On the difficulty to relate the timbral qualities of a bowed-string instrument with its acoustic properties and construction parameters

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Introduction

A long-standing goal in musical acoustics is to identify relations between the perceived qualities (timbre, playability, …) of a given individual musical instrument (as evaluated by players and listeners) compared to other instruments of the same family and the description of its structural and acoustic properties. Here, we are not comparing the timbre of different instruments as explored through the evaluation and measurement of a single note of for example a clarinet versus a single note of a trumpet, but the timbral qualities of one violin (across the whole register) with the qualities of another. Our aim is to identify the acoustic phenomena that can account for these perceptual timbre differences, which could provide insight to violin makers about how to empirically modify some construction parameters in order to reach some desired sound qualities.

Method

While better understanding the perceived qualities of instruments from the violin family and linking them to acoustic properties has been the core of the author's research for over a decade [e.g. references below], the task has proven really challenging and there are, in the end, few clear-cut results. One of the reasons is that players and listeners hardly agree among themselves. Another reason is that any two given instruments differ by so many parameters that it is hard to know what perceived quality (when there is some agreement) is due to what acoustical parameter. Two recent projects, one on the viola (Obialto project), one on the violin (Bilbao project), have been partially designed to address this issue and to explore links between perceptual properties with construction characteristics (and not only acoustical parameters).

While the outline geometry differs slightly between violins, it can vary considerably between violas, which are less standardized. During the 2016 Oberlin workshop (organized by the Violin Society of America), a group of instrument makers have collectively designed the so-called Obialto outline. 25 violas were then built following this model (but without any other constraint except for the set of strings) and brought to the 2017 workshop during which two short excerpts (one in the low register, one in the high) were recorded by a professional player in a recording studio. The recordings were used in a series of listening tests, based on a free categorization task. The data were analysed in terms of statistics (leading to hierarchical trees) and linguistics (analysis of the verbal descriptions of the different classes). In addition, various audio descriptors were calculated on the recordings and vibro-acoustical measurements made on the instruments were processed to characterize their main low frequency resonance modes. Relationships were then searched between the set of perceptual data, the acoustical descriptors and measurements, and the constructional parameters.

The Bilbao project aims at relating intrinsic characteristics of the materials (wood density and stiffness) and some geometric characteristics of the violin's constituent parts (thicknesses of the plates) with the tonal qualities of the complete violins. To this end, six instruments were carefully built at Bilbao's violin making school (BELE): three violins with normal backs, each paired with a thin (pliant), normal or thick (resistant) top; similarly, three with normal tops, each paired with a thin, normal or thick back. The two examples of normal top paired with normal backs serve as a control. 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 Computer Numerical Control routers. The outside surface was not modified, as the graduation was performed entirely on the inside surface. In addition, structural measurements were taken at many steps during the building process and radiation measurements were taken at the end. Another set of six violins was built by six "external" makers, with slightly less constraints in order to have a wider range of plate thicknesses.

This set of violins has been used in a series of experiments; playing tests (a free categorization task involving 20 players in Bilbao and a preference sorting experiment involving 18 players and makers in Oberlin) as well as listening tests in two concert halls, in Bilbao (about 60 listeners) and Oberlin (about 50 listeners).

Results and discussion

In the light of some results of these perceptual tests conducted on violins and violas, we will show that no strict mapping between the perceived timbre and audio descriptors as well as vibro-acoustical measurements could be found, due to the complexity of the concept of timbre that induce a large variability between musicians: the lack of consensus between the musicians' evaluation criteria actually results from the diversity of interpretations when evaluating the timbre of an instrument globally (across the whole register, for different dynamics and playing techniques, …) and assessing the subtle acoustic differences between instruments of the same family. In addition, the multiplicity of the parameters during the building process allow instrument makers to obtain a certain set of perceptual qualities with very different strategies, which makes it difficult to find relationships between perceived qualities and construction parameters if strict constraints have not been imposed on the latter (like in the Bilbao project).

Acknowledgments

The author would like to thank her collaborators (D. Dubois, F. Krafft, G. Stoppani, U. Igartua, R. Jardon Rico,) and students (V. Fraisse, P. Cerântola, B. Souchu, A. Verrier and R. Montero Murillo), as well as all the makers, players and listeners who took part in these projects and experiments.

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