THE STUDY OF VIOLIN TIMBRE USING SPONTANEOUS VERBAL DESCRIPTION AND VERBAL ATTRIBUTE RATING

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ABSTRACT: Timbre of violin tones of five different pitches was studied in listening tests using two methods. In the first experiment timbre differences in pairs of tones were described spontaneously in words. This description enabled assigning the frequency of occurrence of each word as an assessment of the tones. In the second experiment listeners ranked the set of tones according to a given word (words *sharp*, *dark*, *clear* and *narrow* were selected following the results of the first experiment) and then assigned the magnitude of this verbal attribute to every tone (rating). Perceived quality preferences or quality ratings were also determined. Results of both experiments are compared and discussed.

INTRODUCTION

Various appropriate methods were developed enabling the study of timbre of musical sounds. Different kinds of listening test techniques and subsequent statistical procedures are used in psychoacoustic research to study this multidimensional problem (see overview e.g. in [1]). Proximity rating technique (similarity scaling in sound pairs, triadic comparisons) and multidimensional scaling are used for the construction of perceptual space [2], but its dimensions can not be interpreted simply without additional (external) data. Some researchers used the identification method based on free or forced verbal labelling of sounds in a studied context [3]. The classical Semantic Differential Technique (used e.g. in [4]), recently replaced by Verbal Attribute Magnitude Estimation (VAME) [5], leads to correlation analyses of various kinds; the main problem of this method is the choice of appropriate attributes for a given sound context.

The presented study describes and compares two subsequent experiments provided on the same sound context of violin tones and using two different experimental techniques.

METHOD

Violin timbre was studied on five different pitches. The first experiment used **spontaneous verbal description** of sounds (denoted through this article as **SVD**) [6, 7], a modified free verbal labelling technique. The second experiment used selected verbal attributes (words) from the results of the first experiment, with slightly adopted VAME [8]. A different group of listeners but with a similar structure participated in each experiment: students and professors of violin from Prague Academy, as well as sound designers in the second experiment.

<u>Stimuli</u>

The same monophonic recordings of tones **B3** (fundamental frequency 247 Hz, played on G string), **F#4** (370 Hz, D), **C5** (523 Hz, A), **G5** (784 Hz, E), and **D6** (1175 Hz, E), played on eleven instruments of various qualities in *détaché*, *naturale,* non-vibrato, and *mezzoforte,* and recorded in an anechoic room were used in both experiments [6]. The same loudness, pitch and tone duration was maintained during the recording or later equalized. Recordings were subsequently manipulated to disable an influence of transient parts on perception. Signals in both tests were listened to using headphones.

<u>Experiment I: Spontaneous Verbal Description (SVD) of Differences in Pairs of Sounds</u>

The spontaneous verbal description of timbre is a modification of the free identification method [3]. Listeners described perceived differences in timbre in all pairs of sounds spontaneously in words [7]. A separate test for each tone was carried out with a group of ten listeners. Eleven signals gave 55 signal pairs for each test. Perceived sound quality preferences in listened signal pairs were also collected.

Experiment II: Ranking and Rating of Sound Sets on Selected Verbal Attributes

Based on the results of the first experiment described in [9], verbal attributes sharpness, clearness, darkness, narrowness and sound quality were selected for this experiment. The group of eleven listeners assessed all attributes separately for each of the five tones [8]. The test program was developed in a MATLAB (® The Math Works) environment. The listeners' task was to rank (sort) the set of eleven signals according to the specified verbal attribute (thus to press appropriate button on a PC monitor to play the sound or to move the button to the desired place on a scale) and then to rate sorted signals with values from 0 to 10. Thus VAME was applied on an individually ranked sequence of signals; furthermore, the program design allowed the listener to check rated values or rate differences by follow-up listening to any desired signal. This method is denoted through this article as **verbal attribute ranking and rating** – **VARR**.

