan bowl (Beena et. al, 2023)

The study focused on the modal analysis of Tibetan singing bowls using different techniques, including operational modal analysis (OMA) and experimental modal analysis (EMA). Five different OMA techniques were compared, such as basic frequency domain (BFD) and frequency domain decomposition (FDD), as well as time domain techniques LSCE and ERA, along with a transmissibility-based technique called TOMA. The main objective was to extract the natural frequencies and mode shapes of singing bowls without measuring excitation data. OMA, by requiring only response data, was found to be preferable over EMA for sensitive instruments and provided a more realistic analysis.

2.2. The Tibetan singing bowl: acoustics and fluid dynamics (2011)

In this experimental study, the acoustics and fluid dynamics of singing bowls were investigated. The vibrations and waves generated on the surface of the liquid by tapping or rubbing the bowls were examined. Various factors, such as the viscosity of the liquid and the geometry of the bowl, were studied to better understand the behavior of the waves. The results provided information on the conditions for the initiation of Faraday waves and the formation of droplets on the liquid surface. In summary, this study expands our understanding of the physics of singing bowls and their potential applications in various fields.

2.3. Vibro-acoustics of Tibetan Singing Bowls (2021)

Vibration experiments were performed on a singing bowl to understand its physics and how it produces its characteristic sound. Using the finite element method, the bowl was modeled, and vibration data was captured with an accelerometer and pulse hammer. The resonant frequencies, damping and mode shapes of the bowl were analyzed. The results revealed the influence of physical factors on the sound of the bowl and the interaction of nearby modes. These findings are relevant to manufacturers and musicians interested in musical acoustics.

2.4. An electro-acoustic implementation of Tibetan bowls: Acoustic and perception (2014)

The project focused on developing the eBowl, an electronic relaxation device that mimics the acoustics of singing bowls and can generate a wide range of sounds. The goal was to overcome the limitation of requiring a second person to play the bowl, thus allowing the eBowl to be used for relaxation without external assistance. The acoustic characteristics of singing bowls were studied, including monaural and binaural beats, and the concept of brain wave entrainment. Based on these studies, the eBowl was designed with similar characteristics in terms of sound, radiation and vibrations. The device was built using techniques such as modal synthesis for sound, a circular array of speakers to emulate space radiation, and an actuator in the bottom to simulate vibrations. Testing confirmed that the eBowl effectively mimics the sound and experience of singing bowls, and its use was shown to lead to relaxation, supported by objective and subjective measurements. Statistical analyzes also indicated that the eBowl had a significant impact on heart rate, heart variability, breathing, and skin temperature, possibly due to brain wave entrainment caused by acoustic beats.

2.5. Acute Relaxation Response Induced by Tibetan Singing Bowl Sounds: A Randomized Controlled Trial (2023)

In the study, the acute relaxation response induced by Tibetan singing bowl sound-based treatment (TSB) was compared with progressive muscle relaxation (PMR) in a single treatment session in an anxious adult population. The main objective was to investigate the effects of music therapy using Tibetan singing bowls on anxiety reduction. Participants were asked to close their eyes and received different stimuli for 50 minutes, while their heart rate was monitored. The results showed that both the group that received the treatment based on the sound of Tibetan bowls and the group that performed progressive muscle relaxation were able to promote a deeper subjective state of relaxation. Furthermore, it was observed that subjects with higher levels of anxiety showed a decrease in alpha activity, which is considered an index of relaxation, after treatment based on the sound of Tibetan bowls. This indicates that treatment may be effective in reducing anxiety levels in this population.

3. Acoustic Characterization

Tibetan singing bowls can produce various frequencies. Which would be called the "tone" of the bowl. And to determine the frequency of a Tibetan bowl, the vibration of the bowl must be measured while it is played. Additionally, the areas of the singing bowl that are touched change the measured frequency. A high touch on the side wall will create different waves than a low touch on the side wall. Touching the edge of the bowl will create different vibrations compared to touching the side of the bowl. (Singing Bowl Tones and Frequencies: Complete Guide (2022).

