Effect of Vibration Treatment on Guitar Tone: A Comparative Study

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Abstract— In order to study the widely-held belief that the sound of a guitar evolves with use due to vibration-induced changes in the guitar, the tone of guitars subjected to controlled vibrations is investigated. The study uses three pairs of guitars, where each of the two guitars in the pair is the same make, model and year. One guitar from each pair is treated using a commercial device for effecting a tone change through imposition of vibrations. The guitars are evaluated before and after the treatment using double-blind player evaluations and physical property measurements. The player evaluations showed no statistically-significant changes in the differences between the two guitars in each pair. Fourier analysis of instrumented hammer strikes were used to extract the frequency response function. Statistical analysis showed no significant change in the correlation between treated and untreated guitars due to the vibration treatment. It is therefore concluded that this vibration treatment had no significant effect on the guitar tone. It is suggested that the evaluation approach used here could be useful for studies of other instruments or treatments.

I. Introduction

It is a common belief that the tone of wooden string instruments improves with time, and that playing the instrument enhances this improvement [1]–[5]. The evidence for this is mainly anecdotal and qualitative, but, for guitars in particular, improvements in sustain, ease of playing, loudness, and tone have been claimed. The term "opening up" has been coined to describe this effect [6]–[8]. Several physical changes have been suggested as being responsible for this effect, including crystallization of resins or sap in the wood of the guitar, creep of the wood or glue joints, and weakening of the structure allowing for greater movement of vibrating elements.

In order to investigate the effect of vibration on the maturation of guitar tone we conducted a study involving three pairs of guitars. We subjected one guitar from each pair to a vibration treatment from a device that is marketed as improving instruments through vibration. We performed physical tests and player evaluations on the guitars before and after the treatment to comparatively evaluate any changes in guitar performance. This study creates a framework for future studies regarding maturation of tone quality of guitars, and is extensible to the study of other wooden string instruments such as violins.

II. Experimental Procedure

The study used three pairs of new guitars, with the two guitars in each pair being the same make, model, and year. The three guitar pairs covered a range of guitar designs and construction. All had solid spruce tops. One pair (Taylor 110 guitars) had laminated sapele sides and back, solid hardwood neck and a modified dreadnought body design. A second pair (Martin D-1) had solid sapele back and sides, a Stratabond neck (multiple thin strips of wood laminated together) and a dreadnought body design. The final pair (Collings OM2H) had solid rosewood back and sides, solid mahogany neck and an OM ("orchestra model") body design. The list prices range from approximately $700 to $3500.

One guitar from each pair was selected at random to be the control guitar (guitar "A") and the other was given a vibration treatment (guitar "B"). The vibration treatment used a commercially available device made specifically for vibrating musical instruments, and was used following the mounting and operation instructions from the manufacturer. This device imparts a 60 Hz vibration to the strings of the guitar, which then causes vibration of the sound

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Manuscript received July 29, 2014

producing guitar structure. For treatment, the three B guitars were placed in guitar stands and the vibration device was fixed to the strings near the bridge. The guitars were treated for 348 hours, which is nearly five times the minimum recommended by the manufacturer. Three different vibration devices of the same make were used (one first generation model and two third generation models), and the devices were cycled so each of the three treated guitars had approximately equal time with each device. During treatment, the three A, or control, guitars were also placed in guitar stands in the same room as the guitars being treated.

Several different testing procedures were used, based on similar previously-used approaches for analyzing guitar responses [9]–[14]. A calibrated, instrumented impact hammer (PCB Piezotronics, Inc, Model 086B01) was used to impart an impulse to the guitar tops by striking the guitars on the bridge just below where the strings are attached. The response of the guitar was measured using a calibrated accelerometer (PCB Piezotronics, Inc. Model 352B22) mounted with wax to the centerline of the guitar top 10 cm below the saddle. The mass of the accelerometer was 0.5 g. The time response of the hammer accelerometer and guitar top accelerometer were recorded using dedicated preamplifiers (PCB Piezotronics 480E09) fed into a digital mixer console (Yamaha DM2000) and digitized with 24 bits at 48 kHz sampling rate for input to Protools. The sonic output of the guitar was also measured using an omnidirectional microphone (B&K 4006) mounted 61 cm above the strings, directly above the guitar sound hole, fed into the same recording setup. The guitars were held in a cradle that contacted the guitars at specific points on the guitar sides and in the middle of the neck, allowing unhindered motion of the top and back plates. To record the response of the guitar body without the interference of the ringing of the strings, some hammer strikes were performed with the strings damped using several foam dampers between the strings along the neck and at the headstock. Hammer strikes without the string dampers were also performed. For each test, several hammer strikes were recorded to check for consistency and to allow for averaging.

