Comparison of Five Perceptual Timbre Spaces of Violin Tones of Different Pitches

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Summary: Violin timbre was studied for five tone pitches (H3, F#4, C5, G5, D6). A set of violin tones played on different instruments was recorded in an anechoic room. The recordings were subsequently manipulated to reduce the influence of the tones transient parts on perception. Two pair listening tests using headphones were performed for each pitch: the timbre dissimilarity scaling test and a spontaneous verbal description of timbre dissimilarities. Some perceptual attributes and pairs of attributes of violin timbre were specified on the basis of correlation analysis of the frequency of word occurrence for individual tones. A hypothesis of perceptual dimensions of timbre of isolated quasistationary violin tones is formulated. Comparing the results for five studied pitches and using the hypothesis it was possible to establish four perceptual dimensions of timbre ('soft' - 'sharp', 'clear' - 'damped', 'dark' - 'bright', 'narrow').

INTRODUCTION

Timbre perception of musical sound is a multi-dimensional phenomenon. Gray (1) proposed three basic dimensions of timbre together with their substantial physical foundations: spectral energy distribution, synchronicity of attack and decay, and explosiveness of the initial attack. The investigation was realised on a broad variety of instruments.

The aim of our investigation was to find and describe basic timbre dimensions related to the stationary part of the tone of a particular instrument: the violin.

METHOD

The research was based on the performance of **five different pitches**, H3 (played on string G), F#4 (string D), C5 (string A), G5 (string E), D6 (string E). Twenty-four violins representing a large range of instrument quality were played by the same professional violinist in the prescribed manner (down bow *detache*, non vibrato, bow position *naturale*, dynamics *mezzo forte*) in an anechoic room. Tone recordings were adapted in a uniform way to reduce the variability of transient events on perception (2).

Two listening tests for each of the five individually tested tones were conducted. The first was the dissimilarity test. From twenty four recordings the seventeen most appropriate were selected for each tone. Twenty subjects—professional musicians—marked timbre dissimilarities in all pairs of recordings listened to monophonically with headphones.

Resulting dissimilarities were arranged into a group dissimilarity matrix for each pitch. The nonmetric MDS procedure using the Euclidean distance model was used to construct five perceptual spaces (3). A three dimensional solution was chosen for the tones H_3, $F\#_4$, C_5, and two dimensional solution for G_5 and D_6. The second listening test included both verbal descriptions of timbre differences and judgements of preference of the perceived sound quality (2) in pairs of recordings. The test was performed with ten subjects and eleven recordings, selected according to the best representation of the perceptual space of the first test.

This contribution focuses on the result and evaluation of the spontaneous verbal description of timbre differences in the second listening test. The result of the test was the creation of **five vocabularies of descriptive words**. Frequencies of occurrence of words for individual instruments were used to determine **groups of relative/contradictory words**. The following criteria was used:

1. Significant positive correlations between frequencies of occurrence defining groups of relative words.
2. Significant negative correlations defining contradictory groups.

A comparison of the word groups found for the five pitches demonstrated that the words contained, their relations and properties, show common as well specific characteristics. The following **hypothesis of basic perceptual dimensions of timbre** of isolated quasistationary violin tones was formulated to generalise or summarise the results:

a) There is a system of independent basic perceptual dimensions of timbre.
b) All basic perceptual dimensions of timbre are reflections of some spectral or temporal characteristics, specific to each dimension.
c) The interrelationship of basic perceptual dimensions (i.e. the mutual position of their axes in perceptual space) depends on the context of tones judged (e.g. selection of signals, their pitch, loudness, etc.). It means that the angle of two dimensions changes with the context according to the extent of common occurrence of their physical cause on the tones judged.
d) Word description of every basic perceptual dimension does not change with the context of tones judged.

Dimensions may be described with two words of opposite meaning or with only one word.

RESULTS AND DISCUSSION

Two hundred and sixty seven different words were obtained from the spontaneous verbal description of timbre differences. The number of words obtained for individual tones is as follows:

H_3	$F\#_4$	C_5	G_5	D_6
160	149	157	154	194

In the following analyses only words with an overall frequency of occurrence of at least ten were used. The number of words upon reduction varied between 58 and 67. The number of groups determined on the basis of significant positive correlation varied between thirteen and seventeen. The review of negative correlations led to the assessment of two pairs of word groups with contradictory properties for each tone. An example of significant correlations of words from these groups for the tone F#4 is in TABLE 1. The overall frequency of occurrence of words from TABLE 1 is in FIGURE 1.

TABLE 1. Significant correlations between frequencies of occurrence of words from two pairs of groups with contradictory properties, used to describe timbre differences of tone F#4. Correlations of significance level of $\alpha \leq 10\%$ are inserted, $\alpha \leq 5\%$ are bold.

