ACOUSTICS 2012

Vibrotactile feedback in the left hand of violinists

I. Wollman[a], C. Fritz[a] and J. Frelat[b]

[a]LAM, Institut Jean le Rond d'Alembert, UMR CNRS 7190, UPMC, 11 rue de Lourmel, 75015 Paris, France
[b]IJLRDA-UPMC, 4 place jussieu, 75005 Paris, France
wollman@lam.jussieu.fr

The long-term goal of this study is to investigate the differences that can be perceived in the “feel” of a violin across a certain range of instruments. As a first step, we compare the vibration levels in violin necks and the violinists' sensitivity to vibration in their left hand. Absolute thresholds for vibration detection were measured on violinists holding an isolated vibrating violin neck, to mimic normal playing conditions (in particular the pressure and the position of the hand on the neck). A standard alternative forced choice method was used and the measurements were done as a function of frequency in the skin sensitivity range 200-900Hz. Vibration levels of the neck (at different positions along the neck) were measured classically across a large set of instruments, using a laser vibrometer and an impulse excitation at the bridge. Results show that the neck vibration levels are above the perceptual thresholds for most violins and at most frequencies below 900 Hz, and the relative difference between the two can vary a lot from violin to violin.

1 Introduction

By fingering a note and drawing the bow across the string, a violinist excites a complex structure designed to vibrate (and radiate sound). In addition to the resulting sound, the violinist is thereby exposed to the instrument’s vibratory response through different contact points: the left hand holding the neck, the right hand holding the bow, the chin and the shoulder. These perceived vibrations constitute what violinists themselves call the tactile feedback in violin playing and are probably related one way or another to the “feel” of a violin.

Many violinists consider that not only the sound but also the “feel” are really important for the evaluation of a violin, and it is not clear what is responsible for the latter: the ergonomics of the instrument, the response of the violin to the player’s input, the feeling of vibration through the left hand or the chin, etc.

According to Marshall [1], the violin neck plays an important role since “it is highly likely that the "feel" of a violin is principally determined by the lowest order vibrational modes of the violin, and particularly those modes that exhibit strong participation by the neck fingerboard and/or corpus”.

This study aims at determining whether the vibration levels measured at violin necks are above the human threshold of vibration sensation for all violins, and at all frequencies. This study is thus an attempt to discriminate violins according to the vibration levels perceived through the left hand of violinists only, across a certain range of instruments. This step is necessary before exploring whether these perceived vibrations play a role in the evaluation of the quality of a violin.

In a previous study, Askenfelt and al. [2] compared horizontal vibration levels recorded at 4 violin necks by means of a small accelerometer during normal playing with the threshold for detection of vibrotactile stimuli measured by Verrillo at the fingertip ($28mm^2$), the most sensitive part of the human body [3]. They experimentally observed that the violin neck vibrations were above or very close to the sensation threshold. However, the vibration levels at the neck were measured while playing, so were only obtained at the harmonics of the note chosen (lowest G, 196 Hz). Furthermore, the skin sensitivity to vibratory stimuli depending on the location on the body, the contact area, as well as the pressure of the skin on the vibrating surface [4], it is of particular interest to measure the sensation threshold directly on the left hand of violinists to confirm the previous observations.

In the first part of this paper, tactile sensitivity to vibration in the left hand of violinists is examined as a function of frequency in a psychophysical experiment.

In the second part, vibration levels of violin necks and bridges were measured on four violins using a standard impulse response procedure. The instruments were previously evaluated by a professional player. The vibration levels recorded are discussed with regard to the measured absolute thresholds of vibration sensation.

2 Threshold of vibration sensation in violinists’ left hand

2.1 Set-up

Thresholds of vibration sensation in the left hand were determined using a psychophysical method in a "normal playing situation" i.e. when holding the neck of a violin. However, this neck was an isolated neck uncoupled from the rest of the instrument for the following reasons:

- using a real isolated violin neck guarantees that the violinist uses the *same contact area* as in normal playing.
- it guarantees that the violinists have enough cues to exert the *same pressure* as in normal playing, with the so called muscle memory.
- it guarantees that the violinists feel the vibrations *through the left hand only* so uncoupling the structures ensures that we measure the threshold in the body region of interest.
- it prevents the excitation of the violin body by the neck and thus the generation of sound which would interfere with the vibration sensation.

