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By Anders Buen

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On Timbre Parameters and Sound Levels of Recorded Old Violins

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Abstract

A simplified version of Dünnwald's timbre parameters for violin sound [L (bass), ACD-B (nasality), and DE-F (clarity)] is used to compare the sound of 15 violins by Antonio Stradivari and 15 by Giuseppe Guarneri del Gesù. *The parameters were extracted from ⅟₁₂-octave band long-time-average spectra obtained from CD recordings of the same musical excerpt played on each of these fine violins. A considerable spread in these parameters and the sound pressure levels (loudness) was found in both groups of Cremonese violins. A simple statistical analysis indicates that there seems to be a slight trade-off between overall sound power output and high values for the timbre parameters of the 30 violins. A weak trend was found between production year and parameter values. Guarneri violins tended toward less bass and more nasality, increasing clarity, and stronger sound, especially during the maker's later years. Stradivari's violins indicate an opposite trend over a longer time span: more bass, less nasality, and slightly less loud with time. The brilliance of Stradivari violins (in the set of 15) seems to be unaltered with production year.*

This article deals with properties of the long-time-average spectra of recorded music played on violins by Antonio Stradivari and Giuseppe Guarneri *del Gesù*, the two greatest violinmakers. Using a simplified method, I have examined extracts from the violin spectra as used by Heinrich Dünnwald in his large study of the sound spectra of several hundred violins [1, 2]. I compared two groups of violins by the two Cremonese masters using Dünnwald's timbre parameters, looking for any connection between each of these parameters, and between these parameters and the total sound level from the violins. I further looked for the possible evolution of the timbre of the sound of the violins produced by Stradivari and Guarneri over their careers.

The objectives of this work are:

- To gain experience with the meaning of the Dünnwald parameters, and thus Old Italian violin sound, by listening to selected recordings with low and high values for each of the parameters as well as the equivalent sound pressure levels; and
- To recognize any patterns in the audio spectra of the violins and possible correlations between the different timbre parameters and loudness.

COMMON FEATURES IN THE SPECTRA OF OLD ITALIAN VIOLIN SOUND

Dünnwald studied the sound spectra from several hundred violins made by modern violinmakers, both amateur and professional, factory-made instruments, Old Italian violins, and other old masters [1, 2]. He apparently succeeded in finding parameters based on the measured violin spectra that separated the Old Italian violins, or other very good violins, from most of the modern violins. He claimed that his parameters are independent of any preference for dark or brilliant sound [1].

Figure 1 shows the frequency regions Dünnwald used in his study, which he designated with labels A, B, C, D, E, and F. He also used a value, L, for the level of the first air resonance relative to the highest level (top) in the frequency region from 649 Hz to 1090 Hz. In more detail, I inter-

