Discernment of the Sound of a Violin

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Abstract: - Professional players project personality into the generic sound of a violin. Appositely, outstanding violins have measurable properties, some described subjectively, that differentiate violins apart independent of player. The relative contributions that skill of the player and quality of instrument make to outstanding performances is widely debated. However, an outstanding performance invariably involves both a top player and instrument. This paper reports on testing the hypothesis that high quality violins as a cohort have distinctive sounds that differentiate instruments apart and help define their contribution to performance. Comparative studies to test the hypothesis require sameness in player and in work performed whilst changing the instrument and also a need for descriptors used to be relevant, meaningful and comprehensive. A set of recordings has been used in semantic differential tests to discern between sound properties of violins. The recordings were made on instruments that span the making years of both A Stradivari and G Guarneri Del Gesu and already judged very successful samples of the makers' crafts. Two groups of listeners were used, tertiary level music students and professionals, all players of classical instruments. Of the twelve violin samples used, students had significant difficulty in identifying them apart. Professionals were able to hear more distinctively than students, sometimes to a significant extent. A cluster analysis was conducted on the listening results for both groups. Neither the professionals nor students gave answers that clearly distinguished violins made by A Stradivari from those made by G Guarneri Del Gesu in the limited sample used. The generic sound of each violin was also measured by looking at the overtone peaks in the playing of a D6 harmonic. A cluster analysis conducted on their magnitude ratios up to the 10^{th} harmonic was surprisingly similar to that obtained from the student results but less similar to the professional clustering. This may shed light on what it is that professional players hear that is different from the so-called generic violin sound that students seem to be hearing. Correlation checks on violins and descriptors used showed that most but not all the violins were differentiated apart by use of descriptors and some redundancy existed between descriptors.

Key-Words: - Violin sound generic timbre semantic differential measurements cluster analysis harmonics

1 Introduction

In listening to violin sounds, even amongst musicians, no common ground appears on relevant descriptors or categorisation including differences between objective and subjective judgement and their relative importance. Describable sounds are not necessarily measurable and differentiation that is easily measured instrumentally can be non-discernable to the ear. In testing the hypothesis, we first reviewed descriptors for sound used by luthiers, performers and in parametric sound studies, looking for commonality. Secondly, with a chosen set, a test was conducted to see how well the individual sounds of the violins could be discerned by two groups of listener, tertiary level music students and international professional players, all classically orientated. Thirdly, the generic sound of each violin was measured acoustically by determining the peak heights of all overtones up to the 10^{th} when a D6 harmonic was played. Fourthly, cluster analysis was conducted on the two listener results and on the harmonic results to see how the violins could be differentiated apart. Lastly correlation coefficients were obtained both within descriptors and between violins for professional listener results alone to check if descriptors had notable redundancy and whether the violins had been adequately differentiated apart.

2 Sound Samples

Recordings on instruments made by Antonio Stradivari and Giuseppe Guarneri Del Gesu have been obtained. The opening of the first movement of the *Violin Concerto Opus 47* by Jean Sibelius (1865-1957) given by the same player was made on thirty different instruments [1]. The violins are all well-known and revered for their sound qualities which have been described with a wide variety of expression. Elmer Oliviera played all the sound samples and the setting up of the instruments was done by the same luthier, John Becker [1]. The choice of D6 as the harmonic was directly linked to its presence in the recordings used.

3 Sound Categorisation

Luthiers have a range of measurable sound properties of a violin they try to optimise [2][3]. They have continually hypothesized sets of quality parameters containing subjectivity, including tonal qualities, playability and suitability to repertoire [4]. They would claim that major properties are prescribed by setting of the A1-B1 modes [5][6], the use of Bi–Tri octave tuning of free plates [7][8] and shaping of the B/H hill in the frequency response [9][10]. Further refinement in setting up by tuning fingerboard, tailpiece and bridge resonances also help to define the sound a violin is capable of making [11]. A seminal work on the Stradivari technique of violin making has been compiled by Sacconne [12].