The violin neck is suspended by two very thin nylon strings at both ends. The neck is excited with a small vibrator (Dayton Audio DAEX13 Mini Exciter Pair 13mm) positioned on top of the fingerboard (see Figure 1), vibrating in the perpendicular direction of the fingerboard.

The participants were asked to hold the isolated neck as they would do in normal playing.

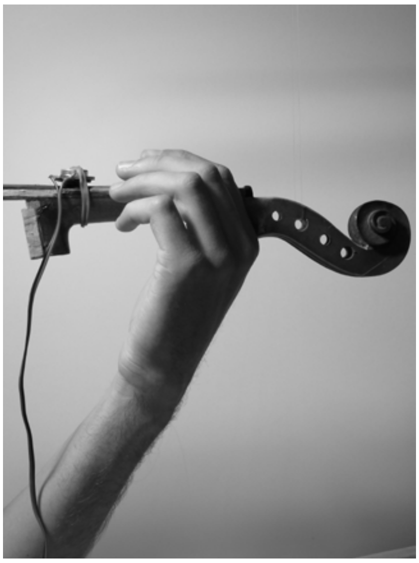

Figure 1: Experimental set up for the vibration sensation threshold measurement

2.2 Procedure

Thresholds were determined for 6 frequencies, ranging from 196 to 800 Hz, in the range of skin sensitivity. The first four frequencies correspond to the frequencies of the four open strings of the violin, 196Hz, 293 Hz, 440 Hz, 659 Hz; the 2 others are 730Hz and 800Hz.

Thresholds of vibration sensation were estimated using a three-alternative forced-choice procedure. A three-down one-up adaptive tracking rule was used which estimated the 79% correct point on the psychometric function [5]. On a computer screen, three blocks lit up to inform the subject of the temporal interval in which the vibratory event could occur. The vibratory event was a sinusoidal burst of duration 600ms, with a variable amplitude. The inter-stimulus interval was 1s.

To ensure a permanent pressure on the violin neck, the subject was asked to say orally in which temporal interval – 1, 2 or 3 - the stimulus appeared, and the experimenter typed the answers. Subjects were given visual feedback during the experiment. The difference in amplitude between the vibratory stimuli of two successive trials was determined by a predefined factor: the step size. The initial step size was relatively large - $2^{1/2}$ - to ensure a rapid convergence around the threshold. When the first turn-point was reached, the step size was reduced to $2^{1/4}$. The procedure automatically stopped after 8 turn-points and the threshold was defined by the mean value of the amplitudes of the vibratory stimuli in the 6 last turn-points.

Subjects familiarized with the experimental procedure by completing a training run at 440Hz before beginning the measurements.

Earmuffs were worn to make high-frequency sounds from the vibrator inaudible.

2.3 Participants

14 skilled violinists took part in this study - 8 females and 6 males - 12 aged between 19 and 36 and 2 between 50 and 65. None of them reported having tactile-related problems.

Subjects were paid for their participation.

2.4 Results

Accelerations of the isolated neck were measured after the experiment with a 3D accelerometer mounted on the neck, at the usual contact between the index of the violinist’s left hand and the violin neck in first position, while feeding the vibrator with the exact sinusoidal signal corresponding to the measured threshold for each participant, at each frequency under study.

Although there are two contact areas between the violinist hand and the violin neck - 1st thumb’s phalanx and base of the index - only one measurement was made at the index locus because the two small loci of stimulation are that close spatially (less than 5cm in between on the body) that only one big locus of stimulation is considered in this study.

The vibrator excited the neck in a direction perpendicular to the neck axis but the direction of the propagating vibration can be somehow modified in the neck. We assumed that at these frequencies (above 50Hz) humans are not able to determine whether a vibrating stimulus is produced laterally or normally to the touched surface but feel the vibration in a whole. We thus decided to consider the energy of the 3D-recorded acceleration signal, namely the magnitude of the acceleration considered in the 3 directions - tangential to the neck, normal to the fingerboard and normal to the contact areas on the sides of the neck - as the perceived stimulus.

An integration of the acceleration magnitude yielded displacement values in microns which were converted to decibels, with a reference of displacement of 1 micron.

