

# Soloist evaluations of six Old Italian and six new violins<sup>1</sup>

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## Abstract

Many researchers have sought explanations for the purported tonal superiority of Old Italian violins by investigating varnish and wood properties, plate tuning systems, and the spectral balance of the radiated sound. Nevertheless, the fundamental premise of tonal superiority has been investigated scientifically only once very recently, and results showed a general preference for new violins, and that players were unable to reliably distinguish new violins from old. The study was however relatively small in terms of the number of violins tested (six), the time allotted to each player (an hour), and the size of the test space (a hotel room). In this study 10 renowned soloists each blind-tested six Old Italian violins (including five by Stradivari) and six new during two 1h15 sessions – the first in a rehearsal room, the second in a 300-seat concert hall. When asked to choose a violin to replace their own for a hypothetical concert tour, six of the ten soloists chose a new instrument. A single new violin was easily the most-preferred of the 12. On average, soloists rated their favorite new violins more highly than their favorite old for *playability*, *articulation*, and *projection*, and at least equal to old in terms of *timbre*. Soloists failed to distinguish new from old at better than chance levels. These results confirm and extend those of the earlier study, and present a striking challenge to near-canonical beliefs about Old Italian violins.

## Significance Statement

Some studies open new fields for investigation; this study attempts to close a perennially fruitless one – the search for the “secrets of Stradivari.” Great efforts have been made to explain why instruments by Stradivari and other Old Italian makers sound better than high-quality new violins, but without providing scientific evidence that this is in fact the case. Doing so requires that experienced violinists demonstrate (under double-blind conditions) both a general preference for Old Italian violins *and* the ability to reliably distinguish them from new ones. The current study, the second of its kind, again **found** that **experienced players** **tended** to prefer **the** new instruments, and **were** unable to distinguish old from new at better than chance levels<sup>2</sup>.

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<sup>2</sup> While it is very clear in the paper that our results only apply to our 10 participants and to the 12 violins we used in this experiment, it was originally less clear in this paragraph. We have therefore modified this sentence to make it more explicit that we do not generalize our results to all soloists, nor to all new and old violins.

Modifications in red have been done after publication, to take into account remarks made by careful readers. As they do not affect any of our conclusions, we decided not to go through the process of sending an erratum to PNAS, which would have been costly in time and money.

The violins of Stradivari, Guarneri ‘del Gesu,’ and other Italian makers of the 17<sup>th</sup> & 18<sup>th</sup> century are widely believed to possess playing qualities that are both immediately discernable to experienced players and not found in new instruments. Over the past two centuries, numerous playing and listening tests have challenged this belief by pitting new violins against old (1,2,3). Though results often favored new instruments, the tests typically lacked sufficient rigor for the results to stand as scientific evidence.

It is only recently that well controlled studies of player-preference have appeared in the literature (4,5,6). In a 2010 double-blind test held in a hotel room at the International Violin Competition of Indianapolis (4), 21 experienced violinists compared three new violins with two by Stradivari and one by Guarneri ‘del Gesu.’ Results showed that the most-preferred violin was new, the least-preferred was by Stradivari, and players seemed unable to tell whether their most-preferred instrument was new or old. However, the small number of violins and brief evaluation periods (less than an hour for each player) left many questions unanswered, the most obvious being whether results would hold with a larger set of test violins, a different group of players, longer evaluation periods, and more true-to-life test conditions.

While the Indianapolis study focused on player-preferences, violin quality can be judged from several other relevant points of view – including those of listeners, colleagues in an ensemble, recording engineers, and orchestral conductors. There is no *a priori* reason to assume that all should agree, or that one party’s preference is more “correct” than the other. For example, a violinist might prefer an instrument that is the easiest or most inspiring to play, while listeners choose another because it carries better in a hall.

That said, violinists have at least two advantages over their audiences when evaluating instruments. They are inside a feedback loop, and so base their judgments upon interaction rather than passive listening. They are also very close to the instrument, where its sound is most intense and least colored by room modes. And in the end, it is violinists who choose their instruments, and whose judgments are therefore most consequential.

The current study was designed to re-test the Indianapolis findings with a larger number of violins, and then explore how well judgments carry from a small venue to a larger one. Where the Indianapolis study relied on 21 players of various levels, this study concentrated on the judgments of 10 renowned soloists. Blind and double-blind tests were conducted in both a small rehearsal room and a concert hall, with the option of piano accompaniment and listener feedback in the latter.

## **Materials and methods**

### **The team**

Though it is unusual to describe the team, given the nature of this experiment we believe it important to provide some details. Designing an ecologically valid experiment that answers questions relevant to the violin world requires a variety of experts with differing interests. The team thus included several scientists, a violin maker and researcher who builds and sells new violins, a violin soloist who owns and plays an Old Italian violin, a professional violist and instrument dealer who owns several old Italian instruments, and a string engineer and amateur violinist who owns and plays an Old Italian violin.

### **General design**

The experiment was designed around the hypothetical premise that each soloist was looking for a violin to replace his or her own instrument for an upcoming solo tour. Tests were structured to emulate as far as possible the way a player might do this in real-life. Typically, a number of instruments are informally tested at a violin shop, then one or more are taken away

for testing in other contexts – almost certainly including a concert hall, with one or more colleagues present to give feedback. We decided to allow the soloists the greatest possible freedom to test instruments as each saw fit, believing this would give the most meaningful results – as opposed to standardizing interactions between players and test instruments (e.g., by requiring players to spend the same amount of time with each instrument, or to play the same musical excerpts on each), which would however have the advantage of eliminating some variables.

We believed that 12 violins (6 old, 6 new) would allow a nice variety of instruments, yet still be manageable for the players. In a real-life situation, players would rarely be presented with so many instruments at once, but in the authors' experience, players tend to quickly eliminate instruments they find unsuitable, then spend more time on those that seem a better fit. We polled nine soloists (by means of a questionnaire sent prior to the experiment) about the time needed to comfortably evaluate instruments within the context of the experiment (i.e., choosing from among 12 violins a replacement for their own for an upcoming tour). Their average estimate was 50 minutes, with a standard deviation of 30 minutes. In light of this, each soloist was scheduled for a pair of 1:15 hour sessions, each held on a different day in a different venue (see section 'Venues'). Before each session they were given written instructions (*SI text*). After their first session they were interviewed; after the second they answered a brief questionnaire.

When testing violins in real life, players typically use their own bows, which through constant use have become, in effect, extensions of their right arms (5). We therefore asked the soloists to use the bow they normally played, and to use that same bow throughout the study. We are aware that the choice of bow may affect the perceived quality of a violin, and so introduce an unconstrained variable - but so too would asking all players to use a single, unfamiliar bow. To facilitate testing, we provided players who used shoulder rests with additional ones of the same model.

