BASQUE TO THE FUTURE

It is well known that making adjustments to a violin top or back will alter its acoustic properties – but demonstrating that scientifically is more difficult. In the first of two articles, maker and researcher **George Stoppani** explains the thinking behind an experiment at the Bilbao School of Lutherie which may provide answers to age-old questions

For many contemporary luthiers, brainstorming and collaborating in group projects with other makers are a valuable part of present-day violin making. Such activities are an effective and enjoyable road to the continuation of learning and professional growth. In this cooperative spirit, a group of us taking part in the VSA/Oberlin acoustics workshop began discussing the possibility of organising an experiment that would provide answers to some of the questions circulating among makers at the moment – among them, is there such a thing as an 'ideal' violin back? How do we match backs and tops to produce particular sorts of violins? We have some confidence with regard to violin top plates – at least in how to get into an approximately optimised zone of characteristics – but the acoustic outcome of using backs with a range of differing characteristics is less clear. But it is not completely mysterious because experience, good practice and anecdotal wisdom can and do lead to excellent instruments.

There are no black-and-white answers to these questions because so many different kinds of tops and backs can be successful, and there is no specific ideal to aim for. We do not seek to create an 'ideal violin' (ironically, that may be an aim of mass production); rather, the survival of the individual craftsperson is more likely to depend on their ability to explore, to push boundaries and to meet the needs of individual musicians. Luthiers in the future will need to be adept in diagnostics and targeted interventions; they will require analytic listening skills and a good knowledge of structural dynamics.

Our intention as a group is to make a systematic study of a group of violins, for which we have a great deal of structural information and acoustic measurements, culminating in a psychoacoustic evaluation event (a playing and listening test). The kind of answers we are looking for are both visceral and intellectual. We need the hands-on connection with the parts during making; the sound and the playing feel; and these sensory experiences reinforced and extended through the complementary lens of detailed modal analysis and sound radiation measurements. We have one foot in the realm of aesthetics, imagination, intuition and manual skills, and the other where our decisions are informed by a systematically organised body of knowledge relating to the perception of sound, material properties and structural vibration. This is a very exciting place to be, not something to fear.

The big breakthrough at the beginning of this project was the decision by the Basque violin making school in Bilbao (BELE, see page 50) to work with us, both by engaging their students in making instruments for the project and in obtaining funding from the Erasmus+ EU education programme for travel and other costs. So it was that in September 2016 we were able to start meeting as a group and thrashing out the details of the experiment's design. The team includes maker and philosopher Roberto Jardón Rico, BELE acoustics teacher Unai Igartua, maker and restorer Andrea Ortona, and Paris-based psychoacoustics researcher Claudia Fritz. Professor Jim Woodhouse of Cambridge University agreed to support us in an advisory role.

From the outset, we decided to be a democratic group of equals. No one person has overall authority, but instead each has a voice on any aspect of the experiment. We each bring our particular area of expertise and resources to the table, and our methodology is built on previous experience of having taken part in psychoacoustic experiments and collaborations. We are mindful of our responsibilities towards the students who are committing their time and effort. It is important that they understand the experiment at all stages in order to maximise the learning experience.

PHOTOS COURTESY BELE

Before discussing the details of the experiment, let us focus on what might be meant by 'characteristics of violin plates' and why they are so important. An assumed article of faith is that the whole is made from the sum of its parts; therefore, by controlling the parts, we can control the whole. Attempts to predict the modes of a complete violin by analysing its *free* plates (not yet glued to the ribs) have had little success. Yet if the 'sum of its parts' premise is taken to be correct, then it must be our personal understanding that is lacking. ▹

The resonances of a whole violin are a consequence of combining the parts and the air enclosed within the corpus, though this is complicated and not amenable to a concise account.

The first few vibrational modes (resonances) of a free plate can usually be found simply by holding and tapping it in selected places. In the 1970s, US researcher Carleen Hutchins and her associates at the Catgut Acoustical Society developed theories on how to use these modes to control the character of a violin. They focused on the first (twisting), second (the 'X mode') fifth (the 'ring mode') of the freely suspended plates (**figure 1**). They believed that tuning the X and ring modes an octave apart (*bi-octave* tuning), and also tuning the first mode (a *tri-octave* arrangement) would result in a superior-sounding instrument. These practices were dominant for decades, though most makers have since walked away from them. Rather than discard everything, we can cherry-pick and develop new protocols.

