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Citation: The Journal of the Acoustical Society of America **151**, 443 (2022); doi: 10.1121/10.0009320
View online: https://doi.org/10.1121/10.0009320
View Table of Contents: https://asa.scitation.org/toc/jas/151/1
Published by the Acoustical Society of America

JASA ARTICLE

A listening experiment comparing the timbre of two Stradivari with other violins

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ABSTRACT:
The violins of Stradivari are recognized worldwide as an excellence in craftsmanship, a model for instrument makers, and an unachievable desire for collectors and players. However, despite the myth surrounding these instruments, blindfolded players tendentially prefer to play modern violins. Here, we present a double blind listening experiment aimed at analyzing and comparatively rating the sound timbre of violins. The mythic instruments were listened to among other well regarded and not so well regarded violins. 70 listeners (violin makers of the Cremona area) rated the timbre difference between the simple musical scales played on a test and a reference violin, and the results showed that their preference converged on one particular Stradivari. The acoustical measurements revealed some similarities between the subjective ratings and the physical characteristics of the violins. It is speculated that the myth of Stradivari could have been boosted, among other factors, by the specimens of tonal superior quality, which biased favourably the judgment on his instruments and spread on all of the maker's production. These results contribute to the understanding of the timbre of violins and suggest the characteristics that are in a relationship with the pleasantness of the timbre.
https://doi.org/10.1121/10.0009320

(Received 15 October 2021; revised 16 December 2021; accepted 28 December 2021; published online 26 January 2022)
[Editor: Psyche Loui] Pages: 443–450

I. INTRODUCTION

To inexperienced observers, violins appear to be extremely similar to one another. However, when it comes to price and prestige, violins are extremely different from one another with a small selection of instruments that can be regarded as high end and an even smaller selection of instruments that reach the status of myth. This is definitely true for the violins produced by Antonio Stradivari (1644–1737). The instruments of Stradivari are a prototypical model for violin makers worldwide (the shapes of some of his most famous violins are widely used as blueprints for the production of new violins) and the ultimate (often unreachable) target for collectors, who are willing to pay millions to have their hands on one of the few, still playable instruments. Stradivari produced a bit less than 1000 violins, but only 450 are still available and, among these, only a few hundred are still active and can be used to play music (Hill *et al.*, 1963).

Despite the enormous cost, allure, and prestige of these instruments, the three studies that investigated the perceptual quality of these violins could not find empirical data supporting the myth. Fritz *et al.* (2012b), Fritz *et al.* (2014) and Fritz *et al.* (2017) asked functionally blindfolded violinists to play a set of new and old violins (mainly Stradivari), select their favourite, and in Fritz *et al.* (2012b) and Fritz *et al.* (2014), tell whether the instruments were new or old. The results of these studies were consistent. The violinists knew their own mind and consistently selected a favourite violin, which, however, was often different from violinist to violinist, a result that is commonly observed when expert players are asked to select their favourite instruments (for a similar result, see also Saitis *et al.*, 2012, and Saitis *et al.*, 2015). The favourite was more often a new violin rather than a Stradivari. Finally, the violinists were unable to distinguish the old from the new violins (Fritz *et al.*, 2012b; Fritz *et al.*, 2014), demonstrating that the mythic Italian violins of the 18th century (the set of old violins included another mythic violin: Guarneri Del Gesù) may not emerge as clearly as some were expecting (Langhoff, 1994). More recently, Fritz, *et al.* (2017) investigated the violin sound projection ("how well an instrument can be heard at a distance," p. 5395) and how it relates to the preference for one or another violin. They found that the old violins (including Stradivari) are judged to project less and are also the least favourite when compared to a selection of the best worldwide production of modern makers.

Fritz *et al.* (2012b) and Fritz *et al.* (2014) suggest that the allure surrounding Stradivari and old Italian makers

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might have been overestimated in recent times. However, those studies did not disentangle the quality of the violin's voice from other characteristics, which may come into play when a player judges the instrument by playing it: the playability, the feeling at touch, the idiosyncratic preference for a specific shape or feeling (e.g., for a violin very similar to that owned and played by the player), the preference for a specific type of instrument because it is particularly suitable for the repertoire usually played by the player, and so on. The study by Fritz *et al.* (2017) focused on the projection and did not shed light on the timbre qualities either: the listeners are known to prefer louder violins (Otcenasek and Stepanek, 2002; Tai *et al.*, 2018). The loudness and preference for one violin's voice are certainly correlated, but the loudness is not the only factor contributing to a sound's pleasantness and, yet, little is known about the other timbre characteristic that may be linked to the pleasantness. All in all, those experiments have largely contributed to demystifying some *a priori* assumptions about the old Italian school, but they did not clarify what makes some violins sound better when compared to other violins. We investigated the association between the pleasantness and timbre.