During both sessions, soloists wore modified welders' goggles, which together with much-reduced ambient lighting made it impossible to identify instruments by eye. The fact that the new violins had been antiqued helped eliminate any tactile clues to age, such as unworn corners and edges. It was proposed that a dab of scent be placed under the chinrest of each violin in order to mask any distinctive smells. This idea was, however, deemed unacceptable by those responsible for the condition of the old violins, who felt the essential oil might possibly infiltrate the varnish. However, no distinctive smells were detected by the authors, nor were any reported by participants.

Two of the authors (CF, IW) were present during the sessions; they made notes of the subjects' comments, but responded only to confirm what had been said, and to move players from one task to the next. The researchers were seated behind the players, and in any case were scarcely visible to subjects, given the dim light and goggles.

A large, back-lit timer helped participants keep track of the time.

### **Tests instruments**

A pool of 15 new and 9 Old Italian violins was assembled by the authors. The new violins (none of which were used in the Indianapolis experiment) were built by professional makers in Europe and North America, and were between several days and two decades old. Makers were invited to submit only instruments that were "antiqued" (i.e., made to resemble old instruments). The makers agreed not to publicize their involvement in the experiment, and were aware they would never know whether their instrument had been included in the set of twelve test violins. Old violins in the pool included two by Guarneri 'del Gesu' (both made after 1740), six by Stradivari, and one by another well-known 18<sup>th</sup> century Italian master. None of these violins belonged to or were played by the invited soloists. All were loaned on

condition that their identity remain confidential, hence the very general descriptions used throughout this paper.

It was assumed that the parties who loaned instruments had an interest in them sounding their best, and so had them set up and adjusted accordingly. All violins were therefore kept in the exact condition in which they were received. This condition was monitored throughout the study by separate “guardians” – JC for new violins, and TG for old. Other than a slight buzz that developed with one of the new instruments, and the replacement of a reportedly-uncomfortable chinrest on one old violin, none of the instruments presented problems, nor did any soloists report difficulties with set-up or adjustment.

Six old and six new violins were selected from the pool by means of informal blind tests designed to eliminate instruments with the least impressive playing qualities (*SI text*). Just which instruments were included in the final twelve was not revealed to the makers, dealers, collectors, and players who submitted them. None of the test instruments were unusual in terms of size, proportions, or set-up. While not all had the same strings, all had very typical combinations of a steel E-string and metal-wound synthetic-core lower strings.

## **Venues**

The experiment took place at two locations, both on the outskirts of Paris, France. The first was the home of a family of professional string players. The room used was one favored for rehearsals and individual practice. The second was a 300 seat concert hall, well-regarded for its acoustics (*SI text*). An acoustically transparent screen was installed between the stage and the seats, where a small, varying audience included at times soloists not currently involved in a test, authors other than CF and IW, and a few interested outsiders.

## **Violinists**

Where the Indianapolis study involved players of varying levels, including soloists, orchestral players, and amateurs, this study involved only soloists. Though the preferences of players at all levels is potentially interesting, those of soloists were felt to be most important for our purposes due to their high playing standards under widely varying conditions, and their (typically) broad experience playing top-quality violins. We also considered the common belief that it takes a top player to “get the most” out of an instrument, especially in terms of projection. And there is the fact that the real-life choices of soloists have been very important in forming the reputation of individual violin-makers, past and present. To give the experiment maximum credibility, we tried to choose internationally known soloists and/or those who had won major international competitions.

Time constraints limited the number of players we could work with. The old instruments were available for just a few days, and the auditorium for a day and a half. Considering the estimated time (50 minutes on average: see section ‘General design’) required by soloists to choose a single favorite violin from a set of twelve, we judged that giving more time to fewer players would lead to more reliable judgments than would the converse.

In the end, ten soloists (*SI text*) were invited, along with an eleventh who participated in the final session only. Ranging in age from 20 to 62, their combined awards include Avery Fisher career grants (2); first-prizes in the following competitions: Tchaikovsky (2), Sibelius (1), Paganini Competition (1), Long-Thibaud (3), along with many other lesser awards, including a silver medal at the Queen Elizabeth Competition.

While ten soloists may seem a relatively small number, it should be remembered that the world population of players at this level is not large – indeed the combined number of first-prizes awarded in the above competitions in the past 50 years is about 90. Given our selection process, however, the ten soloists can hardly be regarded as a random sampling of this population, and we have no information on how and to what extent they might differ from it.

Consequently, in this paper we consider those ten individuals as our population of interest, and limit ourselves to descriptive statistics (i.e. avoiding confidence intervals and significance tests).

Two of the soloists regularly play new instruments, but have in the past played extensively on violins by Stradivari and/or Guarneri ‘del Gesu.’ A third soloist, who owns and performs on both a Guarneri ‘del Gesu’ and new violins, came to the experiment with a new instrument. The other seven soloists play old violins – including instruments by Carlo Bergonzi, Gagliano, Gobetti, Guarneri ‘del Gesu’, Storioni, and Vuillaume. Soloists were given no information about the test instruments, though the publicity generated by an earlier study [1] may well have led them to expect a comparison between new and old.

### **Detailed procedure**

In Session 1, all twelve instruments were laid out in random order on a table. In the authors’ experience, when players test violins they tend to quickly eliminate those they find unsuitable, and then spend more time with those that seem a better fit. Soloists were therefore given 50 minutes to test the instruments as they wished, with the goal of (1) removing any violins that seemed unsuitable; and (2) choosing the four they liked most, and then arranging these in order of preference. As a reference, and to get a sense of the space, they were instructed to play their own violins first, and then anytime it seemed useful thereafter.

For the last 12 minutes of the session, they were presented with three violins. One was their own. One was their chosen favorite. The other was (unbeknownst to them) their most-favored of the opposite new/old category to their favorite. As one player’s top-four were all from the same category, he was given his two most-favored violins. The soloists were then given 30 seconds to rate each instrument (beginning with their own) on a (continuous) scale from 0 to 10 for (1) *loudness under the ear*; (2) *estimated projection*; (3) *playability*; (4) *tone quality*; (5) *articulation/clarity*, and (6) *overall preference/quality*.

These terms, all commonly used by players when evaluating instruments, were left undefined. Note that unlike the other criteria, loudness under the ear is not necessarily a positive attribute for all players. Note too that while projection can by definition be judged only by a distant listener, players routinely estimate projection when testing a violin – and typically acknowledge (as did many of our subjects) the provisional nature of such estimates, and the need to retest in a large hall with trusted listeners. However, this portion of the study was designed to test the subjective preferences of the subjects under a specific set of conditions, rather than objective qualities of the instruments themselves. Due to space constraints, the table on which the instruments were laid was on the small side; to reduce any risk of damage, the instruments were passed from table to soloist by TG, who wore goggles.

We were interested in how choices made in the rehearsal room carried through into the concert hall, and so all violins (including those rejected in Session 1) were presented again in Session 2, though now divided into three groups: the four favorites (in random order); those rejected during Session 1; and any remaining instruments. It was hoped this would best enable soloists to build upon earlier impressions, as they would in real-life tests.

