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Acoustical measurement of Indian musical instruments (vina-s): Towards greater understanding for better conservation

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Among the Musée de la musique collection of non-Western musical instruments are some rare and delicate ones from India, which have been the subject of acoustical investigation for a greater understanding, and hence a better conservation.

In the case of the rudra vina-s, the vibration of the string (exciter) plucked by the musician is transmitted to the resonators made from gourd through a flat bridge thus giving the instrument a remarkably singular timber.

Acoustical and vibrational measurements were applied in order to determine the acoustic properties of resonators. These techniques are based on gauging the radiated acoustical field triggered by a light impact or a frequency sweep. This analysis confirms the importance given by instrument makers to the painstaking choice of gourd resonators. Thanks to the estimation of resonant frequency – and from the vibrating length – it is possible to hypothesise on the type of strings used (the material, diameter and strain).

In short, these analyses make it possible the diagnosis of the mechanical state of constituent elements. These descriptors could facilitate decisions to optimise the choice of gourds in the production of instruments (sitar, tamera) that have today taken on semi-industrial shades.

1 Introduction

1.1 Musée de la musique collection

The conservation and research laboratory of the Musée spends a great deal of attention to improving the care and preventive conservation of its collections. Among the ethnographic musical instruments, there are some rare and delicate Indian pieces, traces of a highly refined culture dating from the Mughal times to the British period (from the 17th to the 19th centuries). Despite the large production of musical instruments in India in the 18th and 19th centuries to supply reputed musical centers as Gwalior, Jaipur, Lucknow or Banaras (Figure 1), very few of them were collected and preserved in the course of time; climatic conditions, inadequate storage facilities and termites proving to be lethal in many cases. The surviving ones kept in India remained unknown for generations of musicians and those which reached foreign museums and private collections were often too difficult to trace. Most disappointingly, once localized, only scanty information regarding their previous owners and their provenance could be gathered. Since it was not possible to rely on any existing study of ancient Indian musical instrument, many questions then cropped up. As a matter of fact, and contrary to contemporary Western makers who used to sign and date their works, most of the Indian production of musical instruments in the 18th and 19th centuries was anonymous. Although the rudra vina or bin has nearly disappeared from the concert circuit, it is still considered in India as the foremost musical instrument of its art culture. The Musée de la musique keeps in its ethnographic collections three ancient and rare specimens dating from the 17th to the 19th centuries (Figure 1).

In addition to insure the best conservation of these instruments, a mission of the Musée is to study the instruments' history, the musical instrument classification, and the technical aspects of how instruments produce sound.

1.2 The rudra vina

The Musée de la musique in Paris includes within its ethnographic collections some ancient musical instruments from India, among them, there are rudra vina-s. The rudra-

vina or bin – a vernacular term used in North India – belongs to the family of tube zithers, a later development of the stick zither. It consists of a long wooden or bamboo tube (dandi) beneath which two resonators (tumba) made of dried and hollowed-out gourd are fixed. Numerous high wooden frets (sarika) are arranged on the tube with the help of a resinous substance or with linen cords. Four melodic metal strings are stretched out on these frets, while two slender rhythmic strings (chikari) and a drone string (laraj), also metallic, are fastened laterally along the length of the tube, on both sides of the frets. The morphology of the rudra-vina as we know it today has scarcely changed since the second half of the 18th century and it had already acquired its near-final features almost two centuries earlier in the southern part of the peninsula. The vina is played sitting down with one gourd over the shoulder. The right hand picks with 2 wire plectrums worn on index and middle finger, while the drone strings are played with the nail of the little finger. The left hand fingering is quite difficult as you have to grip the strings from underneath the horizontal neck. It is rarely used anymore.



Figure 1: rudra vina (foreground). E997.24.2 Musée de la musique. Paris

The vibration of the string is transmitted via a bridge and a wooden tube to two resonators made out of dried, hollowed gourds open at their bottom. The bridge presents a large curved surface that is in contact with the string. This device, which gives a remarkably singular timber, was then adopted on the the *tamera* and the sitar. Bertrand [1] showed that this specific contact between the plane surface of the bridge and the string produces an amplification of the

sound after its excitation and, by then, a progressive damping. This contact which defines the initial string conditions is slightly different between the *bin* and the *tanpura*. In this latter, a small cotton thread placed between the string and the bridge induces a modification of the frequency spectrum with time [2]. An experimental protocol has been developed in the laboratory to study the effect of the initial string conditions on the *bin* [3]. A comparison of sound measurements between a concert instrument and a monochord prototype revealed the importance of the shape of the bridge.

Another acoustical parameter useful to understand the mechanical principles that induce the acoustical response of the instrument seems to be the “harmony” between the two gourds. The gourds’ amplification principle depends on the air resonance phenomenon in a cavity. This resonance is proportional to the gourd’s volume, the cross-sectional area of its hollowed bottom and the acoustic celerity. Thereby, the resonance frequency of the cavity is a specific parameter of the gourd and has a specific value called the Helmholtz frequency.