We conducted a double blind, live listening test, which asked violin makers to judge a few characteristics of the timbre of the sound of the violin as well as the timbre's pleasantness. The timbre was described by a set of verbal descriptors, which are commonly used by the community of our participants. In the experiment, the stimulus presented to the participants was a simple musical scale such that they could focus as much as possible on the timbre only and avoid possible idiosyncratic and unpredictable interactions between a violin's voice and a peculiar piece of music.

II. METHODS

A. Participants

Only expert listeners were recruited for the experiment. Unexpert listeners (e.g., nonmusicians) are usually not sufficiently sensitive and consistent in this type of task (Vattano *et al.*, 1976; Fritz *et al.*, 2007). Seventy participants, ranging in age from 17 to 63 years old [$M = 35.5$, standard deviation (SD) $= 13.1$], volunteered in the experiment. Of the participants, 36 were students of the local violin making school (mean age 25.9 years old, SD $=$ 5.2, and from here on, referred to as "students") and 34 were professional violin makers (mean age 45.1 years old, SD $=$ 11.6) working in the Cremona area. This means about one-quarter of the whole professional violin making community of Cremona, which counts about 150 violin makers. Cremona is, perhaps, the town with the largest community of violin makers in the world.

All of the participants except two reported normal hearing. We asked the participants how many years they have been judging the sound of violins. The students declared an average of 4 years of experience (SD $=$ 4) and violin makers declared an average 20 years of experience (SD $=$ 11). We also asked the participants about their expertise in listening experiments similar to the one presented here and to report how many experiments they participated in in the past. The majority ($N = 55$) reported no experience. The participants completed an anonymous Google form (Google, Inc., Mountain View, CA) after providing informed consent. The study protocol was approved by the Ethics Committee (Comitato Etico della Ricerca Psicologica; Area 17) of the University of Padova and was conducted in accordance with the Declaration of Helsinki.

B. Materials and procedure

The study was run collectively in the modern Auditorium Giovanni Arvedi in the afternoon of 7 May 2019. The auditorium is the concert hall of the "Museo del Violino" (Cremona, Italy), and it is considered a room with very good acoustics, which was designed for performances by soloists and chamber ensembles. In the auditorium, the stage is below the spectators such as those in classic Greek theaters. However, the spectators' seats are both in front of the stage and on the back of the stage. The participants were seated only in front of the stage (see supplementary Fig. S1, right).[1] A 2×2 m white, sound transparent curtain and two panels occluded the view of the participants from the violinists and their collaborators (see supplementary Fig. S1, left).[1] The curtains and panels also occluded the view of the table, which was used to support the violins during the experiment. The experiment was conducted by M.G., who gave instructions to the participants and set the pace of the experiment within each block of trials. The experimenter was seated at stage level about 6 m away from the violinist (who played the stimuli) and his collaborator (who helped the violinists to change the instrument during the experiment). The participants and experimenter were blind about the identity of the violins at the time of the experiment.

The participants were asked to judge the timbre of four test violins (labelled "A," "B," "C," and "D") in comparison to that of a fixed, reference violin (labelled "X"). The labels and roles (i.e., test or reference) were associated with the instruments randomly before the experiment. Violins A and C were modern violins (made in 1988 and 1917, respectively) and both were considered to be of excellent manufacture. Their prices are estimated to be about 20 000 and 100 000 euros, respectively. Violin B and the reference violin X were both produced by Antonio Stradivari. Violin B was made at the end of the so-called "golden period" of the maker, whereas Violin X was made in the late period of the maker. Both of the instruments are estimated to be worth several millions of euros each. Violin D was an industry crafted violin with an estimated value of about 300 euros, and the year of production is uncertain. All of the instruments were equipped with their own strings (i.e., no standard strings were used for the experiment), tuned to A_4 (440 Hz) by the violinist before the experiment, and the bow used for the experiment was the violinist's personal bow. Unlike Fritz *et al.* (2012b), Fritz *et al.* (2014), and Fritz *et al.* (2017), here, the violinist was not blindfolded because during the trials, he was asked to change the instruments quickly, and we were not allowed by the owners of the violins to take the risk of mishandling them. However, we believe that blindfolding is not critical in a study in which the player of the instrument is not among the judges and the performance offers limited degrees of freedom (in contrast with, e.g., Fritz *et al.*, 2012b, Fritz *et al.*, 2014, and Fritz *et al.*, 2017, in which the visual appearance of the violin could have revealed its age).

