MEASUREMENT OF THE EFFECT ON VIOLINS OF AGEING AND PLAYING

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ABSTRACT. This is a report on the first three years of a long-term experiment designed to measure how two very similar violins change with time. After being constructed 'in parallel,' one is stored under controlled conditions in a museum and is played infrequently, while the other is played regularly by a professional musician. Vibro-acoustic measurements were performed on the instruments and parts thereof during and after construction. Playing and listening tests by a panel of experienced violinists were conducted at completion, after three years with no adjustment, and then after minor adjustments were made to the played violin only. Panels of players and listeners rated the two violins at all stages, and all results are consistent with the null hypothesis: at present there is no significant preference for either instrument over a range of categories.

1. INTRODUCTION

There is widespread belief among players of stringed musical instruments, and experienced listeners, that these instruments improve with age and/or playing. A previous study has reported some measurable changes associated with regular playing of a violin [1]. There is at least one commercial enterprise selling treatments that expose the instrument to vibration [2]. However, testing this belief is complicated by other possible factors. For example, for a given player and instrument, these 'improvements' could arise from increased experience in overcoming the deficiencies and exploiting the advantages of that particular instrument [3].

Several reasons may be proposed to explain how improvements to the instrument might occur:

(i) Evolution in parameter space
Players will have made a number of changes and adjustments to an old, regularly played instrument. These could include changes of bridge, type of string and adjustment of the sound-post. In each case the player is likely to reverse the change unless it is perceived to improve the instrument. Thus a violin might gradually evolve towards a preferred region in its possible parameter space. There will also possibly be a different selection pressure here: instruments that are unsatisfactory or that don't improve will, in general, have a lower market value and will often be played by less experienced players. Those instruments that acquire a better reputation and market value will in general be sought and played by more experienced players. These improvements will occur independently of any change in the intrinsic mechanical properties of the instrument.

(ii) Age-related mechanical changes

The intrinsic mechanical properties could change with age or with exposure to different environments. Woods used in string instruments often have a high ratio of longitudinal Young's modulus to density, and drying of wood over time would lower the density. However, there is no simple reason to expect that age-related changes in general would necessarily improve an instrument.

(iii) Playing-related mechanical changes

A violin (and its components) undergoes considerable mechanical vibration during playing and this could alter the intrinsic mechanical properties. There is usually a strong correlation between the age of a violin and the total amount of excitation it has undergone. A study has shown a decrease in internal damping as a consequence of mechanical excitation in isolated samples of violin wood [4]. Extended mechanical vibration of violins has produced improvements as judged by listeners and players [5, 6] as well as measurable changes in the vibro-acoustic properties that are associated with improved tone and playing qualities [5, 7]. However, not all studies have shown a measurable mechanical change of violin wood upon extensive mechanical excitation [8], and there is again no simple *a priori* reason to suggest that these changes will improve the instrument. However it might be argued that mechanisms that produce mechanical loss could be affected by sufficiently vigorous excitation.

A major difficulty with studying the effects of ageing and playing, and separating the relative contribution of each, has been the lack of suitable controls. It is, of course, notoriously difficult to manipulate time as a variable, particularly in the reverse direction. In this study we attempt to tackle the problem of establishing a control from the very start.

The important step was to commission a pair of violins that were as similar as possible. To study ageing we have started a series of measurements of their vibro-acoustic properties and a series of playing and listening tests. To study the effects of playing, one instrument was kept under environmentally controlled conditions in a museum, whilst the other was played regularly by a professional musician. It should thus be possible to distinguish the separate effects of playing and ageing.

No two violins are exactly identical. Even if the process of making instruments were completely standardised, the variation in the mechanical properties of wood would give rise to vibro-acoustic differences. Nevertheless, the aim of this study is to compare two very similar violins as they age, under very different playing and storage conditions.