As the edge of the bowl is rubbed, the friction continues to maintain the sound, which is known as the "resonance" of the bowl. Which would be the sound that has accumulated from many trips around the edge of your bowl with the mallet. The resonance of a Tibetan bowl is quite complex because it is produced through a relationship between three factors: vibrational frequencies, amplitude, and time. However, larger singing bowls tend to experience resonance in a simpler way. (Singing Bowl Tones and Frequencies: Complete Guide (2022).

Once struck, the singing bowl will produce a chord. Many bowls are tuned to a specific chord, such as the flat fifth interval, and depending on that chord, the bowl will produce different layers of harmonics. Usually, these sounds will be the overtones known as the fundamental, the feminine overtone, and a middle tone. On each bowl, rubbing it with a leather mallet around the outer wall of the bowl will produce its fundamental which would be the lowest or deepest sound. (Singing Bowl Tones and Frequencies: Complete Guide (2022).

3.1. Playing the bowl (2016)

Activating a bowl refers to the mechanical action of hitting it with an appropriate tool, such as mallets or specific drumsticks for playing Tibetan bowls (Sánchez & Lozano, 2016).

Mallet finished with a rubber tip - It is used only to strike and activate the middle sounds. Wooden Drumstick - This type of drumstick is used only for beating the bowl. Leather or Felt Covered Drumstick - This style is used to gently strike or beat the instrument. (Sánchez & Lozano, 2016). At this point, it is essential to be clear about the difference between striking, beating and/or rubbing the bowl. Therefore, if the desire is to strike, this will be done with a mallet or drumstick, and the closer the blow is to the edge, the sharper the sound it will emit. On the contrary, the lower the bowl is played, the lower its sound will be. This activation process is done with the wooden drumstick, which may or may not be covered with felt or leather. (Sánchez & Lozano, 2016).

4. Methodology

Initially, 3 Tibetan bowls were selected, from which physical measurements were taken, after which measurements were taken with the Svan 977 sound level meter to obtain and analyze data. From there, a code is created in MATLAB R2023a which helps to visualize the polar pattern obtained from the sound stimuli of each of the Tibetan bowls.

4.1. Selection of the Tibetan Bowls

In this section, 3 Tibetan bowls were selected, and a physical characterization was made, obtaining values for the “small” bowl of 9.7 cm in diameter, the “medium” bowl of 11 cm in diameter and the “medium-large” bowl of 12.6 cm. cm in diameter.

Figure 1. The three Tibetan bowls that were used for the project.

Source: own.

4.2. Measurements with the Sound Level Meter

Having the physical characterization of each of the bowls, the subject who would touch the bowl was placed in the middle of a circle that would be drawn with distance points from 0° to 360° with distances of 45° between them.

Figure 2. Location of the SPL meter measurement points.

Source: own.

At these points, the sound level meter would be located at an approximate distance from the floor at 1.20 meters and the distance from the source to the microphone capsule was 80 cm. To obtain the data, the Svan 977 sound level meter was used, with a calibration of 94.00 dB, with ⅓ of the octave band, in addition to using a Slow filter and a Z-weighted filter.

Figure 3. Svan 977 Sound Level Meter setting.

Source: own.

In this section, each of the participants percussed and rubbed the bowl as required, 20 seconds were applied in each of the measurements, which seemed convenient when collecting the data.

Figure 4. Participants of the project interacting with the bowl.

Source: own.

MATLAB program was used where we involved the data measured by the Svan with its respective positioning. Following results were obtained.

5. Results

5.1. Small Tibetan Bowl

Following data was obtained:

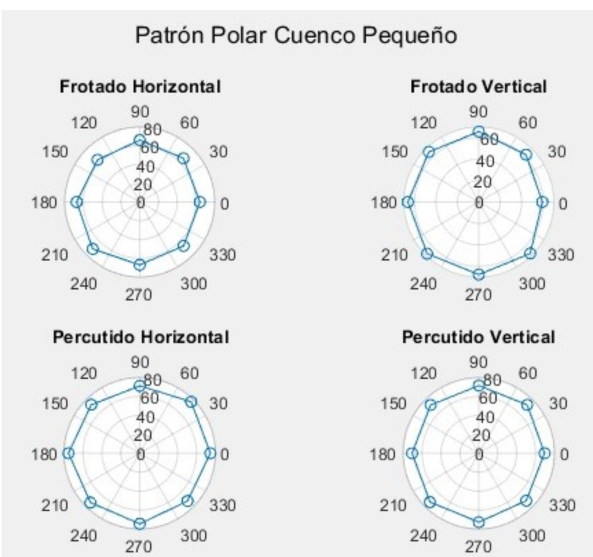
Table 1. Leq values from Small Tibetan bowl.