The A1-B1 modal separation determines both harshness of sound and projection. A small A1-B1 separation (<20Hz) leads to a *soft quiet* sound play, a large separation (>80Hz) to a *harsh* sound and an optimum separation of around 60 Hz gives rise to a *resonant, projecting* sound. Bi-Tri octave tuning is regarded as fundamental to making an instrument that has any worthwhile sound quality but hard to correlate parametrically. The shaping of the B/H hill in which there is a dip in the frequency response of the finished instrument at approximately 1 kHz has also been shown to reduce harshness of sound and is present in instruments of revered sound [9].

Ra et. al. attempted to quantify whether the sound of a violin changes or improves with playing [13]. Two violins were tested from construction where one had been played and the other simultaneously stored in a museum for three years. The violins were virtually identical in woods from the same section of the same tree and in their making process. The categories used for assessing sound were *evenness, clarity, projection, character* and *warmth* and are limited in scope. Ra et. al. concluded no significant change in sound had taken place.

A study by Martin and Kim typifies many approaches to trying to categorise sounds of musical instruments [14]. It dwells almost exclusively on correlation between what is heard and forming an objective, physically based taxonomy rooted on spectral and temporal measurements. The test discrimination distinguished between instrument groups and not between instruments of the same type. They discerned the following sound categories to be helpful and comprehensive: *bright, dark, hard, light, soft, natural* and *heavy*, using cluster analysis but used many synonyms in different tests conducted. Darke tried to discover the reliability of verbal descriptions of sound to the actual sound heard working with a subset of European orchestral instrument sounds and 12 verbal descriptors [15]. Working with instruments that had characteristic sounds easily discerned by the ear e.g. to a musical person, an oboe sounds obviously different to a French horn, he examined collective agreement in describing each sound and found it to be only modest between the listeners.

Experimentation concentrating on identification by synthesis is typified by research conducted by Miller and Carterette [16]. Listeners made similarity judgements over a nine-point scale of pairs of sounds similar to musical instruments. However, categorisation was based on terminology such as *fundamental frequency, duration* and *loudness*. The lack of subjective description makes these studies less relevant to the work reported here. Jensen found that in trying to build a timbral model of sounds, the main descriptors or verbal attributes recognised and used were *dull-sharp, compact-scattered, empty-full* and *colourful-colourless* [17].

Lukasik assembled a comprehensive library of sounds of 70 violins ordered to test aspects of sound to readily compare them [18]. It was centered on recording objective measurements only. Geissler et. al. attempted to find, via subjective listening tests, common verbal attributes to violin sound that evoke the same meaning in listeners [19]. A questionnaire found that musicians used the category *timbre* to account for 38% of the significance of violin sound with lesser contributions from *reaction* (19%), *sustain* (13%), *balance* (11%) and *loudness* (9%). In the listening test, descriptors offered were *bright, nasal, pleasant, reaction, balanced, colourful* and *passionate*. They concluded that descriptors *pleasant, reaction, bright* and *balanced* evoked the same response from listeners but *passionate, colourful* and *nasal* evoked different understandings of what was heard and were not reliable categorisations.

Stepanek examined timbre of five different pitches across the violin audio range and offered the descriptors *sharp, narrow, bright, dark, soft, round, gloomy, clear, metallic, delicate, voiced, rustle, damped* and *bleat* in listening tests [20]. Further descriptors were added and a perceptual space devised. A later paper expanded the technique and concluded it was possible to describe violin sound using descriptors *sharp-soft, clear-damped, bright-dark* and *narrow*-(no opposite was offered) [21].

They then tried to relate the descriptors to changes in the frequency spectrum emanating from the violin and discovered relative changes were significantly dependant on pitch. In addition, all tests were with constant pitch sound giving the listener an option to differentiate two sounds heard close together temporally. The test in this report did not rely on relative judgement but on an absolute assessment of sound for each violin irrespective of what else had been heard. The research of Stephanek and his associates highlighted the problem of sounds and timbre changing as a function of pitch and may lead to the necessity of pitch dependant assessment.

