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SPECTRAL ENRICHMENT IN VALVE TROMBONES

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ABSTRACT

Following the development of practicable valves in the 1810s, valved versions of horns, trumpets and trombones quickly followed. The valve trombone became a popular and widely used brass instrument throughout the 19th century, although employed less commonly today. Not only were valve trombones made in a great variety of wraps, but also in a wide variety of bore profiles. Many valve trombones were close in bore profile to slide trombones (therefore necessarily close to cylindrical for a high proportion of the sounding length), but some employed novel bore profiles. The range of values of the spectral enrichment parameter *E* (derived from physical measurements) for tenor valve trombones overlaps with the range of *E* values for baritone saxhorns. Nevertheless, saxhorns are perceived as *cuivres doux* (mellow) while valve trombones are *cuivres clairs* (bright). This anomaly is partly due to different playing styles of valve trombones and baritones, but subtleties in the rates of expansion in bore are also significant. This paper compares these overlapping categories using detailed bore measurements and analysis of playing tests on instruments from the respective families.

Keywords: *valve trombone, spectral enrichment, brass instruments, timbre, playing tests*

1. INTRODUCTION

Following the development of reliable valves for brass instruments in the 1810s, trombones in which the familiar slide was replaced by a cluster of three or four valves were produced and were widely used in bands and orchestras. Their use declined through the 20th century.

Valve trombones were made in a great variety of configurations with some resembling slide trombones (see Fig. 1), others being more compact or having the bell directed upwards or to the side (see Fig. 2). Without the design constraints imposed by the slide mechanism, some valve instruments marketed or used as trombones departed from the bore profile of the slide trombones, which was necessarily close to cylindrical for a high proportion of the sounding length. In some valve trombones, there was greater expansion in the bore diameter in the region around the mid-point of the sounding length that resulted in less spectral enrichment. These valve trombones have a value of the spectral enrichment parameter *E*, discussed in the previous paper [1], of as low as 4.8[1].

Figure 1. EU 3830. Valve trombone in B♭ (Julius Heinrich Zimmermann, St Petersburg, c 1905).

The species of brass instrument known as the *saxhorn baryton* in France, the 'baritone' in Great Britain and the *Tenorhorn* in German-speaking countries (see Fig. 3)

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[1] The *Armeeposaune* [valve trombone] by Červený in the Lisbon Music Museum (237) has a spectral enrichment $E = 4.8$.

typically has a value of E in the range 4.0 to 5.0 with some examples as high as 5.2[2].

Figure 2. EU 3472. *Armeeposaune* [valve trombone] in B♭ (Karl Schamal, Prague, c 1880).

A form of baritone with the bell directed forwards, designed for use in American-style marching bands (see Fig. 4), has a narrow bore diameter in the region around the mid-point of the sounding length of the tubing to reduce weight, giving a value of E approaching 6.0[3].

Figure 3. EU3887. Baritone in B♭ (Boosey & Hawkes, London, 1962).

Figure 4. GR 537. Marching baritone in B♭ (F.E. Olds & Son, Fullerton, California, 1978).

Predictions of the timbral qualities of instruments can be based on physical bore profile measurements; in particular, the degree of spectral enrichment represented by the parameter E. Specification of the bore profile is principal means by which an instrument maker determines the species and properties of a brass instrument. The primary output of an instrument is the sound heard by an audience, so playing tests under realistic conditions are important to validate the predictions based on physical measurements. However, while the sound quality experienced by a listener depends on the design of an instrument – for example, if it is a trumpet or a flugelhorn – it is also influenced by the technique of the player, the choice of mouthpiece, and the room acoustics. Playing tests of instruments need to be devised so as to minimise the influence of individual player, mouthpiece and room characteristics.

2. PLAYING TESTS

Eighteen instruments, all in 9-ft B♭, were assembled from various collections, consisting of eight valve trombones selected to have low values of E, eight baritones selected to have high values of E, and two other instruments with a very high value of E and with a very low values of E respectively, see Tab. 1.