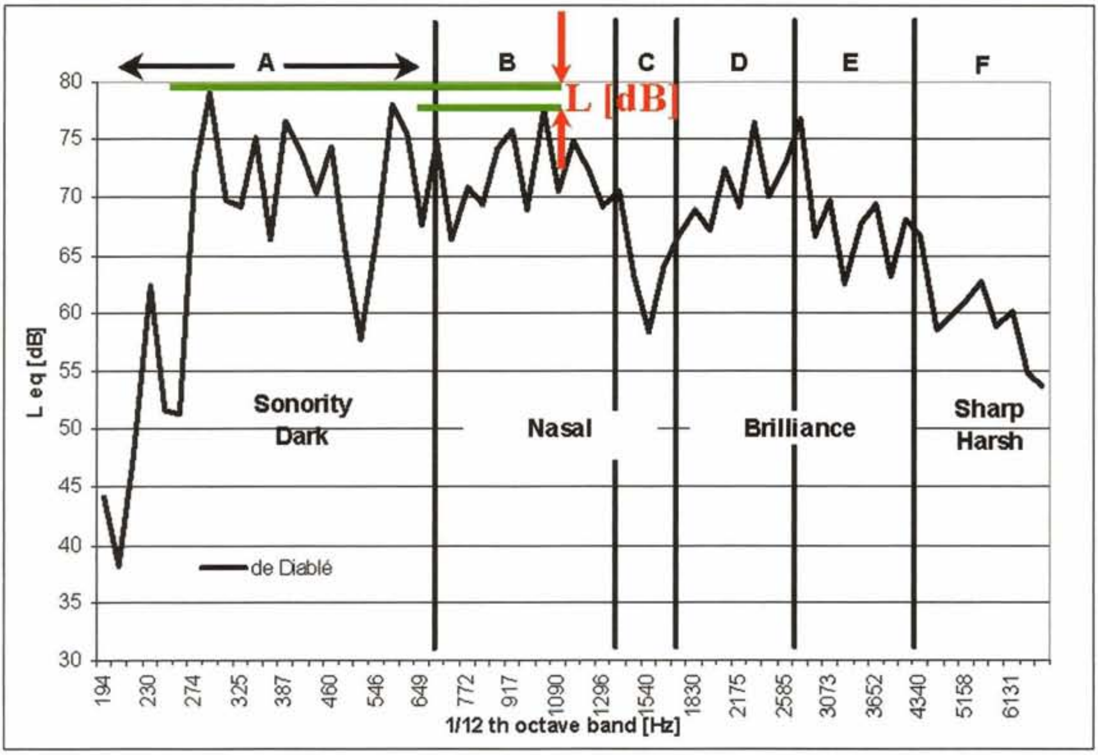

Figure 1. Long-time-average spectrum of the Le Violon du Diablè *made by Giuseppe Guarneri* del Gesù *in 1734. The quantity L (defined in the text) and frequency regions A to F are used for calculation of the Dünnwald parameters. Common words are used to describe the influence of particular spectral bands on the timbre of violin sound.*

pret his parameters and timbre as follows:

Bass: L (dB) = L_{max} (244-325 Hz) - L_{max} (649-1090 Hz),

Nasality: ACD-B (dB) =
L_{eq} (190-650 Hz and 1300-2580 Hz) - L_{eq} (650-1300 Hz), and

Clarity: DE-F (dB) = L_{eq} (1640-4200 Hz) -
L_{eq} (4200-6879 Hz) ,

where L_{eq} represents the equivalent sound pressure level (SPL) measured with an SPL meter [3]. Dünnwald calculated the spectrum for every single played note from measured sine swept-frequency responses of the violins (SPL vs. frequency). He calculated the parameters ACD-B and DE-F for every single tone and used the Sone scale for his parameters [1, 2].

In the present study, the parameters were calculated directly from the time-average SPL spectra in ⅟₁₂-octave bands using the dB scale. The spectra were obtained from CD recordings of performances with the violins. This is an extension of earlier work on these recordings [3, 4]. Table 1 lists Dünnwald's parameters and what they describe.

Table 1. The Dünnwald parameters used in this study [2].

Dünnwald parameter	This study	Comment
L (dB)	L (dB)	High values for good and bass-rich violins
ACD-B (Sone)	ACD-B (dB)	High values for "non-nasal" violins; low values for "nasal" violins
DE-F (Sone)	DE-F (dB)	High values for "clear" violins; violins with low values sound "harsh"

According to Dünnwald, Old Italian violins generally have high values of the parameters L, ACD-B, and DE-F. Approximately 93% of the tested Old Italian violins showed good values on all these parameters, but only 19% of violins made by modern masters after 1800 met the criteria for a very good violin [1, 2].

METHOD

The long-time-average spectra were obtained from a CD recording of Elmar Oliveira playing a short excerpt of the first movement of the Violin Concerto in D minor by Jean Sibelius on 15 violins made by Antonio Stradivari and 15 by Giuseppe Guarneri *del Gesù* [5]. The spectra were analysed in 1/12-octave bands, each covering a single half note.

The statistics used

Correlations were investigated using tables and formulas using MicroSoft Excel™ software. The correlation coefficient, R, is a measure for how close a set of data pairs follows a best-fit straight line through the data. If R is close to 0, then the xy-data points will look like a "cloud" or undefined "ball" of data with no patterns in it. If R is close to 1 or –1, the xy-data points will lie close to a line rising upward toward the right if is R close to 1, or downward toward the right if R is close to –1.

Significance level, s-level or p-value, is a measure for how probable it is that I fail in my assumption that there is a correlation between x and y values in a data set. A significance level of 1% gives a 99% chance of being correct that there is a correlation between x and y. Similarly, a significance level of 32% gives a 68% chance of being right.

A t-test is a statistical test used to compare two sets of y values (with the same x values) to determine if one set is larger or smaller than the other. If a t-test returns a p-value (significance level) lower than 5%, one may expect that there is a difference between the two data sets.

The instruments used for selected data

Table 2 lists the violins and their makers as they are presented on the *The Miracle Makers* recordings [5]. At some time in the last 200-300 years, each of them has been named either after a famous violinist that played them, a well-known owner, a figure from the world of mythology, etc.

Visualization of timbre: A clue to understanding violin sound

The spectral characteristics of the sound produced by these 30 Old Italian violins was the subject of two previous articles [3, 4]. Here, I wish to convert the characteristics of the spectra to single numbers. As an example, the long-time-average spectrum for one of these violins is shown in Fig. 1. Superimposed on this spectrum are Dünnwald's six frequency bands that we will use for calculating the timbre parameters defined in Table 1. The labels of the bands are words commonly used for describing violin timbre. In general, high levels in the frequency region A are connected to what may be called "sonority" or dark sound. High values in the regions B and C relate to what Dünnwald interpreted as a "nasal sound," and the D and E regions may be attributed to "brilliance" [1]. Finally, high levels in the region F are related to the more negative descriptions: "sharp" or "harsh" sound [1, 6].

RESULTS

How do the violins of Stradivari and Guarneri *del Gesù* compare?

