

## Perception of Sharpness and Narrowness in Violin Tones: Influence of Spectral Components with Changing Pitch

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### Abstract

Timbral attributes Sharpness and Narrowness were studied in listening tests with violin tones. Five different pitches (B3, F#4, C5, G5, and D6) were assessed using modified method of Verbal Attribute Magnitude Estimation (VAME). Spectral components possibly influencing amount of Sharpness and Narrowness were detected using correlation analysis and later verified in additional listening tests with manipulated signals. Spectral causes of both verbal attributes in individual pitches were identified from the test results. Spectral components with significant influence on specific attribute in all five studied pitches were compared. Hypotheses (models) of Sharpness and Narrowness dependency on pitch connected with levels of fundamental and higher harmonics are formulated.

### Introduction

Many authors have investigated sound timbre and tried to describe its main features and their spectral sources. The results of these studies turned out to be strongly dependent on the context of listened stimuli. Complex sounds coming from very different sound sources were used in listening tests (noises, vowels, sounds of various musical instruments, artificially generated sounds, etc.). Usually the result of these experiments led to two or three interpretable dimensions. In most of these studies *sharpness* (also called *brightness*) was singled out as the most pronounced timbre dimension [1]. Its connection also has been proven with the location of frequency in the spectral centre of gravity [2]. No other attribute of timbre was described in such detailed way.

In recent years our laboratory had prepared several experiments with violin tones of different contexts (pitches) and using various listening test methods. Introductory experiments led to the construction of perceptual spaces and finding four timbre dimensions for stationary violin sounds [3]. Verbal attributes *sharp*, *dark*, *clear* and *narrow* representing these dimensions were further investigated in listening tests using the same sound contexts [4]. *Sharpness* and *Narrowness* were found as one of basic attributes describing timbre of stationary

violin sound. Their spectral sources were detected and later verified in additional listening tests [5]. Spectral sources for *sharpness* and *narrowness* and for other timbral attributes *rustlessness*, *glossiness* and *buzzing* discovered in other experiments were described in [6].

Hypotheses (models) of *sharpness* and *narrowness* spectral causes according to changing pitch are proposed in this article.

### Overview of previous experiments

Violin sounds of five different pitches were used in all experiments: 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, A). The instruments were played *détaché*, *naturale*, non-vibrato, and *mezzoforte*; recordings were made in anechoic room and uniformly adapted to reduce the influence of transients on perception.

The results of **dissimilarity tests** with twenty judges and seventeen sounds in each pitch led to the construction of perceptual spaces [7]. These spaces were interpreted using results of **spontaneous verbal description (SVD)** performed by ten judges on eleven sounds selected from original seventeen sounds for each pitch [8]. Comparison of verbally evaluated perceptual spaces led to the assessment of four timbre

dimensions proposed for stationary violin sounds [3], see also Table 1.

**Table 1.** Timbre dimensions of stationary violin sounds.

Dim.	Dimensional words: in English (in Czech)
I.	Soft (měkký) – Sharp (ostrý)
II.	Clear (jasný) – Damped (zastřený)
III.	Dark (tmavý) – Bright (světlý)
IV.	Narrow (úzký)

Eleven judges assessed four representative attributes *sharp*, *clear*, *dark* and *narrow* on the same sounds used in SVD experiment. **Verbal Attribute Ranking and Rating (VARR)** method (adopted Verbal Attribute Magnitude Estimation) was used as a next experiment [4]. Results of SVD and VARR methods revealed to be in good agreement (comparison of these methods see [9]). Results of VARR [4] exhibit that *sharp* and *dark* are opposite and *sharp* and *clear* similar attributes of violin timbre. Thus only attributes *sharp* and *narrow* were further investigated.

Various kinds of spectral characteristics were calculated from stationary parts of sounds (levels in individual harmonics, in critical bands, and spectral centre of gravity) and their correspondence with magnitude of verbal attributes *sharp* and *narrow* in all five tested pitches was established using correlation analysis [5].

Hypotheses about spectral sources of *sharpness* and *narrowness* were formulated and verified in **additional VARR** tests performed with subgroup of judges and with signals of three pitches B3, C5, and D6 [5]. Signals were prepared by manipulation of selected original sounds showing extreme magnitudes in both attributes [5]. Results are summarised schematically in Figure 1 (see also [6]). Two different judge strategies were found in pitch C5, one group of judges used strategy similar to strategy used in lowest pitch B3 (dark arrows in Figure 1), second group used strategy similar to strategy used in highest pitch G6 (bright arrows).