While their first task was identical to that in the previous session, they had 45 minutes this time, and the option to:

1. ask for feedback from a designated listener chosen before the session – for example, a friend or colleague, HB, another soloist who had already taken the test, or somebody else from the audience.
2. ask HB (who wore goggles) to play a violin for them, while they listened from anywhere in the hall.

3. ask the professional pianist (available at all times) to accompany them or HB for any of the violin/piano excerpts in the portfolio (Franck Sonata: 2<sup>nd</sup> Mvt, Beethoven Kreutzer Sonata: 3rd Mvt and Brahms Sonata # 1:1<sup>st</sup> Mvt).

In the questionnaire sent to the soloists prior to the experiment, we asked the following: “*If you had a dozen instruments to test in an auditorium in order to choose one to replace your own for an upcoming tour, would you need any help? If yes, which one(s) among the three [above] options?*” Of the nine players who replied, option 1 was chosen four times, option 2 seven times, and option 3 three times. We therefore allowed all three options. During the course of the experiment, nine participants used the piano accompaniment, five asked for listener feedback, and three asked HB to play for them.

As in the previous session, soloists were then given 12 minutes to evaluate their favorite violin, their most-favored of the opposite new/old category, and their own instrument, using the same six criteria.

Next they were presented with a series of violins (one at a time, in random order), and given 30 seconds to play each one before guessing what kind of instrument it was. If a soloist was unclear about the meaning of the question, he/she was prompted to guess whether the violin was new or old. The series consisted of:

1. That player’s favorite old violin
2. The player’s favorite new violin
3. An old and a new violin the player found unsuitable
4. The old violin and the new violin that on Day 1 were most often included in top-four lists, and that were on average most highly ranked within those lists.

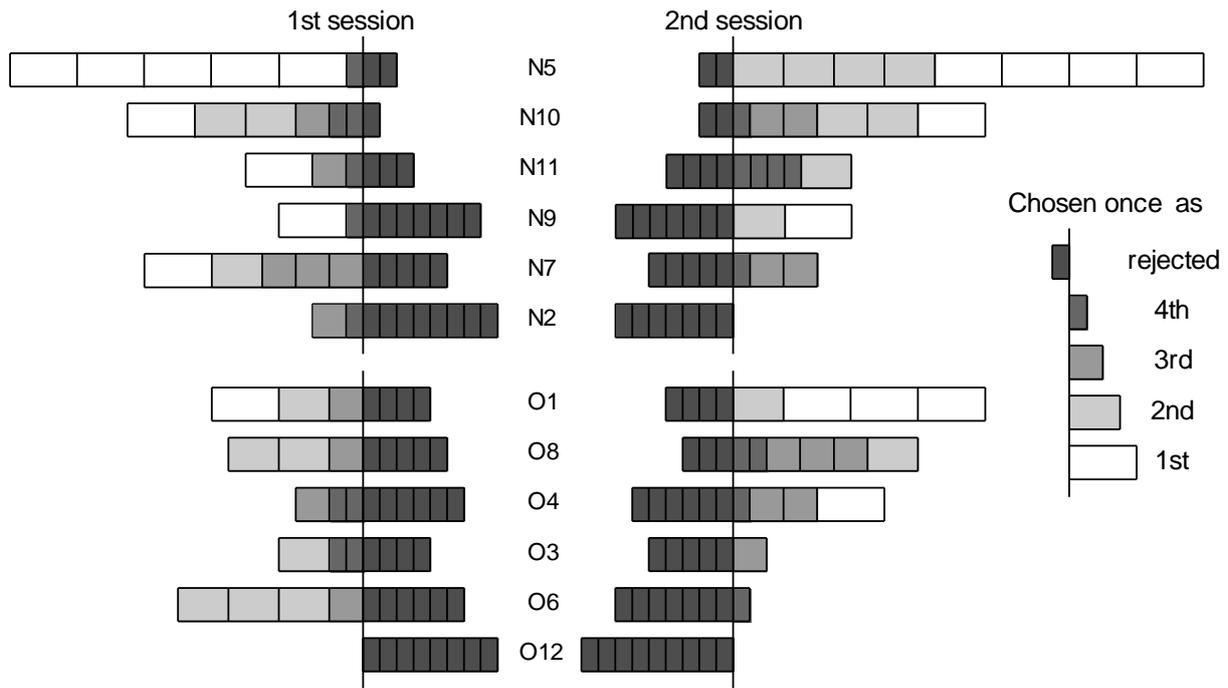
5. The old and the new violin that were most often rejected as unsuitable on Day 1  
If it happened that two of the above criteria described the same instrument, the player was simply given one less instrument to judge. During these sessions, the table size allowed ample space for each violin, and so soloists were allowed to handle the instruments themselves.

## **Results and discussion**

### **Favorite and rejected violins**

Soloists are (almost by definition) individualists, so it is hardly surprising they do not all have the same taste in violins. In this study a large inter-individual variability in preferences (*SI text*) was indeed observed, and this is consistent with the results of previous studies (1, 5, 6).

Fig. 1 shows how often each violin appeared on a soloist’s top-four list, where on that list it appeared, and how often it was rejected as unsuitable. Five of the 12 test instruments were the top-choice for at least one player; 10 were included in at least one top-four list, and all 12 violins were rejected by at least two players. It should be borne in mind that soloists spent very little time with rejected instruments, instead focusing on their favorites. About all that can be said of the least-preferred instruments is that they made a poor first impression on the majority of players.



**Figure 1:** For each session, the number of times each violin was chosen as 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> on a soloists top-four list, and the number of times it was rejected. The horizontal width of each box is proportional to the points scale defined in the description of Table 1.

Preference scores were assigned to each instrument as follows: four points each time it was first on a top-four list, three points for 2<sup>nd</sup>, two points for 3<sup>rd</sup>, and one for 4<sup>th</sup>. A point was subtracted each time it was rejected. Table 1 shows the scores for both sessions.

Violin	Session 1	Session 2
<b>N5</b>	<b>19</b>	<b>26</b>
<b>N10</b>	<b>13</b>	<b>13</b>
<b>O1</b>	<b>5</b>	<b>11</b>
<b>O8</b>	<b>3</b>	<b>8</b>
N11	4	3
<b>O4</b>	<b>-2</b>	<b>3</b>
N7	8	0
<b>N9</b>	<b>-2</b>	<b>0</b>
O3	1	-3
O6	5	-6
N2	-5	-7
O12	-8	-9

**Table 1:** Number of points attributed to each violin in each session. Instruments with Session 2 scores equal to or higher than Session 1 scores are printed in bold. Instruments are listed in order of descending scores in Session 2.

By design, the soloists built on experience gained during Session 1 to arrive at their final choices in Session 2. Here a single new instrument, N5, was easily the most-preferred. It was the top-choice for four soloists, 2<sup>nd</sup>-choice for another four, and rejected just twice, garnering a total of 26 points. Next came N10 with 13 points, the top-choice for just one soloist. Third

was O1, a Golden Period Stradivari, with 11 points. Though it was top-choice for three soloists and 2<sup>nd</sup>-choice for one, it was also rejected four times. At the other end of the scale we see N2 & O12, a new violin and a Stradivari that scored -7 and -9 points respectively, entirely on the basis of rejections.