All of the descriptors listed above were noted as possible candidates for the test used here. The task of discriminating between violins regarded as the best in the world, made by only two makers in the same golden era, is significantly more difficult than distinguishing between obviously different quality instruments, stationary sounds or pairs of sounds as have been used previously in the papers cited.

Pro-Descriptor	Anti-Descriptor
Smooth	Gritty
Resonant	Muffled
Weak, delicate	Strong, firm, robust
Soft	Loud
Empty	Full
Warm, sweet, mellow	Cold, harsh
Light, elegant	Earthy, heavy, deep, dark
Majestic, flamboyant	Plain, conservative
Penetrates,projects,carries	Weak, boxy
Colorful, sparkle, brilliant	Dull
Interesting, responsive	Boring, uninteresting
Focussed, pure	Diffuse, directionless
I like the sound	I dislike the sound

Fig. 1 Listening test descriptors used.

4 Descriptor Choice

Different interest groups describe musical sound in their own way. Experimenting done by luthiers is meant to perfect a method of making (the process) that reliably gives rise to producing a desired sound (the measurement in the hearing thereof). What remains problematic is that measurement is often embodied in a personal opinion and not in objective scientific method. Hence there is difficulty in choice of descriptors to offer in a parametric sound test. In the experiments reported here, it was not assumed that for every descriptor, there was a physical analogue. Such an assumption would postulate that subjective judgement will always be subsumed into or explained away by, given enough insight and proof, objectivity.

The basis of descriptors used needed to be twofold. Firstly, the listener needed options on sliding scales of discernment rather than polarisation choice. Secondly, some descriptors were multi-descriptive with more than one way offered to describe the same sound. To that end, semantic differentiation with lists of pro/anti descriptors was chosen as the experimental method, where categories may overlap or be substitutionary.

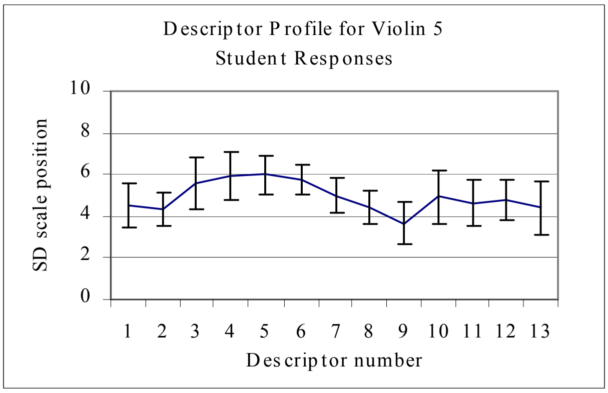
5 Listening Tests

The listening tests used recordings of twelve violins for playing one work, the Sibelius Violin Concerto opening bars covering the full range of pitch of the instrument, all played by one performer. The samples were played to listeners for them to judge the properties of each violin in performance mode assessed and ranked in semantic differential terms between the extremes listed in Fig. 1.

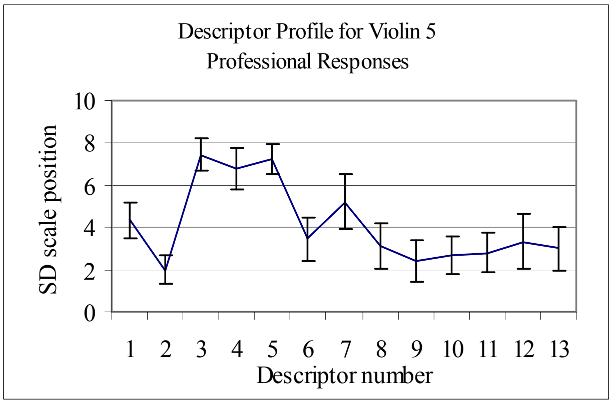
Listeners were also asked to state the confidence of assessment so that this bias could be included as a weighting factor if needed. The test lasted approximately one hour and required significant concentration to discern opinions. The test method was given official approval from the Faculty Human Research Ethics Advisory Panel.