RESULTS

Experiment I: Spontaneous Verbal Description (SVD)

The results of SVD of timbre were the frequencies of occurrence of each used word on each stimulus, later computed for the whole group of listeners. These words were merged into five **lists of verbal attributes**, only words with an overall frequency of occurrence of at least ten were evaluated. This represented 65 words for the B3 tone, 64 for F#4, 58 for C5, 64 for G5 and 65 for D6 tone. The most frequently used words are in Table 1.

Table 1. Rank and overall frequency of occurrence of most frequently used words in individual tones, high ranks (1 – 9) are bold. The English translation of words is in the left column; the original Czech words are in parentheses.

	B3	F#4	C5	G5	D6
sharp (ostrý)	**2** *(176)*	**1** *(185)*	**1** *(208)*	**1** *(174)*	**1** *(249)*
narrow (úzký)	**6** *(105)*	**3** *(107)*	**4** *(140)*	**2** *(151)*	**3** *(124)*
bright (světlý)	**4** *(130)*	**5** *(95)*	**3** *(143)*	**4** *(126)*	**5** *(114)*
dark (tmavý)	**1** *(208)*	**2** *(157)*	**2** *(152)*	10 *(68)*	11 *(60)*
soft (měkký)	**8** *(89)*	**4** *(96)*	**6** *(121)*	**8** *(75)*	**2** *(134)*
round (kulatý)	**5** *(119)*	**8** *(73)*	**5** *(123)*	**7** *(76)*	**7** *(92)*
gloomy (temný)	**3** *(144)*	**6** *(78)*	10 *(75)*	11 *(66)*	**8** *(71)*
clear (jasný)	15 *(48)*	10 *(71)*	**8** *(83)*	**3** *(146)*	**4** *(120)*
metallic (kovový)	**7** *(99)*	**9** *(72)*	**9** *(76)*	**9** *(72)*	**9** *(62)*
delicate (jemný)	18 *(45)*	**7** *(75)*	**7** *(108)*	15 *(50)*	10 *(61)*
voiced (znělý)	16 *(46)*	11 *(67)*	20 *(35)*	**5** *(86)*	13 *(58)*
rustle (šustivý)	14 *(48)*	12 *(51)*	30 *(24)*	18 *(44)*	**6** *(101)*
damped (přidušený)	26 *(33)*	23 *(38)*	13 *(58)*	**6** *(77)*	18 *(40)*
bleat (mečivý)	**9** *(87)*	24 *(31)*	27 *(27)*	56 *(11)*	61 *(10)*

Correlations (Pearson's correlation coefficient) between frequency of occurrence in pairs of words for each of all five tested tones were also calculated. Resulted correlations for five words selected for the second experiment are in Table 2 (lower triangular matrices).

Experiment II: Verbal Attribute Ranking and Rating (VARR)

The main results of the VARR experiment are described and discussed in [8], where the concordance of listeners and repeatability of results are also evaluated. The **average rates** of eleven listeners for eleven signals were correlated for each verbal attribute; results are summarized in Table 2 (upper triangular matrices).

Relations between Results of SVD and VARR Experiments

Correlations from Table 2 are the main basis for the assessment of relations between both experiments. Correlations inside each experiment were calculated for all pairs of verbal attributes: for frequency of occurrence in the SVD experiment and for averaged rates in the VARR experiment. All these correlations are summarized in Table 2. As the same signals were used in both experiments, it was possible to compare directly results in the SVD and VARR experiments. Calculated correlations between results of both experiments are in Table 3.

Table 2. Correlations of selected verbal attributes: a) ***lower triangular matrix***: between frequencies of occurrence of spontaneously used words (**SVD**), b) ***upper triangular matrix***: between mean rates of verbal attributes (**VARR**), in individual tones. Significant correlations at 5% are bold.