The participants responded through a Google form with their own mobile devices. Three participants responded via paper and pencil. In each trial, the violinist first played a portion of a G major scale (ascending from G_3 to D_4 and back to G_3) with violin X and then played the same scale with one of the test violins. The violinist was asked to play all of the scales identically and as neutrally as possible ("detaché," "mezzo forte," and without "vibrato") at a constant rate of 35 notes per minute. The samples of the trials recorded during the experiment can be heard in the supplemental material.[1] During the experiment, the collaborator of the violinist helped him to rapidly change the violin within each trial (i.e., ∼6–7 s separated the two scales).

In four blocks of ten trials, the participants rated the timbre of the test violin on a scale from −2 to +2 in comparison to the reference violin. In the first block, the participants were asked to judge whether the sound of the test violin was more or less "nasal" ("nasale" in Italian, e.g., like the sound of an oboe) than the sound of the reference violin on a five point scale, ranging from −2 to +2 ("0" means no difference). In the second block, with the same five point scale, the participants judged whether the test violin sounded more or less "bright" ("chiaro", e.g., like the vowel "A" is brighter than the vowel "O" in the word "ciao") than the reference violin; in the third block, they judged whether the test violin sounded more or less "open" ("aperto", e.g., as any instrument sounds closed with the mute on and open when the mute is removed). Finally, in the last block, the participants judged whether the test violin sounded more or less "pleasant" ("piacevole") than the reference violin. The very first experimental block was preceded by a couple of familiarization trials. The four timbral dimensions were selected among a wider set of terms, which were familiar to the local community (see Curtin and Rossing, 2010, p. 212). After a number of preliminary tests, the selected terms were found to be the terms associated with the smallest variance within the addressed audience, and the method (i.e., the comparison between a test violin and reference violin presented in rapid succession) was selected because the memory for the sound timbres presented in isolation is short (Tai, 2014).

In each block, the reference violin was compared twice with all of the test violins (eight trials) and twice with itself (two trials). When the reference violin was compared with itself, the violinist waited a fraction of time between the two scales to simulate the interval needed to change the violin. The participants knew that two violins were played in each trial and the first scale was played with the reference violin, but they were not told that in some trials violin X could be played twice. The experiment lasted about 45 min.

III. RESULTS

A. Listening experiment

We analyzed whether the listeners were reliable. In our experiment, a good listener should be able to discriminate the sounds of the violins along the four dimensions of interest. In addition, the listeners should be consistent and return the same response when presented with the same sound-stimulus. It is desirable that our listeners possess both of these qualities. We analyzed the responses to those trials in which the reference violin was evaluated with itself: a good listener should rate the two scales as identical irrespective of the timbral dimension s/he is asked to evaluate. There were eight such trials in the experiment. In each of these trials, the single rate could range from −2 to +2, thus, the sum of the absolute values of these ratings can range from 0 to 16: the closer to zero, the better the listener. But, the listener should also be consistent and return the same reaction in response to the same sound-pair when the reference violin is evaluated in comparison to the test violin. Here, each trial was presented twice during the experiment. For example, twice each listener evaluated how "nasal" violin A was in comparison to violin X. If the listener is consistent, the difference between these two ratings should be as small as possible. For each pair of identical trials, this difference can range from zero to four. Because there were 20 identical trials, the consistency of 1 participant can range from 0 to 80. The above two scores were calculated for each listener, transformed into a percentage, and averaged to have a single reliability index for each listener, spanning from 0% (worst reliability) to 100% (max reliability). These empirical reliability indexes were compared with those of a Monte Carlo simulation of the experiment with 7 000 000 virtual participants responding randomly and the responses −2, −1, 0, +1, +2, which were generated from a flat distribution. Out of 70 participants, 55 had a reliability index that was higher than the 95th percentile of the simulated reliability index. Only 4 violin makers and 11 students were found below this threshold. Supplementary Fig. S2 shows the cumulative density function of the reliability index together with the empirical reliability indexes.[1]