Fig. 2 and Fig. 3 show two typical results of listeners' responses to the twelve violins, subdivided into student and professional groups given with mean and standard deviation per descriptor range. On a scale of 0 to 10, an indication close to 5 could be interpreted at least two ways. Either the sound property was genuinely halfway between the extremes offered or categorisation had less relevance to what was heard. Significant descriptors for an instrument were likely to be indicated when the mean of listeners' results deviated from level 5 on the semantic differential scale position and as the standard deviation reduced toward zero. In this case, the instrument would show a propensity for one extreme of description that would have been corroborated by most listeners.

In examining results, it was found that listeners varied in their confidence levels. The general trends revealed that professional listeners created wider discriminatory ranges than students and, in some cases, with smaller error bars, i.e. there was closer agreement on descriptor usage. There was also a general characteristic curve appearing in results, exemplified most by the professional assessments. The shape of this curve is shown in Fig. 2b and is notably absent in Fig. 3b. The characteristic curve can best be summarised as identifying a violin sound that has the following properties:

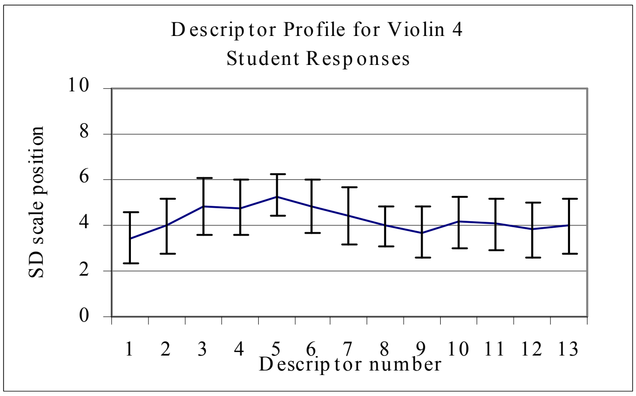


a. student responses

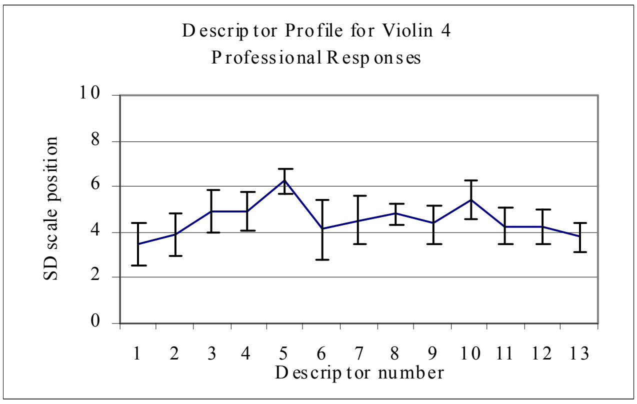


b. professional responses

Fig. 2 Listening test results for violin no. 5 , The King Joseph, made by Giuseppe Guarneri Del Gesu in 1737 where a characteristic response curve was present in the professional result and to a lesser extent in the student result.



a. student responses



b. professional responses

Fig. 3 Listening test results for violin no. 4, The Muntz, made by Antonio Stradivari in 1736 where no characteristic curve was present in either result and no agreement between student and professional listeners was evident.