Photo 1 - Guitar testing set-up, showing instrumented hammer, accelerometer mounted to guitar top, microphone, guitar cradle, strumming apparatus and foam string dampers.

The response of the guitars to a plectrum strum was also recorded. To achieve a consistent strum, the guitar cradle was fitted with a pivoting arm that swung a guitar plectrum through an arc designed to replicate the arc of the string height set by the curved saddle of the guitars. This device imparted a gentle, repeatable strum for a given guitar. However the magnitude of the strum was a sensitive function of the height of the pick, making quantitative comparisons between guitars difficult. For this reason the hammer strikes were used for quantitative measure.

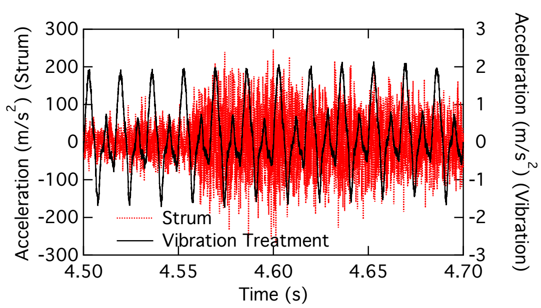

Figure 1 - Output of the guitar-top mounted accelerometer as a function of time during a gentle strum from the strumming device and during vibration treatment. Note that the scale for the acceleration during vibration treatment (right axis) is 100 times more sensitive than that for the strum (left axis).

Each test was performed on each guitar before and after the vibration treatment. Each guitar was measured in the same pre-treatment and post-treatment test sessions. The post-treatment was performed about 16 hours after stopping the vibration treatment. New strings (D'Addario phosphor bronze lights for the Collings OM, and D'Addario phosphor bronze mediums for the Martin and Taylor dreadnoughts) were put on each guitar the night before each of the two test sessions.

In addition to the above tests, the apparatus described above was used to measure the acceleration of the guitar top and the sound emanating from the guitar during the vibration treatment. Figure 1 shows the acceleration of the guitar top as a function of time during a gentle strum and the acceleration of the guitar top during vibration treatment. The acceleration values were extracted using the calibration of the accelerometer and a 10 mV signal played through the same signal chain as the actual data. The magnitude of the acceleration during the vibration treatment is about 100 times smaller than that due to the gentle strum. The sound emanating from the guitar during the vibration treatment and that from the strum showed the same relative magnitudes, consistent with observation that sound from a guitar results largely from motion of the guitar top. Also the frequency of the vibration treatment (60 Hz) is significantly different from the frequencies produced by the strum. Hence the vibration treatment is much more gentle than regular guitar playing and might not be expected to have the same effect.

The guitars were also evaluated by 9 accomplished guitar players, with an average of 24 years of playing experience. Included in this group were advanced amateur, semi-professional and professional guitarists, guitar salespersons, guitar technicians, contributors to popular guitar literature, and players that evaluated guitars as part of their professional duties. The players were asked to evaluate each guitar on five metrics: volume, sustain, warmth, brightness and clarity on a scale of 1 to 5, with 5 corresponding to the highest value. These are somewhat subjective terms, reflecting the difficulty in describing and quantifying the concept of guitar tone, but reflective of the qualities that aging and opening up are purported to change in guitars.