Because of the method used in the current study (i.e., a test violin compared with a fixed reference violin), all of the ratings are valid with respect to the reference violin X. Theoretically, this method does not guarantee transitivity: each comparison rate may be the result of criteria that are idiosyncratic to the specific comparison and may not generalize to other comparisons. However, because of the type of questions asked of the listeners (restricted to the sensory domain) combined with the simplicity of the stimulus (half of a diatonic scale with no ornament), we can reasonably assume that the dimensions investigated were monotonic and unidimensional, and it is possible to rank the ratings given by the participants. We calculated whether each test violin was judged to be significantly more (or less) pleasant than the reference violin via four paired sample t-tests. In addition, for each analysis of variance, we calculated how much that a linear model could explain the given ratings via the $R2$ value, which represents the strength of the fit of a linear model on the data. The ratings of the 55 more reliable participants (see Fig. 1) revealed that the 4 violins were judged differently for nasality, $F(3,162) = 10.63$, $p < 0.001$, $R2 = 0.11$; openness, $F(3,162) = 52.19$, $p < 0.001$, $R2 = 0.39$; and brightness, $F(3,162) = 18.92$, $p < 0.001$, $R2 = 0.18$. As far as the pleasantness is concerned, the violins were also judged differently: $F(3,162) = 75.19$, $p < 0.001$, $R2 = 0.46$. We calculated whether each test violin was judged to be significantly more (or less) pleasant than the reference violin via four paired sample *t*-tests. We also calculated Cohen's *d*, which provides a measure of the effect size of this (possible) difference. Compared to violin X, violin B was considered to be more pleasant than violin C [$t(54) = 4.42$, $p < 0.001$, Cohen's $d = 0.78$], violin C was judged to be more pleasant than violin A [$t(54) = 7.08$, $p < 0.001$, Cohen's $d = 1.16$], violin A was determined to be more pleasant than violin D [$t(54) = 2.87$, $p = 0.005$, Cohen's $d = 0.45$]. These analyses were recalculated, including the data of the nonreliable participants or the participant's expertise (i.e., students and violin makers), as the between factor and outcome did not change. Finally, most of the ratings given to violin C were sharply distributed around zero, which was more than for the other violins (i.e., no difference between violin C and the reference violin X).

For each participant, we also looked for the highest pleasantness score(s) and recorded the violin(s) that received this score. In other words, we counted how many times each test violin received the maximum pleasantness score. Out of 55 participants, 43 gave the highest pleasantness score to Stradivari violin B, 19 participants gave the highest pleasantness score to the modern violin C (1917), 3 participants gave the highest pleasantness score to modern violin A (1988), and only 2 participants gave the highest pleasantness score to violin D. Note that the numbers do not add up to 70 because each listener could give the highest pleasantness score to more than 1 violin.

At the end of the experiment, many of the participants were informally interviewed about the desired qualities of a good timbre. They agreed about the need for balancing the instrument brightness with an adequate presence of bass components to avoid a sense of harshness and minimal nasality. Interestingly, these same aesthetics can be reconstructed from the openness, nasality, and brightness ratings by means of a linear discriminant model (McLachlan, 2004), which can remarkably account for the verbal description of a pleasant sound given by the participants. In the model, the relative pleasantness is categorized with 67% accuracy by the first discriminant coordinate alone (expressed as 0.27 brightness + 1.24 openness − 0.36 nasality). On the other hand, an ordinary least squares minimization (i.e., pleasantness = 0.15