Horizontal rubbing		Vertical rubbing		Horizontally percussed		Vertically percussed	
Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]
0	64,2	0	59,3	0	74,7	0	69,5
45	65,9	45	62,3	45	76,9	45	72,3
90	66,1	90	65,7	90	71,2	90	71,5
135	63,6	135	66,1	135	72,5	135	72,1
180	67,4	180	66,1	180	75,4	180	70,6
225	70,9	225	68,2	225	73,7	225	73,0
270	67,0	270	67,7	270	74,6	270	72,8
315	66,2	315	67,9	315	71,4	315	70,9
360	64,2	360	59,3	360	74,7	360	69,5

Source: Own.

Resulting in:

Figure 5. Polar pattern from the small bowl.



Source: own.

5.2. Medium Tibetan bowl

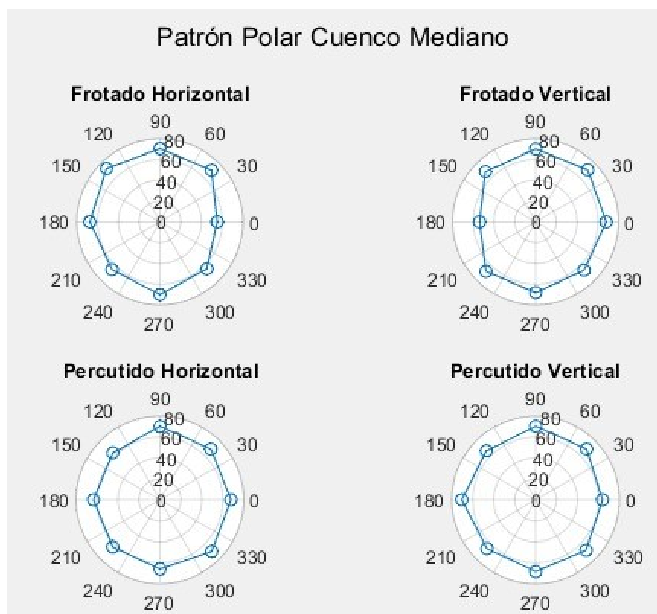
Table 2. Leq values from Medium Tibetan bowl.

Horizontal rubbed		Vertical rubbed		Horizontally percussed		Vertically percussed	
Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]
0	55,1	0	68,0	0	67,8	0	63,8
45	70,2	45	70,8	45	68,7	45	68,7
90	70,5	90	70,2	90	70,2	90	70,4
135	72,6	135	68,4	135	63,5	135	66,4
180	67,5	180	54,0	180	63,4	180	70,5
225	65,2	225	67,6	225	63,6	225	65,7
270	70,1	270	68,2	270	66,1	270	68,5
315	64,0	315	66,0	315	69,7	315	68,0
360	55,1	360	68,0	360	67,8	360	63,8

Source: Own.

Resulting in:

Figure 6. Polar pattern from the middle bowl.



Source: Own.

5.3. Large Tibetan Bowl

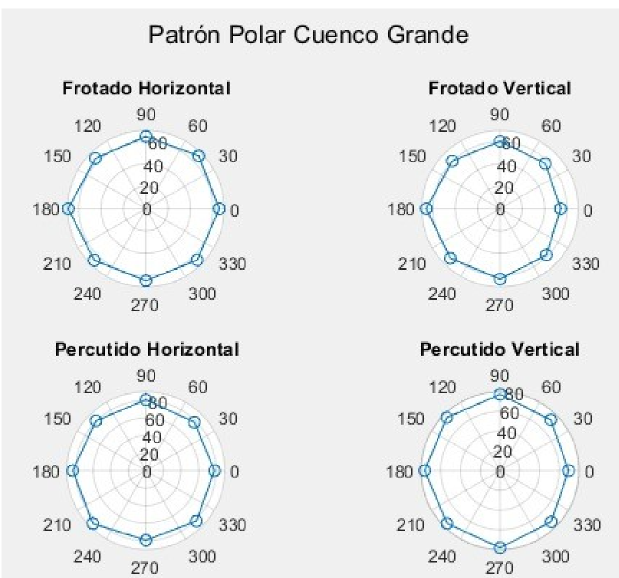
Table 3. Leq values from large Tibetan bowl.