Each player had at least two evaluation sessions; one before the vibration treatment and one after. Some of the players performed two evaluations before treatment to assess consistency of rating. For the trial performed after the vibration treatment, the players were told that one of the guitars of each pair had been given a vibration treatment meant to improve the guitar performance, but not told which guitar of the pair was treated. To ensure that no subconscious clues were given, the person running the evaluation also did not know which of the guitars had been treated, making this a "double-blind" study. In addition to evaluating the guitars on the five metrics, the players were asked which of the two guitars they thought had been treated.

III. Analysis Approach

The frequency response function (FRF) of an instrument is its output magnitude in response to a stimulus at a given frequency [15]. This serves as an acoustic fingerprint for the tone an instrument delivers in response to, for example, the input of the vibrating strings. This is frequently used to evaluate and compare instruments, including guitars and violins [15]–[25].

In this study, Fourier analysis was used to obtain the instrument frequency response function from the hammer strike data. In the time domain, the observed microphone or accelerometer signal $s(t)$ is the convolution of the hammer input $h(t)$ with the frequency response behavior $r(t)$, that is:

$$s(t) = h(t) * r(t)$$

Taking the Fourier transform we find:

$$\mathcal{F}[s(t)] = \mathcal{F}[h(t)] \cdot \mathcal{F}[r(t)]$$

where, due to the convolution theorem, the convolution becomes a simple multiplication. Hence the frequency response function of the guitar can be found as:

$$R(f) = \mathcal{F}[r(t)] = \frac{\mathcal{F}[s(t)]}{\mathcal{F}[h(t)]} \tag{1}$$

Numerical fast Fourier transforms (FFT) of the hammer, accelerometer, and microphone signals were performed using commercial software (IGOR, Wavemetrics, Inc.), and the frequency response functions were computed and averaged for 5 or more hammer strikes. Due to the normalization in equation 1, the frequency response functions were consistent from strike to strike, even though the hammer strike magnitude varied considerably, consistent with the behavior of a linear system. Each FFT was performed over the same time period to insure consistent frequency resolution. The time interval was chosen to begin before the hammer strike, and end after cessation of output signal, so no filtering function was required in the analysis to extract the frequency response functions. The frequency response functions from the microphone (measuring the sound output of the guitar) and accelerometer (measuring the deflection of the guitar top) were similar but not identical for a given guitar. However, the conclusions drawn from comparisons of the frequency response functions between different guitars and between guitars before and after treatment were the same for both output measures.

To facilitate the comparison between the frequency response functions of guitars, the Pearson's r correlation coefficient was calculated using the standard expression:

$$r = \frac{\sum_n \left(R_1(n) - \langle R_1 \rangle\right)\left(R_2(n) - \langle R_2 \rangle\right)}{\sqrt{\sum_n \left(R_1(n) - \langle R_1 \rangle\right)^2}\sqrt{\sum_n \left(R_2(n) - \langle R_2 \rangle\right)^2}}$$

where $R_i(n)$ is the n^{th} frequency data point for the i^{th} frequency response function, and $\langle \ldots \rangle$ refers to sample average of the quantity. The Pearson's r correlation coefficient measures the correlation, or linear dependence, between two variables. Here we used it to quantify the differences and similarities between the frequency response functions of different guitars, and to quantify changes in the frequency response functions of one guitar before and after treatment. Our Pearson's r values were in the range $0 < r < 1$, where a value of 0 would correspond to no correlation and a value of 1 to perfect correlation. Guitars that have similar spectral response functions would give a Pearson's r correlation coefficient close to unity, and would also be expected to have similar tone. A treatment that significantly changed the tone of a guitar would also be expected to reduce the Pearson's r correlation coefficient calculated between the frequency response function of the guitar taken before and after the treatment.

Practically, we find that the extracted Pearson's r correlation coefficient varies with the maximum frequency used, and examination of repeated data for the same guitar revealed that fluctuations in the measuring and analysis procedure made the correlation unreliable for frequencies above about 5 kHz. Hence the Pearson's r correlation coefficients we report here are extracted using the frequency response function data between 0 and 5 kHz.