tone **B3**		sharp	dark	clear	narrow	quality	
sharp		—	**-0.98**	**+0.90**	**+0.64**	**-0.63**	
dark		**-0.89**	—	**-0.93**	**-0.73**	*+0.57*	**VARR**
clear	**SVD**	*+0.45*	*-0.32*	—	*+0.59*	*-0.34*	
narrow		**+0.91**	**-0.91**	*+0.35*	—	**-0.67**	
perceived quality preference		**-0.69**	**+0.85**	*+0.20*	**-0.76**	—	

tone **F#4**		sharp	dark	clear	narrow	quality	
sharp		—	**-0.96**	**+0.68**	*+0.58*	**-0.86**	
dark		**-0.84**	—	**-0.79**	*-0.54*	**+0.77**	**VARR**
clear	**SVD**	*+0.58*	*-0.29*	—	*+0.38*	*-0.37*	
narrow		**+0.62**	**-0.80**	*-0.02*	—	**-0.75**	
perceived quality preference		*-0.48*	**+0.78**	*+0.18*	**-0.70**	—	

tone **C5**		sharp	dark	clear	narrow	quality	
sharp		—	**-0.98**	**+0.79**	*-0.09*	**-0.66**	
dark		**-0.91**	—	**-0.85**	*+0.19*	*+0.58*	**VARR**
clear	**SVD**	*+0.28*	*-0.39*	—	*-0.58*	*-0.08*	
narrow		**+0.71**	**-0.74**	*-0.22*	—	**-0.60**	
perceived quality preference		**-0.63**	*+0.57*	*+0.41*	**-0.87**	—	

tone **G5**		sharp	dark	clear	narrow	quality	
sharp		—	**-0.97**	**+0.83**	*-0.55*	*+0.00*	
dark		*-0.38*	—	**-0.72**	*+0.40*	*+0.15*	**VARR**
clear	**SVD**	*+0.38*	*-0.13*	—	**-0.77**	*+0.48*	
narrow		*+0.27*	*-0.37*	**-0.67**	—	**-0.61**	
perceived quality preference		*+0.07*	*+0.31*	**+0.82**	**-0.90**	—	

tone **D6**		sharp	dark	clear	narrow	quality	
sharp		—	**-0.98**	**+0.86**	**-0.63**	**-0.79**	
dark		*-0.50*	—	**-0.83**	**+0.60**	**+0.76**	**VARR**
clear	**SVD**	*+0.32*	*-0.43*	—	**-0.79**	*-0.43*	
narrow		*+0.04*	**-0.63**	*+0.23*	—	*+0.12*	
perceived quality preference		**-0.75**	*+0.46*	*-0.07*	*-0.36*	—	

Table 3. Correlation between frequencies of occurrence (SVD) and averaged rates (VARR) of studied verbal attributes in individual tones. Significant correlations at 5% are bold.

	B3	F#4	C5	G5	D6
sharp	**+0.84**	*+0.58*	**+0.97**	**+0.72**	**+0.95**
dark	**+0.90**	**+0.89**	**+0.95**	*+0.27*	*+0.56*
clear	*+0.43*	**+0.64**	*+0.55*	**+0.74**	**+0.62**
narrow	**+0.92**	**+0.76**	*+0.42*	**+0.93**	*+0.33*
perceived quality preference	**+0.87**	**+0.96**	**+0.88**	**+0.63**	**+0.92**

DISCUSSION

Many previous experiments have confirmed that the results of listening tests are strongly dependent on the context of stimuli and also on the context of listeners. In the experiments described here the same sets of signals and an identical method of presentation to the listeners were used. The listener groups were different (only two persons took part in both experiments) but with similar backgrounds (culture, music education, experiences) and professional or age structure. Moreover, sound designers in the second experiment did not provide divergent results [8]. Hence, we may suppose that the differences described further in the results of the SVD and VARR experiments arise mainly from the properties of methods used.

Latin squares were used to define the order of tested tones in both experiments. The Ross algorithm [10] was used to define pair order in SVD to minimize the error of individual stimuli assessment in time and position. In VARR, the listener may repeat listening of any signal in case of uncertainty during ranking or rating. Spontaneously used words and their number in SVD depend not only on the previously described listeners' backgrounds but also on his/her communication abilities (richness of personal vocabulary). When more similar (synonymous) words are suitable for the description of perceived timbre aspect the individual choice and number of used words may be different. So concordance and repeatability are difficult to verify in SVD method.