Horizontal rubbing		Vertical rubbing		Horizontally percussed		Vertically percussed	
Grades °	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]	Grades [°]	Lteq [dB]
0	65,7	0	54,3	0	78,1	0	69,5
45	66,8	45	57,2	45	78,0	45	72,6
90	64,7	90	60,3	90	80,8	90	77,3
135	63,8	135	60,4	135	80,3	135	76,1
180	69,5	180	65,9	180	83,2	180	76,2
225	65,3	225	62,8	225	85,5	225	75,8
270	64,5	270	63,0	270	79,4	270	78,2
315	64,9	315	58,6	315	81,4	315	73,3
360	65,7	360	54,3	360	78,1	360	69,5

Source: Own.

Resulting:

Figure 7. Polar pattern from the large bowl.



Source: Own.

Leq (equivalent continuous level) average level from each bowl:

$$L_{eq} = 10log\left[\frac{1}{T}\sum_{i=1}^{n} t_i 10^{L_{pi}/10}\right] \quad [\text{dB}]. \quad (1)$$

T… represents the total measurement time interval, which was 3 minutes per bowl, that is, 180 seconds.

ti… the duration of each sample taken every 45 degrees, which lasted 20 seconds each.

Lpi…represents the sound pressure level measured in each captured sample n, which in the

previous graphs refer to the Leq value.

Table 4. Leq energetic sum from the small Tibetan bowl.

Leq FH (dB)	Leq FV (dB)	Lequ PH (dB)	Leq PV (dB)
66.740883	65.762747	74.254754	71.527719

Source: Own.

Table 5. Leq energetic sum from the medium Tibetan bowl.

Leq FH (dB)	Leq FV (dB)	Lequ PH (dB)	Leq PV (dB)
68.396540	**68.138402**	70.452420	69.928994

Source: Own.

Table 6. Leq energetic sum from the large Tibetan bowl.

Leq FH (dB)	Leq FV (dB)	Lequ PH (dB)	Leq PV (dB)
65.993574	61.156741	**81.279979**	**75.194167**

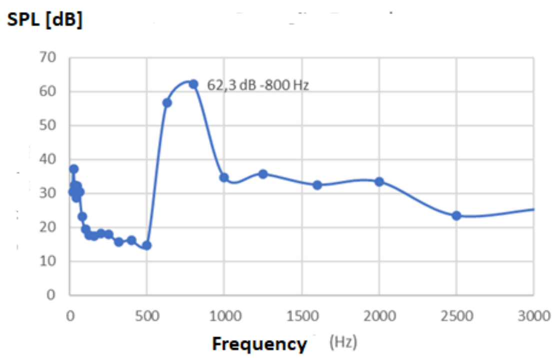
Source: Own.

5.4. Measurement of the medium Tibetan bowl with the SVAN 977 SPL meter

1/3 octave band analysis was performed, where following results were obtained.

For the rubbed small bowl:

Figure 8. Frequency bands centered at 800 Hz and harmonics.



Source: Own.

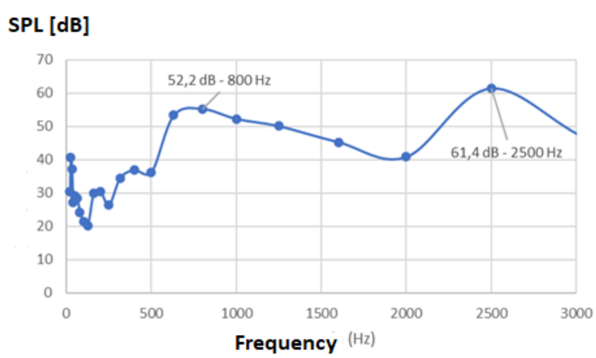
Table 7. Frequencies.