Group	Word	velvety	dark	gloomy	round	soft	sharp	metallic	bright	narrow	blurred	unvoiced	damped	muted	clear	voiced	piercing
1 A	velvety	--	**.86**	**.84**	**.89**	**.89**					.53	**.60**					
	dark		--	**.87**	**.94**	**.79**											
	gloomy			--	**.95**	**.84**											
	round				--	**.87**											
	soft					--											
1 B	sharp	**-.88**	**-.84**	**-.68**	**-.78**	**-.72**	--	**.68**	**.95**	**.62**					.58		.56
	metallic	**-.76**	**-.80**	**-.60**	**-.72**	**-.65**		--	.54	**.92**							
	bright	**-.82**	**-.73**	**-.66**	**-.71**	**-.65**			--	.52					**.74**	.59	**.66**
	narrow	**-.69**	**-.80**	-.59	**-.70**	**-.61**				--							
2 A	blurred										--	**.88**	**.71**	**.61**			
	unvoiced						**-.63**		**-.65**			--	**.78**	**.69**			
	damped												--	**.78**			
	muted						-.53							--			
2 B	clear	-.53									**-.61**	**-.68**	**-.67**	-.58	--	**.91**	**.90**
	voiced										-.55	**-.62**	**-.77**			--	**.85**
	piercing	-.54									-.54	-.59	**-.69**	**-.67**			--

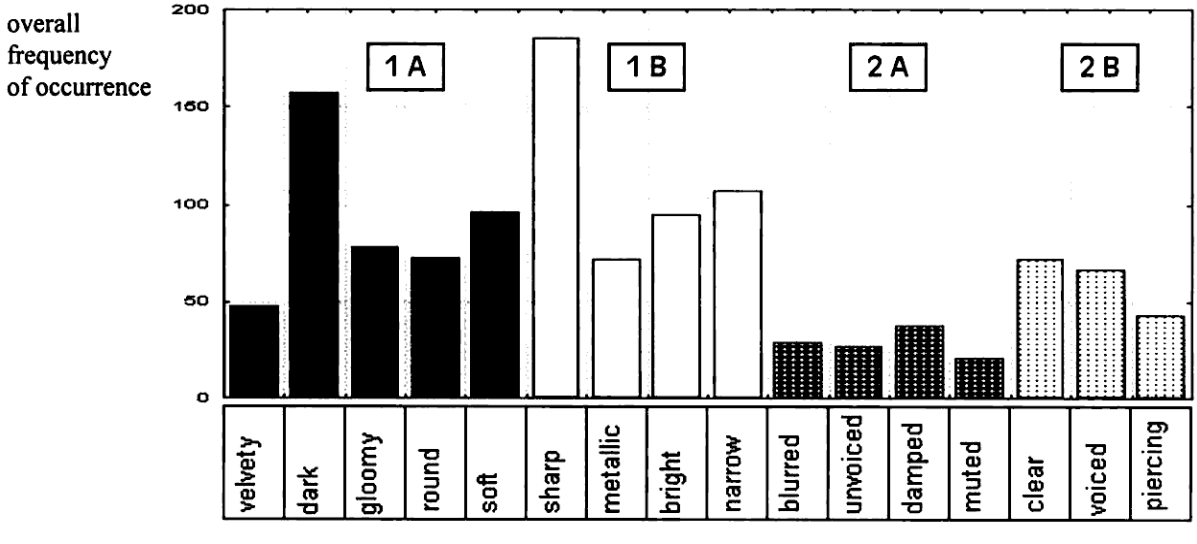

FIGURE 1. Overall frequency of occurrence of words from two pairs of groups describing contradictory properties of timbre, tone F#4.

The hypothesis of basic perceptual dimensions of timbre was applied to the words belonging to the different groups for all five tones. Only words used for the description of timbre differences with a higher overall frequency were taken into account (see TABLE 2).

TABLE 2. Most frequently used words creating two pairs of groups with contradictory properties for five tested pitches. Second pair in tone D6 has two alternatives.

Group	H3	F#4	C5	G5	D6	
1 A	soft dark	soft dark	soft dark	soft	soft	
1 B	sharp bright narrow	sharp bright narrow	sharp bright narrow	sharp	sharp	
2 A	damped	damped	damped	narrow damped	narrow	damped
2 B	clear	clear	clear	clear	voiced	clear

Four salient perceptual dimensions were identified applying the hypothesis to the results of the experiment:

I. '**soft**' - '**sharp**' II. '**clear**' - '**damped**' III. '**dark**' - '**bright**' IV. '**narrow**'

The words defining the first two dimensions are the most stable representative of the pairs of groups. The words in the third dimension deviated in the context of the two highest tested tones, but the negative significant correlation of their frequency of occurrence remained. The forth dimension, which is created only with one word without a stable opposite, is an example of a 'moving' dimension from the first pair to the second one.

As usual in research based on subjective tests the results are not definitive, but stable significant correlations of the frequency of occurrence of the words 'soft' and 'sharp' with a spectral centre of gravity, and 'narrow' with a first harmonic level for all five tones support the existence of identified dimensions. There is also high concordance of the first three dimensions with the dimensions found in (4) from a context-free questionnaire.

It is necessary to verify the dimensions described with the use of listening tests performed on artificially synthesized signals.

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