Figure 2 shows the average level of the long-time-average spectra in each of the Dünnwald frequency bands for the average of the 15 Guarneri violins and the 15 Stradivaris. The average Guarneri has a higher level in the sonority/darkness and nasality band, while the average Stradivari produces more volume in the brilliance region. This is in agreement with our earlier findings using 1/3-octave bands [4].

In Table 3 I show the calculated average of the parameters given in Table 1 for each group of 15 instruments. On average, the recordings of the Guarneris have slightly higher L and lower DE-F than the Stradivaris.

Earlier studies of mechanically excited sound spectra and also spectra from bowed violins have shown that it is possible to predict the sound quality of violins from an analysis of 1/12-octave bands (or bark bands) of the violin spectra [7, 8].

Table 2. The violins of Stradivari and Guarneri del Gesù *analyzed in this study [5].*

No.	Violinmaker	Date	Name
1	A. Stradivari	1679	*Hellier*
2	G. Guarneri *del Gesù*	1742	*Wieniawski*
3	A. Stradivari	1690	*Auer*
4	G. Guarneri *del Gesù*	1742	*Sloan*
5	A. Stradivari	1692	*Oliveira*
6	G. Guarneri *del Gesù*	1737	*King Joseph*
7	A. Stradivari	1701	*Dushkin*
8	G. Guarneri *del Gesù*	1735	*Sennhauser*
9	A. Stradivari	1707	*La Cathédrale*
10	G. Guarneri *del Gesù*	1720	*Kartman*
11	A. Stradivari	1708	*Ruby*
12	G. Guarneri *del Gesù*	1737	*Stern, Panette*
13	A. Stradivari	1710	*Vieuxtemps, Hauser*
14	G. Guarneri *del Gesù*	1740	*Ysaÿe*
15	A. Stradivari	1709	*King Maximilian*
16	G. Guarneri *del Gesù*	1734	*Le Violon du Diablè*
17	A. Stradivari	1715	*Baron Knoop*
18	G. Guarneri *del Gesù*	1735	*Plowden*
19	A. Stradivari	1722	*Jupiter*
20	G. Guarneri *del Gesù*	1744	*Ole Bull*
21	A. Stradivari	1723	*Kiesewetter*
22	G. Guarneri *del Gesù*	1734	*Haddock*
23	A. Stradivari	1727	*Dupont*
24	G. Guarneri *del Gesù*	1739	*Kortschak*
25	A. Stradivari	1734	*Willmotte*
26	G. Guarneri *del Gesù*	1726	*Stretton*
27	A. Stradivari	1736	*Muntz*
28	G. Guarneri *del Gesù*	1738	*Kemp*
29	O. Stradivari	1737	*Rawlings*
30	G. Guarneri *del Gesù*	1735	*D'Egville*

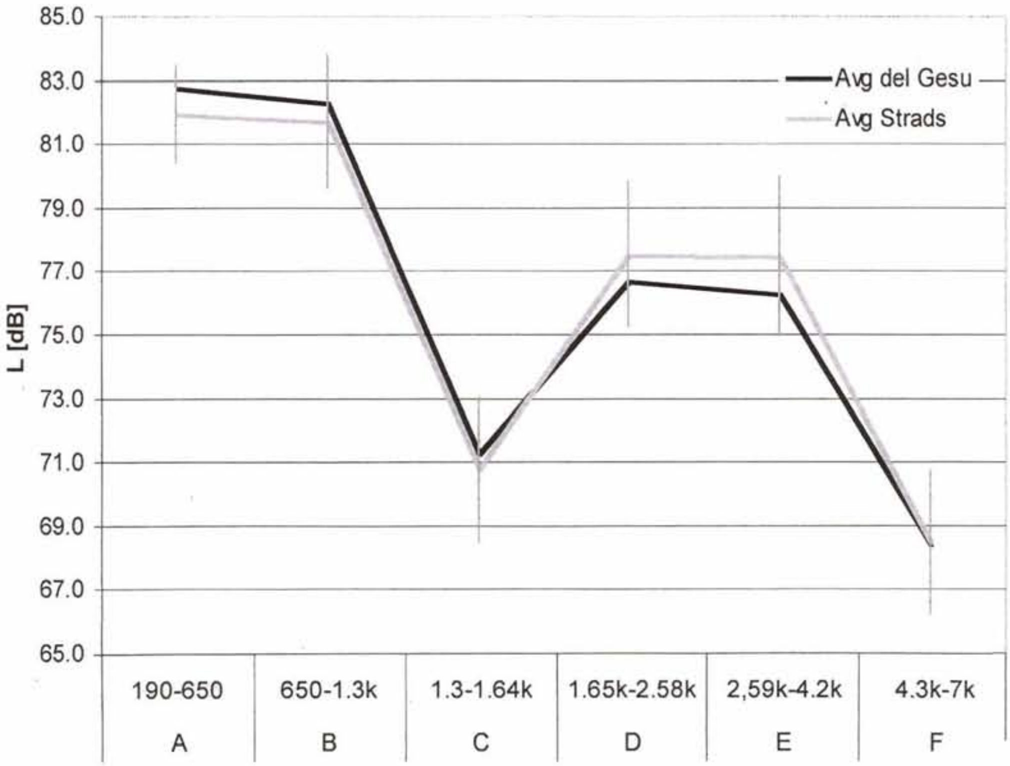

Figure 2. Calculated levels of each Dünnwald frequency band for the average long-time-average spectra produced by 15 violins by A. Stradivari and 15 violins by G. Guarneri del Gesù. *Error bars show one standard deviation variation.*