A plate can be considered *compliant* or *resistant* depending on how it feels in the hands. A maker tries to gauge the stiffness and weight at the same time, as well as how much effort is needed to make it vibrate. In structural dynamics the term *impedance* is the inverse of *mobility*, which is the velocity of a point on a structure for a given force and direction at a particular frequency. An *averaged driving point impedance* describes a global response as though it were measured everywhere at all frequencies.

PHOTO COURTESY BELE. FIGURE COURTESY GEORGE STOPPANI

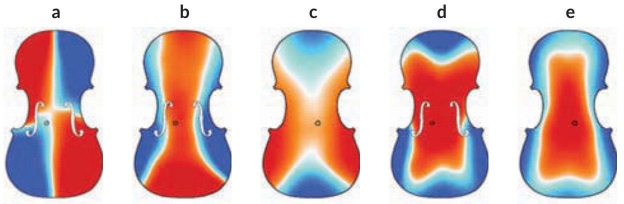
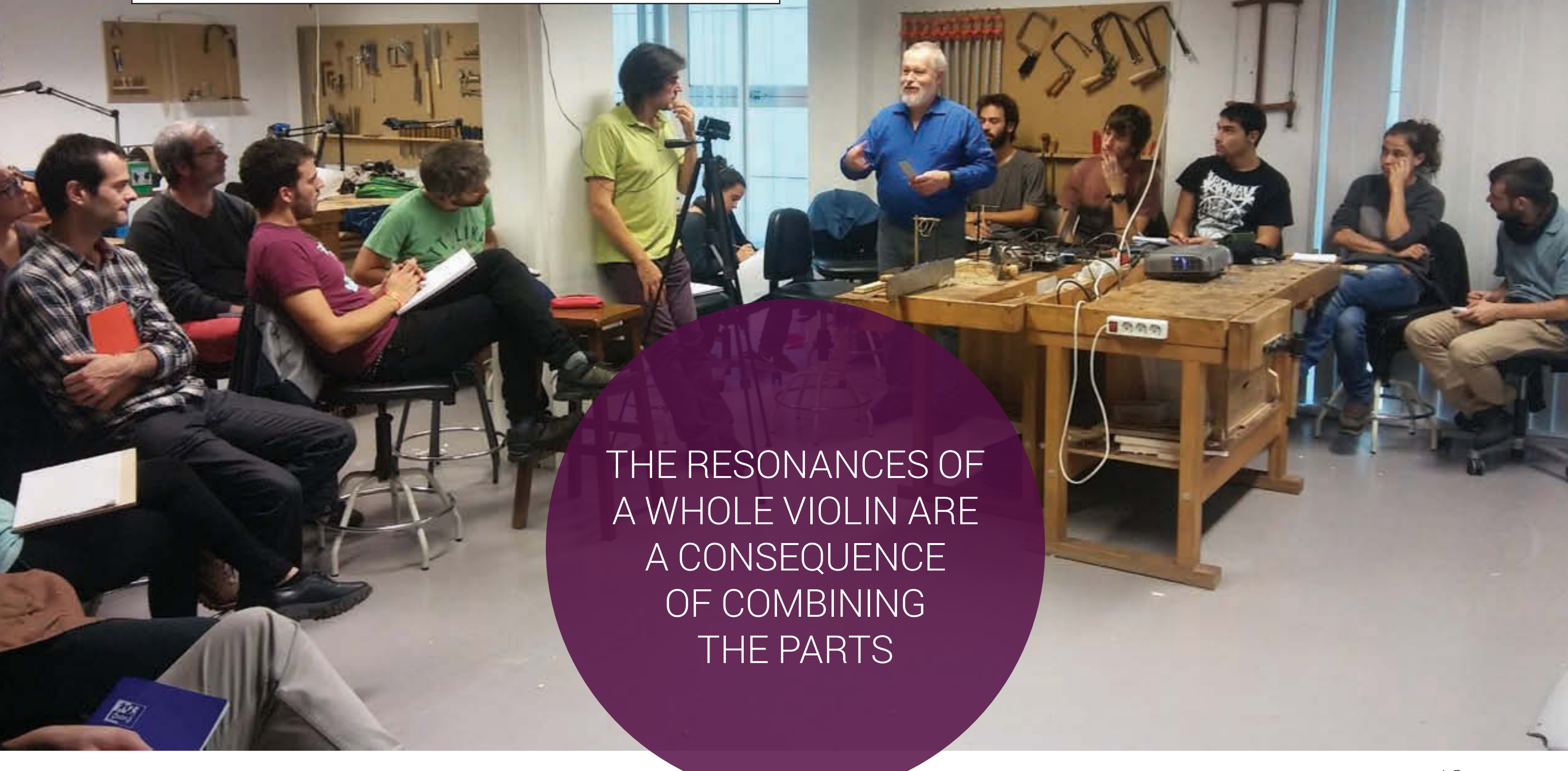