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	SPL [dB]
800	40	71	69,4	70,2	68	67	68,8	65	40	62,2

Source: Own.

For the small Tibetan percussed bowl:

Figure 9. Frequency bands centered at 800 Hz, 2500 Hz and harmonics.



Source: Own.

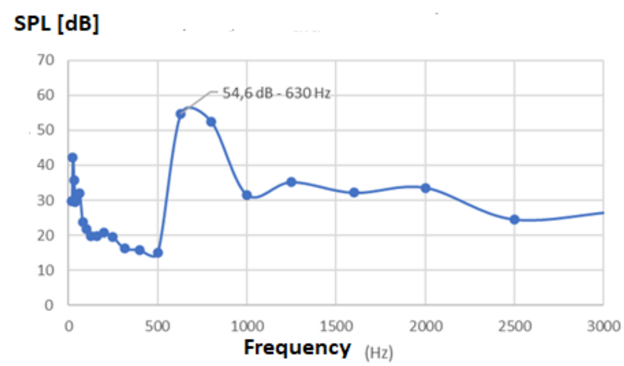
Table 8. SPL values for each position through frequency bands

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	PROM
800	50,4	55,7	53,9	51	52,8	59,2	56,7	62,3	55,3	55,3
2500	42,1	63	61	61,1	61,9	68,2	66	62	67,7	61,4

Source: Own.

For the middle rubbed Tibetan bowl:

Figure 10. Frequency bands centered at 630 Hz and harmonics.



Source: Own.

Obtaining the following values for fundamental frequency in this measurement:

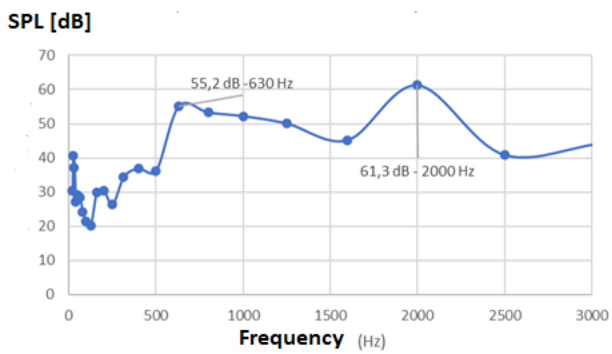
Table 9. SPL values for each position through frequency bands

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	SPL
630	30	69,1	69,4	71,5	66,3	64	68,8	62,2	30	59,1

Source: Own.

For the middle Tibetan bowl horizontally percussed:

Figure 11. Frequency bands centered at 630 Hz and 2 kHz and harmonics.



Source: Own.

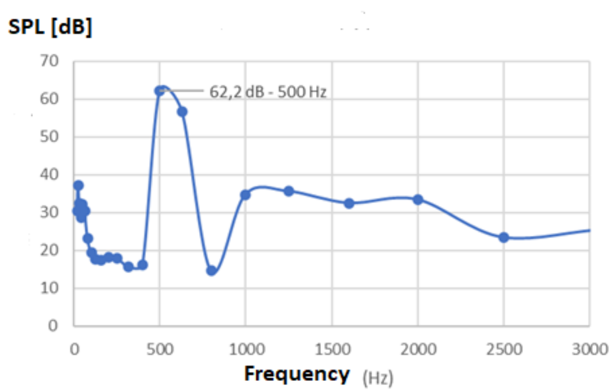
Table 10. SPL values for each position and frequency bands

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	PROM
630	62,3	57,3	59,2	49,5	52,9	55,3	53,9	55,7	50,4	55,2
2000	66,2	66	69,2	61,9	61,1	67,7	61	64,2	34,1	61,3

Source: Own.

For the rubbed large bowl:

Figure 12. Frequency bands centered at 500 Hz and harmonics.



Source: Own.