The Dünnwald (DW) parameters and SPL extracted from the long-time-average spectra of each violin from *The Miracle Makers* recordings [5] are listed in Table 4. The values of the DW parameters and SPL are sorted in decreasing order with the corresponding violin numbers as given in Table 2. Two additional columns include a summation of the DW parameters and one where the SPL is added to the DW parameter sum. These are this author's choice of combined parameters that have not been tested against any subjective tonal evaluations. As they mix numbers for different tonal properties and SPL, their meaning probably is a bit abstract. They may be regarded as a sort of tonal ranking in terms of expanded sets of parameters.

Table 3. Average timbre parameters for 15 violins each by Giuseppe Guarneri del Gesù *and Antonio Stradivari.*

	Guarneri		Stradivari		Difference
	Aver.	Std. Dev.	Aver.	Std. Dev.	Strad–Guarneri
L (dB)	-0.1	2.9	-0.9	2.9	-0.8
ACD-B (dB)	1.8	1.7	1.9	1.4	0.1
DE-F (dB)	11.2	2.3	*12.1*	1.2	*1.1*

Table 4. Sorted Dünnwald (DW) parameters and SPL values extracted from the long-time-average spectra from recordings of 30 violins by A. Stradivari and G. Guarneri del Gesù *[5].*

Violin	L [dB]	Violin	ACD-B [dB]	Violin	DE-F [dB]	Violin	Sum all DW parameters	Violin	SPL [dB]	Violin	Sum all DW parameters + SPL
22	5.0	26	4.4	20	14.7	27	19.2	16	89.5	16	107.0
29	4.1	24	4.0	9	13.6	22	18.3	5	89	22	105.6
24	3.9	27	3.4	2	13.6	29	17.8	12	88.9	27	105.4
27	3.2	29	3.3	19	13.6	24	17.8	7	88.6	3	104.3
26	2.2	16	3.2	25	13.4	3	17.5	6	88.2	17	104.1
3	1.8	11	3.1	17	13.3	16	17.5	14	88.2	20	103.9
10	1.6	14	2.8	4	13.2	17	16.5	18	88.1	14	103.4
16	1.5	3	2.8	3	12.9	10	16.3	13	87.7	24	102.7
13	1.4	13	2.7	16	12.8	20	16.3	15	87.7	13	102.4
17	1.1	28	2.6	12	12.8	26	15.4	20	87.6	5	101.6
28	0.7	10	2.6	6	12.6	9	15.3	17	87.6	25	101.2
8	0.6	22	2.4	27	12.6	14	15.2	21	87.6	9	100.8
14	0.5	9	2.4	5	12.4	25	14.9	22	87.3	29	100.5
23	0.4	25	2.3	7	12.3	13	14.7	2	87.2	10	100.0
30	0.2	21	2.1	23	12.2	23	14.4	8	87	12	99.9
20	-0.5	17	2.1	10	12.1	5	12.6	3	86.8	26	99.8
9	-0.7	20	2.0	11	12.0	11	12.1	25	86.3	6	99.5
25	-0.8	23	1.9	14	11.9	2	11.9	4	86.2	15	99.4
5	-1.5	15	1.8	15	11.8	15	11.7	19	86.2	2	99.1
15	-1.9	6	1.7	22	10.9	8	11.5	27	86.2	23	98.8
12	-2.1	5	1.7	21	10.7	6	11.3	1	85.9	8	98.5
2	-2.3	30	1.0	13	10.6	12	11.0	30	85.5	21	97.3
4	-2.7	19	0.7	8	10.5	19	11.0	9	85.5	19	97.2
11	-2.9	2	0.6	29	10.3	28	10.9	28	85.1	4	96.8
6	-3.1	8	0.4	1	10.3	4	10.6	24	84.9	11	96.0
21	-3.1	12	0.3	24	9.9	30	10.3	26	84.4	28	96.0
19	-3.3	4	0.1	30	9.1	21	9.7	23	84.4	30	95.8
7	-4.9	7	-1.0	26	8.8	7	6.4	11	83.9	7	95.0
1	-6.0	1	-1.2	28	7.5	1	3.1	10	83.7	1	89.0
18	-6.5	18	-2.1	18	7.0	18	-1.5	29	82.7	18	86.6

From Table 4 it is apparent that:

- The violin with the highest L value is the *Haddock;* the *Plowden* has the lowest L value.
- The violins with the highest ACD-B (least nasality) are the *Stretton* and the *Kortschak*; the *Plowden* has the lowest ACD-B value.
- The violin with the highest clarity (DE-F) is the *Ole Bull*; once again the *Plowden* has the lowest DE-F value.
- The loudest violin (largest SPL) is the *Le Violon du Diablè*; the weakest sounding of these 30 violins is the *Rawlings*.
- The violin with the highest sum of Dünnwald parameter values is the *Muntz*; the *Plowden* has the lowest value.
- The violin with the largest sum of parameter values + SPL is *Le Violon du Diablè;* the *Plowden* has the lowest combined total.