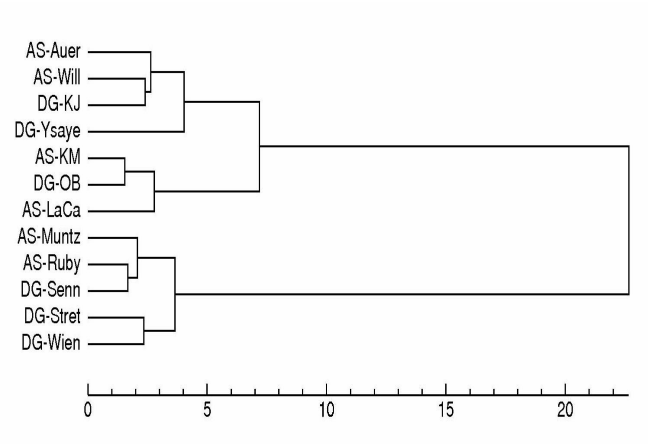
resonant, firm, loud, full, majestic possibly also smooth and *warm.* Occasionally there was strong agreement amongst professionals in the descriptor *loud*. Few student results showed any characteristic curve present and much of the time, had a standard deviation in excess of 2. Also, at the same time, there was little deviation from level 5 indicating no significant consensus on how to describe the sound heard. However, it was interesting to note that a student result was often a less pronounced version of the professional result for the same violin (see Fig. 2a and Fig. 2b).

It was noted that the more a characteristic curve was present, the more student and professional results appeared to agree i.e. the more distinctive the sound the more easily student listeners could categorise what they heard. Another aspect to making this judgement could be that when results gave rise to categorisation midway on the semantic differential scale, listeners were effectively uncertain and a degree of arbitrariness crept into the responses.

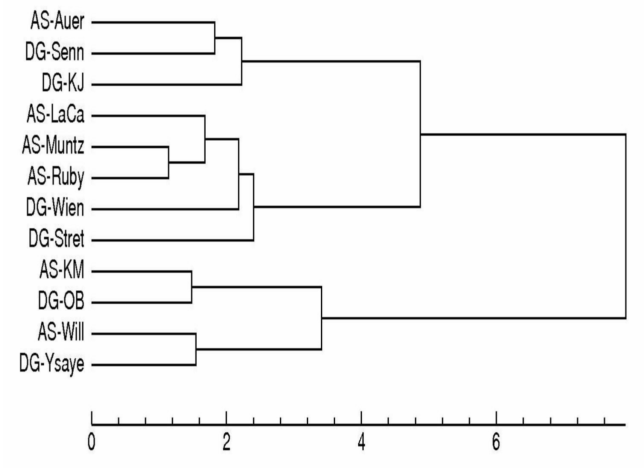
6 Cluster Analysis

A cluster analysis was conducted on all the listener results and on harmonic measurements of D6 on the 12 violins selected. Firstly, the 8 professional listeners' answers were compared over the 12 descriptor categories i.e. 12 degrees of freedom, omitting the like-dislike assessment. Secondly, the 15 student listeners' answers were similarly processed. Thirdly, the harmonic results for playing D6, were also processed for the 12 violins using up to the 10th harmonic, giving 10 degrees of freedom. The results of the clusterings are shown in Fig. 4. Fig 4a and 4b show that professionals and students have clustered their violin sounds differently. Of these two results, professional clustering would, by reason of professional experience, be more informed and reliable. However, the third clustering experiment using the D6 harmonic showed a tendency to cluster significantly more in keeping with the student result than for the professionals.

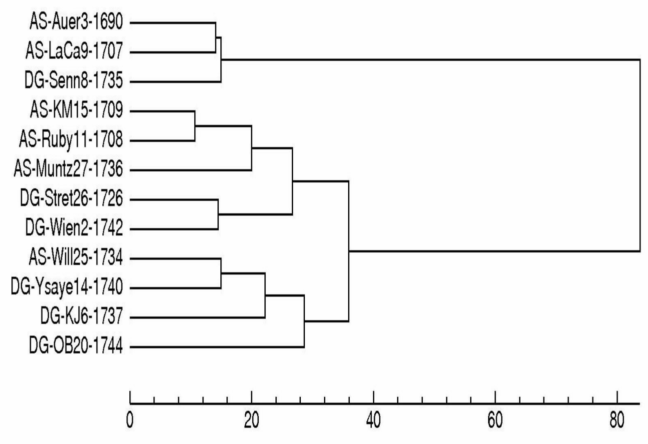
At no time were listeners encouraged to spread their



a. professional listeners.



b. student listeners.



c. clustering using the D6 harmonic.

