International Journal of Music Science, Technology and Art
(IJMSTA) 4 (1): 38-49, Music Academy "Studio Musica", 2022 ISSN: 2612-2146 (Online)

Time Guides Musical Research: which Violins for the Future?

Massimo de Bonfils ✉

Santa Cecilia Conservatory of Rome, Lutherie Department
✉ Corresponding author: m.debonfils@conservatoriosantacecilia.it

ARTICLE INFO

Received: July 26, 2021
Accepted: February 2, 2022
Published: May 31, 2022
DOI: https://doi.org/10.48293/IJMSTA-85

Keywords:
Lutherie;
Sound;
Violin.

ABSTRACT

Time drives research in the music field. Let us consider the concerto for violin and orchestra. In the Baroque era the soloist spoke with a few instruments, almost always of the same type. In the Mozart era some winds were inserted in the orchestra and the violinist therefore needed more power. From Beethoven onwards, the wind section got richer and richer and the soloist needed more and more volume and power. At the end of Romanticism, the situation became more complicated and finally, with the Sibelius and Khachaturian concerts, an entire wind band was now present in the orchestra. All these needs over the centuries have been satisfied by continuous changes and updates in the construction of violins; in fact, it is not possible to compare a baroque violin and a modern violin because they have very different neck, modern strings in composite material and different bows (nowadays those in high quality carbon fiber always ensure an excellent performance) thus producing an incomparable sound mass. Since Sibelius' time, the style of compositions continues to ask for more and more updates to instruments: will classical lutherie be able to answer? The laboratory of the Lutherie Course of the Santa Cecilia Conservatory in Rome has created a new ergonomic model of violin that was conceived with the express purpose of producing more sound with a richer timbre. We are pleased to present it in this article.

1 Introduction

Over time, composers have written works for ever larger orchestras and inserting wind instruments, demanding that string instruments have ever greater sonic power and greater technical agility. In the Baroque era the soloist spoke with a few instruments, almost always of the same type. In the Mozart era some winds were inserted in the orchestra and the violinist therefore needed more power. From Beethoven on-wards, the wind section got richer and richer and the soloist needed more and more volume and power. At the end of Romanticism, the situation became more complicated and finally, with the Sibelius and Khachaturian concerts, an entire wind band was now present in the orchestra. All these needs over the centuries have been satisfied by continuous changes and updates in the construction of violins; in fact, it is not possible to compare a baroque violin and a modern violin because they have very different neck, modern strings in composite material and different bows (nowadays those in high quality carbon fiber always ensure an excellent performance) thus producing an incomparable sound mass. Since Sibelius' time, the style of compositions continues to ask for more and more updates to instruments.
The places used for the concerts have also grown: the violin that in the seventeenth century was good for chamber music (chamber, in fact, is a room) is now invited to perform in huge concert halls for 2000 listeners.
These needs were gradually met by acting on more things: new geometry of the violin neck, new ebony fingerboard, higher bridges, longer f-holes, longer and thicker bass-bars, new strings in new materials (first the steel and then composite materials), new longer wooden bows with greater pressure capacity on the strings and recently new bows in high quality carbon fiber with excellent performances.

2 Evidence of the Violin Evolution

Many researchers have investigated the causes and dynamics that have guided the evolution of the violin over the centuries. Important research has shown that already at the beginning of the history of the violin this process was in fact underway. I am referring to several interesting works like as:

- *Acoustic evolution of old Italian violins from Amati to Stradivari* by Hwan-Ching Tai, Yen-Ping Shen, Jer-Horng Lin and Dai-Ting Chung[1].
- *Imitation, Genetic Lineages, and Time Influenced the Morphological Evolution of the Violin* by Daniel H. Chitwood[2] where we read that "Numerous innovations on violin design have improved the acoustical properties and playability of violins".
- *The evolution of air resonance power efficiency in the violin and its ancestors* by Hadi T. Nia, Ankita D. Jain, Yuming Liu, Mohammad-Reza Alam, Roman Barnas and Nicholas C. Makris[3].
- *The violin music acoustics from Baroque to Romantic* by John McLennan, engineer, physicist and amateur luthier[4]. His really interesting thesis clearly shows what steps the evolution of the violin has taken so far.
- *Violins evolved by Stradivarian design* by Colin Barras[5]
- *The Evolution of the Violin's Sound* by Julia Rothchild[6].
- *The Evolution of the Violin's Sound and Design* by Meridee Duddleston[7]
- *Power efficiency in the violin – A New study identifies key design features that boost violins' acoustic power* by Jennifer Chu[8]
- *The Second Revolution in the History of the Violin: A Twentieth-Century Phenomenon* by Elias Dann[9]
- *Imitation, genetic lineages, and time influenced the morphological evolution of the violin* by Chitwood D.[10]
- *A Brief Introduction into the Violin Acoustics History* by Anders Buen[11]
- *History of the Development of the Violin* by Carl David Nyman[12]
- *The Art Behind the Baroque Violin* by Carolyn Goldstein[13], where I read the phrase 'During the late Baroque period, the design of the violin significantly changed … My opinion is that the demands made by virtuosic performers caused the design to develop into its modern form'.
- *Some Speculations on a Crisis in the History of the Violin* by Kenneth Skeaping[14] where I read 'Let us start by surveying the drastic modifications in design of the bow and fitting-up of the instrument undertaken as a consequence of musical developments afoot during the second half of the eighteenth century – developments which included the continuing growth of public music-making – and then proceed to consider how they may have affected the general behavior of the violin'.

Sometimes I admire the researchers work even if I don't always agree with all their observations. For example, in *Baroque instruments: Period of Adjustment*, Roger Hargrave[15] states that during Stradivari's lifetime no violin player went beyond the third or fourth position. Instead, the life of Stradivari (1644-1737) overlapped both Vivaldi (1678-1741) and Locatelli (1695-

1 https://www.pnas.org/content/115/23/5926 - Proceedings of the National Academy of Sciences of the United States of America – June 5, 2018
2 https://doi.org/10.1371/journal.pone.0109229 - October 8, 2014
3 https://royalsocietypublishing.org/doi/10.1098/rspa.2014.0905 - The Royal Society Publishing, March 8, 2015
4 See https://newt.phys.unsw.edu.au/music/people/mclennan/McLennanThesisComplete.pdf and https://newt.phys.unsw.edu.au/music/people/mclennanappendix.html - - University of New South Wales,August 2008
5 https://www-newscientist-com.cdn.ampproject.org/v/s/www.newscientist.com/article/dn26369-violins-evolved-by-stradivarian- - New Scientist - October 10, 2014
6 https://www.yalescientific.org/2015/05/the-evolution-of-the-violins-sound/ - Yale Scientific, May 8, 2015
7 https://www.wrti.org/post/evolution-violins-sound-and-design - January 2, 2017
8 Massachusetts Institute of Technology News Office - February 10, 2015
9 College Music Symposium 17, no. 2 (1977): 64-71 - http://www.jstor.org/stable/40373889.
10 PLoS ONE (2014) 9(10) - DOI: 10.1371/journal.pone.0109229
11 https://www.researchgate.net/publication/339439790 – Conference paper, November 2006
12 Utah State University, 1975 - https://digitalcommons.usu.edu/gradreports/750
13 https://surface.syr.edu/honors_capstone - Syracuse University, Spring 5-2016
14 The Galpin Society Journal, 8, 3-12. doi:10.2307/842152 - (1955)
15 https://www.thestrad.com/lutherie/baroque-instruments-period-of-adjustment/13263.article - The Strad, July 13, 2021

1764) and the works of these two composers often go up to the 7th position. Obviously, the rest of Mr. Hargrave's work is beautiful and deserves our attention, but in our humble opinion the imprecise musical premise invalidates his conclusions.

Another interesting work is *Some Misconceptions about the Baroque Violin* by Stewart Pollens[16]. Mr. Pollens said that 'This type of neck and fingerboard was developed around the third quarter of the eighteenth century, and violins made in earlier times (including those of Stradivari and his contemporaries) were modernized to accommodate evolving performance technique and new repertoire, which require quicker shifts and playing in higher positions." I do not agree with all of Mr. Pollens' views, but this sentence is important.