2 Helmholtz resonance for museum collection instruments. Preliminary observations

2.1 Experimental set up

This experiment was carried out on five *bin*, whose two gourds were identified as “upper” (left) and “lower” (right) (Table 1).

	rudra vina A	rudra vina B	rudra vina C
Playable state	no	no	no
Collection	Musée de la musique E.997.24.1	Musée de la musique E.997.24.2	Musée de la musique E997.24.3
Period	17 th c. (?)	18 th c. (?)	19 th c.
	rudra vina D	rudra vina E	kinnari vina
Playable state	yes	yes	no
Collection	Private collection	Private collection	Music museum E.1444
Period	2002	1980's	18 th c. (?)

Table 1: studied instruments

An affiliated instrument, a *kinnari vina* (figure 2), composed of three gourds, was also part of the study. The middle gourd and the lower one are nearly similar, while the upper is the smallest



Figure 2 :Kinnari vina E.1444 Musée de la musique. Paris

For each instrument studied, the gourds were disconnected from the tube in order to measure the cavity resonance to avoid any interference. The experimental set up consisted of a loudspeaker emitting a frequency modulation in an audio range (20 Hz – 2500 Hz) located under the opening (Figure 3).

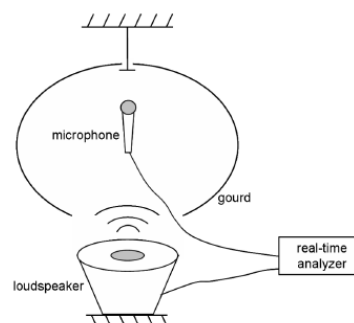


Figure 3:acoustic experimental set up

A microphone (Schoeps cmc6--u, Germany) was placed inside the gourd to record the frequency modulation. The signal is then recorded and analyzed with a portable real-time analyzer (OR 35, OROS, France). The resonance frequency is afterwards determined on the frequency spectrum as the maximum amplitude. The frequency difference Δf between 2 gourds of a same instrument is calculated from the highest frequency and is indicated in %, except for the *kinnari* where it is calculated from the middle frequency (Figure 4).

2.2 Results and discussion

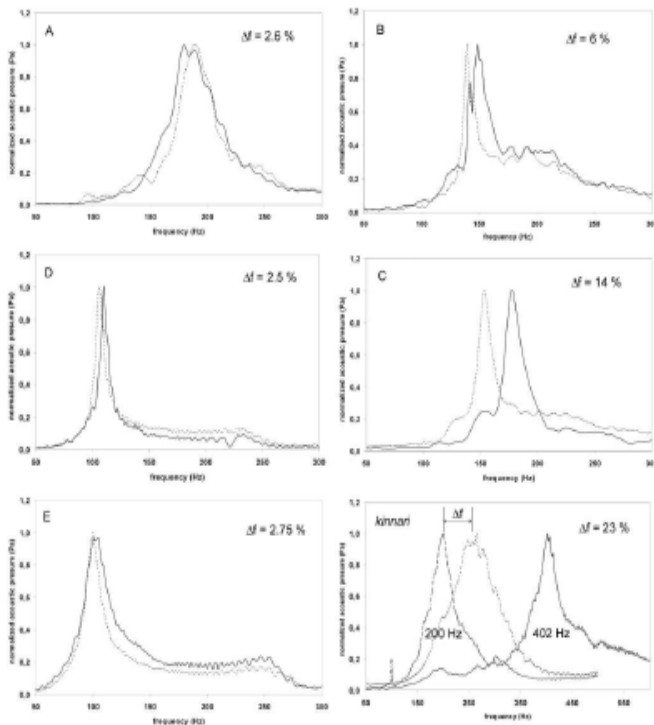


Figure 4: frequency response of the upper (solid line), lower (dashed line) and middle resonator cavities corresponding to each instrument

Two groups of musical instruments are distinguishable on the Figure 4. The first one, including the bin named A, D and E, presents a tiny difference (less than 3%) between the resonance frequencies of the gourds. The two bin D and E are contemporary concert instruments made in Kolkata and are regularly played. The bin A is a unique legacy from the past and has not been played for a very long time. It has been kept in an exceptional condition and its gourds are the original ones. Both of them have been repaired with attentive care before they were painted.

In the second group, including the kinnari vina and the bin B and C, the frequency difference is more than 6%. None of the musical instruments included in the second group are played anymore. Curiously, the upper resonator of the bin B was made with papier-mâché. On bin C, an overall visual examination of the lower gourd is sufficient to conclude that it is not the original one. Both the orifices of the two largest gourds of the kinnari contain significant damages, and as well an irregular cross sectional area. This instrument with three resonators of different sizes belongs to another musical tradition.

Looking at these results and observations, several hypotheses may be brought forward: the maker might have been striving empirically to minimize the frequency difference between the gourds. We know that a tiny difference between the resonance frequencies produces a specific acoustical phenomenon. Were the makers looking for such an effect? This could explain why the gourds of the bin A were repaired instead of being changed for new ones.