Other scoring systems produce slightly different rankings. For example, if rejections are ignored, or if top-choice instruments alone are considered, O1 moves up to second place, and N10 (which is on average more popular) moves down to third. O8 seems to appeal to many players, but is never a top-choice. By contrast, O4 and N9 are the top-choice of one soloist each, but are also rather frequently rejected. Still, if a “successful” violin is defined as one that a soloist would use on a concert tour, both O4 and N9 are successful instruments. Their appeal, however, seems rather narrower than that of N5 and O1.

Summing the scores for new and old separately, we get 35 and 4 respectively – almost 6:1 in favor of the new. If rejections are ignored, this changes to 62 and 38, or about 3:2 in favor of the new. Ignoring all but the **four** top-choice violins, it is 24 and 16 – again 3:2 in favor of the new. We can find no plausible scoring system by which the old fare any better than this.

### **Evolution of preferences from rehearsal room to concert hall**

The Indianapolis Experiment was criticized for its use of a relatively small room for testing instruments. As one distinguished violinist remarked, “you don’t test a Ferrari in a parking lot.” While this study does indeed take the instruments out of the parking lot, keep in mind that other factors were almost certainly involved in the observed preference shifts, including:

- more time spent with the violins
- the possibility during Session 2 of playing the violins with piano, and of receiving listener feedback
- intra-individual variability: a player would not necessarily give the same rating if asked to repeat the task under strictly identical circumstances – i.e. if it could have been possible that he/she had forgotten doing it the first time!
- individual violins may or may not have been recognized or remembered across the sessions, so the extent to which Session 2 ratings are affected by those made in Session 1 is not known.

That said, Table 1 shows that the two top-scoring violins from Session 1 do as well or better in Session 2: N10 maintains its score, while N5 gains 7 points. The converse is true for the two lowest-scoring violins, O12 & N2, which lose 1 and 2 points respectively. For instruments at either end of the preference scale at least, impressions formed in the rehearsal room seem to be reinforced in the hall. But for the other instruments – whether old or new – all patterns can be observed. For example, N7 (3<sup>rd</sup> highest score in Session 1) and O6 (tying with O1 for 4<sup>th</sup> highest in Session 1) lose 8 and 11 points respectively, while O1 gains 6 points in Session 2 and moves up from 4<sup>th</sup> to 3<sup>rd</sup>. (The above pattern is very similar with other scoring systems, such as an exponential one, where the top-four violins are given 8, 4, 2 and 1 points respectively, thus weighting in favor of the most-preferred instruments.)

At an individual level (*SI text*), four players chose the same favorite in both sessions. **For two players, their Session 2 favorites had been their 3<sup>rd</sup> choice in Session 1, and for a further player his 4<sup>th</sup> choice.** So in total, **seven<sup>3</sup>** of ten players chose their Session 2 favorites from their Session 1 top-four-lists, suggesting that meaningful testing about general preferences is possible outside a concert hall. Indeed, loudspeaker research (7) shows that within certain limits listeners are quite capable of subtracting the effects of room acoustics from their

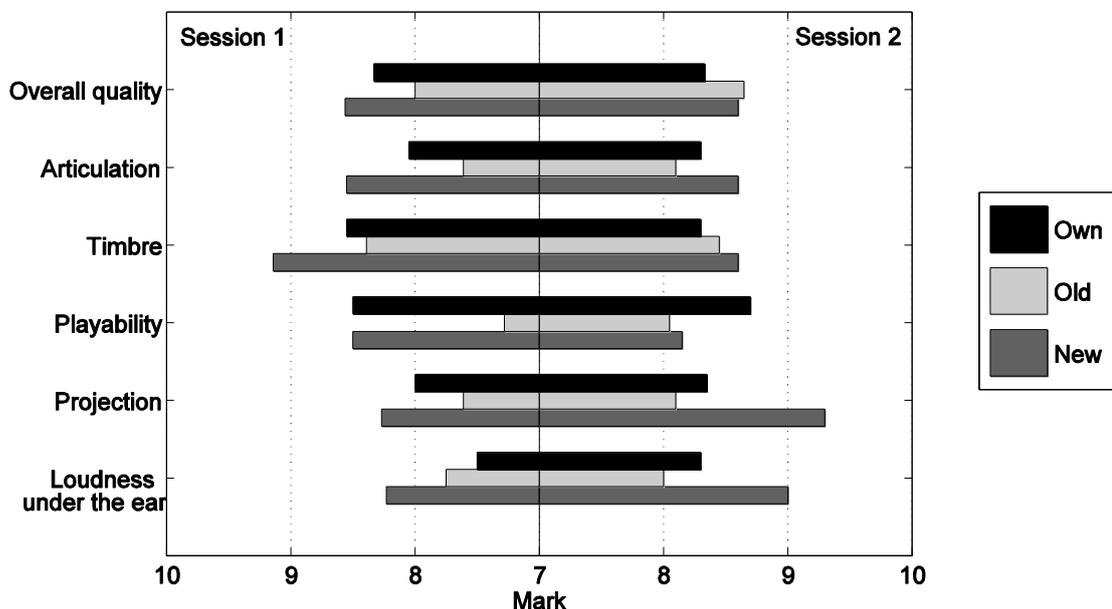
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<sup>3</sup> *Eight* in the original paper. This error was due to one player who could not make up her mind between O1 and N11: She definitely preferred N11 but thought she would be more comfortable on O1 for an upcoming tour the following week. While N11 was among her top-four violins from Session 1, O1 was not. We finally decided to put O1 first in her ranking to be as fair as possible with the old violins.

judgments of loudspeaker quality. Given a few minutes to adjust, they arrive at the same judgments in a wide range of listening environments. The same may prove true when evaluating violins; more research is needed. In terms of old versus new, some old violins score much higher in the hall, as predicted by critics of the Indianapolis study, but then some do worse – and this is true for old and new alike. There is certainly no evidence here to support the belief that Old Italian violins come into their own in concert halls, while new ones fall behind.

### Evaluation by specific criteria

Figure 2 shows the ratings (on a 0-10 scale, averaged over 10 soloists) for each of six criteria: *overall quality*, *articulation*, *timbre*, *playability*, *projection*, and *loudness under the ear*. Each soloist rated their own instrument, their chosen-favorite, and their favorite of the opposite new/old category. In Session 1, 11 ratings are for new violins, and 9 for old, since one player’s top-four list contained only new violins. In Session 2, 10 ratings are for new, and 10 for old.



**Figure 2:** Averaged ratings for each criterion for each category of violin (new, old, own). Session 1 is left of the centerline, and Session 2 is right.

On average, the ratings given to test violins are similar to those given to the soloists’ own, suggesting the two groups are similar in terms of their playing qualities. In both sessions the soloists rate new violins more highly than their own for all criteria except playability. While old violins are rated much lower than both new and soloists-own in Session 1, they almost catch up to the soloists-own in Session 2. Keep in mind, however, that for these averaged ratings, (1) each violin was evaluated by a somewhat different group of soloists in Sessions 1 & 2, and (2) inter-session differences may also be attributable to one or more of the factors mentioned in the previous section.