Figure 1 The nodal lines of violin plates. (a) shows Mode 1 in a top plate. (b) and (c) show Mode 2 (the 'X mode') on a front and back plate respectively. (d) and (e) show Mode 5 (the 'ring mode'), again for front and back plates. The differences between the top and back plates arise from the fact that the top is very much stiffer along the grain than across.

We can derive an approximation of this quantity by using a formula containing the mass and the frequencies of the X and ring modes, which provides a much more accurate placement along a scale, from *compliant* to *resistant,* and one that can be retained (by being recorded in a spreadsheet for instrument data). The significance here is that when the parts are put together, their impedances at the junctions will control how they interact. This includes the junctions of bridge feet to the instrument's top, and of the strings to the bridge notches, thus defining the instrument's response to the string vibration. Of course, the arching geometry is also very important, though difficult to define concisely. It is now common practice to estimate the wood's density and sound speeds, and calculate the *radiation ratio*. If we can hold all this information in our minds then we have a multi-dimensional description of the *plate characteristics*, which is both tactile and numerical.

An ancestor of our experiment took place in Stockholm in 1984, devised by Jesús Alonso Moral, then a PhD student working with Erik Jansson at the KTH Royal Institute of Technology. Three tops, three backs and three rib garlands were selected from a pool of ten, five and five respectively. Each plate was characterised as 'pliant', 'normal' or 'resistant' on the basis of mode 2 and 5 frequencies, and the ribs by thickness. 'Normal' was close to the average frequencies of the whole set; pliant was in the low range; and resistant in the high range. The possible combinations of tops, backs and rib garlands was 27 violins, of which 12 were built in that experiment, but only a few could exist simultaneously. More detailed measurements were recorded for the plates, although they were not matched for density or elastic modulus, and the archings were deliberately different. All the plates were supplied by Hutchins and bi-octave tuned, which makes sense in the historical context. The objective of this experiment was to ▹



THE RESONANCES OF A WHOLE VIOLIN ARE A CONSEQUENCE OF COMBINING THE PARTS determine how the mode frequencies of free plates affected the modes of the violin when assembled. Moral further sought any correlation between player preferences and mode frequencies of the completed instruments.

In 2012, team member Andrea Ortona organised a revised version of Moral's experiment at the international violin making school in Cremona. Moral had found that the ribs were the least significant factor, and Ortona opted to keep to standard, medium ribs, allowing him to concentrate on the plates. Therefore there were only nine combinations of the three types of plates. The experiment was run twice, with a total of 18 instruments built. All the violins were from the same model and arching templates. For administrative reasons, Ortona was not able to have as much control over the selection of wood as he wanted. The plates were characterised as 'thin', 'medium' or 'thick' but the main criterion was mode 5 frequency. This strategy partly compensated for the variations in density but tended to pull the plate impedances towards a similar value. At evaluation, two stood out as preferred while the others ▹

THE BILBAO SCHOOL OF VIOLIN MAKING

The acronym BELE comes from *Bilboko Euskal Lutheria Eskola* ('Bilbao Basque Lutherie School' in the Basque language, Euskara). Ever since its creation in 1986, the school has put an emphasis on the scientific understanding of violin-family instruments – a legacy of its founder, the physicist and acoustic researcher Jesús Alonso Moral (1945–2006).

Moral studied the violin in Madrid before moving to Sweden, where he completed a PhD thesis on the subject of 'Violin acoustics: function and quality'. His supervisor, Erik Jansson, then arranged for him to spend 18 months working in New York with Carleen Hutchins. On returning to Europe, he began teaching a course on musical acoustics at the Conservatorio Juan Crisóstomo de Arriaga in Bilbao, where he became the driving force behind the creation of a school of violin making, as an adjunct to the conservatoire. The school opened its doors in 1986, with the techniques of acoustic and sound radiation firmly integrated into the traditional learning processes of stringed instrument making.