Those that have access to the recordings on *The Miracle Makers* [5] may find it interesting to compare the sound of particular violins with high and low values of any of the parameters. Using Table 4 as a guide, you could learn what the parameters mean and judge for yourself if they give meaningful information about the sound qualities heard.

The listening tests on artificially manipulated violin spectra by Fritz et al. [9] have shown that human sensitivity to changes in any of the Dünnwald bands is ~2-3 dB [9]. We do not know how this compares for each of the parameters that combine several band values (from A-F). If our ears have similar sensitivity to the DW parameters and ~1 dB for the SPL, then there should be audible differences between the upper and lower violins in Table 4.

Potential correlation between the timbre parameters and loudness

The parameter values in Table 4 may be used to determine if there are any correlations among the DW timbre parameters. We may also determine if the parameters and the SPL are correlated. The extent of the correlations may be interpreted from xy-plots of pairs of parameters, such as shown in Figs. 3 and 4. Both the correlation coefficient-squared R^2 and the average slope are derived from the equation for the best-fit straight-lines through the data points. Note that the data points may be quite well spread around the regression line, but still the best-fit line will give the trends (if any) of the data. (Some caution may be needed to ignore "outlyers," that is, single points at extreme locations relative to the other points that may destroy an otherwise good correlation.)

A listing of the calculated correlation coefficients and slopes of the regression lines is presented in Table 5. For this set of 30 violins the low-frequency parameter L and the nasality parameter ACD-B follow each other and are thus statistically dependent. Violins with higher L values (a strong Helmholtz resonance in comparison to the frequency region 630 Hz–1.1 kHz) also tend to have a non-nasal sound. The slope for ACD-B/L is 0.42 dB/dB, i.e., ACD-B increases by 0.42 dB for each dB increase in L. This correlation between the L and the ACD-B parameter agrees with Dünnwald's original work [1], where he found that the L parameter alone correlated highly with violin quality.

The L and DE-F parameters seem to be independent, and the same is true for the ACD-B (nasality) and the DE-F (clarity-harshness) parameters. This is promising. Could it be that we can influence them independently?

There seems to be a dependency between the L and ACD-B timbre parameters and the loudness of the violins. Violins whose sound spectra have high L and ACD-B values (a very "Italian" timbre) tend to have a weak, but significant, lower SPL. According to the calculated results listed in Table 5, for each dB increase in L (or ACD-B) there is on average a decrease in SPL of 0.2 dB. (Similarly, a 1 dB increase in ACD-B is accompanied by a 0.46 dB decrease in SPL.) If we generalize this, we might assume that maximizing the sound output of a violin might result in "less good" timbre. There is, however, a weak indication that the violins with higher DE-F tend to sound louder.

How did the tonal timbre of the violins of Stradivari and Guarneri develop through their careers?

Stradivari's violins from the period after 1700 are generally regarded as being his best. There is also an idea among players that the later violins of Guarneri *del Gesù* are better than his earlier ones. His late violins, like the *Ole Bull* and *Il Cannone,* were both rather heavily built [10, 11]. Can we see a development in any of the timbre parameters with time?

Combining the production years listed in Table 2 with the parameter values (L, ACD-B, DE-F, and SPL) listed in Table 4, construction of x-y plots might help reveal patterns that indicate correlations with time. Table 6 shows the degree of correlation between these timbre parameters and the production year for the two sets of 15 violins by the two Cremonese masters. Both the correlation coefficients and the corresponding values of the slope of the regression line (dB per year) are listed. Also listed are the calculated total changes in dB for each parameter from the first to the last instruments made by Guarneri and Stradivari (in two sets of 15) when we use the slope of the regression line as the guide for that calculation. The correlation coefficients in bold are large enough to be considered significant.

