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Scientific Analysis Of The Various Strokes And Tones In Tabla, The Hindustani Percussion Musical Instrument

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Abstract: The Hindustani musical instrument tabla is made up of two drums, right handed "daya" and the left handed "baya". The various tones generated from this instrument is determined by the way in which the strokes are being made and its mode of applying. The syahi component fabricated on the playing surface of the drums determines the quality of the sound generated. The significance of the "syahi" preparation and the method of playing in contributing the musical tones of the instrument were investigated. Detailed analysis of the tones using digital audio workstation at various scales with the respective frequencies gave an inner sight into the scientific basis of the quality of the music generated from this percussion instrument. An attempt has been made to characterize the sound formed from tabla in terms of the pitch generated at all the scales from F to F'' using different tabla of varying syahi character.

Keywords; Percussion Instrument, Tabla, Strokes, Tones , Syahi , Digital audio work station

INTRODUCTION

Tabla set is a pair of 2 handed drums, "daya and baya" from the Indian subcontinent. Since 18th century tabla has been the principal percussion instrument in Hindustani classical music (Sadanand Naimpalli, 2005). Tabla is a solo and accompanying instrument which can be played with vocals and other instruments. It is frequently played in folk music performance in India, Bangladesh, Pakistan, Nepal, Afghanistan, and Sri Lanka (Vijayshanker Mishra, 2012). It is also used in the bhakti devotional traditions of Hinduism and Sikhism such as during bhajan and kirtan singing (Kirthirenjan 2016). Tabla is the main Kawali instrument used by Sufi musicians. Tabla has been used for kathak dance performances too (Sadanand Naimpalli, 2006) (Fig.1).

Fig.1.The musical Instrument "Tabla"

The name tabla is originated from the Persian and Arabic word for drum. There are many theories concerned with the origin of table (Vijayshanker Mishra, 2015: Sathyanarayan Vasishtu, 1977). Small drums were popular during the Yadava rule (1210 to 1247) in the south, at the time when Sangita Ratnakara (The fundamental music text of Carnatic Music) was written by Sarangadev. In the 14th century Assamese poet and writer of Saptakanda Ramayana lists several instruments in his version of Ramayana such as tabla, jhajhar, dotara, vina, rudra-vipanchi etc. It means that these instruments existed since his time in the 14th century or earlier. According to classification of m usical instruments defined in the 'Natyashastra' tabla is in the Avanadha Vadya category of rhythm instruments which are made by capping an empty vessel with a stretched skin. Scientifically it is a drum based percussion musical instrument (Sadanand Naimpalli, 2005)

METHODOLOGY

1.Making of Tabla

The tabla set consists of two single headed barrel shaped drums of slightly different sizes and shapes. Right-handed side drum is called "Dayan" and the left-handed drum is called "Bayan"(Sadanand Naimpalli,2006). Height of these two drums, normally lies in the range 26.67-30.48 cm. Diameter of "bayan" is normally 20.32 - 23.50 cm and that of dayan is 12.70 to 17.78 cm (Fig.2).

Fig.2.The technical parts of "Tabla"

Previously wood was used for making the body of both the drums. Nowadays, Baya is constructed with metals like Aluminum, steel, Iron, Brass or Copper (Sadanand Naimpalli, 2005)(Fig.3) Clay was also being used to make baya. Daya body is usually made up of wood including mango tree, jack fruit tree, rose wood or sheesham golden shower tree.