The main discussion of results and methods is based on evaluation of correlations between pairs of verbal attributes in the SVD and VARR experiments (Table 2).

Sharp – Dark
Negative and highly significant correlation in all five tested tones in VARR suggests that the verbal attributes *sharp* and *dark* in violin tones constitute one timbre dimension, with *sharp* and *dark* on opposite poles. One possible explanation for nonsignificant correlations (even if still negative) in SVD in G5 and D6 tones provides rank and frequency of occurrence of the word *dark* (see Table 1), which are dramatically less frequent in these two tones. A substantial decrease of correlations between SVD and VARR results for *dark*, noticeable in Table 3, also supports this explanation. Graphic forms of frequencies and correlations are found n Figure 1 and Figure 2.

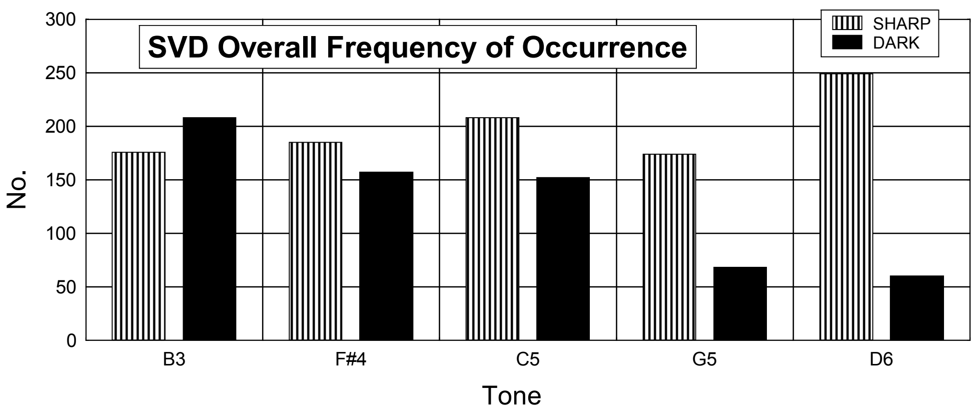

Figure 1. Overall frequency of occurrence of words *sharp* and *dark* in the SVD test.

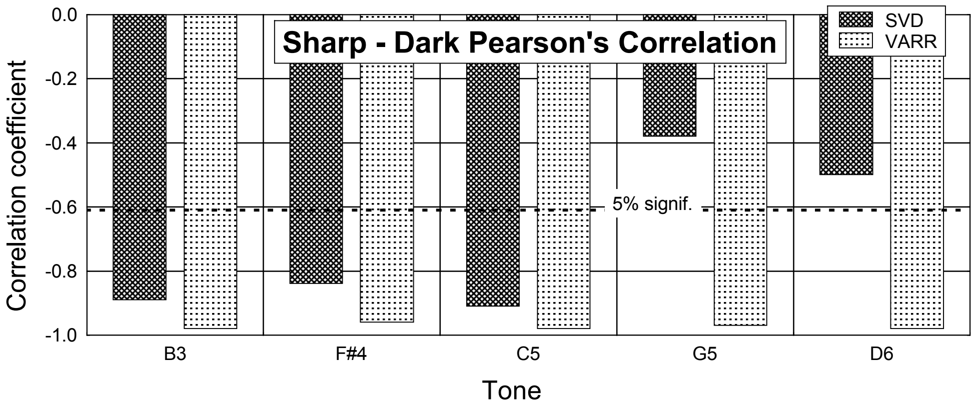

Figure 2. Correlations between verbal attributes ***sharp*** and ***dark*** in the SVD and VARR tests.