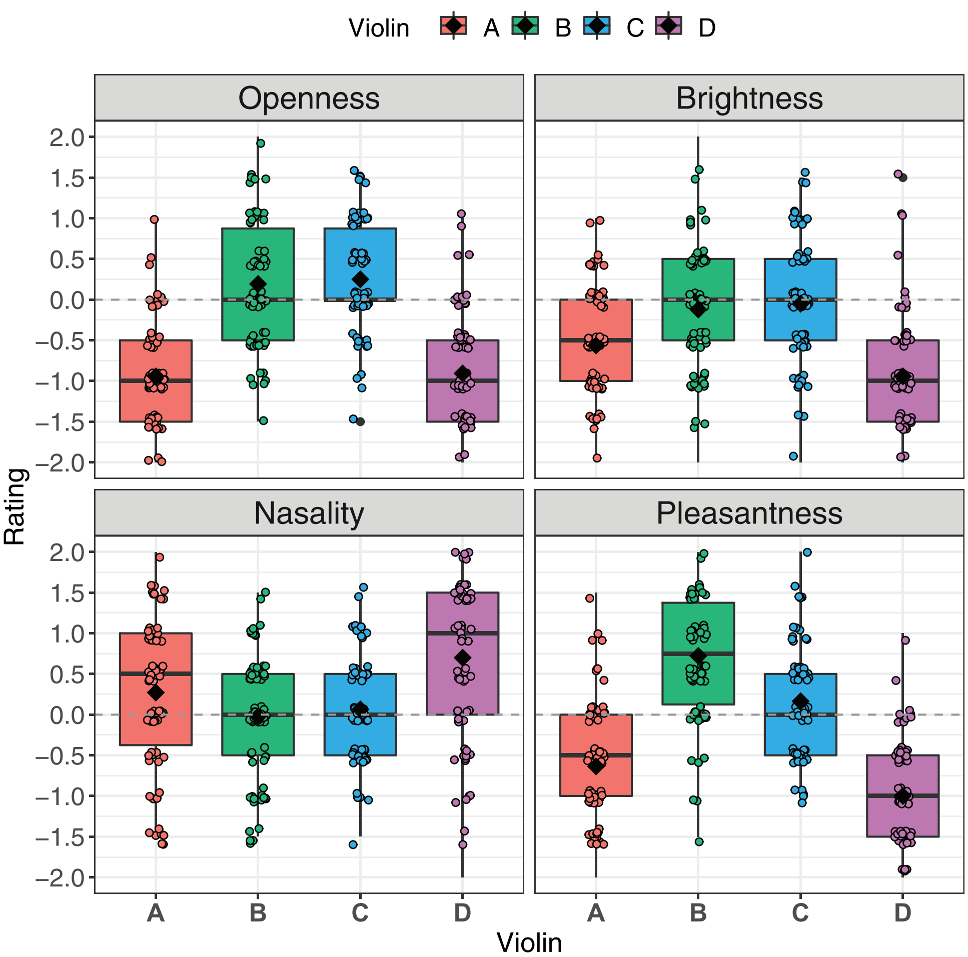

FIG. 1. (Color online) The ratings for "openness," "orightness," "nasality," and "pleasantness" per violin. The circles represent the individual judgments given by the participants. The diamonds represent the average values. In each boxplot, the thick black lines represent the median, and the boxes span over the second and third quartiles. The upper (lower) whiskers is the distance of 1.5 times the interquartile range from above (below) the upper (lower) quartile, drawn up (down) to the largest (smallest) observed point from the dataset, which falls within this distance. The violins are A (modern, 1988), B (Stradivari, end of golden period), C (modern, 1917), and D (industrial). The ratings were given in comparison to the reference violin X (Stradivari, late period).

brightness + 0.62 openness − 0.12 nasality) already explains 43% of the pleasantness's variability, showing that whereas a linear relationship between the dimensions clearly exists, possibly other factors, which are not considered here, contribute to the sensation of the pleasantness (see also the supplementary material for further details).[1]

B. Acoustical response of the violins

The listening experiment showed that the test violins were perceived differently along the four timbral dimensions. We sought a footprint of these differences in the physical acoustical properties of the violins. Studies about the physical acoustic properties of ancient instruments are relatively abundant in the literature. Hutchins and Voskuil (1993) first suggested that good violins could be built by carefully tuning the first few modes of vibration, opening the quest for a physics-driven violin making process. Unfortunately, this recipe turned out to be too simple to capture the complexity of the problem. The quest for the objective markers of classic violins led many researchers to devise classification schemes with the aim to distinguish the old masters' violins from the new ones (Gabrielsson and Jansson, 1979; Jansson, 1997; Buen, 2005; Bissinger, 2008; Nagyvary, 2013; Nia *et al.*, 2015; Tai *et al.*, 2018). A systematic study was performed by Dünnwald, who examined about 700 violins both old and new. He concluded that, although modern instruments with a sound quality comparable to that of the classic masterpieces do exist, the appearance of "good" values for these classifiers was more frequent in the old violins (Dünnwald, 1990). However, the relevance of these classifiers is debated. Recently, advanced techniques for data mining were employed in the attempt to automatize the classification tasks and correlate the low-level sound features with high-level perceived sound qualities (Wrzeciono and Marasek, 2010; Fritz *et al.*, 2012a; Zanoni *et al.*, 2014; Satragno *et al.*, 2017; Giraldo *et al.*, 2019). Despite this body of clues, there is, thus far, no unique way to correlate the sound quality of violins to their vibroacoustic properties and regardless of the collaboration between violin makers and the scientific community (Schleske, 1996; Schleske, 2002), there is no magic recipe currently available for makers to guarantee that the sound of a violin will be good, and the most common practice ultimately consists in the replication of known models (mostly famous old violins).

We recorded the sound, emitted by the violins when struck by a small impact hammer, with the strings muted. Successively, we computed the corresponding frequency response function (FRF) (see supplementary Fig. S6).[1] The direct comparison of the FRFs shows marked differences in the amplitudes and frequencies (see Fig. 2).