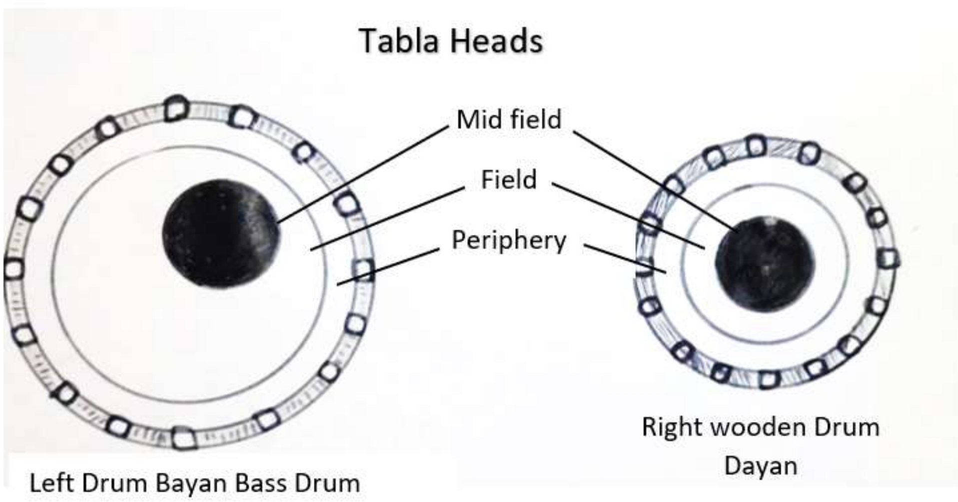

Fig.3.The sound generating tabla heads

Tabla head is generally consists of three layers made up of goat's skin (Raman, 1934). The first layer of skin in which a hole is to be made is placed initially on the body and above that the second layer is fitted. After tightening the 2nd layer properly (the layer which vibrates more) the syahi will be pasted on it and subsequently the 3rd layer with a hole at the centre (in the position of syahi pasted on the second layer) is placed. These top layers are combined, tightened and considered as the 'pudi' of tabla (Fig.4). Then 16 holes are to be made in the sides of the wooden body of Tabla. The three-layer assembly made is tightened with a leather cord through the 16 holes made on the body of the tabla.

The pudi made using the above mentioned 3 layers of leather is to be dried. Then the pudi is to be removed from the wooden body and according to the thickness of side of the wooden body, the inner part of 1st leather layer (which is the lower one) is to be cut. Again, it is to be fixed in the same position of wooden body and to be tightened using the leather wire. After fitting the pudi properly on the top of wooden body to get the 'Keenar'(shore) part of Tabla, the extended leather can be cut to fit in the circle shape to form the top layer.

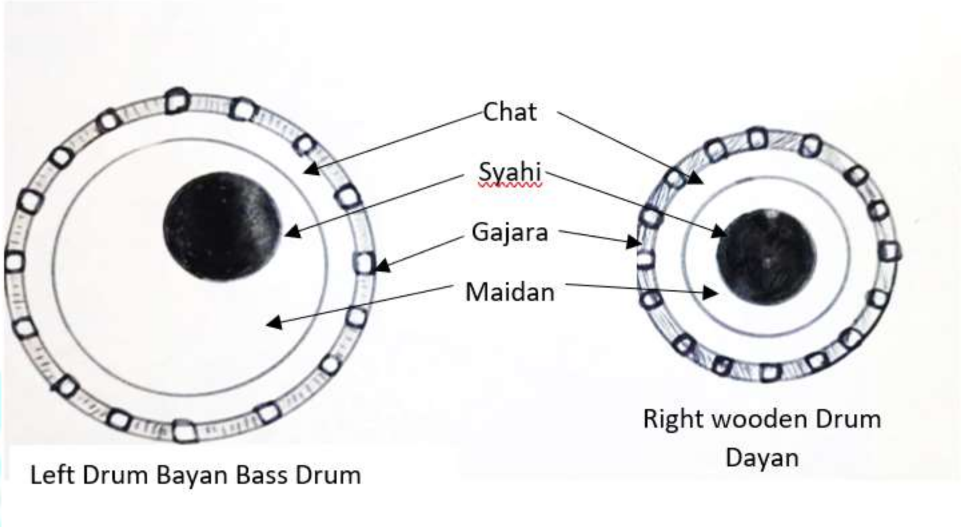

Fig.4.Parts of Pudi

2. Making of Syahi - The black portion on the top of Tabla

Syahi, the key sound generating part of the instrument is made out of a stone regionally called "Puranakeedam" which is mainly inclusive of iron fillings (Rameshan, 1988). Initially a homogeneous mixture of iron filings is made with rice and pasted on the top of the tabla as layers (one after other). The stone is grinded well and mixed with rice to form the paste. Iron particles have weight so it will energize the membrane (Raman, 1934). The number of layers of syahi will determine the vibrational status of the layer. The syahi is further dried by rubbing it with smooth surface after getting it perfectly fixed. When it becomes dry, small cleavages or cracks will be formed on it. Without losing the shapes of these cracks next layer is to be pasted. It is a sensitive process and the fine tuning of tabla is taking place at the time of syahi pasting and curing. If the thickness of syahi increases the sruthi or pitch of the tabla decreases and vice versa (Raman, 1934, ;Kirthirenjan, 2016).