3 A better CLASSIC violin is possible

The modern violin is good, but we need a better one. Today it's possible; many researchers have demonstrated this over the last few years and we have also pointed this out in two recent articles*: Knowledge and Innovation on Classic Italian Lutherie: A Competitive Education in Market Economy* by Massimo de Bonfils[17] and *Beyond Stradivari: The New Santa Cecilia Violin - An Essay on Research of the Classic Italian Lutherie* by Massimo de Bonfils and Mauro Fabretti[18].
Scientists are trying to uncover what makes Stradivarius violins special – but are they wasting their time? by Bruno Fazenda and Trevor Cox[19] is an excellent article summarizes several concepts: Stradivari and Guarneri's violins sounded good not because they were from the 18th century and Italian, but because they were well made. Today it is possible to make instruments that can sound even better, as the double-blind experiment conducted in Indianapolis, Paris and New York has shown several times (see *Million-dollar Strads fall to modern violins in blind 'sound check'* by Adrian Cho[20]). The final confirmation can be read on *Tests challenge whether centuries old violins really are the best ever - Again and again, scientists find, new instruments can sound as good as the famed oldies* by Sid Perkins[21] mainly with its subtitle *Evolution in Action* and with its conclusion 'For young musicians, the message is: "They should be open-minded about using a new violin" instead of an older one, even if was made by someone famous. "A musician should be recognized for how they play, not for the instrument that they're playing.' However, all these experiments do not concern an INNOVATIVE violin model.

4 Is it possible to imagine an INNOVATIVE violin with a better sound?

Yes. The history of violin making is full of innovative models, especially violins and violas; among the many we remember Jean-Baptiste Vuillaume, Hermann Ritter, Thomas Zach, Johannes Matthias Augustus Stroh, François Chanot, Felix Savart, Theophile Villard, Lionel Tertis, Heinrich Dessauer, Alfred Stelzner, Eugen Sprenger, Carleen M. Hutchins, Franz Zeyringer, Otto Erdesz, Giuseppe Virzi, F.A. Saunders, David Rivinus, Marty Kasprzyk, Joseph Curtin, Douglas Martin, Hans Johannsson, Tyler Thackray, Berl Mendenhall and so on.
The lutherie course of our Santa Cecilia Conservatory in Rome also took up the challenge and, alongside the classical lutherie courses, decided to try their hand at a new model of ergonomic violin with a better sound, richer in harmonics and more powerful.

16 http://scholarship.claremont.edu/ppr/vol14/iss1/6 (Copyright © 2009 Claremont Graduate University)
17 Educational Alternatives, ISSN 1314-7277, Volume 15, 2017 - Journal of International Scientific Publications, www.scientific-publications.net, Page 391
18 SIMP – Studia Instrumentorum Musicae Popularis (New Series) VI Serie of the ICTM Study Group On Musical Instruments, Edited by Gisa Jähnichen. Verlag: Logos, Berlin. 2019. ISBN 978-3-8325-4988-6, ISSN 2191-5261 - Logos Verlag Berlin GmbH
19 The Conversation, University of Salford, Manchester -December 19, 2016 - https://theconversation.com/scientists-are-trying-to-uncover-what-makes-stradivarius-violins-special-but-are-they-wasting-their-time-70604
20 American Association for the Advancement of Science – Science Mag on May 9, 2017 https://www.sciencemag.org/news/2017/05/million-dollar-strads-fall-modern-violins-blind-sound-check
21 December 12, 2019 - Science News for Students - https://www-sciencenewsforstudents-org.cdn.ampproject.org/v/s/www.sciencenewsforstudents.org/article/tests-challenge-whether-centuries-old-violins-really-are-best-ever

