BOWS AND TIMBRE - MYTH OR REALITY?

Anders Askenfelt and Knut Guettler

Dept. of Speech, Music and Hearing
Royal Institute of Technology
Dr. Kristinas väg 31
SE-10044 Stockholm
Sweden
andersa@speech.kth.se

Norwegian Academy of Music
P.O. Box 5190
Majorstua
N-0302 Oslo
Norway
knut.guettler@nmh.no

Abstract

Professional string players unanimously claim the importance of the tonal qualities of the bow. Previous studies of the bow-string interaction have, however, not given any clear-cut physical explanation of the phenomenon. In this study an attempt is made to verify professionals′ ability to discriminate between bows when listening only, and to suggest two mechanisms by which the bow would influence the bow-string interaction. (*Work supported by the Swedish Natural Science Foundation*)

INTRODUCTION

The importance of the bow with regard to the tonal quality of bowed string instruments is emphasized by professional string players. The outmost care which is devoted to the selection of a new bow, including long-lasting playing tests, bear witness of this importance, and it implies that it is the particular combination of instrument and bow which constitutes the instrument. The price level is also an indicator of the importance of the bow. Nowadays a good violin bow is rarely sold under 3000 – 4000 €. Examples of common terms in rating the tonal qualities of bows would be "warm – brilliant", "full – thin". The feeling of the bow, often described in terms of "heavy – light," "stiff – soft," would be more relevant in characterizing a bow for the maneuverability in fast bowing gestures like spiccato and ricochet. Certain bows seem to be more forgiving than others, enabling a easy start of tones with little noise. This would correspond to a short portion of the aperiodic part of the attack before Helmholtz motion is achieved. In this sense the bow contributes to the "playability" of the instrument, often defined as the space of bowing parameter combinations which produces a normal string tone (Helmholtz motion) [1].

In this study a listening test is reported in which professional string players′ ability to discriminate between bows was examined. Following, two mechanisms are proposed by which an influence of the bow on the string motion would be possible. The magnitude of the effects are illustrated by computer simulations.

LISTENING TEST

A sample of five bows ranging in quality from very good to very poor was included in the listening test. Two French bows were used as examples of high-quality bows. These bows had different timbral characteristics according to players′ informal judgements; "full", strong tone (*Fétique*) and "supple, warm" (*Voirin*). A bow of carbon fiber composites (*Spiccato*) represented a medium-quality bow. A bow of birch or sallow (*Bjork*) was included as an example of a poor bow (very light and short). A bow substantially deviating from normal standards (*Spiccato M*) was obtained by modifying the carbon-fiber bow. The bow hair was supported by a thin wooden bar (2 mm thick), pressed in position between the tip and frog and supported against the stick at the middle by a connecting piece of wood.

NAME	ABBR.	PRICE est. €	WEIGHT g	LENGTH total/hair mm	MATERIAL	OVERALL RATING
Fétique V.	Fet	6 000	62.0	740/ 648	pernambuco	8
Voirin F. N.	Vor	5 500	57.7	744/ 650	pernambuco	7
Spiccato Super Solo	Spc	1 400	59.9	747/ 650	carbon fiber	5
Bjork	Bjk	0	44.9	715/ 615	birch or sallow	1
Spiccato Modified	SpM	0	71.7	747/ 650	see text	0

Table 1. Bows included in the listening test. The overall rating was given by the player on a scale from 0 ("useless") to 10 ("excellent")

Recordings of the bows were made by a professional violinist, giving several renderings of two short examples; a cantabile phrase played on the G-string ("Melody," duration 4 s) and an excerpt with fast notes on the A and E strings from the standard violin literature ("Czardas" by *Monti,* duration 6 s). A near-field microphone position was used, with the microphone mounted on the violin (BK4021). A listening test was designed using the ABX procedure. In this type of test the listener hears a stimuli (phrase) played three times; first played with bow A and then with bow B, and finally with either bow A or B. The task is to decide whether the last example X was played with bow A or bow B. Five pairs of bows were compared in the test (see Fig. 1).

Eight professional string players aged between 28 and 59 years participated in the test. Using a computer-based presentation procedure, each subject rated 16 ABX versions of each pair of bows. The presentations were randomized. The listeners were seated in a sound-treated studio (3 x 3 x 2 m) with high-quality loudspeakers (Boston Acoustics BA7500) positioned rather close to the ears (2 - 3 dm). In combination with the near-field recording the impression was resembling normal listening conditions for a violinist with the instrument under the chin. The result of the listening test is shown in Fig. 1.

