DEVELOPING METHODOLGIES TO CORRELATE PERCEIVED SOUND QUALITIES OF VIOLINS WITH CONTROLLED CONSTRUCTION PARAMETERS

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ABSTRACT

The holy grail for violin makers is to find correlations between construction parameters and sound qualities. This is challenging for two main reasons: it is difficult to build violins reliably enough to ensure that the change in the sound is indeed a result of the change of construction parameters; when listening to the violins being played, differences are smoothed out by the players who adapt very quickly. Therefore, while players had so far been preferred in our experiments to maximise the ecological validity and take into account the complexity of the interaction between the player and the instrument, we have decided to test whether other methods, that reduce the influence of the player but are quite artificial, may be useful to explore the influence of some construction parameters on the tone. In the context of two sets of violins built with controlled thickness variations of their plates, we will compare the results of listening tests based on real recordings with a player and with a bowing machine as well as synthesised recordings (from the convolution of an excerpt recorded with piezo sensors and radiation measurements in an anechoic chamber) and discuss them in the light of vibroacoustical measurements.

Keywords: *violin, perception, construction parameters, sound quality.*

1. INTRODUCTION

Since the pioneering work by Carleen Hutchins and Frederik Saunders in the 1950s, a lot of studies by researchers and violin makers have been dedicated to the finding of relationships between construction parameters and sound qualities of violins [1]. However, there were two main limitations. First, the control of the construction parameters was difficult because the violins were made by hand. Second, the sound qualities were almost taken for granted and not really studied as perceived by players and listeners.

Recent projects [2,3] have used modern technology, in particular CNC routing, to control with high accuracy the constructions parameters. The resulting violins have been used in playing and listening tests but results were less clear than expected.

Three main aspects are of relevance to players: the playability (response, comfort), the sound intensity and the timbre/tone quality [4]. These three aspects seem to interact and players may find it difficult to judge them separately. Moreover, they may be largely influenced by what instrument they usually play.

In addition, violin makers would like to find correlations with vibro-acoustical measurements as well, and the ones that are commonly conducted rely on removing the player and replacing them by a controlled excitation via an impact hammer, and looking at frequency responses (measured with a microphone or an accelerometer). Such measurements for sound radiation will certainly be difficult to relate to playability but may be informative about tone quality and sound intensity which are the two quantities we would like to focus on for now. In the very particular case of the wolf note a bridge admittance (processed to estimate minimum bow force) is a better predictor.

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Due to the difficulty for players to decouple the various qualities, we believe that listeners may have more robust judgements, which could be more easily correlated with acoustical measurements. Of course, we do not advocate total disregard of the player's responses but recognize that they have a different relationship with the instrument. Many questions follow. How to listen to the violins? Played by whom? What excerpt? In which venue? Live or via recordings?

So far, the authors have tried to favor ecological validity [5] though there is a fundamental conflict of requirements. On the one hand we would like the listening judgements to be made in the most natural conditions while collecting data that is free of bias and can be meaningfully processed statistically. Our natural listening involves combining all our senses plus all kinds of prior knowledge about what we are observing. When we know the "answer" we can usually hear it, which does not constitute a valid psychoacoustic experiment. Our compromise, so far, has been to allow the player to perform the selected material as they wish, but to deprive the audience of knowing which instrument they are playing by interposing an acoustically transparent screen. This is usually short musical phrases from famous violin concertos, covering the full range of the instrument [e.g. 6] Also the player may be asked to were dark goggles so that they cannot see which instrument is in their hands. Others like Nastac et al. [7] preferred to record one violinist in a concert hall and use the recordings in a listening test. In both cases, the listening test relies on the reproducibility of the player, which appears to be lower than expected due to a strong (presumably unconscious?) will to make their "own sound". Their goal is to deliver a "musical" performance. Thus, differences between instruments seem to be smoothed out, to the extent that listeners are not even able to tell whether a player plays twice on the same violin or two different violins in a row [8]. In addition, if the player plays slightly differently, only very experienced listeners may be able to tell whether the differences heard are due to differences in playing or differences between instruments.

The goal of this study is therefore to explore and compare, within an online listening test, different recording methodologies in order to investigate which one would be best for maximizing i) differences between instruments and ii) likelihood that these differences can be correlated with acoustical properties and construction parameters (and not with playing variations). To this end, two sets of violins (described in Section 2) whose manufacturing was carefully controlled were recorded with three different methodologies (described in Section 3): live recordings, recordings with bowing machine and synthesized recordings. The recordings were then used in an online listening test that is presented in section 4. The results of the listening test will be presented at the conference.