Fig. 4 Cluster analysis on listener results and for the D6 harmonic on 12 violins. Names are abbreviated. Date made is present in c.

responses over the full range available but were given opportunity to respond as they saw fit. Nevertheless, professional clustering was more widely dispersed than for students, assumedly demonstrating better discriminatory ability. Students were probably hearing the generic properties of the violin sound as epitomized by harmonics whereas professionals may hear differently. The similarity cannot be given more significance than that pertaining to the one harmonic analysed because harmonic timbre has been cited as a potential parameter in assessing sound types [21].

Of particular note was The Auer, placed at the same extreme in all three clusters. A check on the harmonic characteristic showed it was the prime candidate for having the fundamental harmonic dominating all others i.e. all overtones sounded less in intensity than the fundamental. A further detailed check of Fig. 4c showed that the harmonic clustering at the lowest level was dominated by the ratio of fundamental to first harmonic i.e. for the top cluster of 3 the ration was >1, for the next 3, <1, for the next 2, ~1 and for the bottom 4, <1. This observation is consistent with the sound level of the fundamental and first overtone normally accounting for over 70% of overall sound intensity heard when found to be a function of pitch.

7 Correlation Matrices

The covariance matrices were calculated for both the usage of sound descriptors and the discrimination made between violins as judged by the professional listeners only. At a level of +/- 0.9 significance threshold, amongst the sound descriptors, listeners used the following:

weak-strong and *soft-loud*
empty-full and *interesting-boring*
penetrates-weak and *interesting-boring*
focused-diffuse and *like-dislike*

as virtually synonymous with the listeners using *empty-full* and *interesting-boring* as the antithesis of one another. This looks like there was, in the first instance, an opportunity to reduce the set of descriptors used. However, taking the view that one should eradicate redundancy in descriptors is problematic for two reasons. Firstly, there is no agreed method of understanding what is meant by particular descriptors except those automatically attached to physical analogues e.g. *soft-loud*. It may so be that two properties were being detected simultaneously and both present when heard. Secondly, should synonyms be agreed, it offers a check on the consistency of listener's responses to see how much integrity went into judgments. No formal check on the consistency of listener response was attempted in this work.

The original descriptions of the sound of the violins obtained from [1] were compared with more prominent characteristics detected by the professional group of listeners. There was mild agreement for some violins, significant disagreement on three and indeterminacy for several. Using recognised names, the Auer was agreed to *penetrate* and *project*. The Ruby was seen to be *warm* if *thick tone* in the lower register was a synonym for *warm*. For the King Joseph, agreement on *firm* was present and also on *full* if synonymous with *broad* and *deep*. The Willemotte, Ysaye and Ole Bull were identified differently by the two sources. Here it was disappointing no properties *pure*, *focussed* and *warm* were highlighted by the professional listening group.

8 Conclusion

Only the acclaimed best of classical performers appear equipped to make reproducible value judgements on violin sound and, even at this elite level, agreement is not good. Preliminary vetting or sound characteristic initiation of terminology may improve consistency of choice. The question to be put is: "Have violins been significantly differentiated apart by the listeners and could this then be achieved reliably to grade a wider range of violins?"

There were properties in the sound of each violin that have been systematically identified but discrimination was not optimised nor an agreed basis found for a scientific refutation of the hypothesis. More study of the psychological basis and categorisation of subjective descriptors is required to create an improved test procedure.

Finally, of particular concern has been the mixed usage of subjective and objective means to test the hypothesis. Human subjects are not objective but cannot be set aside in hypothesis testing. Social science relies upon human judgement all the time. Luthiers rely on objective data over which they lay subjective terminology. Performers and listeners often speak subjectively about what they experience. Here, the use of scientific method is clearly inadequate.

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