That said, the improved ratings, in particular for *playability*, for old violins in Session 2 could be taken as support for a commonly-held belief that it takes more time to learn to play an old violin than a new one, or it may be that player judgments are affected by the change from rehearsal room to concert hall – positively for old violins and negatively for new. More evidence would be needed to make a case for either of the above explanations. Easier to understand are the higher playability ratings soloists give their own violins in both sessions:

they have played these instruments for years, and the test violins for some fraction of two hours.

Old Italian violins are commonly believed to project better in a hall than new ones, despite seeming less loud under the ear. Figure 2 shows that the soloists do indeed rate the old lower than the new for *loudness-under-the-ear*, but they also rate them lower for projection. (This of course says nothing about actual projection, as evaluated by listeners).

It is widely believed that new violins may be louder than old ones, but at the expense of tone quality. Our data shows that while the new violins are indeed more highly rated for *loudness-under-the-ear* and *projection*, they are also rated equal to or better than the old for *timbre*. Their perceived advantage in the former two criteria seems to account for the overall preference for new violins, as both categories are rated quite equally on the other criteria.

Critics of the Indianapolis experiment voiced the importance of testing violins in a large space, where the (supposedly) superior projection of Old Italian violins would become evident. While these old and new violins (all of which are favorites) are generally rated more highly for individual criteria during Session 2, the effect is slightly greater for the old violins, but the difference is too small to make a convincing case that Old Italians have any special advantage in the hall, especially since their averaged ratings were lower than new violins (see section ‘Favorite and rejected violins’). Remember too that differences could be related to the other factors listed above.

A surprising result is that while old and new violins have similar ratings for overall quality, the old are on average lower for the other five criteria. Looking at individual results, this can be explained by a single outlier: One soloist gave very high scores to his second-favourite violin (new) for all criteria except overall quality, which received a surprisingly low rating. We have no way knowing why, since a player’s estimate of overall quality is not necessarily the simple average of our five criteria. For example, timbre may be especially important, or loudness under the ear may be a negative criteria. There are also numerous factors outside our criteria that may affect a sense of overall quality, such as neck-thickness, bridge curvature, string heights, type of strings, or wolf notes. Still, if we ignore this player’s data, the overall quality becomes higher for new violins (8.9) than for old (8.5), in total agreement with the averaged marks over the four positive criteria *projection*, *playability*, *timbre* and *articulation* (*loudness-under-the-ear* being potentially negative for some players) – 8.7 and 8.1 for new and old respectively.

It is interesting to put these results into perspective with responses to the question asked at the end of session 1: “*In your experience, are there general differences in playing qualities between new and old violins?*” Seven soloists responded that there are general differences; six of them believe that (in summary):

- 1) New violins are easier to play, speak more easily or more immediately, and are more powerful and “direct” than old ones.
- 2) Old violins may not be powerful enough to play with a modern orchestra
- 3) Old violins have more colors, personality, character, refinement, and are sweeter and mellower than new ones.

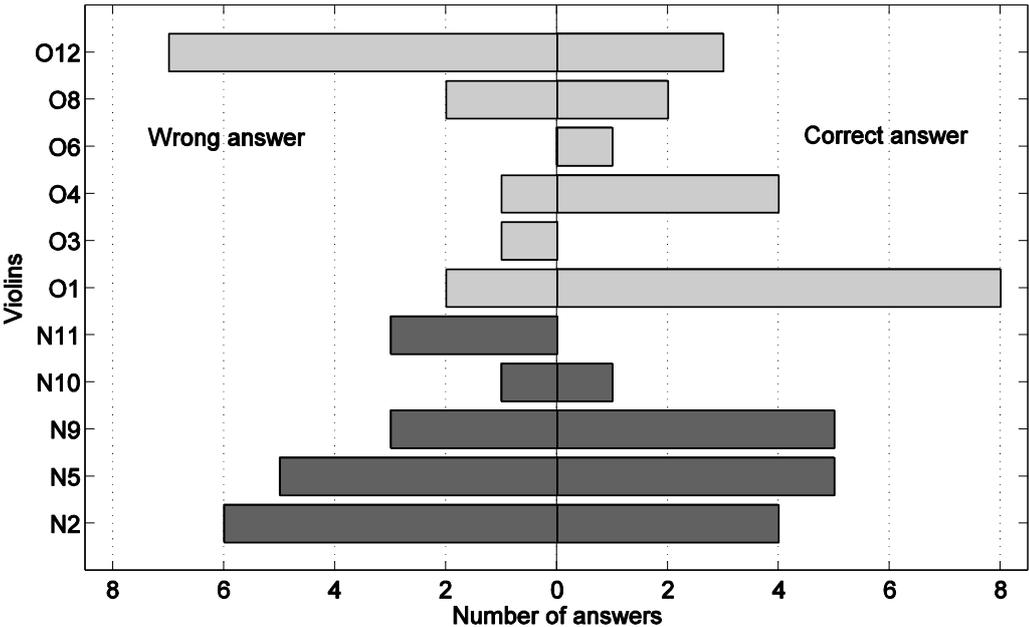
The soloists’ responses are in agreement with the averaged ratings for (1) and (2), but not for (3), at least not if the characteristics listed in (3) can be considered aspects of *timbre*.

### **Old or new?**

Each soloist was presented with a series of violins and, after playing each of them for 30 seconds, was asked to guess what kind of instrument it was. If the instrument was new, a correct guess was “modern,” “new,” or some similarly unambivalent attribution. If old, a correct answer was any that suggested the instrument was an Old Italian, regardless of whether it was attributed to the right maker (thus “Guarneri del Gesu” was considered correct for a Stradivari. Five answers (e.g. “19<sup>th</sup> Century French”) were considered indeterminate.

The soloists played between 6 and 8 violins each, and made a total of 69 guesses – 33 of them about new violins, and 36 about old. Note that these guesses were made at the very end of Session 2, by which time the soloists had typically spent a good deal of time with their more-preferred violins, and very little with rejected ones.

Soloists’ guesses are compiled in Figure 3 and summarized by category of instrument in Table 2. Considering all guesses about all instruments, 33 were wrong, 31 right, and 5 indeterminate. These guesses were rather evenly divided between old and new violins (36 and 33 respectively - see Table 2), so the data rather clearly demonstrate the inability of the players to reliably guess an instrument’s age, whether the instrument is in fact new or old.



**Figure 3:** Soloists’ guesses about the age of each test instrument. Five indeterminate guesses about old instruments are not represented here.