3. The tabla used for the present study

For the frequency analysis, eight tabla daya of one full octave from "F" base scale to "F" high scale have been designed as follows (Table 1).

Table. 1. Details of various parameters fixed for designing the eight daya of tabla with various scales

Scale of table	**Material of the body**	**Height of the body** ***Centimeters***	**Air column height Centimeter**	**Air column bottom diameter** ***centimeters***	**Air column top diameter Centimeter**	**Outer diameter of the body** ***centimeters***
F base	Rosewood	27.94	16.51	13.97	12.70	15.24
G	Golden flower tree	27.94	10.92	11.43	12.70	15.24
A	Jack fruit tree	27.94	13.34	13.34	12.07	14.66
B	Polycarbonate	29.21	12.07	13.97	12.70	15.24
C	Rose wood	26.67	15.88	12.70	11.43	13.97
D	Jack fruit tree	2 6.67	12.70	11.43	12.70	13.97

E	Rose wood	27.94	12.70	12.70	10.41	13.72
F high	Golden flower tree	27.31	15.24	10.16	9.91	12.70

The above details showed that the standard height of the dayan body was in between 26.67 and 29.21cm. The required scale was mainly attained through the engineering of syahi making and air column management. The air column height was below the half of the height of the body. According to the shape of the daya the air column bottom diameter was higher than the air column top diameter. The outer diameter of the body had been selected according to the required scale of Dayan.

4. Fine Tuning of the Instrument

The syahi content lowered the resonance frequencies of the layers in the sound spectrum and brought them into a nearly harmonic relationship giving a platform to tune the instrument. Adding or removing the syahi changed the mass of the top skin layers subsequently helping in finely tuning the instrument to the required scale.

Commonly in a tabla set, the left drum (baya) is meant for creating the bass tone and its making is not to be changed according to the pitch or scale. The body of baya is completely hollow and outer diameter is very large. The leather must be in a flexible condition to balance with hand wrist of the player enabling to tune the same drum to different scales. Baya will be tuned to shadja (Sa), Gandhara (Ga), Madhyama (Ma), and Panchma (Pa) according to the scale of right-hand drum to synchronize with the generated sound. The flexibility of leather offers a platform for making the different notes using the pressure applied or balancing of the wrist. As per the scale sense, knowledge, practice and experience of the artist the baya can be tuned automatically.

5. The Methodology used for the frequency analysis of the sound generated from tabla

The audio samples (tones of tabla) were selected in a studio environment digitally with the help of a computer and interface (mic amplifier with Analogue to digital and digital to analogue converter).The tones were recorded in a digital audio work station(DAW) using a commercial audio recording software known as CU BASE (Steinberg Media Technologies GmbH'- 5.1.0, 2009). The tones were recorded in a mono track separately with 24-bit depth and 48000hz sampling rate. The microphone used for the recording is Perception 420 model condenser microphone of AKG brand.

RESULTS AND DISCUSSION

Tabla is a Hindustani classical percussion instrument having 2 drums to get treble and bass tones. The tonal quality depends on the material of construction, method of construction of the instrument, quality of the leather. quality and quantity of the syahi ,air column length and diameter

<u>1. Sound propagation from tabla</u>

When a tabla player strikes the drum head the physical energy caused the drumhead to vibrate which in turn transforms the mechanical energy into sound energy that travels through air in the form of waves. When a drumhead vibrates, it rapidly moves inwards and outwards. Inward movement of the vibrating surface creates a vacuum which pulls air resulting in " rarefactions". Subsequent outward vibration puts pressure on the air causing "compressions". The compressed air further passes on its energy to the adjacent layer of air. Thus, sound waves progress through air causing a series of compressions and rarefactions. These waves strike the eardrums of the listener making them vibrate. The nerves associated with the auditory system then picks up the signals and conveys it into the brain causing a perception of the sound. In short there are two different aspects to sound. There is a physical process that produces sound energy to start with and travels as waves in air and there is a psychological process that happens inside our ears, which convert the incoming sound energy into sensation.