2. THE 'POWERHOUSE TWINS'

This study was conceived when Michael Lea (curator of musical instruments at the Powerhouse Museum, Sydney's museum of science, technology and applied arts) and Romano Crivici (a prominent Sydney musician) both sought to acquire instruments from Sydney luthier, Harry Vatiliotis. Vatiliotis was a student of Arthur Edward Smith, one of Australia's first renowned luthiers, and has a reputation for being able to make fine instruments reproducibly.

Although a study involving a larger set of 'identical' instruments, or even pairs of 'identical' instruments, would certainly improve the statistics, it would have required specific funding. It would also prove increasingly difficult to find very closely matched blocks of wood as the number of instruments increased. Finally, the idea of

keeping a statistically significant number of similar, fine, hand-made instruments that would not be played regularly would be hard to defend to the musicians who might otherwise have acquired them.

The violins were made from wood that had originally been intended for a violoncello. Hence it was possible to make both top-plates from the same block of wood (quarter-sawn European/Alpine Spruce, *Picea excelsa*), and likewise the back-plates (German/European Maple, *Acer pseudoplatanus*). The wood had been seasoned for over 80 years. This does not give identical plates, of course, because of the spatial inhomogeneity of the wood. This was investigated by measuring important bulk material properties of samples taken of the wood directly surrounding the plates. These include the spatial distribution of Young's moduli (using resonance techniques [9, 10]) along the grain and transverse directions, the mass densities, growth-ring densities and moisture contents.

A summary of values measured is presented in Table 1. Over 12 samples of various size (100 mm or less in length, 20 mm or less in width and all roughly 5 mm thick) were taken in the direction of the grain and two across the grain were obtained from the wood immediately surrounding the top-plates. The variation in longitudinal Young's modulus for the top-plates is largely the result of a single sample having an anomalous value. Nevertheless, these variations show the difficulty confronting a luthier who might set out to make an instrument similar to an instrument s/he had previously made, and which was highly appreciated.

The results are consistent with what we would expect to find in good quality Spruce at equilibrium with the Sydney atmosphere [10].

These samples will provide a useful control for future studies on wood ageing, distinct from those of the violin itself, and are stored with their respective violins. Several measurement techniques were applied at six stages of construction:
- When the top and back plates had been carved to shape,
- When the *f*-holes had been cut and bass-bar installed,
- When the violins had been finished,
- One year later,
- Three years later and then
- A further four days later, after the played violin had been adjusted by its maker, in a session with the owner, for the first time.

	Played violin	Unplayed violin
E_L (GPa)	10 ± 2 (7)	10 ± 1 (6)
E_T (GPa)	0.9 ± 0.1 (2)	0.7 ± 0.1 (2)
ρ (kg m^{-3})	473 ± 9 (22)	447 ± 13 (12)

Table 1. Measured properties (mean ± standard error (number of samples)) of wood samples from material surrounding the violin plates. Here, E_L and E_T denote the Young's modulus in the longitudinal (grain) direction and the transverse direction respectively, and ρ denotes the mass density.

3. MECHANICAL MEASUREMENTS

Before the violins were assembled, vibro-mechanical measurements and Chladni patterns were made on the carved plates, before and after the cutting of *f*-holes and adding the bass bar. An impedance head was mounted axially on a shaker and coupled *via* a magnetic clamp system to the plate, which was excited with a synthesised broadband signal over the frequency range 50-1000Hz [11]. The results are shown in Fig 1. Note that there are clear differences in resonances between 500 and 800 Hz, as one might have expected from the measured inhomogeneities in the wood (Table 1). On the other hand, the low frequency responses are similar, and that there are some similarities in the envelope of these plots. The inset photographs show Chladni patterns and the frequencies at which they were most strongly detected.