	Correct	Wrong	Indeterminate
New violins	15	18	
Old violins	18	13	5

**Table 2:** Soloists’ guesses about the age of old and new test instruments

Table 3 shows the distribution of right and wrong guesses about the top-choice instruments (i.e., the instrument chosen at the end of Session 2 to replace a soloist’s own). The preponderance of wrong guesses can be attributed to chance, or there may be an easily understandable tendency to believe one’s favorite violin is old. Indeed, out of the seven wrong guesses about top-choice violins, five were due to guessing that three new violins (N5, N9 and N10) were old.

Violin	Wrong guess	Right guess
N5	3	1
N9	1	0
N10	1	0
O1	1	2

O4	1	0
<b>total</b>	<b>7</b>	<b>3</b>

**Table 3:** Wrong and right guesses about the five violins chosen as the single-favorite by at least one soloist

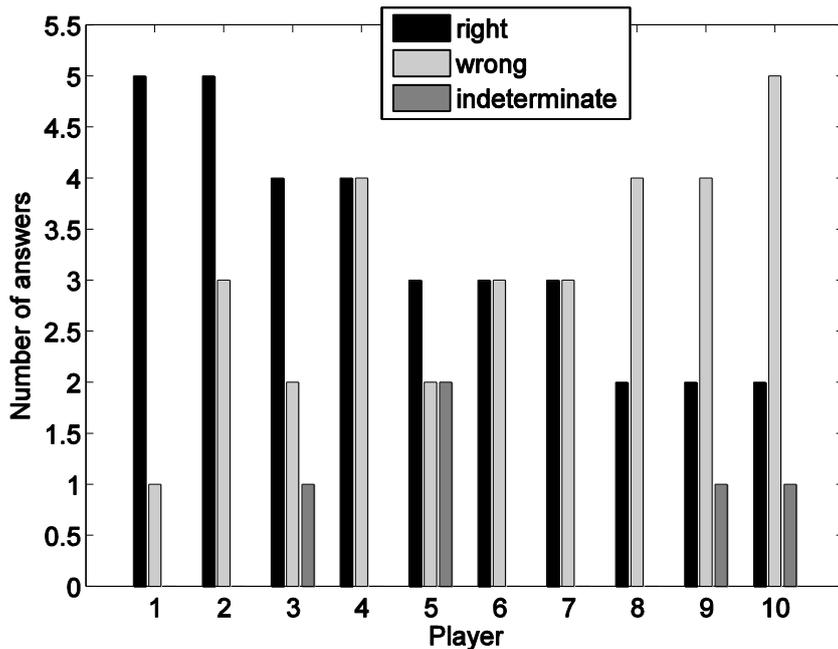
Table 4 shows how the guesses were distributed among (1) rejected, (2) intermediate (i.e., neither rejected by a player nor on his/her top-four list), and top-four instruments. Data for individual soloists are provided in *SI text*.

	rejected			intermediate (neither favorite nor rejected)		top-four			total
	guesse d new	guessed old	?	guessed new	guessed old	guessed new	guessed old	?	
new violins	11	<b>7</b>		0	<b>3</b>	4	<b>8</b>		33
old violins	<b>9</b>	10	4	<b>1</b>	2	<b>3</b>	6	1	36
Total	20	17	4	1	5	7	14	1	69

**Table 4:** Number of guesses about rejected, intermediate, and top-four instruments. Bold type indicates wrong guesses.

Considering now the top-four instruments, 12 guesses were made about new instruments and 9 about old, yet the instruments were guessed-old 14 times and guessed-new just seven – suggesting again a tendency to believe a favorite instrument is old (*SI text*). Given the small size of this study, however, further research is needed to establish whether or not this effect is real.

While one might expect a converse tendency to believe that rejected instruments are new, the evidence for this is very weak. Though O12 was guessed-new seven times and guessed-old just three times, N2 was guessed-old five times and guessed-new three times. And of the 37 guesses made about rejected violins (18 about new and 19 about old), 20 are guessed-new and 17 guessed-old.



**Figure 4:** Number of indeterminate, wrong, and right guesses made by each soloist

Figure 4 compares the number of right and wrong guesses made by each soloist. One soloist had five right and one wrong, while another had five wrong, two right, and one indeterminate. The other soloists were somewhere in between, including three with an equal number of right and wrong guesses. Without further testing, it is not possible to know the extent to which the results of any given soloist are due to skill or to chance.

### Soloist confidence in the validity of the protocol

After each session, the soloists answered a series of questions (*SI text*) pertaining to their confidence in the choices they made, and how these might carry over into a real-life situation. Their answers (summarized in *SI text*), indicate that most of the soloists found the sessions in the rehearsal room and concert hall quite sufficient for choosing an instrument for an upcoming tour – but not for purchasing one. We freely admit that meeting all requirements for a real-life violin search would have been quite impossible within the course of an experiment!

### Conclusions

The nominal premise of this study was that soloists choose from among six new and six Old Italian violins one that might plausibly replace their own violin for an upcoming tour. After evaluating the instruments first in a rehearsal room and then in a concert hall, six soloists chose new violins and four chose Stradivaris. A single new violin was chosen four times, a single Stradivari three times, and two new violins and a Stradivari once each.

Preference scores were assigned to each instrument based on its placement in top-four lists compiled by each soloist, and by how often the instrument was rejected as unsuitable. By this measure, new violins out-scored old by almost 6:1. If rejections are ignored, or if only the five violins that were the favorite of at least one soloist are considered, the ratio drops to about 3:2. But no matter how results are tallied, it is clear that among these players (seven of whom regularly play Old Italian violins) and these instruments (five of which were made by Stradivari), there is an overall preference for the new.

Ratings for individual quality criteria suggest this preference is related mainly to better *articulation*, *playability*, and estimated *projection* – but without trade-offs in *timbre*. New violins were on average more highly rated for *loudness-under-the-ear*, and while this is not

necessarily a positive attribute for all players, instruments more highly rated for *loudness-under-the-ear* were also more highly rated for (estimated) *projection* – an unquestionably positive criterion for soloists.

By the end of their time in the hall, eight of ten the players chose an instrument that was one or their top-four in the rehearsal room. While no one would propose that real-life instrument searches should rely entirely on impressions formed in a small room, these results do suggest that meaningful testing about general preferences can be conducted outside a concert hall. There remains the important question of how well player-preferences correlate with those of listeners, particularly with regards to projection in a hall – the topic of a forthcoming study.

Soloists readily distinguished instruments they liked from those they did not, but were unable to tell old from new at better than chance levels. This emphatically confirms the findings of the Indianapolis experiment – and indeed many informal listening tests conducted over the years.

There is no way of knowing the extent to which our test instruments (old or new) are representative of their kind, so results cannot be projected to the larger population of fine violins. But given the stature and experience of our soloists, continuing claims for the existence of playing qualities unique to Old Italian violins are strongly in need of empirical support.