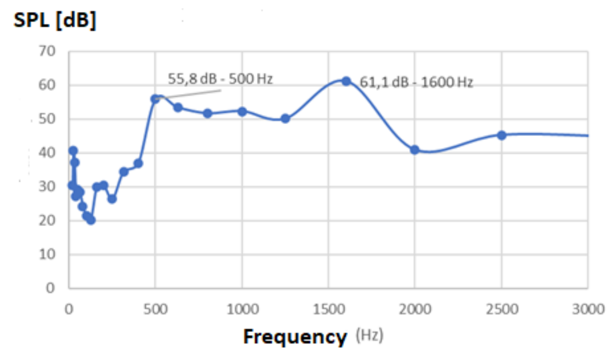
Table 11. SPL values for each position and frequency bands

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	SPL
630	30	69,1	69,4	71,5	66,3	64	68,8	62,2	30	59,1

Source: Own.

For the percussed large bowl:

Figure 13. Frequency bands centered at 500 Hz, 1.6 kHz, and harmonics.



Source: Own.

Table 12. SPL values for each position and frequency bands.

Freq [Hz]	0°	45°	90°	135°	180°	225°	270°	315°	360°	PROM
500	50,4	55,7	53,9	54	55	59,2	56,7	62,3	55,3	55,8
1600	42,1	63	61	61,1	60	68,2	65	62	67,7	61,1

Source: Own.

5. Results analysis

In this project, the measurements shown above were carried out to obtain the acoustic characterization of the sound stimuli generated by the Tibetan bowls and thus better understand their acoustic behavior. In this case, three Tibetan bowls of different sizes were used. The main objective was to analyze various acoustic properties of the three Tibetan bowls, such as their radiation, intensity, and fundamental frequencies along with their harmonics.

When analyzing the results, it is observed that the pattern obtained from the three Tibetan bowls gave a very similar result, a type of omnidirectional acoustic radiation. Since, both when the edge of each of the bowls was hit and rubbed with the mallet, sound waves were generated that propagated in all directions (in this case in 9 positions, in a 360-degree circumference), with almost the same intensity in dB. But the result obtained in terms of the equivalent continuous sound level did present slight differences, both due to the way of exciting (rubbing or hitting), as well as the size (small, medium and large).

For example, the medium bowl radiated the sound with the highest intensity, 68 dB, when rubbed, this compared to the other two bowls, which radiated with a lower intensity, around 3 dB less. This could be because the size was the most comfortable for holding it more easily and rubbing it, it rarely moved from the center of the pad, therefore, the movement of the subject who was touching it could be more constant, which allowed the increase and maintenance of loudness.

On the other hand, in percussion mode, the large bowl was the one that registered the highest loudness values, this being approximately 80dB, this with respect to the other two bowls, which radiated with a lower intensity, around 6dB less. This is because since the bowls are larger, they have a larger vibration area compared to the medium and small ones. When struck, a greater surface area encounters the mallet, allowing for a more efficient transfer of energy, consequently generating more intense sound waves. In addition to this, larger bowls usually have a greater amount of mass, which gives them greater inertia and, therefore, a more significant capacity for storing and releasing acoustic energy. When you strike the bowl, the stored energy is released more forcefully, generating a more intense sound.

Another difference worth highlighting is that the loudness levels recorded horizontally, both when striking and rubbing, were higher by at least 20% compared to those recorded vertically. And it is analyzed that this may be due to the hemispherical or concave shape of the bowls, because the sound emission is mainly concentrated at an angle towards the horizontal plane. Therefore, this directivity of the bowl makes the sound project more efficiently in this plane. Furthermore, when struck, the emitted sound is diffracted and reflected in the environment, and in the case of the horizontal plane, there was less obstruction to the propagation of the sound, compared to the vertical plane, since the nearby surfaces, such as the floor or ceiling can reflect and disperse sound, reducing its perceived sound level.

When the analysis was carried out by 1/3 of an octave, very similar values were obtained in terms of the way the bowl was played. For this purpose, it is important to separate this analysis by several characteristics, such as resonance, sound quality and energy. and vibration.

For the small bowl it was observed that when

Resonance: We consider a frequency band of 800 Hz with an SPL of 62.2 dB, it is inferred that this is a relevant frequency band in the Tibetan singing bowl. The presence of a higher sound amplitude at this frequency suggests that the bowl is designed to resonate and amplify harmonics in that range.

- Sound quality: The value of 62.2 dB indicates a slightly higher sound pressure level compared to the values shown for the medium and large bowl. This may indicate that the sound intensity at 800 Hz is slightly higher and may result in a more noticeable and energetic sound. However, it is still within the range of levels appropriate to appreciate the sound quality and subtleties of the bowl.