5 We did it

At the *10th International Scientific Meeting for Sound and Musical Instrument Studies* at Gardunha, central Portugal - Castelo Branco – Fundão (organized by *Animusic Portugal* on August 28, 2021) we presented our project *Modernity from The Past, A New Violin based on Traditional Italian Lutherie and Inspired by Nature*. After having exposed some historical and economic considerations of the Lutherie market that motivated our work, we explained that our innovative work was inspired both by the need to obtain a more powerful and rich in harmonics sound and by following the lines of the geometry Nature's geometry.
In fact, everyone knows that the best art of violin making was born in Italy but the ancient Italian instruments for professionals have very high prices. Today all over the world we have many low-priced low-quality factory products for younger students and few high-end high-priced handicrafts for professionals. So, we need new professional luthiers to build good violins for professional players at reasonable prices! In another world, we need better luthiers.
In Rome, at our Santa Cecilia Conservatory, we teach not only to play an instrument but also Lutherie, String Instruments' History and Technology. Our Lutherie course was founded in two thousand eleven. Today, the Santa Cecilia Conservatory is the only one 'University-Level' Institute in Italy that organizes a Violin Making Course. We have two professors (see figure 1): me as lutherie history and technology teacher and Maestro Mauro Fabretti, the laboratory teacher, the real father of our new violin. Actually, we have fifty students from twelve different countries. Over the years we have also worked for a course in engineering in musical instruments in collaboration first with the La Sapienza University of Rome then with the Polytechnic University of Ancona. We focus our attention on the next luthiers to providing them adequate training and culture. In two thousand sixteen we also organized the first edition of Santa Cecilia.

Fig. 1. Mauro Fabretti and Massimo de Bonfils (Sala Accademica, Santa Cecilia Conservatory of Rome).

Violin Making International Competition where we received more than one hundred instruments participants of twenty-four different nations. Two juries worked together, one of luthiers and the other of musicians, and the competition attracted the interest of various Italian and foreign press. In October 2019 we open our stand at the World Music China Expo, in Shanghai. Moreover, we promoted several Seminars on Lutherie in several Italian Conservatories and Universities and abroad. Moreover, we promote the instruments built in our Laboratory by playing them in concert. For example, in 2017 we played in concert a violin (see figure 2) built by our course at the Castello Sforzesco in Milan, at the Italian Embassy in in Paris, France, during the European Music Fest, and finally at the Mirabell Schloss in Salzburg, Austria.
Obviously, our course is not concentrated only on classical lutherie but also on the experimental one, inspired by concepts and evidences known in the world of Nature, such as the Fibonacci sequence. Leonardo Pisano, a famous Italian scientist known as Fibonacci, discovered his sequence that create a geometric spiral. The design of the spiral is evident in several aspects of Nature. Observing the geometry of plants, flowers or fruit, it is easy to recognize the presence of recurrent structures and forms. The Fibonacci sequence, for example, plays a vital role in phyllotaxis, which studies the arrangement of leaves, branches, flowers or seeds in plants, with the main aim of highlighting the existence of regular patterns. The various arrangements of natural elements follow surprising mathematical regularities: D'arcy Thompson observed that the plant kingdom has a curious preference for particular numbers and for certain spiral geometries, and that these numbers and geometries are closely related.

Fig. 2. A Violin built by Lutherie students' staff at our Laboratory in 2016.

We can easily find the numbers of the Fibonacci sequence in the spirals formed by individual flowers in the composite inflorescences of daisies, sunflowers, cauliflowers and broccoli. Another simple example in which it is possible to find the Fibonacci sequence in nature is given by the number of petals of flowers. Most have three (like lilies and irises), five (parnassia, rose hips) or eight (cosmea), 13 (some daisies), 21 (chicory), 34, 55 or 89 (asteraceae): these numbers are part of the famous Fibonacci sequence. The Fibonacci spiral appears not only in the perfect nautilus shell but in events and objects viewed from afar. Spirals are the most common galaxy shape. Galaxies group together in superclusters and superclusters group together in walls. These walls or filaments of numerous superclusters, gravitationally-bound and separated by large areas of void, are the largest known structures in the universe. The Milky Way's dust obstructs us from seeing the depth of these filaments or sheets, so we do not yet know the exact shape of these walls[22].