[2] The *saxhorn baryton* [baritone] by Van Engelen in the Royal Conservatoire of Scotland has a spectral enrichment $E = 5.2$.

[3] The marching baritone by Lafleur (author's collection) has a spectral enrichment $E = 5.9$.

Table 1. Instruments tested with calculated spectral enrichment *E* (*C* = 88mm). The instruments are from the collections of Arnold Myers (AM), the Royal Conservatoire of Scotland (GR), Edinburgh University Collection of Historic Musical Instruments (EU), Bryce Ferguson, Edinburgh Music Centre (BF); the inventory numbers and serial numbers provide identification.

Ref	**Instrument**	***E***
AM 1795	Slide trombone in B♭, narrow bore (Courtois); serial 3417	6.7
GR 38	Valve trombone in B♭ (Santucci)	6.0
GR 535	Valve trombone in B♭ (Kessels); serial 5048	6.0
EU 4631	Ventil [valve] trombone in B♭ (Boosey); serial 25642	5.9
EU 6432	Valve trombone in B♭ (Klimesch)	5.7
EU 3830	Valve trombone in B♭ (Zimmermann); serial 7973	5.6
EU 3832	Baritone [valve] trombone in B♭ (Seltmann)	5.5
EU 3472	*Armeeposaune* [valve trombone] in B♭ (Schamal)	5.5
EU 6649	Valve trombone in B♭ (Higham); serial 26104	5.2
AM 1729	Marching baritone in B♭ (Lafleur); serial 155101	5.9
GR 537	Marching baritone in B♭ (Olds); serial A37978	5.8
GR 430	Baritone in B♭ (Van Engelen)	5.2
EU 6394	Saxotromba [baritone] in C with B♭ extension (Labbaye)	5.1
EU 2726	Baritone in B♭ (Boosey); serial 108832	4.7
BF 5	Baritone in B♭ (Besson); serial 855666	4.7
EU 3887	Baritone in B♭ (Boosey & Hawkes); serial 338333	4.7
EU 3875	*Tenorhorn* [baritone] in B♭ (David)	4.7
AM 1828	Euphonium in B♭, Courtois model (B&S); serial 329946	3.3

The tests were conducted in a moderately reverberant church chosen for its quiet location and for its room acoustics, which correspond to those of a typical performance venue. Four experienced players (RA, DMC, WG and AM) were asked to play a steady crescendo from pp to ff on the note B♭3, each player using a single mouthpiece for all instruments. Each crescendo was repeated at least three times. The radiated sound was recorded on an HP Envy laptop using Audacity software. The microphone was a Bruel & Kjaer Type 2669, which was calibrated before each session using a Norsonic nor1251 calibrator, and placed 2m in front of the player. The recordings were edited in Audacity: for each instrument with each player the smoothest three crescendos were selected. The 216 recorded sound files were processed in Matlab to produce plots of magnitude spectral centroid, normalized to the playing frequency, against sound pressure level, as in Fig. 5. This shows the plots for two players on the instruments with a very high value of *E* and with a very low values of *E*. Fig. 6 shows the plots for one player on the same two instruments together with one of the valve trombones and one of the baritones.

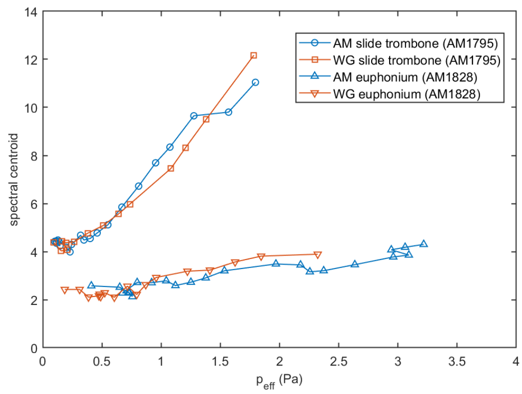

Figure 5. Spectral centroid plotted against sound pressure level for two of the players each playing crescendos on two of the instruments. The spectral centroid increased from 4 in pianissimo to 11 or 12 in fortissimo for the slide trombone (upper curves) but only from 2 to 3 for the euphonium.