The peak at the lowest frequency corresponds to the so-called A0 mode (the Helmholtz resonance of the air mass within the instrument in a nonrigid top and bottom boundary). The features around 500 Hz include the lowest body resonances (often called B1+ and B1−). Violin B has the strongest response in both of these ranges. These features greatly enhance the response in the bass register of violin B with respect to the other instruments. The frequency response of violin D is mostly concentrated between 0.8 and 1.4 kHz. This feature reveals the "weakness" of violin D (the least preferred by the listeners): its body acts very much like a narrow bandpass filter with the maximum response around 1 kHz. This is mirrored by the listeners' responses: violin D was rated as more nasal and less open than the reference violin X. Violin B also excels in the 1.5–5 kHz band. Some authors suggested that this region contributes to the brightness of the timbre (Buen, 2007; Dünnwald, 1991), however, the direct association between the individual spectral bands and perceptual dimensions is questionable. In violin B, the strong response at a high frequency is balanced by a strong bass response (i.e., the strongest of the lot), whereas this is not the case for violin A, which has the weakest A0 resonance. The frequency responses of violins C and X are very similar to one another. Unsurprisingly, the ratings gathered by violin C in our behavioural experiment were mostly distributed around the "0" value. The superimposed FRFs, averaged over the equivalent rectangular bandwidth (ERB) windows are shown in the bottom plot of Fig. 2. Figures S7 and S8 show alternative methods for analyzing the response functions, which all lead to the same conclusions. In Fig. S10, we report the bridge admittances.

The above analysis surely cannot explain, in full, the complexity of the perceived timbre of each note (and even less, the preference for a specific violin when played in a concert). In particular, it neglects the aspects such as the time-domain transients and directional characteristics of the sound. However, the spectral features are surely relevant in this case, considering the nature of the chosen stimulus (steady pace and dynamics, no vibrato, very limited frequency range). Moreover, they offer additional objective information, which could be used to assist the process of violin making, e.g., when included in a machine-learning loop (Gonzalez *et al.*, 2021). In our case, the impulse-response measurements clearly highlight some distinctive features, which make the most and least preferred violins B and D substantially different from the reference violin X and each other.

We also controlled for the possible role of loudness in the participants' responses (Fritz *et al.*, 2017; Otcenasek and Stepanek, 2002; Tai *et al.*, 2018). This analysis was made on the audio recording of the behavioural experiment. The violinist was explicitly asked to play all of the violins with the same mezzo forte dynamics throughout the whole listening test. Nevertheless, to rule out a possible cross-effect of the sound power on the rated pleasantness, we computed the root mean square (RMS) of the sound pressure of the performance recordings, which were sampled at 48 kHz in 30 ms, half overlapping time-windows. The RMS levels of all of the violins are shown in Fig. 3. The violins were played at a very similar level during the experiment, and it is reasonable to infer that no violin was preferred just because it sounded louder than the reference violin.

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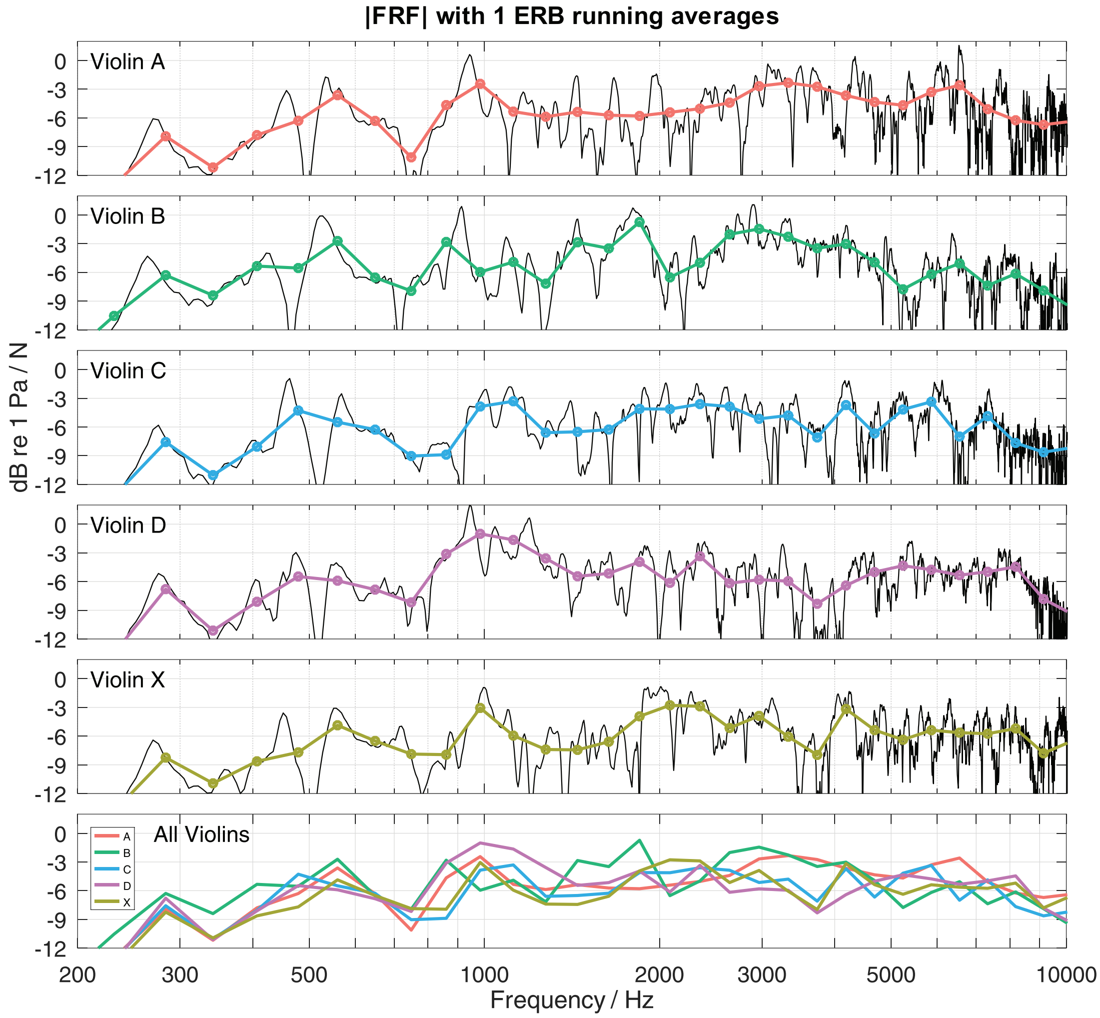