### **Acknowledgements**

We would like to thank all dealers, makers, players, and collectors for their kindness and trust in making available these valuable instruments. Special thanks go to the ten soloists for their participation, enthusiasm, and patience! We would also like to acknowledge the pianist Emmanuel Christain for his enthusiasm and endurance, Philip De La Croix and Stéphane Agasse for the use of the auditorium, and their logistical help, and the Borsarello family for their extraordinary hospitality. Thanks too to David Griesinger, Stefan Avalos and Suzanne Ortmeier for their kindness and help throughout the experiment, and to another soloist and another maker for their help during the preselection process. And finally, we are grateful to the CNRS and Université Pierre et Marie Curie for funding this experiment, and to the Violin Society of America for their additional financial support.

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## Supplementary information

### Written instructions for players, session 1

#### Part 1: 50 minutes

*Imagine you are looking for a violin to replace your own for recitals and concerto performances in an upcoming tour. We will present you with a variety of instruments for evaluation. Please use your regular bow, and a shoulder-rest if you use one. And please feel free to comment out loud about the selection process.*

*We have twelve violins for you to try. Here they are, laid out in random order, plus your own on the far right. Each violin has a number on the scroll - and will have this same number throughout the experiment, to help as all keep track of which is which. Your own violin will always be placed on the far right.*

*You have 50 minutes to:*

- 1) Place on this empty table to the left any violins you feel are not suited to you.*
- 2) From the remaining violins, choose the four you like most and put them on this empty table here on the right.*
- 3) Arrange these 4 instruments from left to right, in order of increasing preference.*

*To get a feel for the room, you may want to start with a few notes on your own violin, which you can also use as a reference any time you like.*

*You will have a chance to play all these violins in the hall tomorrow, and you may then revise your choices. But for now, go by how the instruments sound and feel to you in this room.*

#### Part 2: 12 minutes

*Instructions will be given orally in due course.*

### Written instructions for players, session 2

#### Part 1: 45 minutes

*Once again, imagine you are looking for a violin to replace your own for recitals and concerto performances in an upcoming tour. Please use the same bow you used yesterday, and feel free to comment out loud about the selection process.*

*Here are the 12 instruments you tested yesterday. Those you thought unsuitable are on the far left. In the center are those that didn't make it into the four favorites. To the right are the four favorites in the order you arranged them. Your own violin is on the far right.*

*Based on how the instruments sound here in the hall, please take 45 minutes to*

- 1. Remove those not suited to you (though not necessarily the same ones as yesterday), and put them on the empty table to the left.*
- 2. From the remaining violins, choose the 4 you like most and put them on this empty table on the right.*
- 3. Arrange these 4 instruments from left to right, in order of increasing preference*

*To get a feel for the hall, please start with a few notes on your own violin, then test the violins in any way you like.*

*Feel free to ask for feedback from your designated listener, if you chose one: the friend you came along, or Hugues Borsarello or somebody else in the audience.*

*If you would like Hugues to play a violin for you, place it on this small table. You may then listen from anywhere in the hall.*

*If you would like Hugues to compare two instruments, place them both on the table, and refer to the violins with the number which is visible on the chinrest To protect the identity of all instruments, Hugues will be wearing goggles.*

*Our pianist is happy to accompany you or Hugues for any of the violin/piano excerpts in the portfolio.*

#### Part 2: 12 minutes

*Instructions will be given orally later.*

**Part 3: 7 minutes**

*Instructions will be given later.*

**Oral instructions for players,**

**Part 2 (session 1 and 2)**

*Here are three violins – your violin on the right, your chosen favorite in the center, and your 2<sup>nd</sup> (or third or least) favorite on the right.*

*Starting with your violin, rate each instrument on a scale from 0 to 10 for loudness under the ear, estimated projection, playability, tone quality, articulation/clarity and overall preference/quality.*

**Part 3 (session 2 only)**

*We will now present you with a series of violins one at a time in random order. Play each for 30 seconds then guess what kind of instrument it is.*

**Pre-selection of the instruments**

We assembled a pool of thirteen new violins (from professional makers around the world) and nine distinguished Old Italians, including six by Stradivari (made between 1710 and 1730) and two by Guarneri del Gesu (circa 1740). Twelve test instruments were chosen from these, using a double-blind process involving two soloists, one being HB. Neither soloist was a subject in the experiment-proper, and neither had any contact with the instruments prior to the pre-selection. Each soloist was asked in turn to demonstrate the instruments, and to form their own judgments while doing so. Also judging was a panel of listeners consisting of the other soloist, the authors, and a renowned violin-maker not otherwise involved in the experiment. The pre-selection took place in an approximately 40m<sup>2</sup> room with pleasant acoustics.

The violins were divided in three groups, one containing the nine Old Italians, one a random selection of seven new violins, and the third the remaining six new violins. The procedure for each group was as follows: One of the soloists donned goggles and stood behind an acoustically transparent screen, so neither he nor the listeners could recognize the violin being played. The violins from the group were then presented (in random order) to the soloist, who played a brief excerpt on each instrument. He then replayed the instruments in the same order with a second then a third excerpt. (The excerpts were short passages from the Tchaikovsky, Brahms and Mendelssohn concertos.) This entire process was repeated by the second soloist.

The goal of the procedure was to eliminate three instruments from the first and second groups, and two from the third group. This was done by averaging the votes of the players and listeners, each of whom submitted a simple yes-or-no vote for each instrument. The results (which showed good agreement among all parties) yielded six old violins and eight new violins. A further iteration of the process reduced the eight new violins to six.

**Auditorium Jean-Pierre Miquel (Coeur de Ville) in Vincennes**

This 300 seat auditorium was built in 2001 by architect Henri Gaudin, in Vincennes, on the outskirts of Paris (France). It is renowned for its excellent acoustics.

**The soloists**

The ten soloists were (in alphabetical order): Olivier Charlier, Pierre Fouchenneret, Yi-Jia Susanne Hou, Ilya Kaler, Elmar Oliveira, Tatsuki Narita, Solenne Païdassi, Annick Roussin,

Giora Schmidt, and Stéphane Tran Ngoc. They were thus divided in 7 males and 3 females, and their mean age was 41 years (std = 14 years). All started playing violin between the age of 3 and 7.

Charlier, Fouchenneret, Hou, Narita, Paidessi, Roussin and Tran Ngoc brought the old violins they use regularly, while Kaler and Schmidt brought the new violins they use regularly. Oliveira currently divides his time between a Guarneri del Gesu and a new violin, and brought the new one.

The soloists, who came from Europe or North America, were reimbursed for travel expenses and accommodation, but received no other compensation.

### Preferences of individual players

Table S1 summarizes how each player evaluated and categorized the twelve violins, in both sessions.