- Energy and vibration: The presence of a greater sound amplitude at 800 Hz suggests that this frequency is rich in energy and vibration in the Tibetan singing bowl. There may be specific design and construction features of the bowl that contribute to the generation of greater energy and vibration at this frequency.

When considering a frequency band of 800 Hz with an SPL of 62.2 dB, it is observed that the singing bowl shows resonance, sound quality and energy at this frequency. This adds variety and richness to the sound experience of the bowl and can influence how it is perceived and used in practices such as meditation, relaxation, or sound therapy.

By the time the bowl is struck, a sound pressure level of 55.3 dB is obtained for the frequency band centered on 800 Hz, which produces a sound of moderate intensity at that frequency when struck. For the frequency band centered at 2500 Hz with a sound pressure level of 61.4 dB the singing bowl produces a louder sound in that frequency band when struck compared to the 800 Hz frequency band. This suggests that the bowl has a more prominent response in the frequency band centered at 2500 Hz when struck. By analyzing the frequency bands of 800 Hz (55.3 dB) and 2500 Hz (61.4 dB) when the Tibetan bowl is struck, we can deduce that the bowl shows a prominent sound response at both frequencies. The bowl produces a moderate intensity sound in the 800 Hz band and a more prominent sound in the 2500 Hz band.

For the medium bowl rub it was observed that when rubbed:

- Resonance: The fact that the highest SPL is recorded in the 630 Hz band indicates that it is a prominent frequency band in the bowl. The bowl is likely tuned to resonate in this band and will produce a distinctive, enveloping sound in that range.

- Sound quality: The value of 59.1 dB represents the sound pressure level compared to a reference level. This indicates that, in the 630 Hz band, the singing bowl emits a sound of moderate intensity. 59.1 dB can be considered an adequate level to appreciate the sound quality and subtleties of the bowl.

- Energy and vibration: The presence of a greater sound amplitude at 630 Hz suggests that this frequency band is particularly rich in energy and vibration in the Tibetan singing bowl. It is possible that the vibration of the walls of the bowl, its design and construction contribute to the generation of a greater sound amplitude at that specific frequency. This vibration and energy can influence the sensory and therapeutic experience associated with singing bowls.

When considering a frequency band of 800 Hz with an SPL of 62.2 dB, it is observed that the singing bowl shows resonance, sound quality and energy at this particular frequency. This adds variety and richness to the sound experience of the bowl and can influence how it is perceived and used in practices such as meditation, relaxation or sound therapy.

By the time the bowl is struck, a sound pressure level of 55.3 dB is obtained for the frequency band centered on 800 Hz, which produces a sound of moderate intensity at that frequency when struck. For the frequency band centered at 2500 Hz with a sound pressure level of 61.4 dB the singing bowl produces a louder sound in that frequency band when struck compared to the 800 Hz frequency band. This suggests that the bowl has a more prominent response in the frequency band centered at 2500 Hz when struck. By analyzing the frequency bands of 800 Hz (55.3 dB) and 2500 Hz (61.4 dB) when the Tibetan bowl is struck, we can deduce that the bowl shows a prominent sound response at both frequencies. The bowl produces a moderate intensity sound in the 800 Hz band and a more prominent sound in the 2500 Hz band.

For the medium bowl rub it was observed that when rubbed:

- Resonance: The fact that the highest SPL is recorded in the 630 Hz band indicates that it is a prominent frequency band in the bowl. The bowl is likely tuned to resonate in this band and will produce a distinctive, enveloping sound in that range.

- Sound quality: The value of 59.1 dB represents the sound pressure level compared to a reference level. This indicates that, in the 630 Hz band, the singing bowl emits a sound of moderate intensity. 59.1 dB can be considered an adequate level to appreciate the sound quality and subtleties of the bowl.

- Energy and vibration: The presence of a greater sound amplitude at 630 Hz suggests that this frequency band is particularly rich in energy and vibration in the Tibetan singing bowl. It is possible that the vibration of the walls of the bowl, its design and construction contribute to the generation of a greater sound amplitude at that specific frequency. This vibration and energy can influence the sensory and therapeutic experience associated with singing bowls.