FIG. 2. (Color online) In the four top plots, the thin lines represent the magnitude of the FRFs of the test violins; the thick colored lines represent the responses averaged over the equivalent rectangular bandwidth (ERB) windows (1 ERBN; Glasberg and Moore, 1990). In the bottom plot, the latter responses are superimposed. The averaged response of violin B dominates the band below 0.7 kHz (low range) and between 1.4 and 5 kHz (high range). Violin D is the highest between 0.8 and 1.4 kHz (middle range). Violins C and X are more similar to each other. Violin A has an overall slightly stronger response than violins C and X, especially above 3 kHz (very high), whereas the response is smaller between 2 and 3 kHz (middle).

IV. DISCUSSION

In the present double blind listening experiment, the participants clearly distinguished the violins along several timbral dimensions and the Stradivari violin B emerged as the preferred violin with respect to the reference violin X. Here, the participants listened to (i.e., they did not play) the violins, and the stimulus (i.e., a musical scale) was extremely simple such that the judgments were likely driven only by the timbre of the violin. The participants could focus on the sound and ignore other confounding factors (these factors have no role here) such as the playability of the violin, the feeling at the touch, the visual aspect, etc. Note that, here, in comparison to the individual differences observed in the previous studies (Fritz *et al.*, 2012b; Fritz *et al.*, 2017; Saitis *et al.*, 2012; Saitis *et al.*, 2015), the preference of the participants converged on one particular instrument similar to that in Fritz *et al.* (2014). In addition, the participants agreed about the desired qualities of a good timbre, and their descriptions matched the ratings they gave in the experiment. The most pleasant timbre (violin B) seems to be a good balance of openness, brightness, and nasality (see the additional analysis in the supplementary material).[1] In contrast, the least pleasant timbre (violin D) is closed, dull, and nasal. We sought and found a footprint of these aesthetics in the vibro-acoustical properties of the instruments. Violin B (the preferred one) had the strongest response at the low and high frequencies; in contrast, violin D (the least preferred) was characterized by a pretty narrowband response, peaking in the mid-range frequencies. The frequency responses of violins X and C (which seemed similar to one another along the four timbral parameters) were very similar to each other.