After assembly and finishing of the violins, the impulse response was measured using the method described by Jansson [12]: an impact hammer was positioned at the tip of a pendulum to impart reproducible mechanical impulses at the bridge, and a microphone was placed at the bass *f*-hole to measure the resulting pressure response in the near field of the violin. These measurements were also performed after one year, after three years and after subsequent adjustment of the played instrument. The pressure responses of the two instruments are given in Fig 2. The acoustic pressure in the near field of the violin was also measured while the bridge was driven with broad band excitation. The transfer functions of this measured pressure to the force applied to the bridge of the two instruments, is given in Fig 3. Although there are differences between the two instruments, they are small in comparison to the differences between either instrument and an inexpensive, mass-produced instrument ('Lark' brand).

4. PLAYING AND LISTENING TESTS

Listening and playing tests were conducted three times: First, when the two violins were new, the second was three years later (before any changes or adjustments had been made to either) and the third time was four days after this, following the installation of a new bridge and strings and a minor adjustment of the position of the sound-post of the played violin only. All tests were conducted 'live' in a concert hall (the Clancy Auditorium, at the University of New South Wales), which is regularly used for chamber, orchestral and choral music concerts. The playing and listening panel in each experiment were recruited from the most able members of the violin section of the University of New South Wales Orchestra. Their minimum formal qualifications varied from 7th grade to Licentiate in the Australian Music Examinations Board system. Each member of the listening panel in turn became a player. A few days before the first experiment, members of the panel were asked to fill a questionnaire in which they listed categories and qualities they would use in evaluating a violin for purchase. The more common words were retained for use in the questions given to players and listeners, as listed below. (Although there are published lists of terms that listeners and players might use for their assessment [13], these terms do not have universal acceptance and we preferred to use a list of terms that were judged relevant to our particular group of subjects.)

The same bow was used in all trials. Each player played three consecutive tests. In the first test, a player was given an instrument and played a G major scale over three octaves, from G3, ascending and descending, followed by a short piece chosen by that performer (the same for each test by that performer). After each test, the violin was taken from the player and placed behind a screen on the auditorium stage.

According to a predetermined sequence, the player was given either the same instrument, or the other member of the pair being compared. A test was then conducted and the violin was again returned behind the screen. For a third time, the player was given an instrument and asked to play the scale and the test piece. Behind the screen, the neck and chin rest of the instrument not being played were kept warm by being held in the hands of one of the investigators. The sequence of presenting one or other of the violins was arranged in pseudorandom order, with the constraint that all possible arrangements of two violins in trial sets of three were completed with each group of 8 sets of tests. The participants were not told of the aim of the experiment. (One performer asked if he had been given the same violin each time, while many who actually had been given the same instrument each time did not comment on this.) Each player rated the instruments in the three tests on a scale from 1 (poor) to 10 (excellent) in 8 categories: 'evenness', 'playability', 'speaking ability', 'distinctive character', 'warmth', 'brightness', 'responsiveness' and 'dynamic range'. They were also asked to rate their preference for 'sound', and the overall 'playability' of each test they performed.

The listeners rated 5 categories for each test, also from 1 (poor) to 10 (excellent): 'evenness', 'clarity', 'projection', 'distinctive character' and 'warmth.' They were asked to rank each set of 3 tests in order of preference for the sound of the instrument. They were told to evaluate the *sound only*, as opposed to the performance quality, and were asked to use their own definitions for each of the terms listed.

In the first experiment, the new violins looked very similar and the players and listeners were not blindfolded. After playing, however, the two instruments could be readily distinguished upon close inspection: the bridge on the played instrument was noticeably darker in colour, and its varnish had a different texture. Consequently, for the later tests, players (but not listeners) were blindfolded. From the designated seats in the auditorium, the owner of the played violin could not distinguish them visually.