IV. Results

A. Player Evaluations

It was clear from their comments during the player evaluation tests that players had a hard time distinguishing which of the guitars had been treated. Comments such as “I am just guessing” and “this one might be the one that was treated” were common. This is also reflected in their lack of success in identifying the treated guitar. Of the nine players, one player missed on all three pairs, five players identified one correctly, three players identified two correctly, and one player identified one correctly, one incorrectly, and thought the third pair was indistinguishable in tone. No player was able to identify the treated guitar for all three guitar pairs. For each of the three guitar pairs, five out of the nine players identified the incorrect guitar as the one that had been treated. A tenth player that played the guitars before and after, but not in a monitored trial, also was unable to identify which of the guitars had been treated. So it is clear that the players were unable to consistently identify which of the guitars had been treated, which suggests that they were unable to detect the effect of the vibration treatment on the sound of the guitar.

The inability to consistently identify a change in tone associated with the vibration treatment is also reflected in the player-assigned scores for the five metrics. Figure 2 shows the averaged player-assigned scores for the guitars before and after the treatment. To account for differences in player scoring and player mood in different trials, the player-assigned scores are divided by the average for that player for that metric at that trial. The scores on the metrics (volume, sustain, warmth, brightness, clarity) show significant variations reflected in the estimated standard error of the mean (SEM).

To evaluate the statistical significance of the vibration treatment on the player evaluations of the guitars, a two-way MANOVA was applied. The comparisons were made between guitars before and after treatment, where the treatment was application of the vibration treatment or a control treatment where nothing was done to the guitar between the two testing days. The results indicate that there was no statistically significant effect of the vibration treatment on any of the five measured qualities of the guitars (p=0.89). The analysis indicates that there are statistically significant differences between the three guitar models as scored by the players. The Collings guitars scored better than the Martins in the Brightness and Clarity categories in both comparisons. The Collings guitars scored better than the Taylors in the Sustain category in both comparisons. The never-treated Collings guitar scored better than the never-treated Marin guitar in the Sustain category, and the Collings A guitar scored better than the Taylor A guitar both before and after treatment. Since the trials were not brand blind (the players knew which brand of guitar they were playing, but not whether it had been treated) it is not possible to discount the effect of brand biases. The guitar players were all sophisticated in the guitar market and aware that, for instance, the Collings guitars were high-quality, expensive instruments from a small manufacturer known for its consistency, while the Taylors were near the bottom of the model line from a large factory producer. It is also important to note that these differences, while evidence

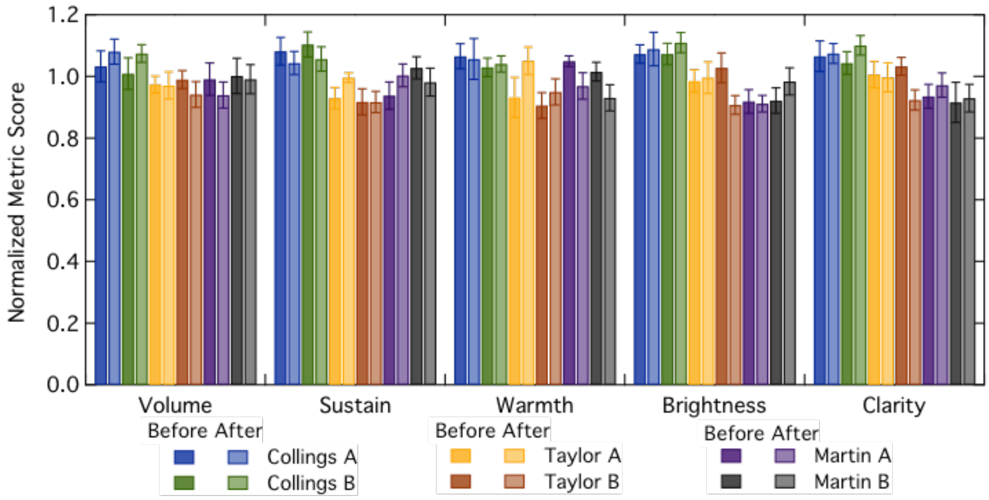

Figure 2 - Average player-assigned scores for the guitars before and after the treatment. In each case, guitar "B" received the vibration treatment and guitar "A" did not. To account for differences in the players and the player moods in different trials, the player assigned scores are normalized by the player average for that metric for that trial before being averaged. The error bars are the estimated standard error of the mean.

of the ability of the players to discern differences between various guitars, are not necessarily indicative of general differences between these guitar models but are comparisons of the specific guitars used in this study.