In 2007 BELE relocated from the centre of Bilbao to a modern building in Sarriko, in the northern part of the city. With a more spacious work space and state-of-the-art facilities, the school also looked at updating its curriculum, which took effect in 2014. The three-year curriculum now comprises: making a string quartet; repair and restoration techniques; bow maintenance and rehairing; acoustics and performance; varnishing; instrument playing; and internships.

There is one tutor for each of the three years, while Unai Igartua teaches acoustics to all the students. A maximum of eight students are accepted each year, so the school never has more than 24 students at one time. As the school is still a part of the Conservatorio, the students can learn about instrument playing from faculty members, and have conservatoire teachers and students frequently coming in to test their instruments.

The school collaborates with professional workshops for student internships, and with institutions such as the violin making school in Cremona. It regularly invites professional makers from around the world to teach short courses every year. These are usually divided into two parts: four or five days for the students, and three days for professional makers from outside the school.

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COURTESY BELE

PLAYING AND LISTENING TESTS SHOW THAT THOSE WHO ONLY LISTEN ARE LESS CONSISTENT THAN PLAYERS

were so similar that it was difficult to discriminate between them. The purpose was to provide a hands-on experience for the students in which they could observe the effect on the finished instruments of combining these different plates.

Our version of the experiment will inherit from and revise Ortona's. It is slimmed down, and has tighter controls. Only six instruments will be built at BELE and preserved as a resource for subsequent generations and visitors to the school. There will be three instruments with normal backs, each paired with a pliant, normal, or resistant top. Similarly, there will be three with normal tops, each paired with a pliant, normal, or resistant back. There will therefore be two examples of normal top paired with normal back, serving as a control. We have wood for tops and backs that is closely matched in density and sound speeds – all tops and backs from the same trees. Since the wood is well matched, both the weight and frequencies – and therefore also the impedance estimate – will be strongly correlated to the thickness. We have decided to go for greater control by having all plates and scrolls cut by CNC routers. The outside surface will not be changed during the experiment, with the graduation performed entirely on the inside surface. Thus our plates will have closely matched characteristics apart from the single parameter of thickness, and it will therefore be more likely that it is this structural feature that is responsible for the perceived playing difference.

The collection of violins to be evaluated will be expanded by several extra examples built by professional makers from diverse countries and backgrounds. They will provide their own wood, which must be within a specified density range, and they will retain ownership of their work. The parts will also be cut by CNC. While the school instruments will be built to very strict specifications, the external makers are free to decide how to make the best use of the wood that they have selected. However, we are asking them to document their work in some detail.

Sam Zygmuntowicz and Joshua Bell have kindly allowed us access to the CT data for the 'Huberman' Stradivari to use as the model for our violins. Although we could have concocted a perfectly viable model to replicate, we felt that using a prestigious original would add excitement to the project, plus a couple of extra learning dimensions. Actually working on a close replica of an original plate or scroll is an encounter that might lead to a better internalisation of the shape than is provided by the more usual routine of working from templates. Students will also learn something about CT and the potentially contentious CAD wizardry employed in generating the files that control the CNC router. For some this heralds the death of violin making as we know it, but obviously these technologies are here to stay and we believe it prudent to understand them and make informed choices about their use.

Since BELE is in the same building as the Conservatorio Profesional de Música Juan Crisóstomo Arriaga, we have access to an excellent recital room and concert hall for our evaluation work. Previous experience with playing and listening tests show that those who only listen are less consistent than players. Players have much more information on which to base their judgements, and are more self-consistent, but they do not always agree with each other or the listeners. Among other evaluation methods, we plan to use sorting by *free categorisation*: musicians will be asked to group the violins according to how similar or different they are, using as many or few groups as they feel are needed. When this method has been used in previous experiments, different musicians made similar groupings, though offering different explanations for their decisions. Up to a point, we can slip through the linguistic minefield: individuals attach different meanings to the same word and it can be difficult to tell exactly what they intend. We will consider directly how the configurations of plate characteristics (as embodied in a particular violin) are ranked and how far such configurations can be characterised by verbal description or acoustic measurements. We hope this will enable us and other makers to identify where our instrument lies in terms of these characteristics and therefore how we could move in a desired direction.

The evaluation phase will take place next year. The plans are still a work in progress but we envisage a public event where people who are interested can hear the violins, examine and play them. Several detailed publications will also be produced.