<u>2.Pitch in the tabla</u>

In a successive note of an octave, the characteristics that help us to differentiate between one note to another is pitch. It depends on the frequency of the vibrating source. Higher the frequency higher will be the pitch. In the Hindustani music system, the frequencies of various (in Hz) notes in the middle octave are approximately

Sa = 240, Re =270, Ga =302, Ma = 320, Pa = 360, Dha = 405, Ni =452

In general, the pitch of membranous percussion instruments depends upon the shape of the drum and the material of the drum, quality of timbre, material of the membrane, size and thickness of membrane, tension applied on the membrane, the air column inside the drum, the quantity and quality of syahi and the diameter of the face of the drum. Whereas the loudness of percussion instruments (membranous) depends on the force given in the strokes, the size of instrument, the surface area of the membrane, the density of the surrounding medium and the thickness of the membrane. The following data is generally adopted for comparing the diameter and pitch in tabla making (Table 2).

Table.2. The diameter of the face of the daya of tabla and the contributing pitch

Diameter in Centimeters	Pitch
17.78	C , C Sharp (lower octave pitch)
15.875 to 16.51	D sharp , E (Lower octave pitch
15.24 to 15.88	F (Lower Octave pitch)
14.61 to 15.24	G sharp , A sharp
13.97	C sharp (High pitch)
13.34	D sharp , E (High pitch)
12.70	G sharp . A sharp(High pitch)

For making the octave out of daya the height of the daya bodies were almost made equal and the diameter of dayas were kept different for different scales. A particular scale could be obtained by increasing or decreasing the thickness of the syahi or number of layers of the syahi. The air column height was kept below half of the height of the body.

3.Frequency analysis of some basic strokes on daya in an octave

Octave in music, is an interval whose higher note has a sound wave with frequency of vibration twice than that of its lower note. Here the frequencies obtained were from the combined three layers on the face of daya. Multiple layers are the speciality of Indian percussions such as tabla, mrudangam, pakhawaj etc. whereas most of the western drums have only one layer The selected tones of tabla used for the analysis were "***Tha***"," ***Thi***"," ***Thin***", and "***Thun***". All these tones were single letters of right-handed drum daya which were the basic single tones mostly used.

Tha - This tone is the result of a stroke on the margin of daya using index finger. The finger strikes on the margin (kinar) and gets released in a fraction of a second like a bouncing ball.

Thi - This is a closed tone generated using index finger on the centre of syahi of daya. Here the finger presses at the centre for a fraction of a second and then gets released.

Thin - Here the index finger strikes near the centre of syahi of daya and suddenly released.

Thun - "***Thin***" and "***Thun***" are almost same. In "***Thin***" only one finger is used but for "***Thun***"4 fingers are used together. Four fingers are combined together closely and strikes on the centre of syahi of daya and released quickly." ***Thun***" have soothing effect than that of "***Thin***".

In the present study all the above basic tones were subjected to frequency analysis in an octave of dayas (8scales- Octave "F' base scale base to "F" high scale). The details of the results obtained are given below (Table 3).

Table.3. Frequency analysis of the basic tones of daya in an octave

Pitch Hz									
Strokes	Tones/Playing method	Scale F (base)	G Scale	A Scale	B Scale	C Scale	D Scale	E Scale	F ‘ High
	***Tha*** Moderately strong, quick release	526	582	654	490 -	770	578	980	1035
	***Thi*** Strong stroke pressing for a fraction of seconds and a quick release	240	210	245	294	238	240	238	371
	***Thin*** Moderately strong, quick release	199	222	257	272	298	305	362	385
	***Thun*** Moderately strong, quick release	199	222	257	272	298	305	362	385

From the frequency analysis of the tone “***Tha***” in the 8 dayas in 8 scales (Pitch), the frequencies were almost in the increasing order. The frequency of “F” high tabla was almost nearer to the double of “F” base frequency. It was almost same with the lower octave and the higher octave music notes.