Player	Session	Top-four violins (in order of descending preference)	Intermediate violins	Rejected violins
1	1	N5, O1, O4, N10	O3	N2, N7, N9, N11, O6, O8, O12
	2	N5, O1, N10, N11	O3	N2, N7, N9, O4, O6, O8, O12
2	1	N5, N7, N10, O3		N2, N9, N11, O1, O4, O6, O8, O12
	2	N10, N5, O8, N11		N2, N7, N9, O1, O3, O4, O6, O12
3	1	N7, O6, N2, N11	N5, N10, O1, O8	N9, O3, O4, O12
	2	O1, N11, N7, O8	O3	N2, N5, N9, N10, O4, O6, O12
4	1	O1, N10, N7, O4	O12	N2, N5, N9, N11, O3, O6, O8
	2	O4, N10, O8, N7	O1, O12	N2, N7, N9, N11, O3, O6
5	1	N5, O3, O8, N10	N11, O12	N2, N7, N9, O1, O4, O6
	2	N5, N10, O3, O8		N2, N7, N9, N11, O1, O4, O6, O12
6	1	N10, O6, N7, N9	N11	N2, N5, O1, O3, O4, O8, O12
	2	N5, N9, O4, N11	N7, N10, O6, O8	N2, O1, O3, O12
7	1	N5, O6, O1, O4	N10, N11, O3, O8	N2, N7, N9, O12
	2	O1, N5, O4, O6	N2, N7, N11, O3	N9, N10, O8, O12
8	1	N11, N10, N7, N2	N5, N9, O1	O3, O4, O6, O8, O12
	2	O1, N5, N7, N11	N2, N10	N9, O3, O4, O6, O8, O12
9	1	N5, O8, N11, O3	N10, O1, O4	N2, N7, N9, O6, O12
	2	N5, O8, N10, O4	N2, N9, O1, O3	N7, N11, O6, O12
10	1	N9, O8, O6, N5	N11, O3	N2, N7, N10, O1, O4, O12
	2	N9, N5, O8, N10	O6	N2, N7, N11, O1, O3, O4, O12

**Table S1:** Preferences of individual players. The numbering assigned to the players is the same as in Figure 4 (players ordered by decreasing number of correct answers to the “old versus new” question).

### Old versus new guesses

Table S2 summarizes all individual results – i.e. shows the old/new guesses of each player about each violin, and indicates the position of each violin in the ranking of that player.

Violin	Player	Guesses			Preference category		
		Old	New	?	Rejected	Intermediate	Top 4 list
N2	1		X		X		
	2	X			X		
	3	X			X		
	4	X			X		
	5		X		X		
	6		X		X		
	7	X				X	
	8	X				X	
	9	X				X	
	10		X		X		
N5	1		X				X
	2		X				X
	3		X		X		
	4		X		X		
	5	X					X
	6	X					X
	7	X					X
	8		X				X
	9	X					X
	10	X					X
N9	1		X		X		
	2		X		X		
	3		X		X		
	4	X			X		
	5		X		X		
	7		X		X		
	8	X			X		
	10	X					X
N10	2	X					X
	4		X				X
N11	3	X					X
	9	X			X		
	10	X			X		
O1	1	X					X
	2	X			X		
	3	X					X
	4	X				X	
	5	X			X		
	6	X			X		
	7	X					X
	8		X				X
	9	X				X	
	10		X		X		
O3	5			X			X
	6		X		X		
O4	1	X			X		

	<b>2</b>	x			x		
	<b>3</b>			x	x		
	<b>4</b>		x				x
	<b>5</b>			x	x		
	<b>6</b>	x					x
	<b>8</b>	x			x		
	<b>10</b>			x	x		
<b>O6</b>	<b>4</b>	x			x		
	<b>9</b>			x	x		
<b>O8</b>	<b>2</b>		x				x
	<b>7</b>		x		x		
	<b>9</b>	x					x
	<b>10</b>	x					x
<b>O12</b>	<b>1</b>		x		x		
	<b>2</b>	x			x		
	<b>3</b>	x			x		
	<b>4</b>		x			x	
	<b>5</b>		x		x		
	<b>6</b>		x		x		
	<b>7</b>	x			x		
	<b>8</b>		x		x		
	<b>9</b>		x		x		
	<b>10</b>		x		x		

**Table S2:** Old versus new guesses for each violin and each player. The numbering of the players is the same as in table S1.

Statistical analysis: Because our population of interest is the ten soloists, there is no question of inferring their results to a larger population. But what if their new/old guesses were governed entirely by chance, so that the soloists were in effect tossing coins? All guesses would then be independent one from each other – both from one soloist to the next, and among the guesses of each soloist. In this case, the number of correct guesses would be distributed as a binomial distribution with parameter  $n$  being the total number of guesses (10, 64, or 69, depending on the case, see below), and parameter  $\pi = 0.5$  being the probability of a correct guess. This would constitute the null hypothesis, and the following inferences can then be made.

- Considering only the 1<sup>st</sup> choices (3 right guesses, 7 wrong):  $p$  (two-sided) = 0.34; 95% CI for  $\pi$  : [0.07; 0.65].

- Considering all guesses (33 right, 31 wrong, 5 indeterminate).

When excluding the 5 indeterminate guesses (33 right, 31 wrong):  $p$  (two-sided) = 0.90; 95% CI for  $\pi$  : [0.39; 0.64].

To deal with the indeterminate guesses, we can consider the two extreme situations (all indeterminate guesses are considered correct guesses, or all indeterminate guesses are considered wrong guesses):

38, 31 :  $p$  (two-sided) = 0.47; 95% CI for  $\pi$  : [0.43; 0.67].

33, 36 :  $p$  (two-sided) = 0.81; 95% CI for  $\pi$  : [0.36; 0.60].

So that, in any case, the chance hypothesis cannot be ruled out.

It should be emphasized that these inferences concern the (virtual) population of infinite repetitions of the same task by these ten soloists under exactly the same conditions, which implies (among other things) the absence of any kind of memory effect.

## Questionnaires and summary of the answers

First questionnaire (after session 1)

<i>About how long would you need to play a violin in order to get a good impression of its overall quality?</i>	Answers ranged from a minute to a few months, depending on the violin
<i>In what contexts would you need to play it</i>	A variety of contexts needed, including home practice, performance of a sonata or concerto, and testing in both a small room and a large hall (preferably 1500+ seats)
<i>How long did you play the violins you have owned before deciding to purchase them?</i>	Varied between 20 min and 6 months, with an average of 1 month, and a standard deviation of 2 months.

Second questionnaire (after session 2):

<i>Do you think this space was useful / appropriate for testing violins?</i>	10 positive answers, ranging from <i>very good</i> to <i>perfect</i> , going through <i>wonderful</i> , <i>excellent</i> , <i>generous</i> and <i>great</i> .	
<i>Did you have enough time with the instruments?</i>	6 positive answers, ranging from <i>more or less</i> to <i>plenty</i> .	4 negative answers (one would have asked for two days)
<i>How confident are you in the choices you made?</i>	8 x confident, ranging from <i>pretty / quite</i> to <i>very</i> . 2 soloists specified that this was for their first or top-four choices, but less true for the others 1 x limited confidence due to lack of time. 1 x no answer.	
<i>If this were a real-life search, what further tests would you do with the instruments?</i>	6 x Spend more time / play for a few days / play on a daily basis 5x Play in a bigger hall / other halls 3x Play in concert (with orchestra and audience) 1x Play with other string instruments 1x Play in different climates and temperatures 1x Ask other external ears 1x See it! 1x Try different bows to find one that maximizes tone quality	