To evaluate equivalence of the two treatments (vibration treatment and control), the differences of means and 95% confidence intervals were calculated using the TukeyHSD test. The resultant differences of means were plotted with error bars representing the 95% confidence intervals (Figure 3). In this type of analysis, two treatments are considered equivalent if the 95% confidence intervals lie entirely within the range of scientific irrelevance. The range of scientific irrelevance should be chosen such that changes within the range, regardless of statistical significance, are too small to be considered interesting.

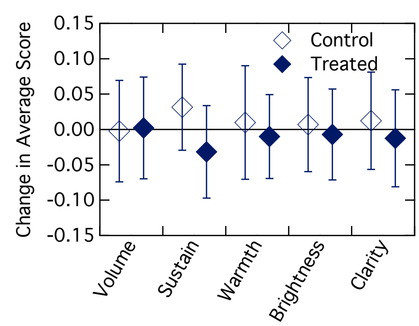

Figure 3 - Change in normalized score between the trials after and before the vibration treatment of one guitar from each pair. The scores were averaged over all the guitar pairs and over all the players. Since the scores were normalized by averaging over all guitars for each player for each metric, the increase or decrease in the average score will be equal and opposite for the untreated and treated guitars. The error bars show the 95% confidence intervals.

In this study, the scored differences between guitar models are on the order of 0.1, or 10 percentage points. Presumably it is worthwhile for guitar aficionados to purchase a more expensive guitar based on a perceived change of 10 percentage points. Some musicians may claim that changes more subtle than 10 percentage points are interesting. However even the most refined instrumentalist, when subjected to blinded tests, has trouble discerning differences of less than 10 percentage points. [2] It is reasonable, then, to set the range of scientific irrelevance at ± 10 percentage points. To repeat, this range does not imply that changes of less than 10 percentage points are statistically insignificant; it merely suggests that changes on this order are uninteresting in the context of evaluating structural differences between instruments.

The 95% confidence intervals of all of the mean differences in this study fall within the ± 10 percentage point range (Figure 3), and so the effects of treatment with the vibration device and the effects of control treatment can be considered equivalent.

B. Physical Measurements

The frequency response functions (FRF) for all guitars before and after treatment were extracted from both the accelerometer and microphone measurements of the guitar response. Since both response measurement techniques