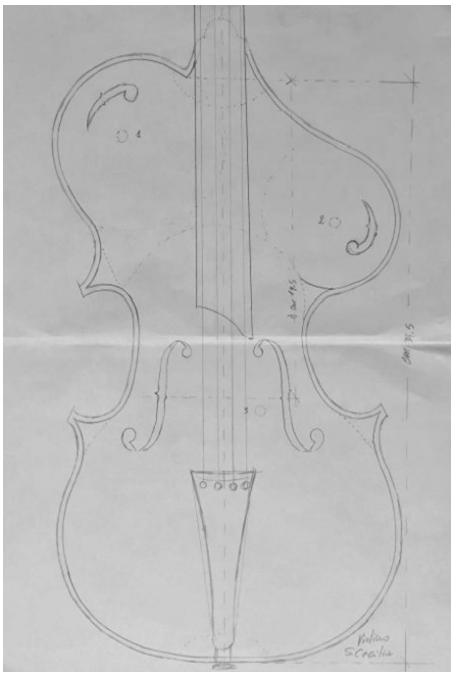


Fig.3. Santa Cecilia experimental violin project designed by Mauro Fabretti.

[22] Benedetta Palazzo, *The numbers of nature: the Fibonacci sequence* (News and Events, June 27, 2016) - http://www.eniscuola.net/en/2016/06/27/the-numbers-of-nature-the-fibonacci-sequence/

So, wanting to modify the design of the new ergonomic violin, we decided to follow the curve suggested by the Fibonacci sequence. Maestro Fabretti designed (see figure 3) the new model project and our staff began to build it (see figure 4) following the teacher's precious instructions. This new violin (see figure 5) is easier to play, powerful and with a better sound quality.

Fig. 4. The Lutherie students' staff at work in our Laboratory.

It's easier to play because the ergonomic body helps the playing on higher positions pushing down his left shoulder. Moreover, we pulled up the right shoulder to recover the cubage of the sound box. We have a better sound quality because the player can choice, following the repertory to play, if using one or two or three sound-posts in the same time for a richer timbre. We have a more powerful sound because the sound comes out of 4 harmonic holes. Obviously, we preferred to use a longer and thicker bass-bar for a better transmission of acoustic vibrations. We are pleased to say that the International Press has already begun to notice our work starting with the celebrated English review Strad – printed (see figure 6) and digital (see figure 7) edition (see

figure 8) - and so on with articles and news on the main specialized sites in Europe, America and Asia (see figure 9). Obviously, we also played this instrument in concert both in Italy and abroad (see figure 10)[23], but it would be better to make a direct comparison with the sound of another violin, perhaps that of a great Italian luthier of the eighteenth century. For that reason, our next step will be to involve our Electronic Music Department to make acoustic measurements which will then be compared with those of the "Tuscan" Stradivarius of the Santa Cecilia Academy Museum of Musical Instruments in Rome. This will be the subject of a forthcoming scientific publication. In this photo Maestro Fabretti with his assistant Maestro Massimo De Notti (see figure 11).
We are proud to say that that all this comes from the work that is carried out in our regular violin making course (see figure 12).

Fig. 5. The Santa Cecilia experimental violin finally completed.

[23] See fig. 10 here at the *Nova Universidade* in Lisbon, Portugal on April 11, 2019

Fig. 6. The Santa Cecilia new violin (The Strad print edition).