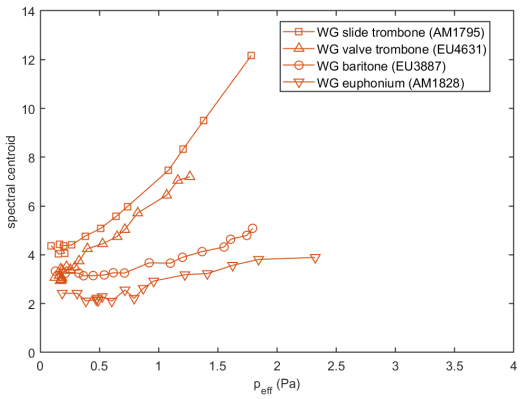

Figure 6. Spectral centroid plotted against sound pressure level for one of the players playing crescendos on four of the instruments. The spectral centroid curves for the valve trombone and the baritone lie between the curves for the slide trombone (with a very high value of *E*) and the euphonium (with a very low values of *E*).

3. INSTRUMENT COMPARISONS

Plots of amplitude spectral centroid against sound pressure level (as in Fig. 6) for the valve trombones and baritones confirmed that they are all intermediate between the narrow bore trombone (AM 1795) and the euphonium (AM 1828). There was some variation between the plots of the crescendos performed by the four players on the each instrument. The increase of spectral centroid (*SC*) with sound pressure is in general a rising curve, but not strictly linear. To focus the results on the instruments rather than the players, the mean of the spectral centroids at a sound pressure of 1Pa for the three crescendos from the four players was calculated for each instrument, given in Tab. 2. 1Pa was selected as the sound pressure level for these comparisons since it is high enough for differences between instruments to be well differentiated but low enough to be achievable by players on all the instruments. In musical terms, 1Pa represents a *forte* dynamic (94dB): in *piano* playing brass instruments cannot be so readily distinguished, while some instruments cannot support a crescendo to higher than *forte*.

Table 2. Instruments tested with mean measured spectral centroids at 1Pa *SC*

Ref	Instrument	*SC*
AM 1795	Slide trombone in B♭, narrow bore (Courtois)	7.2
GR 38	Valve trombone in B♭ (Santucci)	5.4
GR 535	Valve trombone in B♭ (Kessels)	5.0
EU 4631	Ventil [valve] trombone in B♭ (Boosey)	5.4
EU 6432	Valve trombone in B♭ (Klimesch)	4.7
EU 3830	Valve trombone in B♭ (Zimmermann)	5.2
EU 3832	Baritone [valve] trombone in B♭ (Seltmann)	5.6
EU 3472	*Armeeposaune* [valve trombone] in B♭ (Schamal)	4.8
EU 6649	Valve trombone in B♭ (Higham)	4.6
AM 1729	Marching baritone in B♭ (Lafleur)	4.4
GR 537	Marching baritone in B♭ (Olds)	5.5
GR 430	Baritone in B♭ (Van Engelen)	3.7
EU 6394	Saxotromba in C with B♭ extension (Labbaye)	3.3
EU 2726	Baritone in B♭ (Boosey)	4.0
BF 5	Baritone in B♭ (Besson)	3.7
EU 3887	Baritone in B♭ (Boosey & Hawkes)	3.9
EU 3875	*Tenorhorn* [baritone] in B♭ (David)	3.3
AM 1828	Euphonium in B♭, Courtois model (B&S)	2.6

A plot of the mean spectral centroids at 1Pa against the respective spectral enrichment *E* (Fig. 7) shows the expected general trend of increasing *SC* with increasing *E*. There is some spread in the *SC* values which can be attributed to (a) residual differences in playing styles of the four players, (b) variation in the performance of successive crescendos by each player, (c) varying levels of instrument condition (several were historic instruments not regularly in playing use), and (d) directionality effects of instruments in different wraps.