When the bowl is struck, we obtained values in the 630 Hz band with a pressure level of 55.2 dB, and for the 2000 Hz frequency band a pressure level of 61.3 dB was obtained, so we can deduce which, in the frequency band centered at 630 Hz, indicates that the bowl produces a relatively moderate sound pressure level at that frequency when struck. On the other hand, the response in the frequency band centered on 2000 Hz is 61.3 dB. This indicates that the bowl produces a higher sound pressure level at that specific frequency when struck compared to the 630 Hz frequency. So, we can say that when the bowl is struck you get more relevance in other octave bands. For the large bowl it was obtained that when rubbed:

- Resonance: The presence of a relatively high sound amplitude in the 500 Hz frequency band suggests that this is a relevant frequency band in the singing bowl when struck. This indicates that the bowl is designed to resonate and amplify harmonics in that specific range.

- Sound quality: The value of 61.2 dB indicates a high sound pressure level compared to the previous values. This suggests that the sound intensity at 500 Hz is higher and may result in a more powerful and resonant sound. This sound pressure level can contribute to a more immersive and dynamic sound experience by striking the bowl at that frequency.

- Energy and vibration: The presence of a greater sound amplitude at 500 Hz indicates that this frequency is also associated with greater energy and vibration in the singing bowl. This may be due to the specific design and construction features of the bowl, which allow for greater energy transfer and generation of vibrations at that frequency.

By considering a frequency band of 500 Hz with an SPL of 61.2 dB, we can conclude that the singing bowl displays outstanding resonance, powerful sound quality and vibrant energy at this frequency. This adds variety and richness to the sound experience of the bowl when struck at that frequency.

And finally, when this bowl is struck, we obtain that, for 500 Hz, the presence of a sound pressure level of 55.8 dB indicates that, when the bowl is struck at this frequency, a sound of moderate intensity is produced. Although it is not a very high level, it can still be noticeable and generate a pleasant sound experience. At this frequency the bowl vibrates and resonates in a particular way, which contributes to the generation of harmonious and harmonically rich sounds. Then for 1600 Hz the value of 61.1 dB indicates that when the bowl is struck at this frequency, a higher sound pressure level is produced compared to 500 Hz. This suggests that the bowl vibrates and resonates more in the sound pressure band. frequency centered at 1600 Hz when struck. There may be a greater number of harmonics present at this frequency, contributing to a more energetic sound with greater intensity.

6. Conclusions

The first conclusion is that Tibetan bowls, due to their circular shape and the way they are played, can emit sound waves in all directions. This means that the sound generated by the bowl spreads evenly in the surrounding space, without a specific direction. Thus, omnidirectional radiation allows sound to be perceived from any position around the bowl, providing an immersive and enveloping listening experience. Furthermore, it was concluded that Tibetan bowls do have variations in the frequency and intensity of sound depending on their size. Larger bowls tend to generate a deeper, bassier sound due to their greater size and mass. These low frequencies can provide a sense of calm and a more resonant sound experience. On the other hand, smaller bowls emit a higher, more vibrant sound due to their smaller size and mass. These higher frequencies can add an element of energy and brightness to the sound of the bowl. This is evident in the results, since each size of singing bowl showed a prominent resonance in a specific frequency band. The small bowl resonated in the 800 Hz band, the medium bowl resonated in the 630 Hz band, and the large bowl resonated in the 500 Hz band. These frequency bands indicate that the bowls are designed to amplify and resonate ranges, which contributes to its distinctive character and sound. Furthermore, all three bowls showed greater energy and vibration in a lower frequency range and these results suggest that these frequencies are associated with greater sound amplitude and therefore greater energy and vibration in the bowls. This can be attributed to the design and construction features of the bowls, as well as the efficient transfer of acoustic energy at those frequencies. Finally, it can be concluded that all the measurements carried out and their respective analysis provide a more detailed understanding of the acoustic characteristics of Tibetan bowls and their response to different ways of playing them. These findings may be useful in selecting singing bowls with specific characteristics based on the user's preferences, as well as in understanding how to use the bowls therapeutically or in practices such as meditation and relaxation.

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