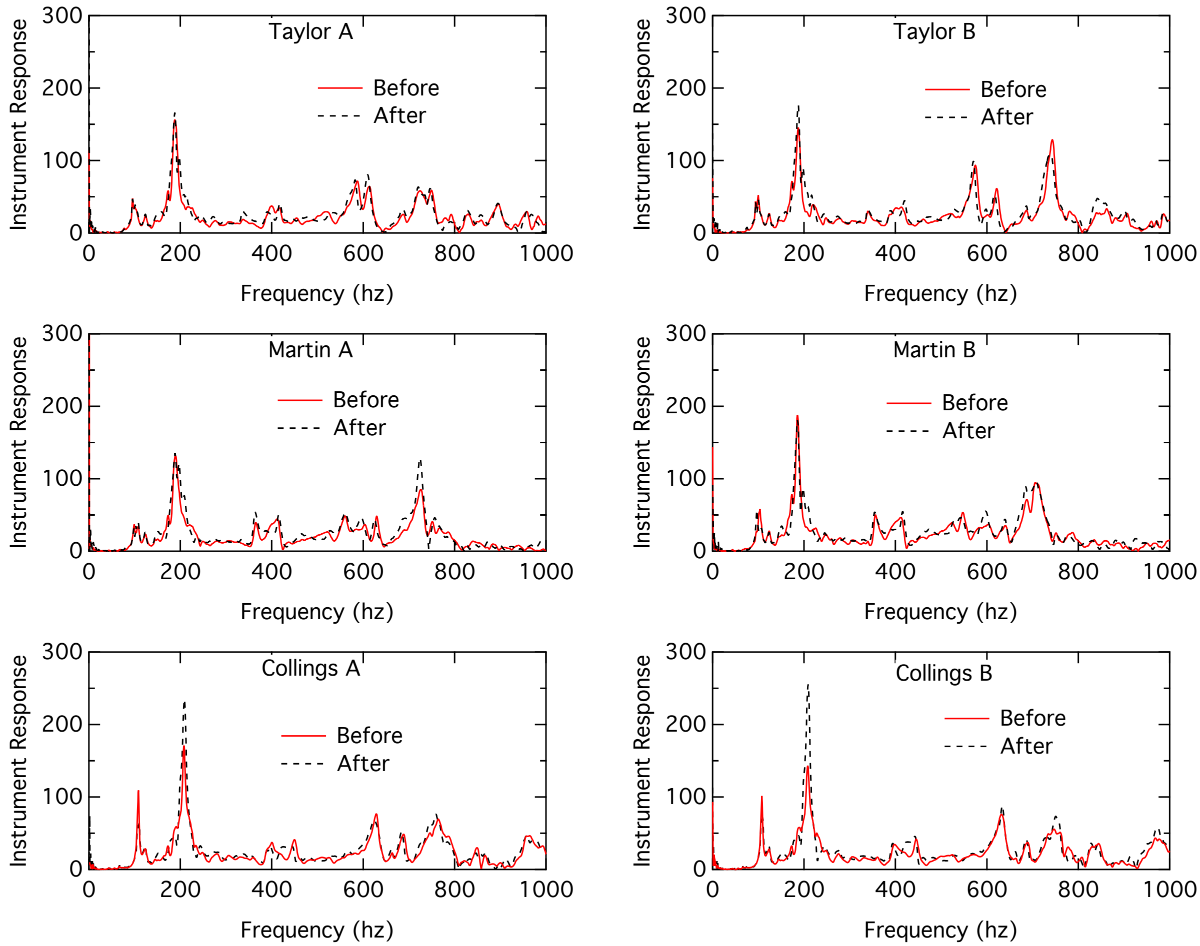

Figure 4 - Frequency response function magnitude for all six guitars before and after the vibration treatment or non-treatment period. For each pair, guitar A was the un-treated, control guitar, and guitar B is the guitar subjected to the vibration treatment. The frequency response functions were extracted from the microphone response from hammer hits with damped strings.

yield the same relative behavior and lead to the same conclusions, for brevity we discuss here only the results from the microphone data. The frequency response functions extracted from microphone data for all six guitars before and after vibration treatment (or non-treatment period) are shown in Figure 4. To help with comparing and interpreting these curves, the Pearson's r correlation coefficient is tabulated in Table 1 for several pairs of guitars. To clarify, the numbers in Table 1 are comparisons between two guitars, not absolute measures of guitar quality. Furthermore there are statistical uncertainties and repeatability variations in these numbers. For example the Pearson's r correlation coefficient value for the frequency response function for different hammer hits of the same guitar was typically in the range 0.97 - 0.99. For some guitars we performed several sequences of hammer hits, and the Pearson's r correlation coefficient between the averages of frequency response function was also in this range. The pure statistical uncertainty was in the range of 0.01 - 0.02, with larger uncertainties for smaller correlation coefficients. Therefore changes of a percent or two are probably not significant. Nonetheless, there are clear differences in the frequency response functions that can be observed in the graphs and tabulated correlation coefficients.

Turning first to comparisons between different guitars, we see that the two guitars in the Collings pair are the most similar to each other, followed by the two guitars in the Taylor pair and the two guitars in the Martin pair. Interestingly Talyor A is also close to Martin A, and both Martin guitars are closer to both Taylor guitars than they are to the Collings guitars. These comparisons hold for both before and after the treatment, as shown by the near-symmetry in Table 1. This is perhaps not surprising due to the similarity of body size and design for the large Martin and Taylor dreadnoughts compared to the smaller, OM-size Collings.