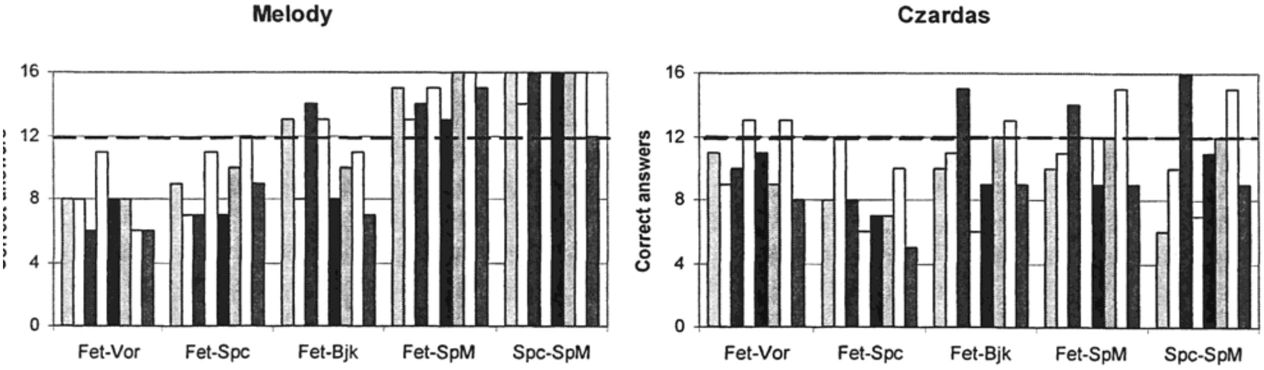

Fig.1. Number of correct answers for all 8 subjects in the listening test for a cantabile melody (left) and a passage with fast notes (right). Five bows were paired in 5 combinations (see Table 1). The dashed line represents the minimum number of correct answers for discriminating between the two bows in each pair (p<.05).

Each answer in an ABX test is either correct or wrong. The statistics of ABX tests and the many possible pitfalls have been discussed in connection with evaluations of hi-fi equipment [2]. In a test with 16 repetitions at least 12 correct answers are required to reject the null hypothesis, i.e. that the differences between the two bows A and B are inaudible, at the 0.05 level of significance. As seen from Fig. 1 the listeners ability to discriminate between the bows varies largely.

The modified bow could be assumed to be easy to recognize. In line with expectations, all listeners could discriminate between the two bows when the modified bow (*SpM*) was included in the pair for the Melody, but surprisingly not for Czardas. In contrast, no listener could discriminate between the two high-quality bows (*Fet-Vor*) in the Melody, but two could do so for Czardas. Further, it was surprising that so few subjects could discriminate between the bows in the *Fet-Bjk* pair (3 listeners in Melody and 2 in Czardas), in which a very good bow was contrasted against a very poor.

When data were collapsed over all subjects, giving 128 answers for each pair of bows, the result was that the listeners as a group could discriminate between the bows in 8 of the 10 tested pairs at the 0.05 level of significance. The two exceptions were *Fet – Vor* in Melody, and *Fet – Spc* in Czardas. The reason may be that both *Fétique* and *Voirin* are high-quality bows which produces full, "good" violin sound. The *Fétique and Spiccato* bows seem to behave somewhat similarly in attacks, giving a crisp, fast start of the tone.

It is worth remembering that in listening tests there is always a risk of making the error of concluding that the differences are inaudible to the listeners when their true ability to choose correctly in the ABX test in the long run actually is higher than chance, say above 60%. Even when the sample size is as large as 128 this risk may be as high as 30%.

In conclusion, the listening test indicated that experienced violinists are able to discriminate between bows from the sound produced. There are, however, large variations in this ability between individuals.

BOW-FORCE MODULATION — A POSSIBLE PATHWAY FOR SPECTRAL INFLUENCE

The influence of bow force ("bow pressure") on the spectral envelope is well established, initially through Cremer's analysis on "the rounded corner" [3]. This impact is, however, far from linear. Pickering [4] measured the output spectra of a number of violin strings of various design under controlled bowing conditions. For a given bow speed and bowing position he found that each type of string had a range in bow force within which the energy content of higher partials would change drastically even for small changes in the force. These differences are related to the core material. Fig 2. shows an example for a violin A string with Perlon core

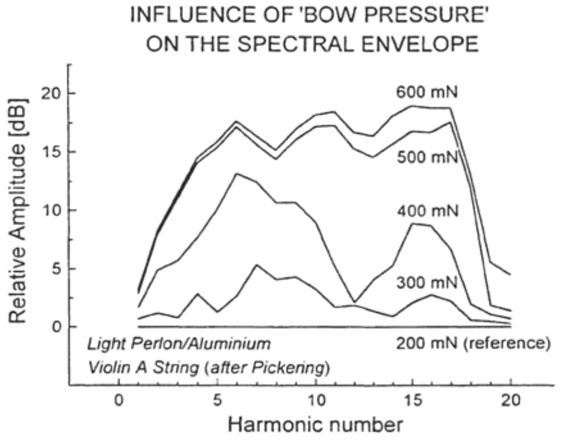

Fig. 2. Influence of bow force ("bow pressure") on the spectral envelope of a light-gauge aluminium-wound violin A string with Perlon core. Bow-bridge distance 14 mm (centre), bowing speed 10 cm/s. The string shows a particular sensitivity to bow-force variations within the 300-500 mN range. (Compiled from [4]).