In the above column of frequencies, the frequency of “***Tha***”on B” scale was not in the increasing order from the note behind it. It might be due to the thickness of the membrane or thickness of the syahi on it. If the thickness of membrane is more, the intensity of sound and frequency will be less.

From the data obtained it could be observed that the frequency of “F” high of “***Thi***” was much different but not the double of “F base “***Thi***”. This letter is a closed note so the scale difference will not affect much. The scale difference will affect more on open sounds. Frequencies of letters (sounds) “***Thin***” and “***Thun***” were same because in this case only the fingering was different and the nature of strokes were same.

From the frequency analysis of an octave of dayas (increasing order of scales,8 tabla) it could be established that the frequency increases according to the scales just like in music notes . It was observed that the peak frequency of “F” high was almost near to double value of “F” base .

3.1. Tuning of Daya

The natural sounds we hear every day are never only a single frequency. The process of breaking down a sound into its component frequencies are referred to as spectral analysis. In this the lowest component frequency will be the fundamental and others are called as overtones, which forms the major physical foundation of Timbre (Quality of sound). In the spectral analysis of tabla tones, we got a bunch of frequencies for each tone instead of a single frequency.

Even though “Tha and Tun” are resonating syllables of daya, “Tha” is taken as the basic pitch for tuning the instrument. “Tun” is a fully open note emerging without muting any positions of daya whereas for the tone “Tha” we need to mute a point in the border of syahi. So “Tun” is a completely open tone and having much clearer pitch. ”Tha” is the tone which is very important in tabla and maximum use of this syllable is made while playing the instrument. The combined tone “Dha (Tha +Ga- (combined strokes from both daya-Tha and baya-Ga) is the most important syllable of tabla having maximum use . In almost all the rhythm,” Dha “is the starting syllable and to end tabla compositions “Dha” is used to represent the completion. It is very difficult to find out 100 percent perfect daya having same pitch for “Tha” and “Tun”. In an untuned tabla the tension of leather in the pudi is not equal around the perimeter. The letter “Tha” which is played in the kinar allows to see the tension under a small section of the perimeter (45 ^{0} x 4). Then by listening the pitch we can decide whether that section needs to be raised or lowered according to the basic pitch.

In the frequency analysis of an octave of tablas and spectral analysis, when we compared the frequency data, and spectrums of all these 8 dayas the frequency (peak) of "Tun" was lower than that of "Tha". When we played a fully open tone the lower frequency components were dominated in a bunch of frequencies. But when we analysed the spectrums and compared the resonance or sustain of the tone, "Tun" was having resonance higher than that of "Tha". It was due to the absence of muting point in the tone "Tun". The decay of the tone "Tha"and its release in terms of the frequencies were faster than that of "Tun".

3.2. Relations of Scale C (Panchamam), Scale A# (Madhyamam) with basic pitch Scale F base (Shadjam) based on spectrum analysis

The correlation of basic pitch with various scales in tabla was established by the analysis of the tabla sound in an octave with spectrum analyser. In the analysis of an octave from F base to F high, the pancham is C scale, madhyam is A# scale and adhara shadjam is F base. Spectral analysis of the sound from tabla represented many peak frequencies for each scale of tabla (Table 4).

Table 4.Frequency analysis of Scale C in comparison with F base and F

Scale	Pitch	Frequency (Hz)
Scale F base Adhara Shadjam	**F** **C**	349 526
Scale C Panchamam	**C**	523
Scale F high Tara Shadjam	**F** **C**	699 1040

In these bunch of frequencies of tabla sound there were matching frequencies with 349 Hz for F base (adhara shadjam), 699Hz for F high (tara shadjam) and 523 Hz for C scale (panchamam). The peak frequency of 699Hz for F high was approximately double that of F base which was true as per scientific theory of music. An approximate frequency of scale C was seen in the frequency bunch of scale F base at 526Hz.In the frequency bunch of F high there was a peak frequency 1040Hz which was approximately double that of Scale C and scale F.