2. VIOLINS USED IN THE STUDY

The heritage of high quality old instruments has all kinds of graduation schemes for which we lack knowledge of how the playing quality is affected and how the decisions were made. To this end, two series of violins have been made to study different graduation patterns.

2.1. The Bilbao set

In the Bilbao project [2], six instruments were carefully built to investigate the influence of the plate thickness on the sound qualities: three instruments with normal backs, each paired with a pliant (thin), normal, or resistant (thick) top; similarly, three with normal tops, each paired with a pliant, normal, or resistant back. The two examples of normal top paired with normal back serve as a control. Plate weights and mode frequencies were used to estimate characteristic impedance values. Wherever possible, thicknesses were kept uniform to avoid the effects of localized differences. Wood for tops and backs were closely matched in density and sound speeds – all tops and backs from the same trees. Greater control was achieved by having all plates and scrolls cut by CNC routers. The outside surface was not changed during the experiment, as the graduation was performed entirely on the inside surface. The high control of the construction parameters of these violins provide unprecedented opportunities for exploring correlations with sound qualities.

2.2. The ABCD set

This is another set of four violins that was carefully built (though with a bit less control than for the Bilbao set) after a pilot experiment during which we experimented with plates (CNC routed) simply supported around the edges (pinned edges) giving boundary conditions that are very different from the usual free plate measurements but closer to those of the closed corpus and reasonably reproducible. We graduated the plates in three zones, one zone changed at a time: upper bout, lower bout and central area (which was the "island", bounded by the f-holes, and for the back the area between the C bouts. We found that for the top the upper bout had little influence on mode frequencies and amplitude but the island, followed by the lower bout did have a large effect. Conversely, for the back it was only the upper bout that was very sensitive to thickness.

The ABCD set were created from a selection of factory build corpora and necks that were alike in arching shapes and wood characteristics. We wanted to see to what extent the behavior in the "pinned edge" state is carried over to the assembled violin. From the structural measurements perspective this was shown to be the case. We reduced the number of zones to two per plate (top: upper bout & lower bout plus island; back: upper bout & lower bout with no change to the C bout region). We started with four very similar factory violins and each instrument was measured and evaluated at three steps: both plates full thickness, one zone in either the top or back reduced and one zone each in top and back. Here we will only consider the fours instruments in their final state (thinner upper (resp. lower) zones for both plates; thinner upper (resp. lower) zone for the top and thinner lower (resp. upper) zone for the back).

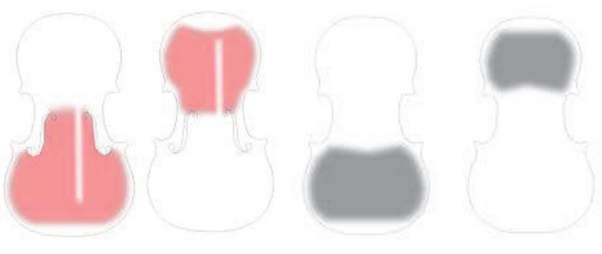

Figure 2. The two zones (per plate) in which the thickness could be reduced to constitute the ABCD set: for the top plate (red) on the left, for the back plate (grey) on the right.

3. THREE RECORDING METHODS

3.1 Live recordings: a real player and real violins

We recorded a semi-professional violinist in a large seminar room, playing a short excerpt from the Glazunov concerto (Fig. 1) on the ten violins described above. The position of the player was kept constant relative to the microphone (DPA 2006C) throughout the session, at a distance that had been adjusted at the beginning of the session to obtain pleasant recordings.
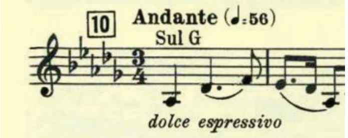
Figure 1. Excerpt from the Glazunov concerto

Each violin was recorded between two and three times, so we can potentially study reproducibility.

3.2 Bowing machine: an artificial player and real violins

The goal of this methodology is to replace a not so reproducible player by a reproducible excitation (though artificial). The bowing machine is shown on Fig. 2. The ten violins were recorded on each of the four open strings with an omnidirectional microphone (DPA 2006C) placed vertically above the bridge at a distance of 185 mm when the violin lays flat. That distance was adjusted to have, qualitatively, a strong direct sound with a bit of reverberation, in the room that was available at the time to make the recordings (different from the seminar room used for the live recordings). The violins were rotated for the different strings in order to keep a bowing direction tangent to the bridge curvature.