Can the ratings or acoustical analysis explain why violins by Stradivari became and still are a myth? Are some of these instruments a myth because they are tonally superior? It was established that Stradivari, indeed, produced very well crafted and good sounding instruments (a finding stressed also in Fritz *et al.* (2012b), Fritz *et al.* (2014), and Fritz *et al.* (2017), and he is still considered one of the most influential makers of all times, and further and other (i.e.,

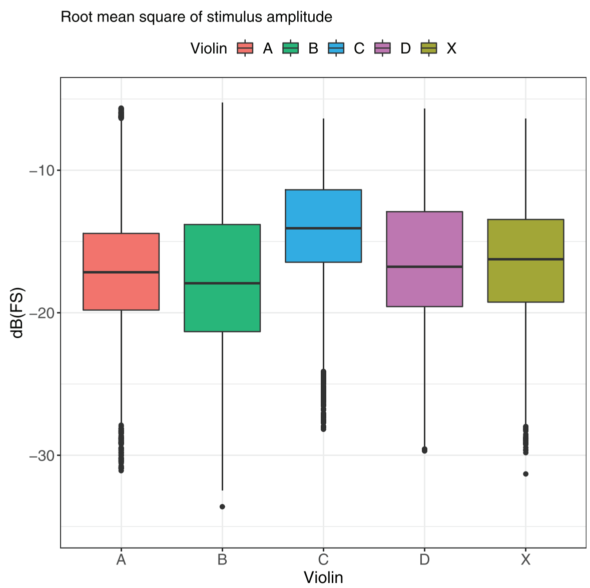

FIG. 3. (Color online) The RMS amplitudes of each violin, calculated from the audio recording of the experiment.

non-sounding) factors are responsible for the myth. For example, there is no doubt that the popularity of the maker was boosted by favourable historical conditions and well-known virtuosi (Giovanni Battista Viotti; see Cattani *et al.*, 2013) in the same way that Jimi Hendrix boosted the popularity of the Fender Stratocaster in more recent years. Noticeably, Stainer (not Stradivari) was the violin everyone aimed to possess at the end of the 18th century when Stradivari instruments were already well known and circulating (Wechsberg, 1973). We may conjecture another factor that may have contributed to the myth: tonally superior specimens. The large preference observed for the Stradivari violin B (but see also violin N2 in Fritz *et al.*, 2012b) suggests that, occasionally, tonally superior instruments may exist. If some of the violins produced by Stradivari were particularly well sounding, these tonally superior specimens might have contributed to spreading a favourable bias on all of the maker's productions (Levitin, 2014) by triggering a heuristic-type of preference toward his instruments (i.e., "Stradivari are tonally superior"). Whatever the reasons why the violins by Stradivari are considered a myth today, the reader should be aware that no study can shed full light on the sonic quality of old Italian or new violins: timbre evaluation depends on the set of stimuli (Thoret *et al.*, 2021). In addition, it makes little sense to judge the violin qualities in classes (e.g., "the violins of Stradivari," "the Amati's violins," "the new violins," etc.): the timbre quality of a violin can only be judged individually regardless of the maker. By the same token, we believe that asking the listeners to distinguish between new and old by sound (Fritz *et al.*, 2012b; Fritz *et al.*, 2014) is not an appropriate question in the same way it would be inappropriate to ask whether a piece of fabric is new or old by touch.

V. CONCLUSIONS

Here, the participants discriminated the sound of the industrial violin from that of the high-end, hand crafted, prestigious companions. Among these latter violins, the participants showed clear preferences for the Stradivari B, which was preferred even against another Stradivari: the reference violin X. The pleasantness ratings seem to be in a relationship with the peculiarities in the timbres of the instruments, which, in turn, seem to be in a relationship with the specific acoustical characteristics of the violins. Our findings support the idea that not all of the instruments are created equal regardless of whether they are made by Stradivari or not. The timbre is an elusive quality of the sound and by focusing on stationary sounds in a very limited range, our results minimized the effect of other confounders on the perceived sound color and contributed to identifying the aspects that make the sound of some instruments particularly appreciated by the listeners.

ACKNOWLEDGMENTS

The authors would like to thank the "Fondazione Museo del Violino" and the "Comune di Cremona" for offering the instruments and the venue, Edoardo Zosi, the violinist, the "Distretto Culturale della Liuteria" and all of the participants who contributed with their ears to this study. We thank Professor Charalampos Saitis for insightful discussions. C.A.R and A.V. initiated this work; M.G. and C.A.R. oversaw the research planning and execution; M.G., M.N., C.A.R., and A.V. designed the methodology for and performed the perceptual experiment; F.A., C.A.R., and A.V. designed the methodology for and performed the physical measurements; M.G., M.N., and C.A.R. analyzed the data; M.G. and M.N. validated the data; F.A. and A.V. provided the study material and laboratory instrumentation; M.N. wrote and maintained the software; and M.G. and C.A.R. wrote the original draft. All of the authors revised and edited the draft. The authors declare no competing interests.

[1]See supplementary material at https://www.scitation.org/doi/suppl/10.1121/10.0009320 or at https://osf.io/aws49/ for an excerpt of the execution of the sound-stimulus, the database, including the raw data collected during the listening experiment, and the *R* code and data for the statistical analysis.

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