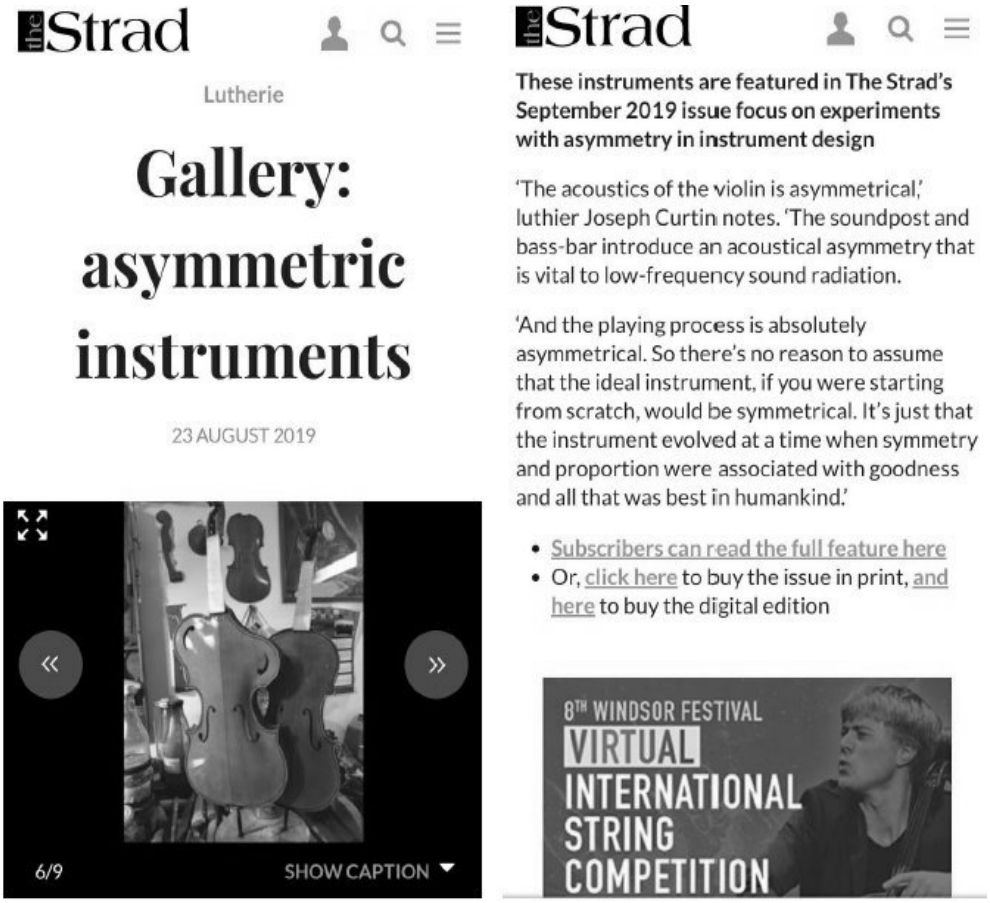
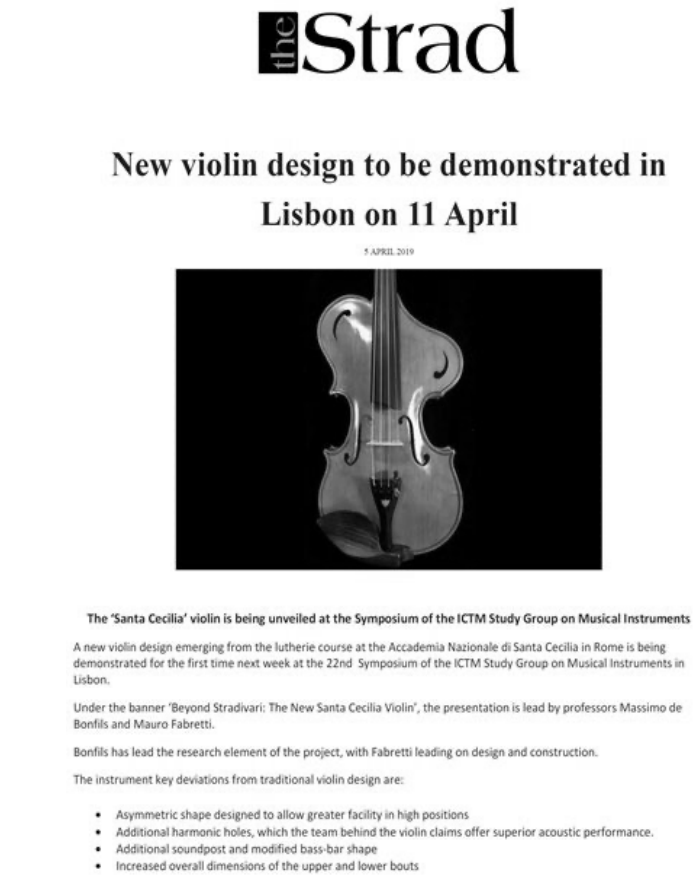


Fig. 7. The Santa Cecilia new violin (The Strad digital edition).



the Strad

New violin design to be demonstrated in Lisbon on 11 April

5 APRIL 2019

The 'Santa Cecilia' violin is being unveiled at the Symposium of the ICTM Study Group on Musical Instruments

A new violin design emerging from the lutherie course at the Accademia Nazionale di Santa Cecilia in Rome is being demonstrated for the first time next week at the 22nd Symposium of the ICTM Study Group on Musical Instruments in Lisbon.