The results in Table 6 indicate that Stradivari's violins exhibit significant development with production year. The apparent trend is toward less nasality (higher ACD-B) and more

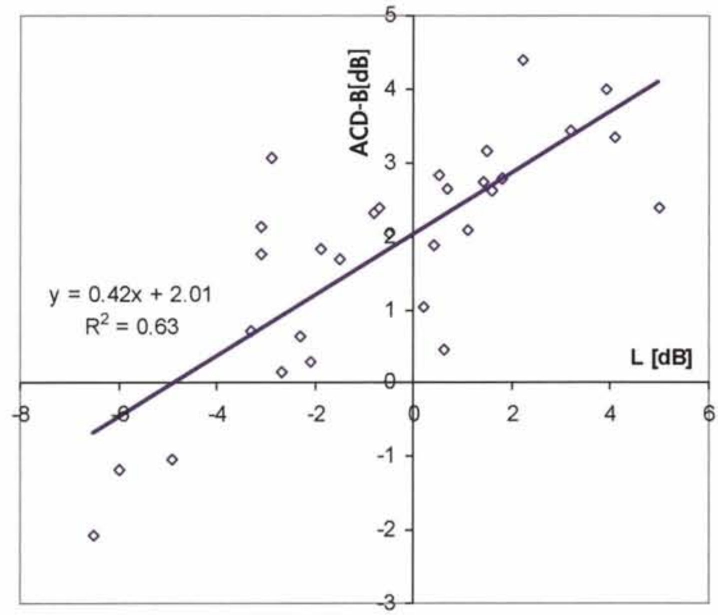

Figure 3. Dünnwald timbre parameter ACD-B versus L for 30 violins by A. Stradivari and G. Guarneri del Gesù *listed in Table 2. The correlation coefficient R is 0.79 and the slope of the regression line is 0.42. This is an example of a significant correlation (s-level < 1%).*

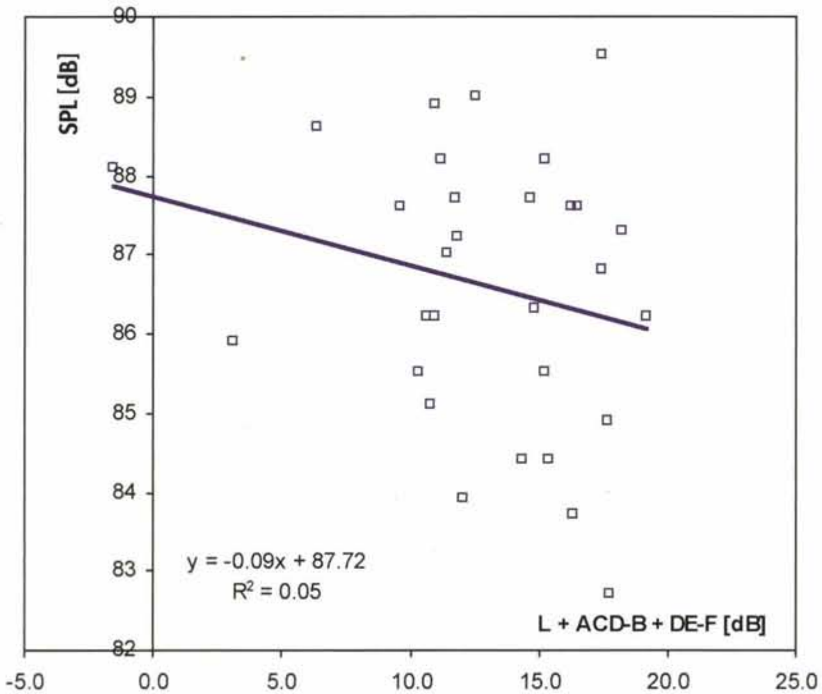

Figure 4. Sound pressure level (SPL) versus the sum of the Dünnwald timbre parameters (L + ACD-B + DE-F) for 30 violins by A. Stradivari and G. Guarneri del Gesù *listed in Table 2. The correlation coefficient R is 0.23 and the slope of the regression line is –0.09 dB/dB. This is an example of an interesting, but not-so-significant, correlation (s-level = 22%).*

*Table 5. Correlation and slopes for the regression lines between timbre parameters and total sound pressure levels (SPL).**

Correlations between:	**L** *and*			**ACD-B** *and*		**DE-F** *and*	**Sum of L, ACD-B, DE-F** *and*
	ACD-B	**DE-F**	**SPL**	**DE-F**	**SPL**	**SPL**	**SPL**
Correlation coefficient	**0.79**	-0.05	*-0.33*	0.06	**-0.37**	*0.26*	*-0.23*
Slope of regression line, dB/dB	**0.42**	---	*-0.20*	---	**-0.46**	*0.24*	*-0.09*

*Bold numbers are better than significant on the 5% level; those in italic font are significant on the 22% level, or better. The data are based on sound recordings of 30 violins by A. Stradivari and G. Guarneri *del Gesú* [5].