The results of the comparisons are given in table 2. Does playing make a violin 'warmer', more 'even', 'brighter' (and the rest of the categories), as determined by players and listeners? The choice of confidence level for tests of this nature is a compromise. If one chooses a level of 99% or 98%, it might be argued that the demands are too stringent: positive differences will only be noted if the panels could very confidently distinguish between the instruments. Conversely, if one were to choose a level of 95%, we would expect false positives in approximately 5% of comparisons: about one in twenty results would yield false positives. In each set of tests, we compared responses in 16 different categories, so, at the 95% confidence level, the probability of no false positives in a single experiment is $(0.95)^{16}=44\%$. In other words, it is more probable to have one or more false positives than none at all. The chance of false positives increases with the number of comparisons. Over the years we conducted 3 sets of comparisons in each of sixteen categories, *ie* a total of 48 comparisons. Hence, even at the 98% confidence level, the chance of no false positives is $(0.98)^{48}=38\%$. Again, one or more false positives is more likely than none.

In the 48 comparisons, no difference between the violins was significant at the 98% confidence level. In just one of the comparisons, there was one comparison that, on its own, would have been significant at the 95% confidence level. At the first trial, the violin that was to become the played violin was judged to 'speak' better (a mean of 7.2 compared to 6.3 for 'speaking ability'). However, in 48 tests, it would have

been very surprising to have no false positives at the 95% level: 0.95^{48} is 9%, so, ten times out of eleven, 48 tests would yield at least one false positive at this level.

These results suggest that three years of regular playing, and the adding of new bridge, new strings and a slight adjustment of the sound-post, has not made a statistically significant difference to the performance of one of the pair of violins, as determined by playing and listening panels of experienced violinists who were unfamiliar with either instrument.

What of someone who is familiar with at least one of the violins? In a separate, blind playing trial conducted after the last comparison experiment, Romano Crivici, the owner of the played violin, was asked to play a scale and a short piece on the instruments as they were presented to him in random order, and to identify each instrument by saying "mine" or "museum's". He was correct in 20 out of 24 trials, which is significant at the 99% level.

Listening tests	New		3 years		3 years, with adjustments	
	Played	Unplayed	Played	Unplayed	Played	Unplayed
Evenness	6.7±0.1(113)	6.9±0.1(121)	6.1±0.2(56)	6.0±0.2(52)	6.5±0.2(78)	6.6±0.2(99)
Clarity	7.0±0.2(79)	7.0±0.1(119)	5.7±0.3(56)	5.6±0.3(52)	6.4±0.2(78)	6.4±0.1(99)
Projection	7.0±0.1(79)	7.1±0.1(121)	6.0±0.2(56)	5.8±0.3(52)	6.4±0.2(78)	6.6±0.2(99)
Character	6.2±0.2(79)	6.2±0.1(119)	5.4±0.3(56)	5.4±0.3(52)	6.1±0.2(79)	6.2±0.2(99)
Warmth	6.6±0.2(79)	6.7±0.1(120)	5.3±0.3(56)	5.4±0.3(52)	6.4±0.2(79)	6.2±0.2(98)
Preference	1.0±0.1(107)	1.1±0.1(118)	1.2±0.2(56)	1.0±0.2(52)	0.9±0.1(75)	1.1±0.1(93)