Under the banner 'Beyond Stradivari: The New Santa Cecilia Violin', the presentation is lead by professors Massimo de Bonfils and Mauro Fabretti.

Bonfils has lead the research element of the project, with Fabretti leading on design and construction.

The instrument key deviations from traditional violin design are:

- Asymmetric shape designed to allow greater facility in high positions
- Additional harmonic holes, which the team behind the violin claims offer superior acoustic performance.
- Additional soundpost and modified bass-bar shape
- Increased overall dimensions of the upper and lower bouts

Fig. 8. The Lisbon presentation of the Santa Cecilia new violin (The Strad).

99.5 WCRB
A service of WGBH

Chances are that you have a pretty good idea what a violin looks like.

But that image may soon change: lutherie students at the National Academy of St. Cecilia in Rome will debut a new violin shape that they say improves performance in higher registers.

Here's what it looks like:

Eyes On World Cultures

APRIL 16, 2019

New Violin Design

The 'Santa Cecilia' violin is being unveiled at the Symposium of the ICTM Study Group on Musical Instruments

ArtsJOURNAL
arts, culture, ideas

New Violin Design (Only Somewhat Unorthodox) Gets First Major Demo

musictrust.com.au

MUSIC TRUST E-ZINE

The design has emerged from the lutherie course at the Accademia Nazionale di Santa Cecilia in Rome. Research has been led by Professor Massimo de Bonfils and construction by Mauro Fabretti. The instrument key deviations from traditional violin design are:

- Asymmetric shape designed to allow greater facility in high positions
- Additional harmonic holes, which the team behind the violin claims offer superior acoustic performance.
- Additional soundpost and modified bass-bar shape
- Increased overall dimensions of the upper and lower bouts.

A new violin design

Fig.9. The Santa Cecilia new violin on abroad digital press review.

Fig. 10. Luca Minervino and Massimo de Bonfils playing at the Nova Universidade in Lisbon, Portugal (April 11, 2019)

Fig. 11. Massimo De Notti and Mauro Fabretti with the Santa Cecilia new violin.

Fig. 12. Poster of our Lutherie Cours at the Santa Cecilia Conservatory.

References

[1] Hwan-Ching Tai, Yen-Ping Shen, Jer-Horng Lin and Dai-Ting Chung, *Acoustic evolution of old Italian violins from Amati to Stradivari* https://www.pnas.org/content/115/23/5926 - Proceedings of the National Academy of Sciences of the United States of America – June 5, 2018.

[2] Daniel H. Chitwood, *Imitation, Genetic Lineages, and Time Influenced the Morphological Evolution of the Violin* - https://doi.org/10.1371/journal.pone.0109229 - October 8, 2014

[3] Hadi T. Nia, Ankita D. Jain, Yuming Liu, Mohammad-Reza Alam, Roman Barnas and Nicholas C. Makris, *The evolution of air resonance power efficiency in the violin and its ancestors, https://royalsocietypublishing.org/doi/10.1098/rspa.2014.0905 - The Royal Society Publishing, March 8, 2015*

[4] John McLennan, *The violin music acoustics from Baroque to Romantic, https://newt.phys.unsw.edu.au/music/people/mclennan/McLennanThesisComplete.pdf and https://newt.phys.unsw.edu.au/music/people/mclennanappendix.html* - University of New South Wales, August 2008.