*Table 6. Correlation coefficients and slopes between timbre parameters and production year.**

	Guarneri *del Gesú* (15 violins)		**Stradivari (15 violins)**		**Change of Guarneri violins**	**Change of Stradivari violins**
Spectral Band	**Correlation w/prod year**	**Slope (dB/year)**	**Correlation w/prod year**	**Slope (dB/year)**	**during 24 years (dB)**	**during 58 years (dB)**
L	*-0.31*	*-0.15*	**0.52**	**0.09**	*-3.6*	**5.3**
ACD-B	*-0.28*	*-0.08*	**0.54**	**0.04**	*-1.9*	**2.3**
DE-F	*0.31*	*0.12*	0.09	--	*2.9*	--
SPL	**0.48**	**0.14**	*-0.41*	*-0.04*	**3.4**	*-2.3*

*Bold numbers are better than significant on the 5% level; those in italic font are significant on the 22% level, or better. The data are based on sound recordings of 30 violins by A. Stradivari and G. Guarneri *del Gesú* [5].

bass (higher L). His later violins (at least those included in this study) also have a weak tendency of sounding less loud. This is basically opposite of the development of the violins of Guarneri, which tend to sound louder, a little more nasal, and with less bass through the maker's career. The later Guarneri violins also have a slight tendency toward enhanced clarity (higher DE-F) while the Stradivari violins seem to exhibit no significant change in this parameter. The brilliance seems to be maintained throughout Stradivari's longer career.

The small slopes listed in Table 6, ranging from 0.04 to -0.15 dB/year, indicate that, averaged over their careers, these two masters altered the sound qualities of their violins gradually. Larger slopes (faster change) are seen for the violins of Guarneri. The production time span for the 15 Stradivari violins was from 1679 to 1737, about 58 years. The 15 Guarneri violins were produced from 1720 to 1744, only 24 years. In Table 5 we see that the parameters change by ~2 to 5 dB on average through the production years of the two makers. If we assume that a 2-3 dB change in any parameter is just barely audible [9], it is evident that the changes over their careers, for most of the parameters, are not likely to be clearly audible. The two exceptions to this are changes in the L parameter of Stradivari's violins and the SPL of Guarneri's violins. These are the most likely to be heard. If the reader has *The Miracle Makers* recordings, you may use your own ears to test this observation using the sorted parameters in Table 4.

DISCUSSION AND CONCLUSIONS

We have used a simplified method for extracting Dünnwald parameters from long-time-average spectra from recordings of 30 violins by Stradivari and Guarneri *del Gesù*. The average parameter values for these violins included in *The Miracle Makers* are probably not audibly different. However, the average Guarneri violin response is somewhat higher in the lower frequency bands and a bit lower for the higher frequency bands, as reported earlier [3, 4].

Undoubtedly, many attentive listeners are able to detect the difference in sound between the typical violins of Stradivari and Guarneri *del Gesù*. For those perceptive individuals, the parameters investigated here may not provide useful information on that sound difference, such as relative darkness or brilliance of tone. It is thus probably more important to compare spectra instead of only the single parameter numbers. Averages in Dünnwald bands (A-F) seem to give the needed information.

When it comes to parameter values, there seems to be large enough differences between the instruments to be able to distinguish the sound of particular violins with high or low values for any of the parameters. Table 4 gives a guide for comparing the violins. (Such sorted tables for the violins included in the two recordings, *The Glory of Cremona* [12] and *The Legacy of Cremona* [13], can be downloaded from this author's website [14].)

We have also noticed a weak correlation between the L, ACD-B, and the SPL of the violins. There are, however, violins in the set that have both high values of L, ACD-B, and DE-F and also a high SPL. An example is *Le Violon du Diablè*, a violin with a rather high score for any of these parameters.

Finally, our analysis reveals that over time the loudness of Guarneri's violins increased. In contrast, Stradivari's production evolved with audibly higher L values (richer bass component).

SUGGESTIONS FOR FURTHER WORK—CALL FOR DATA

The statistical method used here has also been used to look for possible correlations between the values of the Dünnwald parameters and how these fine Old Italian violins were constructed, their plate thicknesses, arching heights, etc. Fortunately, dimensional measurements of 11 of the 30 instruments listed in Table 2 have been published [10]. Data for nine more of the instruments have been collected from anonymous sources as well as from work carried out at the VSA-Oberlin Violin Acoustics Workshop. (Those interested in the subject of plate thickness graduations of fine old violins should consult Jeff Loen's compilation of such data [15]). One preliminary result is that there is a weak, but not statistically significant, correlation between thinner plates (especially around the border area of the backs) and higher DW parameters. Arching heights show a similar weak trend. However, in order to improve the statistics, the data set should be extended.

To carry the analysis further, the author would like to acquire data regarding the spruce and maple—including thicknesses, weights, and tap tones—for the violins listed in Table 2. Dimensional information, as described in Table 7, would also be much appreciated. If acquisition of such data proves to be difficult, this puzzle could persist for a decade or more, so any pertinent information will be much appreciated!

With the above essential data in hand, the next step will be to look more into any correlations between the Dünnwald band spectra and how violins are constructed.

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REFERENCES

[1] H. Dünnwald, Ein erweitertes verfahren zur objektiven bestimmung der klangqualität von violinen (Engl. transl.: An expanded procedure for the objective determination of the sound quality of violins), *Acustica*, Vol. 71, pp. 269-76 (1990). Repr. in *Res. Papers in Violin Acoustics 1975-1993*, C.M. Hutchins and V. Benade, Eds. (Acoust. Soc.