Playing tests	New		3 years		3 years, with adjustments	
	Played	Unplayed	Played	Unplayed	Played	Unplayed
Warmth	6.4±0.4(20)	6.2±0.3(22)	5.6±0.5(23)	5.1±0.5(22)	5.8±0.5(17)	6.2±0.4(22)
Evenness	7.0±0.2(18)	6.4±0.3(21)	5.7±0.5(23)	5.5±0.5(22)	5.9±0.6(17)	6.2±0.4(22)
Brightness	7.0±0.2(20)	6.5±0.2(22)	5.8±0.4(23)	5.3±0.5(22)	6.2±0.4(17)	6.5±0.3(22)
Speaking ability	7.2*±0.3(20)	6.3*±0.3(22)	5.6±0.4(23)	5.1±0.6(22)	5.9±0.6(17)	6.5±0.3(22)
Playability	7.2±0.3(20)	7.0±0.2(22)	5.8±0.5(23)	5.2±0.6(22)	6.1±0.5(17)	6.2±0.4(22)
Responsiveness	7.3±0.3(20)	6.7±0.3(22)	5.6±0.5(23)	5.6±0.5(22)	6.1±0.5(17)	6.2±0.4(22)
Character	6.2±0.3(20)	5.9±0.3(22)	5.4±0.5(23)	5.3±0.6(22)	5.7±0.5(17)	6.1±0.5(22)
Dynamic range	7.0±0.3(20)	6.3±0.3(22)	5.4±0.4(23)	5.2±0.6(22)	6.1±0.3(17)	6.2±0.4(22)
Sound preference	0.8±0.2(16)	1.2±0.2(20)	0.8±0.2(23)	1.2±0.2(22)	0.9±0.2(17)	1.1±0.2(22)
Playing preference	1.1±0.2(16)	1.0±0.2(20)	0.8±0.2(23)	1.2±0.2(22)	0.9±0.2(17)	1.1±0.2(22)

Table 2. Combined results of comparisons from the listening and playing tests. Listed are the mean values of each category. The pair that significantly differs at the 95% level is marked with an asterisk.

It is not known to what extent he may have used tactile cues, which obviously are an important part of the playing sensation [14]. Further, his test was arguably a simpler one than that faced by the panels: he gave a binary choice rather than a ranking or rating.

Can we extract the effects of age alone from these experiments? In principle, listening tests could be conducted using the recordings made during these experiments. These experiments have not been conducted yet, in part because they would be expensive and this project has no formal funding. There is little point in using the data in Table 2 for this purpose: the playing and listening panels were recruited from a student orchestra and there is no overlap in members between the first two tests. Even if there had been common members, it is possible that the playing skills and musical tastes of a musician might change more rapidly than those of the instrument.

5. CONCLUSIONS

Mechanical measurements show noticeable differences between the two violins built from the same wood samples. Although the frequency envelopes are similar, there are differences in detail. Nevertheless, rankings of the instruments by experienced playing and listening panels showed no statistically significant differences in the finished instruments. This implies that measured changes in mechanical properties alone are not enough to suggest that an instrument has 'improved.' Three years after they were finished, with one instrument having been played and the other having been kept in museum conditions, the results still showed no statistically significant differences.

This suggests that the effects of playing are small after only 3 years.

Three years is not considered a long time for an instrument of which there are examples still being played after hundreds of years. The investigators hope that this study will continue, with this pair of instruments, for a time comparable with the age of these older violins.