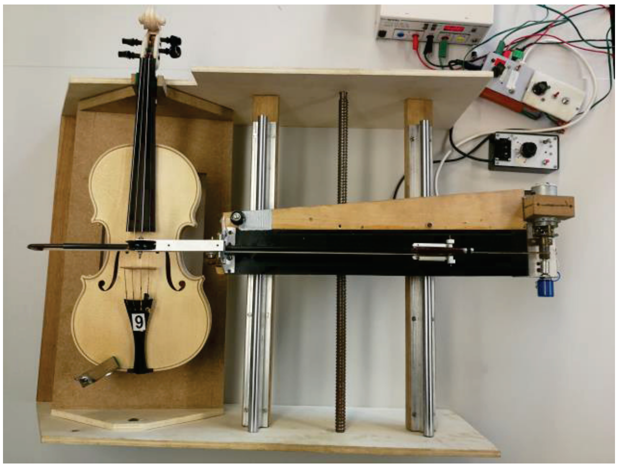

Figure 3. Bowing machine

3.3 Hybrid sound synthesis: a real player and virtual violins

The hybrid synthesis is based on the convolution of the recording of an input signal (the force applied by the bowed strings on the bridge) during a live performance with the inverse Fourier transform of a frequency response function of the chosen violins [9]. For the input signal, we used recordings of the same Glazunov excerpt made on a violin whose bridge was instrumented with a piezoelectric force sensor under the G string. For the frequency response function, we used a complex average of twelve radiation measurements, made in an anechoic chamber, with a hammer excitation, and an omnidirectional microphone (see Fig. 4). The violin could rotate around the vertical axis, and the measurements were taken at six different angles (every 60°) between the violin plane and the microphone for two excitation directions (tangential and perpendicular to the bridge). The distance between the microphone and the bridge was set to 20 cm when the microphone was at the front.

This hybrid synthesis allows to drive different virtual violins by the same realistic forcing waveform (measured during real playing) so that sound differences can be compared with no complications arising from variations in playing.

Figure 4. Radiation measurement rig

4. LISTENING TEST

Many listening tests can be designed with recordings from this database. Our first goal is not to compare directly the recordings made with different methodologies, but to compare violins within a set for each recording methodology, and explore whether listeners' evaluations are similar in the three cases, qualitatively and quantitatively. Thus two tests have been designed, one for each of the violin sets. Their structures are identical, only the numbers of violins compared differ (6 for the Bilbao set, 4 for the other set).

We opted for an online test which allows a larger number of participants (in particular the violin makers who took part in both the Bilbao and ABCD projects and who live across Europe), without necessarily compromising the results due to a lesser control [10]. As the differences between the instruments can be subtle, the participants are recommended, at the beginning of the test, to use the best audio equipment possible (good quality headset).

We used the option Audio Perceptual Evaluation [11] available in the Web Audio Evaluation Tool [12]. This consists in comparing and ranking stimuli on a criterion, using a 0 to 10 scale. We decided to focus on the two main criteria that are relevant for players (see introduction) and which can also be evaluated by listeners: *loudness* and *timbre quality*.

Each test is thus divided in two sub tests, one for each criterion. Each sub test consists of a series of 6 pages (in random order): on each one, recordings made with a given methodology (real player, bowing machine on each of the 4 open strings, hybrid synthesis) for a given violin set are compared. As timbre quality differences are hard to evaluate when there are loudness differences, the stimuli were compensated in loudness for the timbre sub test. Fig. 5 illustrates one page of the timbre quality test on the ABCD violin set and one page of the loudness test for the Bilbao set. The green bars correspond to the stimuli. Listeners first click on them to listen to all stimuli (in any order and as many times as they want) and can then move them freely along the scale to order them according to their judgements). 0 on the left corresponds to the poorest timbre quality / softer stimulus while 10 on the right corresponds to the highest timbre quality / loudest stimulus.

Figure 5. Listening test interface: Ranking by timbre for the ABCD set (top) and ranking by loudness for the Bilbao set (bottom).

5. CONCLUSION

Tools that can in some way quantify perception and relate it to construction differences are needed. This study aims, via an online listening test, at exploring the influence of three recording methodologies on perceived differences between violins in order to investigate which methodology leads to the largest and most robust differences, that could then possibly be linked with acoustic properties and construction parameters.

The results of the listening tests will be presented and discussed at the conference.

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