Table 7. Dimensional information sought by the author for particular violins by Stradivari and Guarneri del Gesù.

Violinmaker	Date	Name	Information Needed
A. Stradivari	1692	*Oliveira*	Dimensions and plate thickness graduations
A. Stradivari	1701	*Dushkin*	Arch heights, body length, and *f*-hole width, length, & spacing
A. Stradivari	1707	*La Cathédralè*	"
A. Stradivari	1708	*Ruby*	"
A. Stradivari	1709	*King Maximilian*	Dimensions and plate thickness graduations
A. Stradivari	1710	*Vieuxtemps, Hauser*	Arch heights and *f*-hole width, length, & spacing
A. Stradivari	1715	*Baron Knoop*	Dimensions and plate thickness graduations
A. Stradivari	1722	*Jupiter*	"
A. Stradivari	1723	*Kiesewetter*	"
A. Stradivari	1727	*Dupont*	Arch heights, body length, and *f*-hole width, length, & spacing
A. Stradivari	1734	*Willmotte*	Arch heights and body length
A. Stradivari	1736	*Muntz*	Dimensions and plate thickness graduations
O. Stradivari	1737	*Rawlings*	"
G. Guarneri *del Gesù*	1720	*Kartman*	"
G. Guarneri *del Gesù*	1735	*Sennhauser*	"
G. Guarneri *del Gesù*	1742	*Wieniawski*	"
G. Guarneri *del Gesù*	1742	*Sloan*	Arch heights, body length, and bout widths

Am., Melville, NY, 1997), pp. 51-58.

[2] H. Dünnwald, Deduction of objective quality parameters on old and new violins, *Catgut Acoust. Soc. J.*, Vol. 1, No. 7 (Series II), pp. 1-5 (May 1991). Repr. in *Research Papers in Violin Acoustics 1975-1993*, C. Hutchins and V. Benade, Eds. (Acoust. Soc. Am., Melville, NY, 1997), pp. 59-63.

[3] A. Buen, Comparing the sound of golden age and modern violins: Long-time-average spectra, *VSA Papers*, Vol. 1, No. 1, pp. 51-74 (Summer 2005).

[4] A. Buen, Differences of sound spectra in violins by Stradivari and Guarneri *del Gesù*, *Catgut Acoust. Soc. J.*, Vol. 4, No. 8 (Series II), pp. 14-18 (Nov. 2003).

[5] R. Bein and G. Fushi, *The Miracle Makers—Stradivari • Guarneri • Oliveira* (Bein & Fushi, Chicago, 1998). Book and 3 CDs.

[6] J. Stepánek and Z. Otcenásek, Interpretation of violin spectrum using psychoacoustic experiments, in *Proc. Intl. Symp. on Musical Acoustics (ISMA 2004)*, Nara, Japan, pp. 324-27 (2004).

[7] A. Gabrielsson and E.V. Jansson, Long-time-average spectra and rated qualities of twenty-two violins, *Acustica*, Vol. 42, pp. 47-55 (1979). Repr. in *Res. Papers in Violin Acoustics 1975-1993*, Vol. 1, C.M. Hutchins and V. Benade, Eds. (Acoust. Soc. Am., Melville, NY, 1997).

[8] P. Bazant, J. Stepánek, and A. Melka, Predicting sound quality of violin from its frequency response, in *Proc. of Stockholm Music Acoustics Conf. (SMAC93)* (Stockholm, 1993), pp. 351-54.

[9] C. Fritz, I. Cross, B.C. Moore, and J. Woodhouse, Perceptual effects of violin acoustical modifications, in *Proc. Intl. Symp. on Musical Acoustics (ISMA 2007)*, Barcelona, Sept. 9-12, 2007; also Perceptual thresholds for detecting modifications applied to the acoustical properties of a violin, *J. Acoust. Soc. Am.*, Vol. 122, pp. 3640-50 (2007).

[10] C. Chiesa, J. Dilworth, R. Hargrave, P. Klein, S. Pollens, D. Rosengard, and E. Wen, *Giuseppe Guarneri del Gesù* (P. Biddulph, London, 1998).

[11] H. Kraggerud, Interview at the Norwegian Broadcasting Co., NRK, Spring 2004.

[12] R. Ricci and L. Pommers, *The Glory of Cremona, Ruggiero Ricci plays 15 famous violins*, STRAD 6 CD of orig. 1964 recording (MCA Records, Inc. for *The Strad*, Orpheus Publ., London).

[13] R. Ricci and N. Shiozaki, *The Legacy of Cremona, Ruggiero Ricci plays 18 contemporary violins*, book + CD, CDS 373 (Dynamic Srl, Genoa, 2001).

[14] Website of Anders Buen: <http://home.online.no/~an-buen/publications1.htm>

[15] J.S. Loen, *Thickness Graduation Maps of Classic Violins, Violas and Cellos* (J.S. Loen, Kenmore, WA, 2003).