Sharp – Clear

Correlations between these two verbal attributes are positive and significant in all five tones in the VARR test, positive but never significant in the SVD test. Many researchers use the word *bright* instead of *sharp* or tried (unsuccessfully) to distinguish these two attributes. The English translation of the Czech word *jasný* is *clear* or *bright*; we preferred to use *clear* to distinguish these two attributes, but it seems they are related also in violin tone context. Coincident occurrence and slight differentness of these two attributes may be the reason for their lower correlation in SVD: listeners prefer to express spontaneously in word on individual signals only the more pronounced attribute (sharpness in some signals, clearness in others). Only some of them express both. This is not the case of VARR, where listeners focus on only one attribute (and its rating) in each test.

Sharp – Narrow

The overall frequency of occurrence of both attributes in SVD is high and relatively stable. Correlation between these two attributes decreases with increasing pitch in both methods used, from highly significant and positive to zero in SVD and from significant and positive to significant and negative in VARR (Figure 3). Change of spectral sources for narrowness [11] is one possible explanation for this phenomenon. Very similar correlations between ***dark*** and ***narrow*** (but with opposite signs) corroborates the relations among attributes *sharp* – *dark* and *narrow*. The relation between ***clear*** and ***narrow*** is unstable in SVD but similar to *sharp* – *narrow* in VARR, although with a systematic shift to negative correlation values.

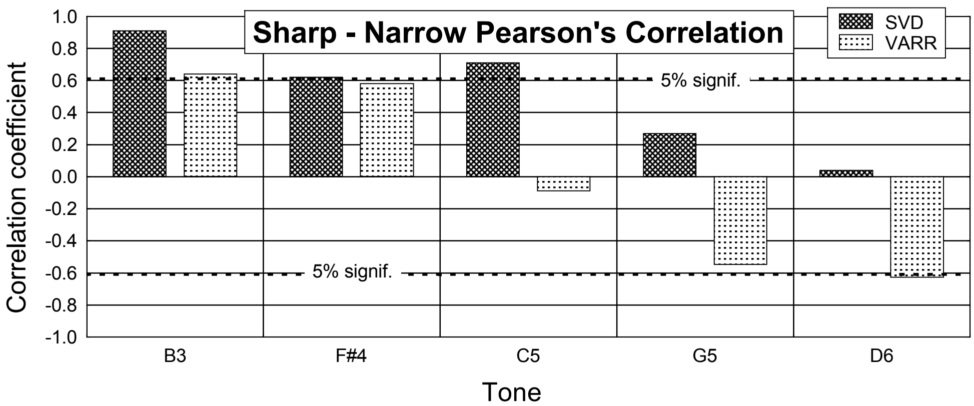

Figure 3. Correlations between verbal attributes ***sharp*** and ***narrow*** in the SVD and VARR tests.

Sound quality

Perceived sound quality was assessed in the first experiment as a preference test (not SVD), so it is not surprising that there was high agreement between listener groups in both experiments (last row in Table 3). The main influence on perceived sound quality in both tests had the attributes *sharp* (negative), *dark* (positive) and *narrow* (negative) in all tones except G5, in which *clear* (positive) and *narrow* (negative) had the strongest influence. Correlations of sound quality preferences with other words used in SVD are also discussed in [12].

Comparison of results in SVD and VARR (correlations in Table 3) revealed a probable influence of lesser overall frequency of occurrence (Table 1) in *dark* (tones G5 and D6) and *clear* (B3, F#4, C5), but not in *sharp* (F#4) and *narrow* (C5, D6). Individual models of timbre evaluation could be useful to explain these phenomena.

CONCLUSION

Both used methods, spontaneous verbal description of timbre differences in pairs of sounds (SVD) and verbal attribute ranking and rating of sounds for a tested attribute (VARR), revealed good agreement of results in general. In our experiments the modified VARR seemed more robust. This was possibly caused by listener focus on only one timbre feature in each test session.

A remaining problem in the application of the VARR test is the selection of an adequate and complete set of verbal attributes. Preliminary use of SVD on the studied context could be helpful to select verbal attributes salient to the studied context, and to avoid the loss of important features of timbre.

It would be useful to test other verbal attributes on our signals to arrive at a successful description of sound quality or its prediction based on tested attributes. More attention must be paid to individual models of timbre evaluation.

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