Figure 2 shows the absolute threshold of vibration sensation measured at six frequencies on the left hand of violinists. All reported values are medians of measurements made on the 14 subjects and are plotted as the minimal detectable displacement in decibels as a function of stimulus frequency in Hertz.

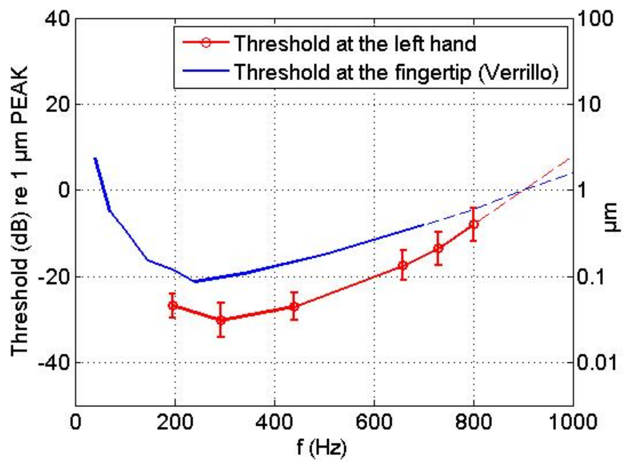

Figure 2: Absolute thresholds of detection for sinusoids measured at the left hand of 14 violinists (red) and at the fingertip (blue) (from Verrillo, 1963). Dashed lines represent the extrapolated thresholds. Standard deviations are represented by vertical bars.

The data are superimposed with the threshold curve of vibration sensation obtained by Verrillo [3] on the tip of the index for comparison purposes. The variability of results among subjects is small, as shown by the errors bars representing the standard deviation.

The graph shows that the maximal sensitivity of the hand is in the region around 300Hz. The most sensitive frequency range for the hand skin is then within the register of the violin. The sensitivity slightly increases with frequency from 196Hz to 293Hz. At this frequency, the skin of the hand can detect displacements as small as 0,03 µm. Above 300Hz and up to 1000Hz, sensitivity decreased rapidly until becoming impossible to measure.

3 Towards violin discrimination

A set of 10 violins was assembled for this study in order to explore the possibility of discriminating them according to their vibrational behaviour. The violins were chosen by a luthier for their different playing characteristics (ranging from 800 euros to 6000 euros, and made from early 19th century to early 20th century).

3.1 Perceptual evaluation of a professional violinist

A professional violinist was invited to play and evaluate freely the set of violins for quality evaluation purposes. He was encouraged to comment on his evaluation and to report orally his feelings regarding the sound and the "feel" of each violin. His comments about how four violins "felt" led us to restrict the study to these four instruments that were perceived as the most different violins of the set in terms of vibratory behaviour.

Two of these four violins were described as "vibrating" violins. One of them was perceived as "very pleasant to the touch, it responds very quickly" (*« très agréable au toucher, il répond très vite »*) with the comment: "by playing a G on the D-string, it makes me vibrate down to the belly" (*« en jouant le ré sur la corde de sol ça me fait vibrer jusqu'au ventre »*).The other violin "gives a good hand massage" (*«ça fait un bon massage de la main»*).

On the other hand, the two other violins were described as "non- vibrating" violins. One of them was described as "more inert to the touch*" (« il est au toucher plus inerte»*) and the other "hard to play, it doesn't respond quickly" (*« difficile à jouer, il ne répond pas vite»*) with an "inert neck" (*« manche inerte»*).

As a preliminary study, we decided to focus on these four violins in order to investigate how this perceptual feeling of a "vibrating" violin, regardless of its overall quality, relates to its vibrational behavior relative to the threshold of vibration sensation measured in section 2.

3.2 Vibrational measurements

The strings were tuned and classically damped and the instrument was held clamped on a rigid board, using a fixture replacing the chinrest, while the neck was attached to a foam block (in order to emulate approximately the hold of a violinist). The same standard impulse response technique was used to measure (i) bridge admittances and (ii) sideways neck vibrations at the points where the index and the thumb of the left hand typically hold the neck in the first and third positions respectively. In practice, the G-string corner of the bridge was excited with a mini-force hammer (PCB, Model 086E80), in the direction of the bowing plane, and the bridge velocity (for the bridge admittance) and the neck velocity (for the neck vibrations) were detected by a laser Doppler vibrometer (Polytech, PDV 100).