### Models for *sharpness* and *narrowness*

Models for attributes *sharpness* and *narrowness* are formulated based on the results of correlation analyses of all five pitches B3, F#4, C5, G5, and D6 but above all on the results of additional listening tests in pitches B3, C5, and D6.

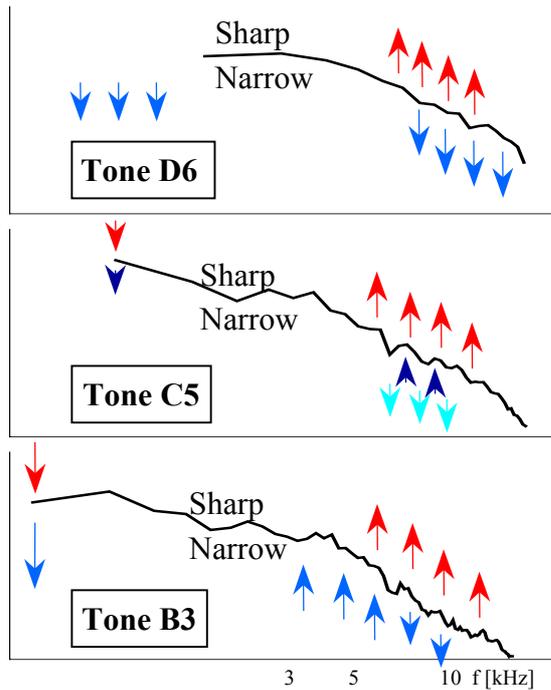
The ***sharpness* model** is relatively simple (Figure 2). The main sources for the perception of *sharpness* are high levels of harmonics in the band from 5 to 10 kHz in all studied pitches. According to the *sharpness* calculation formula [2], the higher the frequency (harmonic number) the higher the contribution to *sharpness*. In real sound the influence of very high frequencies is limited by their decreasing level (shape of spectral envelope). The influence of the first harmonic is opposite but diminishes with increasing pitch; this implies that there must exist a neutral frequency range, which we place at somewhere in the 1200 – 1400 Hz band.

The ***narrowness* model** is rather more complicated (Figure 3). According to the first harmonic it is similar to *sharpness*. The perception of *narrowness* according to higher harmonics is strictly influenced by the highest audibly pronounced harmonic (see A in Figure 3), which can be changed in the following ways:

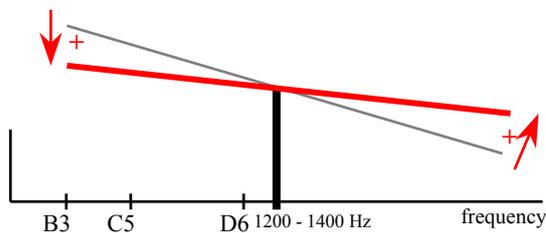
- by lowering its level;
- by increasing the level of some lower frequency harmonic.

In both cases the harmonic of lower frequency (B or C in Figure 3) takes over the role of the highest audibly pronounced harmonic, thus increasing the *narrowness*. The frequency position of highest audibly pronounced harmonic depends on the shape of the spectral envelope and masking, and can be also influenced by individual experience, focus or ear characteristics (see also two strategies for note C5).

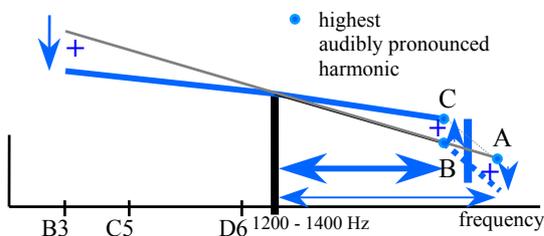
The development of significant correlations in changing pitch (Figure 1) is in accordance with the moving position of *narrow* in perceptual space of verbal attributes [4].



**Figure 1** Increase of the *sharp* and *narrow* attributes caused by spectrum level change in arrow direction (the length corresponds to the size of increase); there are two different judge strategies for C5 and *narrow*. Spectral envelopes are mean values of eleven signals used in original VARR experiment.



**Figure 2** Schematic model for *sharpness* evaluation in violin tones. The change in level in arrow direction causes an increase in *sharpness*. (See text for a more detailed explanation.)



**Figure 3** Schematic model for *narrowness* evaluation in violin tones. The level change in the arrow direction causes increase of *narrowness*. Highest

audibly pronounced harmonic frequency and level: original position (A), after the A-level decrease (B), after the B-level increase (C). (See text for a more detailed explanation.)

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