In the analysis of madhyamam (A# scale) frequency bunch included 258Hz that shows C scale in the spectrum,341Hz showing F scale and 469Hz showing A#. 697Hz in the F scale of tara shadjam was nearer to double the value of 341 Hz in the same scale of madhyamam (Table 5).

Table 5.Frequency analysis of Scale A# in comparison with F base and F

Scale	Pitch	Frequency (Hz)
Scale F base Adhara Shadjam	**F** **C**	349 526
Scale A# Madhyamam	**C** **F** **A#**	258 341 469
Scale F Tara Shadjam	**F** **C**	697 130

In the frequency bunch of scale F (tara shadjam) there was a peak of 130Hz. 258Hz of scale A# (madhyamam) was approximate double of this peak frequency. In the frequency bunch of scale F base (adhara shadjam) there was 349 Hz which was approximately near to 341Hz in the scale A # In the frequency bunch of scale F (tara shadjam) there was 697Hz which was nearly double than 341Hz in the spectrum of A# scale . Due to the matching frequencies of C scale and A# scale with base pitch scale F, these two scales were accepted as base scales of tabla. This could be the reason behind the usage of scale C or scale A# in playing tabla by most artists in accompanying performances.

4. Frequency Analysis of some basic strokes of baya

The left-handed drum (baya) notes in different scales were also analysed. The baya tuning could be done while playing, automatically by the balance of hand wrist which depended on the regular practice and the pitch sense of the artist. The details of baya used were as follows

Material of baya body -Copper metal
Height of Baya body -25.67cm
Air column height -25.40cm
Outer diameter -22.86cm
Frequency analysis of the various notes were performed and compared (Table 6).

Table.6. Frequency Analysis of Some Basic Strokes of baya (Left Drum of Tabla Set)

Strokes	Pitch Hz	Method of playing
	***Ga*** 82	Placing the wrist on the maidan having more space and striking the middle or index finger over the syahi by bending the palm (Resonant)
	***Ge*** 94	Holding wrist down and arching the fingers over the syahi striking on the maidan using index finger with some more pressure than the letter "Ga" (Resonant)
	***Ke*** 70	Striking with the flat palm and fingers of the hand. Closed note or tone. Fingers touches the kinar with metal part of the drum body, so tone will be little metallic according to the baya body. (Non resonant)

In a tabla set, the bass drum (baya) need not to be changed according to the pitch or scale. The reason is that the body of baya is completely hollow and outer diameter is comparatively large. Height is almost same as that of daya, The basic baya tones are "Ga"."Ge"", and "Ke" . In the closed tones the difference was less probably due to the less resonance generated. In baya the leather is not to be tightened to the maximum level to get the bass tone and hence will be flexible to balance with wrist of the artist to different scales. According to the scale sense, knowledge, practice and experience of the artist the baya can be tuned automatically.

5.Frequency Analysis of some basic combined strokes of daya and baya

Compound letters or combined tones were obtained on playing with two strokes simultaneously on both right hand and left hand drums together at the same time (Table 7). In the present approach the sample strokes taken were "Dha" and "Dhin". The tone "Dha" is the combination of the tones "Tha" (Right)and "Ga" (Left hand)." Dhin" is the combination of "Thin" (Right) and "Ga" (left hand)

Table 7. Frequency analysis of some combined strokes of daya and baya in an octave

		PITCH Hz							
Strokes	Tone	Scale F(base)	G Scale	A Scale	B Scale	C Scale	D Scale	E Scale	F Scale high
	***Dha***	82 526	82 587	82 654	82 735	82 770	82 872	82 980	82 1043
	***Dhin***	82 199	82 222	82 257	82 278	82 296	82 312	82 362	82 385
Dha – Combination of "Tha"and "Ga" Dhin – Combination of "Thin"and "Ga"									

From the frequency table of basic baya strokes (Table 6) the very common baya tone "Ga" was found to have the frequency 82 Hz. If the 1st string(deepest) of guitar is pinched, a fundamental frequency of 82 Hz is generated which is tuned to "E"scale normally. In the frequency data of combined tones (Table 7) a common frequency 82 Hz could be identified as linked with the "Ga" already obtained in the analysis of basic baya tones.