3.2.1. Bridge admittance

Figure 3 shows the bridge admittances (the ratio of the resultant velocity over the excitation force) of the four selected violins in the skin sensitivity range 196-1000Hz.

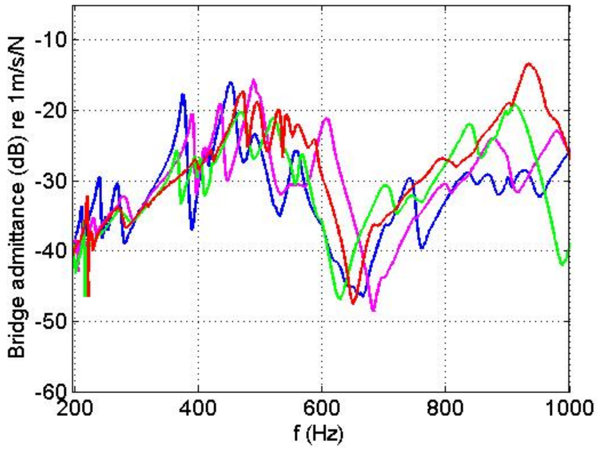

Figure 3: Bridge admittances of the four violins selected according to their perceived vibratory behaviour. Levels are plotted in dB re 1 m/s/N.

The four displayed curves have the same general shape in the chosen frequency range and the vibration levels seem to be of relatively equal magnitude among the four violins. There are no obvious differences which could explain the perceived differences by the violinist regarding the "vibrating" feel of the instruments.

3.2.2. Transfer functions Bridge-Neck

As we want to investigate the vibrational behavior of the violin necks relative to the threshold of vibration sensation, the measured transfer functions bridge-neck were converted in displacements in two steps. An integration of the velocity yielded displacement values in microns which were converted to decibels, with a reference of displacement of 1 micron. Second, the excitation force was chosen equal to 1N as it corresponds to the playing dynamics *mf* [5].

Figures 4a and 4b show the neck vibrations of both "vibrating" violins (figure 4a) and both "non-vibrating" violins (figure 4b), measured at the location of the index in the first position, superimposed with the measured sensation threshold.

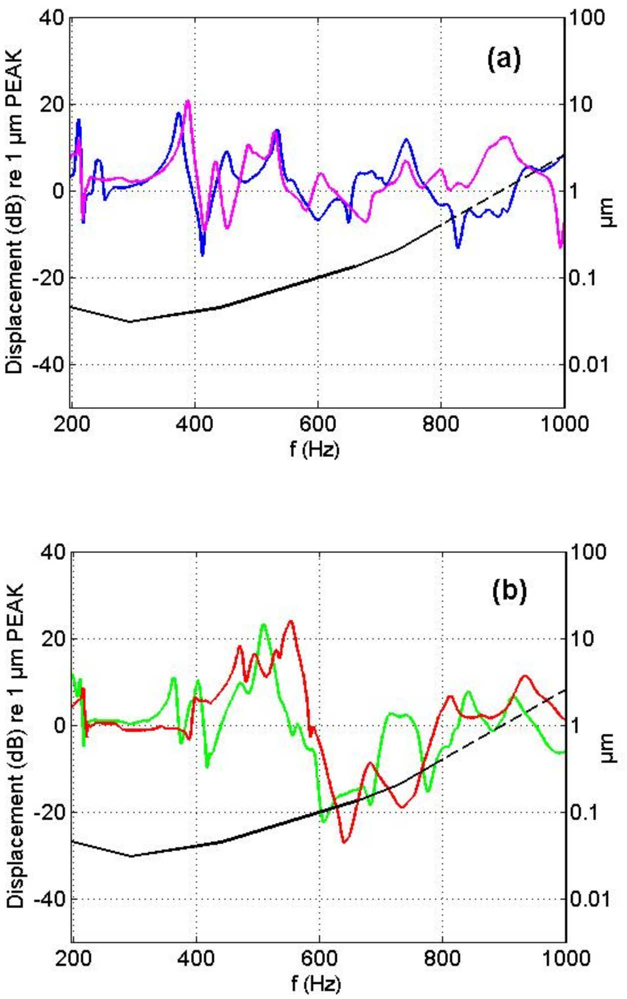

Figure 4: Vibration levels at necks of violins perceived as (a) “vibrating” violins (b) “non-vibrating” violins. The measured threshold of vibration detection is reported on the graphs (black curve)

Figure 4 shows that the vibrational amplitudes of the necks of “vibrating” violins are well above the measured threshold of vibration sensation up to 800Hz.