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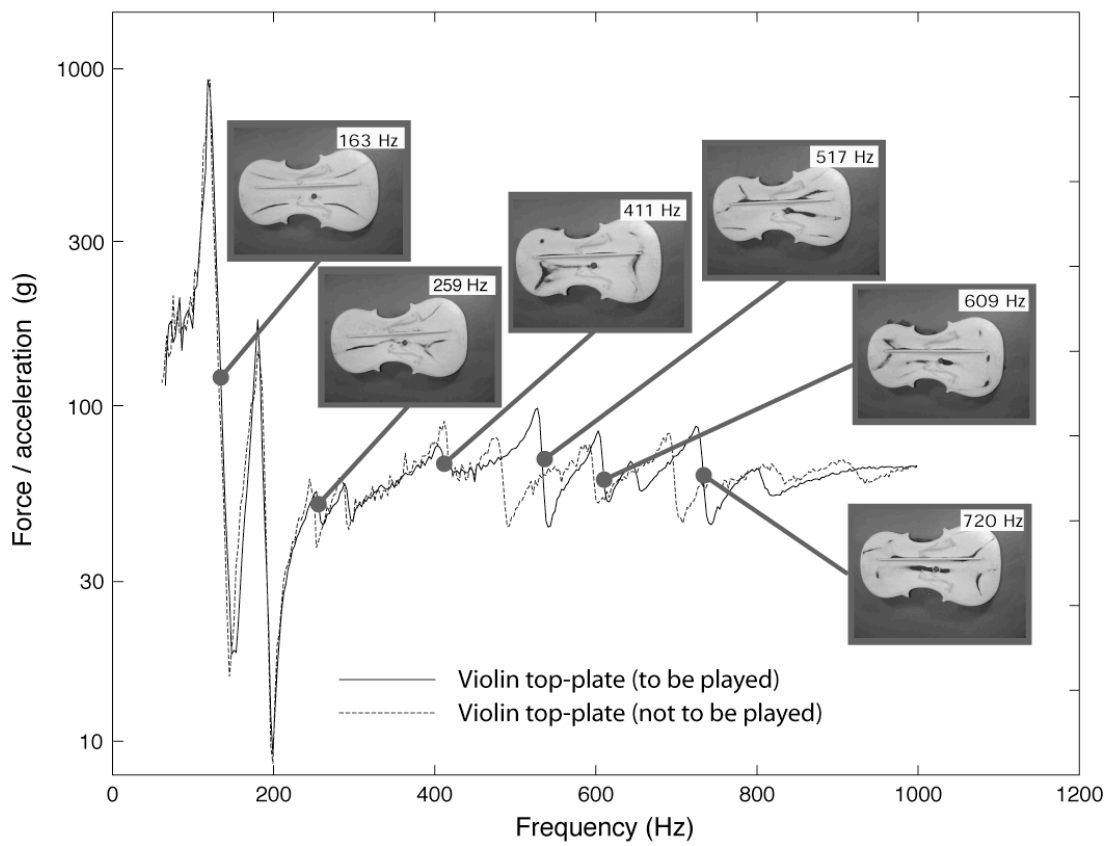
Fig 1. The ratio of the force applied by the shaker to the acceleration measured at the point of application for the two top-plates with f-holes (before assembly) as a function of frequency.
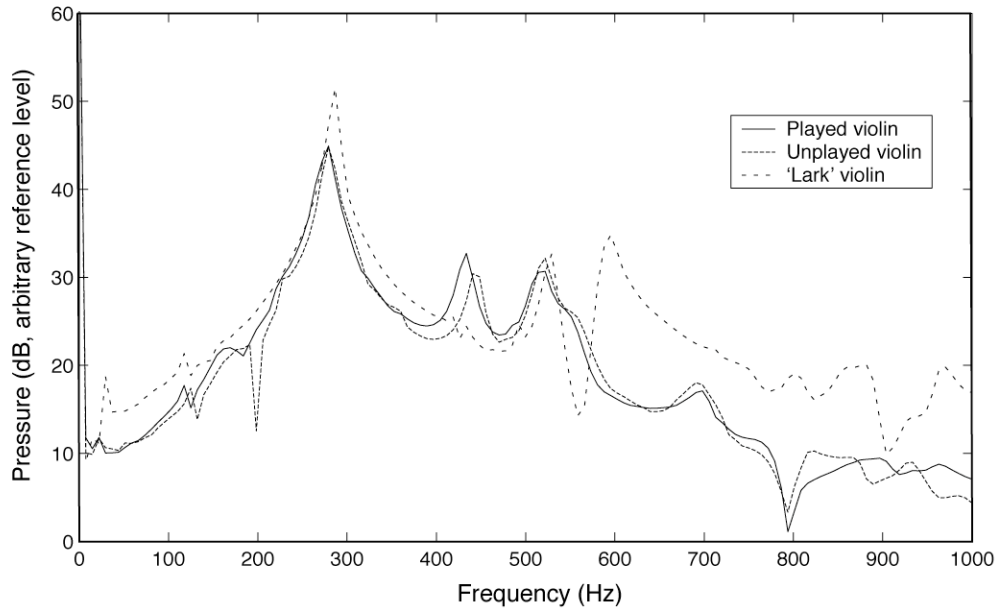