Conclusion

In the eight daya prepared in respect of an octave the height remained same but the diameter was different for daya of different scales. The particular scale was obtained by increasing or decreasing thickness of the syahi or number of layers of the syahi. The diameter of daya was inversely proportional to the scale or pitch. The frequency analysis of an octave of dayas showed that the frequency increased according to the scales. But the frequency range of percussions are totally different than music notes . Indian percussions are generally of 3-layer percussions and hence a bunch of frequencies are obtained. The peak frequency of "F" high was almost near to double the value of "F" base satisfying the theory that the notes (swaras) double in every next octave. But for closed tones there was not much differences due to less resonance. In the base drum (baya) the lower frequency is dominated and the same is reflected in the spectrum of combined tones. The combination of treble and bass tones has certainly different effects. The scientific study of different frequencies of the music notes from the percussion instruments will lead to the exploration of the impact of these frequencies in living systems and will improve the quality of measurements and tones .

Declaration of Competing Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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REFERENCES

1) Sadanand Naimpalli, Pt.(2005).Theory and practice of Tabla. Popular Prakashan Pvt .Ltd Mumbai, Edition 1.
2) Sadanand Naimpalli, Pt. (2006).Theory and practice of Tabla. Popular Prakashan Pvt Ltd, Mumbai, Edition 2 .
3) Vijayshanker Mishra, Pt. (2012). Tablapuran, Kanishka Publishers, New Delhi.
4) Raman, C.V. (1934). The Indian Musical Drums. Proceedings of the Indian academy of sciences, 179-188,1 Doi.10/1007/BF03035705.
5) Arvind Mulgaonkar, Pt. (2018).Tabla. Luminous books, Varanasi, Edition 1.

6) Vijayshanker Mishra, Pt. (2015).Art and science of playing table. Division Ministry of information and broadcasting, Government of India .
7) Sathyanarayan Vasishtu, Pt. (1977). Taal. Marthand, Sangeeth Karyalay, Uttarpradesh, Edition 5.
8) Yadav, B.L. (1999). Tablaprakash . Sangeeth Sadan Prakashan, Allahabad.
9) Yadav, B.L. (2009).Tablaprakash . Part1, Prayag Sangeeth Samithi, Allahabad.
10) Raman. C.V. and Shivalikumar. (1920) .Musical drums with Harmonic Overtones. Nature, 104,453-454.
11) Rameshan, Sivaraj.(1988).Scientific papers of C.V Raman. Acoustics, ,Indian Academy of sciences, Volume 2 .
12) Sudhir Mainkar, Pt. (2008).Austhetics of tabla. Saraswathy Publications, Mumbai.
13) Sree Vastav, Acharya Gireesh Chandra.(2010). Taal. Prabhakar Prasnothari Hindi book, Roobi publications, Allahabad.
14) Kirthirenjan, Jena. (2016). Importance of tabla in Music tradition of India. International journal of scientific Research, 5,11,726-727, DOI 10.36106/ijsr.
15) Patranabis, Anirban., Kaushik Banerjee, Vishal Madhya, Sneha chakroborty, Shankha sandal, Archi Banerjee, Ranjan Sen Gupta, Dipak Chandra Ghosh. (2015). Harmonic and timbre analysis of tabla strokes, Medicine – arxiv, 978-981, DOI:10/1007/978-981-15-0790-8-29.
16) Roy,Uttamkumar.(2015).Concatenated Tabla sound synthesis to help musicians. Research in computing science,103(1),29-39, DOI:10.13053/RCS 103-1-3.
17) Raut, Sandipkumar.(2020). Role of tabla in Indian Music. Indian journal of applied research 10,8, 1-21, DOI 10.36106/ijar.
18) Allen Roda, P. (2015).The tabla past and present ,Analysis of materials in Indias most Ionic drums. The Galpin society journal, 68, 193-214, DOI 186 10.07.2021/JSTOR.
19) Rao, K.N.(1938). Theory of the Indian Musical Drums. Proceedings of Journal of Material Science, Indian Academy of science, 7A,75-78.