The vibrational amplitudes of the neck of “non-vibrating” violins are above the reported threshold and of same magnitude as those of the “vibrating” violins for frequencies lower than 600Hz. However, above 600Hz, the curves of the “non-vibrating” violins present an abrupt decrease and stay below or just about the threshold. The curves appear to be less “even” over the frequency range.

The same trends are observed when comparing the other vibration measurements, made under the thumb in 1st position on the neck and under the index and the thumb in 3rd position, with the measured absolute thresholds of vibration sensation.

4 Discussion and conclusion

If the classical bridge admittance curves in the skin sensitivity range do not bring compelling evidences that violins can be perceived as different in terms of vibratory feeling, it is interesting to note that the displacement levels recorded on violin necks in the skin sensitivity range can significantly vary from one violin to another, especially around 600Hz. Interestingly, amplitudes of vibration at violin necks seem to be more representative of the violinist’s evaluation. They are well above the threshold of sensation at all frequencies under 800Hz for both violins that were described as “vibrating” violins, whereas the relative position of the vibration curves of both “non-vibrating” violins compared with the threshold curve depends on the frequency. More precisely, the vibration level curves of the “non vibrating” violins can be split into two clear zones of frequencies: below 600Hz where they are well above the threshold and above 600Hz where they stay below or close to the threshold, with a very abrupt level decrease in-between, of approximately 40dB. This could be described as a cutoff frequency at about 600Hz. This partition in two frequency zones cannot be done for the vibration level curves of the “vibrating” violins, more “even” over the frequency range.

These observations mean that for notes higher than D5 (587 Hz), the vibrations can be sensed for “vibrating” violins but not for “non-vibrating” violins. For notes lower than D5, the vibrations can be sensed in both types of violins but the intensity of the perceived vibration should be different considering that the amplitude of the lowest partials of each note played can change the strength of the vibration felt. The fundamental vibration for notes lower than D4 is indeed of relatively equal magnitude for both types of violins but the partials in the range [600Hz – 1000Hz] will be perceived for the “vibrating” violins only.

With this in mind, one could infer that the relative position of the vibration level curve of violin necks compared with the threshold of vibration sensation would then reflect the vibrating character of a violin. Further work is necessary to confirm this trend with a larger panel of violinists who would evaluate the violins according to their “feel”.

This paper is a preliminary descriptive stage to assess the existence of violin-dependent tactile feedback in the left hand of violinists that can help discriminating violins across a certain range of instruments. Besides, this existence was heavily supported by the evaluation of a professional violinist. Future studies are now needed to investigate whether the perceived vibrations can be of any help to explain the quality of a violin.

Acknowledgments

The authors would like to thank all the violinists who participated in this study and in particular the professional violinist Adrien Rodrigue. We would also like to acknowledge the luthier Pierre Testa who kindly let us ten violins.

References

[1] K.D Marshall, "Modal analysis of a violin", *J. Acoust. Soc. Am.* 77, 695-709 (1985)

[2] A. Askenfelt, E.V Jansson, "Vibration Sensation in Stringed Instrument playing", *Music Perception* 9(3), 311-350 (1992)

[3] R.T Verrillo, "Effect of contactor area on the vibrotactile threshold" *J. Acoust. Soc. Am.* 35, 1962-1966 (1963)

[4] R.T Verrillo, "Vibrotactile threshold measured at finger", *Perception & Psychophysics* 9(4), 329-331 (1971)

[5] H. Levitt, "Transformed up-down methods in psychoacoustics", *J. Acoust. Soc. Am.* 49, 467-477 (1971)

[6] A. Askenfelt, "Measurement of the bowing parameters in violin playing. II: Bow-bridge distance, dynamic range, and limits of bow force", *J. Acoust. Soc. Am.* 86(2), 467-477 (1989)