4. CONCLUSIONS

Among the sample instruments selected for the playing tests the populations of valve trombones and baritones display some overlap in terms of both spectral enrichment *E* derived from physical measurements, and the mean spectral centroid at 1Pa achieved in the playing tests. If the marching baritones are regarded as a distinct form of baritone, the instruments selected for this study show a clear differentiation between valve trombones and baritones, with the marching baritones sharing the characteristics of the valve trombones. The playing tests demonstrated broad consistency between the spectral enrichment parameter *E* derived from physical measurements and the measured spectral centroids across the sample set of eighteen instruments. This validation is important since it is more practicable to measure instruments of interest than to conduct playing tests in a reproducible way. In particular, use of the spectral enrichment parameter *E* has the potential to enhance our understanding of museum instruments that for whatever reason (such as fragility or less than perfect condition) cannot be played.

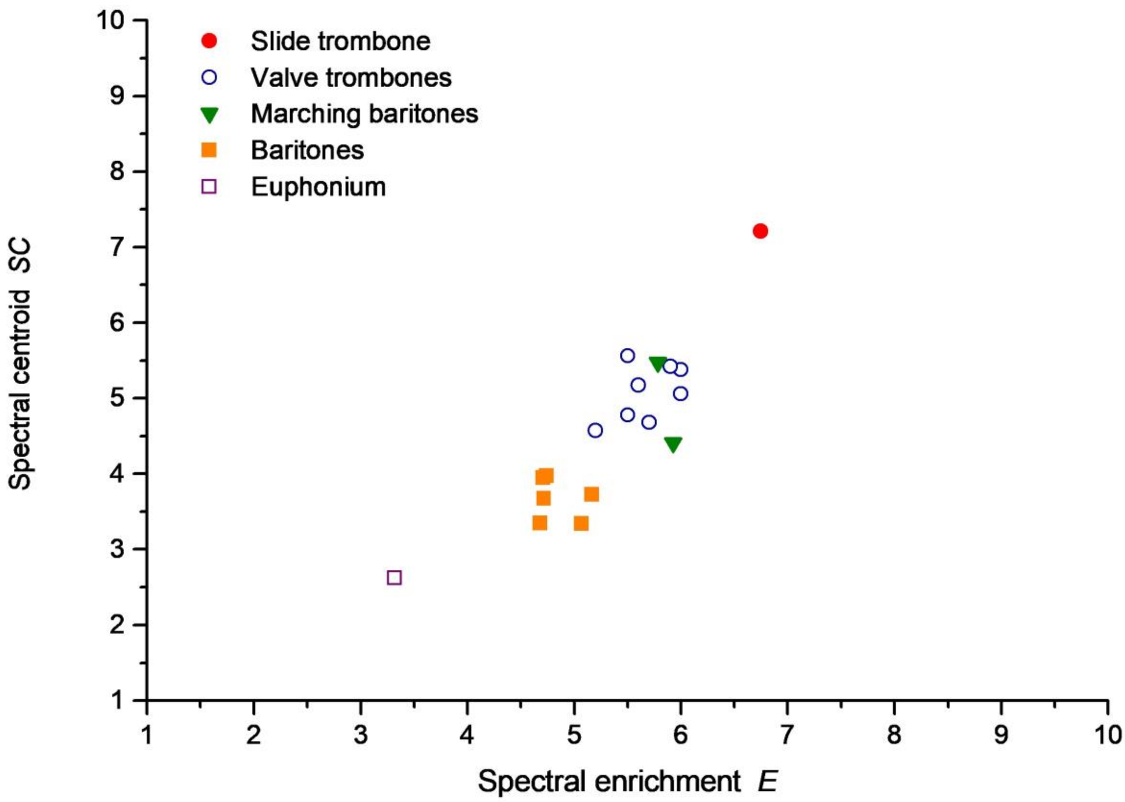

Figure 7. Spectral centroid at 1Pa sound pressure level at the microphone for each instrument averaged for all performances by all players plotted against the respective spectral enrichment *E*.

5. ACKNOWLEGEMENTS

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6. REFERENCE

[1] D.M. Campbell and A. Myers: "The contributions of Joël Gilbert to the understanding of 'brassiness'" in *Proc. of Forum Acusticum* (Torino, Italy) 2023.