Although the kinnari vina features three sizes of resonators, it is remarkable that the Helmholtz frequency of the smallest gourd is twice the frequency of the lower one

(Figure 7). In musical language, this would mean that they are tuned to the octave. This suggests a remarkable traditional know-how.

As this study shows, acoustical analysis could be regarded as a suitable process for a better understanding of these ancient musical instruments. The results obtained on several bin allow us to venture the hypothesis that a great care was brought to select the gourds according to a desired pitch. To go ahead, the next step would consist in psycho-acoustical measurements while a bin is played and its Helmholtz frequency is simultaneously modified (by a variation of the orifice of the gourd).

3 Resonance frequency modification

3.1 Experimental set-up

The experiments described below have been realized with an actual musical instrument, made in Kolkata in 2000, so it is in a playable state.

To evaluate the effect of the two resonators tuning, one of the gourd opening has been modified with a diaphragm. Only the opening diameter is controlled. Three sizes were used. The first one corresponds to the same Helmholtz frequency for the two gourds; the second one allows a gap of 7%, and the last one, a gap of 17%.

For each configuration, the musician played the same musical sentence, and didn't know which diaphragm was used. The records were realized in a semi-anechoic room.

The signal was recorded with a microphone located at 1,5 m in front of the musician (figure 5).



Figure 5: position of the musician

3.2 Results and analysis

The recorded signals are compared using the ISD ([4]), which means that the energy of the Fourier transform, after normalization, is divided into frequency bandwidths, according to the ear sensitivity (from 20 Hz to 15000 Hz). Figure 6 represents these results for the different gourd openings.

4 Conclusion

This study was a preliminary one in the museum, and we are looking for acoustical descriptors for the ageing and the conservation of these musical instrument. The experiments realized with a bin in a playable state help us to understand the coupling between the strings and the resonator. Indeed, we have shown that the tuning between the two gourds is may be not so precise. We hope that we will be able to determine structure frequency and modelize the mechanical behaviour for the better preservation of this corpus.

Acknowledgments

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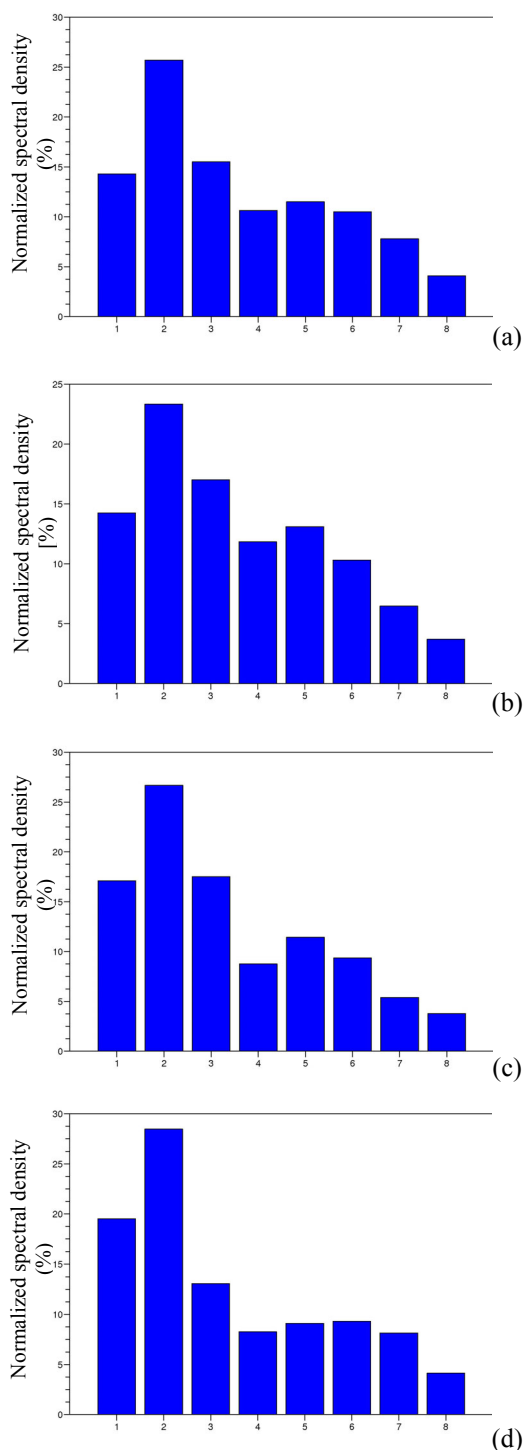


Figure 6: ISD results for (a) no diaphragm; (b) $\Delta f = 0\%$; (c) $\Delta f = 7\%$; (d) $\Delta f = 17\%$

According to the figure 6, it appears that the energy is allocated into the frequency bandwidths in the same way independently of the opening bandwidths, except for the last one (the biggest gap between the two resonators). Moreover, the musician didn't succeed in distinguishing the configurations. Whereas Schmitt [2] proposed the hypothesis of a flapping phenomenon in low frequency, this experiment shows that until a gap of 17 % between the two Helmholtz frequency resonators, the acoustical energy is not disturbed.