Turning next to comparisons between the same guitar before and after the treatment period, we find that there are changes in the frequency response function for all the guitars, mainly in peak height differences and small changes in peak position. However, there is no significant difference between the changes for the control treatment (no vibration) and the changes from the vibration treatment. For all six guitars, the Pearson's r correlation coefficient that compares the frequency response before treatment versus after treatment is about 0.91$\pm$ 0.02, independent of whether the guitar was vibrated or not. Furthermore, even though the changes due to the control and vibration treatment are significant, a given guitar after the treatment is significantly more similar to the same guitar before the treatment than it is to any of the other guitars, including the other guitar of the pair. An exception is the Collings pair, where there is remarkable similarity between the two guitars of the pair both before and after the treatment. So, in other words, the change in frequency response function due to the control treatment is indistinguishable from that due to the vibration treatment, and the difference in frequency response behavior associated with either the control or vibration treatment is less than or equal to the frequency response behavior differences between guitars of a matched pair. The frequency response functions extracted from the accelerometer showed this same behavior.

vs		Taylor		Martin		Collings	
		A	B	A	B	A	B
Taylor	A	***0.92***	*0.84*	*0.75*	*0.69*	*0.40*	*0.40*
	B	0.81	***0.89***	*0.72*	*0.60*	*0.39*	*0.35*
Martin	A	0.79	0.70	***0.93***	*0.80*	*0.45*	*0.43*
	B	0.69	0.59	0.81	***0.93***	*0.29*	*0.29*
Collings	A	0.41	0.39	0.47	0.27	***0.92***	*0.95*
	B	0.45	0.45	0.50	0.30	0.92	***0.90***

Table 1 - Table of Pearson's r correlation coefficients for the frequency response functions from 0 to 1000 Hz for the six guitars before and after treatment or non treatment period extracted from microphone data. The "A" guitars were given the control treatment (no vibration), and the "B" guitars were given the vibration treatment. The bold, italicized numbers are comparisons between the same guitar before and after the treatment. The plain numbers are comparisons between different guitars before the treatment, and the italicized, non-bolded numbers are comparisons between different guitars after the treatment.

V. Discussion and Conclusion

We performed player evaluations and physical property measurements on three matched pairs of guitars, before and after subjecting one guitar from each pair to a vibration treatment. We find no discernible difference in the changes due to this vibration treatment from those due to a control or "null" treatment. Players were not reliably able to tell which guitar of the pairs had been subjected to the vibration treatment - for each of the three guitar pairs, five out of the nine players identified the incorrect guitar as the one that had been treated. Statistical analysis of the evaluations by the players on the five metrics of guitar tone showed no significant difference in the before and after changes due to either the vibration or control treatment. While there were differences in the averages of the metric scores, with the vibration treatment resulting in a decrease for four out of the five metrics, the 95% confidence intervals for both control and vibration treatment lie within the range of scientific irrelevance.

Changes due to the vibration treatment were also not discernible with our measurements of physical properties, despite the demonstrated sensitivity to measure the subtle differences between guitars of the same make and model as well as changes due to weather or a relatively short aging and playing time. Comparisons of the frequency response function for different guitars before and after treatment was made using the Pearson's r correlation coefficient, and while it may be fair to say that the Pearson's r correlation coefficient does not represent all the complexity of comparing the frequency response functions in Figure 4, and that the frequency response behavior in the graphs in Figure 4 does not represent the full complexity of a guitar sound, we maintain that these quantitative measures should exhibit significant changes if the guitar sound is influenced by a given treatment. Indeed, significant differences can be detected between matched guitars of the same make, model and year.

Interestingly, subtle but significant changes are also observed for the guitars before and after treatment. However, these changes were essentially the same whether or not the guitar was subjected to the vibration treatment. So these differences are due either to the small amount of playing during the player trials (about 1-2 hours total), the passage of time (about three months), the changing of weather from late summer to fall in Palo Alto, or irreproducibility of our measurement method. The later could be from the placement of the microphone relative to the guitar, mounting of the accelerometer onto the guitar, or changes in the sonic characteristics of the testing environment. However effort was made to be as consistent as possible in accelerometer mounting and microphone placement, and the testing was performed in a controlled sound studio. Furthermore, some guitars were tested more than once on the same day. This involved placing the guitar in the cradle, adjusting the microphone placement, and re-mounting the accelerometer. These tests showed much better reproducibility than the tests done before and after the vibration treatment or waiting period. Furthermore, the correlation in frequency response function between different guitars shows almost no change associated with the control or vibration treatment, so changes are not due to random experimental error. Hence it is likely that the changes in frequency response function represent a real change. However, there is no significant difference between the effects of the control treatment and the vibration treatment.