[5] Colin Barras, *Violins evolved by Stradivarian design, https://www-newscientist-com.cdn.ampproject.org/v/s/www.newscientist.com/article/dn26369-violins-evolved-by-stradivarian*- New Scientist - October 10, 2014

[6] Julia Rothchild, *The Evolution of the Violin's Sound, https://www.yalescientific.org/2015/05/the-evolution-of-the-violins-sound/* - Yale Scientific, May 8, 2015

[7] Meridee Duddleston, *The Evolution of the Violin's Sound and Design, https://www.wrti.org/post/evolution-violins-sound-and-design* - January 2, 2017

[8] Jennifer Chu, *Power efficiency in the violin – A New study identifies key design features that boost violins' acoustic power,*

Massachusetts Institute of Technology News Office - February 10, 2015

[9] Elias Dann, *The Second Revolution in the History of the Violin: A Twentieth-Century Phenomenon,* College Music Symposium 17, no. 2 (1977): 64-71 - *http://www.jstor.org/stable/40373889.*

[10] Chitwood D., *Imitation, genetic lineages, and time influenced the morphological evolution of the violin, PLoS ONE (2014) 9(10) - DOI: 10.1371/journal.pone.0109229*

[11] Anders Buen, *A Brief Introduction into the Violin Acoustics History,* https://www.researchgate.net/publication/339439790 – Conference paper, November 2006

[12] Carl David Nyman, *History of the Development of the Violin,* Utah State University, 1975 - https://digitalcommons.usu.edu/gradreports/750

[13] Carolyn Goldstein, *The Art Behind the Baroque Violin,* https://surface.syr.edu/honors_capstone - Syracuse University, Spring 5-2016

[14] Kenneth Skeaping, *Some Speculations on a Crisis in the History of the Violin, The Galpin Society Journal, 8, 3-12. doi:10.2307/842152 - (1955)*

[15] Stewart Pollens, *Some Misconceptions about the Baroque Violin*, http://scholarship.claremont.edu/ppr/vol14/iss1/6 (Copyright © 2009 Claremont Graduate University)

[16] Massimo de Bonfils, *Knowledge and Innovation on Classic Italian Lutherie: A Competitive Education in Market Economy*, Educational Alternatives, ISSN 1314-7277, Volume 15, 2017 - Journal of International Scientific Publications, www.scientific-publications.net, Page 391

[17] Massimo de Bonfils and Mauro Fabretti, *Beyond Stradivari: The New Santa Cecilia Violin - An Essay on Research of the Classic Italian Lutherie, SIMP – Studia Instrumentorum Musicae Popularis (New Series) VI Serie of the ICTM Study Group on Musical Instruments, Edited by Gisa Jähnichen. Verlag: Logos, Berlin. 2019. ISBN 978-3-8325-4988-6, ISSN 2191-5261 - Logos Verlag Berlin GmbH*

[18] Bruno Fazenda and Trevor Cox, *Scientists are trying to uncover what makes Stradivarius violins special – but are they wasting their time? The Conversation, University of Salford, Manchester -December 19, 2016 - https://theconversation.com/scientists-are-trying-to-uncover-what-makes-stradivarius-violins-special-but-are-they-wasting-their-time-70604*

[19] Adrian Cho, *Million-dollar Strads fall to modern violins in blind 'sound check', American Association for the Advancement of Science – Science Mag on May 9, 2017 https://www.sciencemag.org/news/2017/05/million-dollar-strads-fall-modern-violins-blind-sound-check*

[20] Sid Perkins, *Tests challenge whether centuries-old violins really are the best ever - Again and again, scientists find, new instruments can sound as good as the famed oldies*, December 12, 2019 - Science News for Students - https://www-sciencenewsforstudents-org.cdn.ampproject.org/v/s/www.sciencenewsforstudents.org/article/tests-challenge-whether-centuries-old-violins-really-are-best-ever

[21] Benedetta Palazzo, *The numbers of nature: the Fibonacci sequence* (News and Events, June 27, 2016) http://www.eniscuola.net/en/2016/06/27/the-numbers-of-nature-the-fibonacci-sequence/

[22] The Strad, September 2019 (printed edition)

[23] The Strad, August 23, 2019 - https://www.thestrad.com/lutherie/life-out-of-balance/9298.article

[24] The Strad, April 5, 2019 - https://www.thestrad.com/galleries/new-violin-design-to-be-demonstrated-in-lisbon-on-11-april/8786.article