Figure 2. Near field pressure spectra of the violins excited by controlled impulses at the bridge. The third violin is an inexpensive mass produced model ('Lark' brand) included for comparison. Measurements were made after 3 years and adjustment of the played violin.
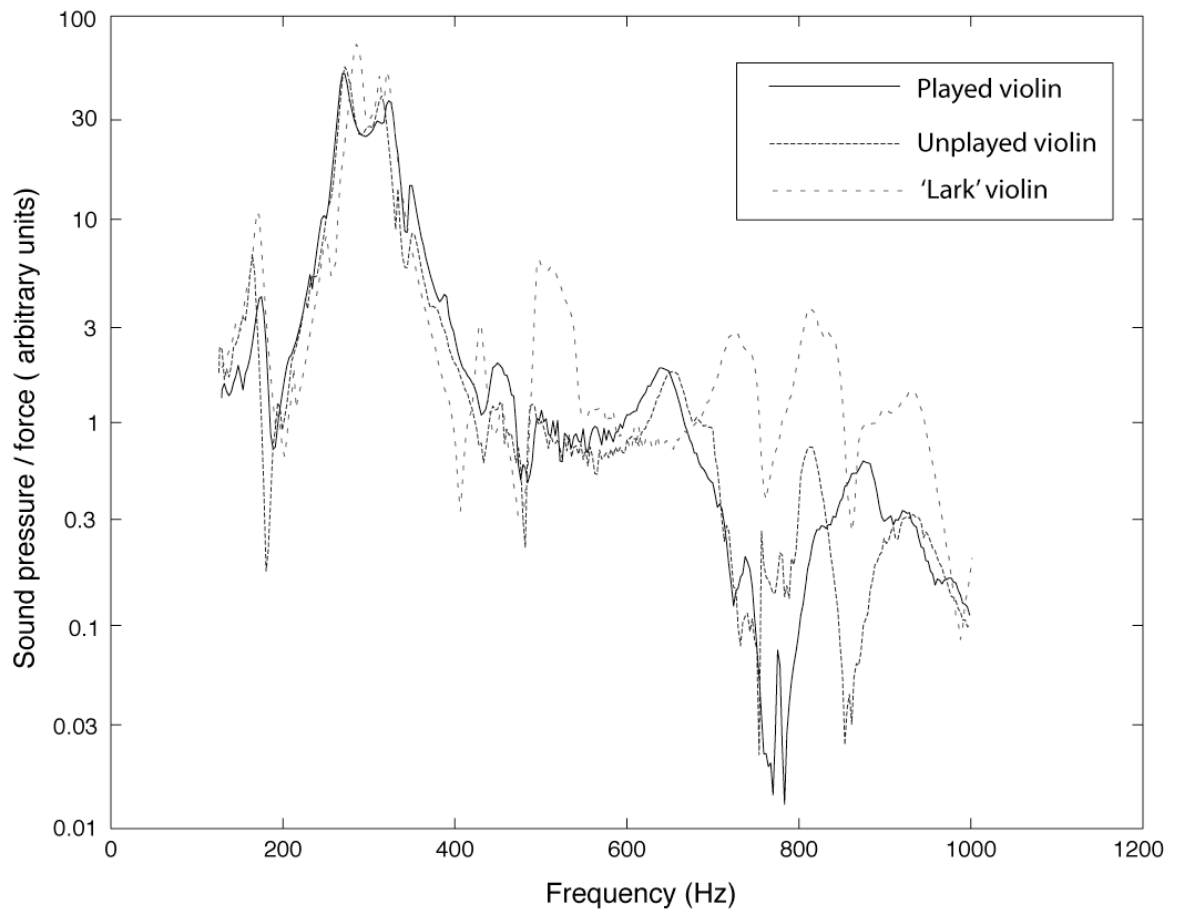
Figure 3: The ratio of near-field sound pressure to the applied force upon application of broad-band vibration to the bridge.