A violin bow displays strong resonances around 50 and 65 Hz [5,6], which, in addition to the "bouncing-rate" frequency between 6 and 40 Hz [7], may modulate the bow force. These resonances will be excited at note onsets, but also during the quasi steady-state of the note by the periodically varying frictional force between bow and string. Simulations show that when the bow force is modulated at a certain rate, a *reduction* in bow force temporarily causes an *increase* in the maximum flyback velocity of the string, and vice versa. Normally, a higher bow force implies a higher flyback velocity due to a higher friction delta. However, if the bow force suddenly drops from a higher value, the string will all of a sudden meet less frictional resistance during flyback, and the peak flyback velocity will increase for a while. This occurs, however, only as long as the string motion is in a transitional state with reminiscences of the previous wave pattern still present.

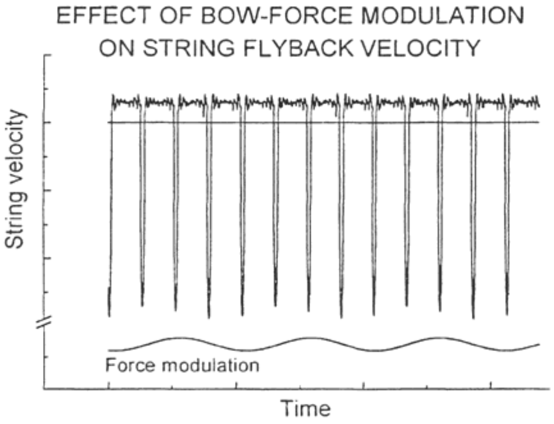

Fig 3. Simulations indicate that rapid changes in the bow force introduce (out-of-phase) changes in the flyback velocity. The figure shows the string velocity under the bow during a stroke with constant velocity and 10% modulation of the bow force. The modulation frequency is four times lower than the fundamental frequency of the string.

A modulation in bow force seems typically to influence the string partials in the following manner (see Fig. 3). About 90 degrees after a maximum in the bow-force, the flyback velocity reaches a maximal magnitude and so do most high partials, in particular those partials which are close to the "node frequencies," $f_{node} = nf_0/\beta$, where β is the relative bow-bridge distance. Similarly, about 90 degrees after a minimum in bow force level, the flyback velocity and the partials reach their minima.

The activity in a bow during normal playing as measured in the vertical motion of the bow stick (normal to the string) differs between bows. Acceleration magnitudes in the bow stick corresponding to a modulation of bow force up to 6 % of a nominal statical value of 800 mN have been observed in our measurements. According to Fig. 3 such variations would be able to influence the spectral envelope in a region around the 15th partial by about 1 dB. The difference limen for detecting a amplitude difference for a certain partial in comparisons between steady complex tones is 1.5 dB at a minimum [8], but it may well be lower for modulated partials. Spectral variations caused by a modulation in bow force might thus be perceivable to the advanced listener, especially if working within the string's most sensitive range.

BOW VELOCITY MODULATION

The bow hair will gain a modulation of the steady bow velocity in the longitudinal direction (along the hair) due to the periodically varying frictional force. The longitudinal admittance of the bow (as seen by the string) is, however, quite low compared to the point admittance of the string [5], and the components of the bow hair velocity will be substantially lower than in the string. Only around the node frequencies where the string velocity components are of low amplitude, the bow hair velocities may reach comparable magnitude. Even so, bow hair velocities are at least a factor 5 lower in amplitude than the string velocity components, according to measurements. Simulations have shown, however, that a longitudinal resonance of the bow hair would be able influence the string velocity and bridge force substantially [9]. When the resonance is close in frequency to a node frequency the influence on individual partials may as much as 3 – 4 dB. This means that a modulation in bow hair velocity, boosted by bow resonances, would be an efficient mechanism for the bow to influence the string motion and hence timbre. Convincing experimental validation is however still lacking.

CONLUSIONS

Professional string players are able to discriminate between bows when presented to pair-wise comparisons of recorded phrases. The differences in this ability between individuals is however large. Modulations in bow force and bow velocity caused by resonances in the bow may offer two separate pathways for an influence on timbre by the bow. Simulations indicate that the resulting variations in string partial amplitudes due to such modulations are of a magnitude which would be possible to perceive.

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