It is interesting to estimate the deflection and stress in the guitar structure to ascertain whether high cycle fatigue could result from the vibration treatment. While a full elastic analysis is beyond the scope of this paper, we can make simplifying assumptions to allow for an order of magnitude estimate. We first assume the guitar is exhibiting harmonic oscillation at the peak resonance frequency of $\nu \approx$ 200 Hz. In this case the maximum acceleration $a_{\max}$ and maximum deflection $x_{\max}$ are related through:

$$x_{\max} = \frac{a_{\max}}{(2\pi\nu)^2}$$

Taking the maximum strum and vibration accelerations from figure 1 to be

$$a_{\max}^{\text{strum}} = 200 \text{ m/s}^2 \quad \text{and} \quad a_{\max}^{\text{vibration}} = 2 \text{ m/s}^2$$

we find:

$$x_{\max}^{\text{strum}} = 140\ \mu\text{m} \quad \text{and} \quad x_{\max}^{\text{vibration}} = 1.4\ \mu\text{m}$$

Next we calculate the maximum stress associated with this deflection. We take a grossly simplified structural model of the guitar and replace the top and bracing structure with a single beam with the length l equal to that of the lower guitar bout and the height h equal to that of the guitar bracing. From elementary beam mechanics we find the stress:

$$\sigma = \frac{6E_Y x_{\max} h}{l^2}$$

where E_Y is the Young's modulus of the wooden bracing. Taking $h = 1$ cm, $l = 40$ cm, and using the modulus for sitka spruce $E_Y = 11$ GPa, we find:

$$\sigma_{\max}^{\text{strum}} = 400 \text{ kPa} \quad \text{and} \quad \sigma_{\max}^{\text{vibration}} = 4 \text{ kPa}$$

The yield stress of sitka spruce is about $\sigma_{\text{yield}} = 86$ MPa, so the maximum stresses from the strum and vibration treatment are about 0.5% and 0.005% of the yield stress respectively. Wood is thought to have good fatigue resistance, and and can withstand cyclic stresses of $\sim 0.4\sigma_{\text{yield}}$ for $\sim 10^8$ cycles. Thus our simple analysis here indicates that the stress during the vibration treatment, with a duration of 7.5×10^7 cycles, was extremely low relative to stresses that cause changes in elastic modulus or strength of wood. Sobue and Okayasu have measured the effect of vibration on the elastic modulus and loss modulus of wood, and find that imposing vibrational stresses of the order of 300 kPa does not change the elastic modulus, but does reduce the loss modulus by 5-15% [26]. This, combined with our simple analysis here, suggests that the vibrational stresses associated with normal, gentle playing might result in a modest decrease in the loss modulus of wood, but that the stresses from the vibration treatment, which are two orders of magnitude lower, are unlikely to produce changes. So it is not surprising that we were unable to detect any changes in guitar tone associated with this vibration treatment.

We therefore conclude that any changes associated with the vibration treatment we performed are negligible. We do not make conclusions on the origin of the widespread anecdotal reports of improvements in sound associated with this vibration treatment, but note that the well-established effects of the power of suggestion and marketing [27], as well as the lack of double-blind, control testing might be a factor in these anecdotal reports. We also do not make conclusions about possible effects of more vigorous vibration treatment, including that of playing the guitar for decades, or of the effects of simple aging on guitar tone. We do however suggest that the methods utilized in this study can be used to investigate the effects of these treatments and others on wooden string instruments of various types.

Acknowledgements

The authors would like to gratefully acknowledge Gryphon Stringed Instruments of Palo Alto California for providing the instruments used in this study.

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