IS IT THE PLAYER OR IS IT THE INSTRUMENT?

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ABSTRACT

Previous measurements of trombone tones [1] showed considerable player-to-player variability in the degree to which the radiated spectrum changes with different bell alloys. This might arise in the following way. Consider two very different players, W and G. Player W is able to produce the desired timbre, independent of the bell alloy, by altering the embouchure as needed. Given a choice of instruments, player W will presumably pick the one that, for him, most easily produces that timbre. Player G, on the other hand, always blows each instrument as freely as possible, allowing the instrument to determine the tone quality, and then chooses an instrument with the desired timbre. It is plausible to think that the characteristics of the sound pressure in the mouthpiece cup will show greater variability (with changes of bell alloy) for player W than for player G due to the embouchure adjustments by player W. An attempt was made to test this hypothesis by simultaneously measuring sound pressure internally within the mouthpiece and externally on the bell axis. However, a more effective means for separating the influence of the player from the properties of the instrument was to perturb the feedback loop to the player's ear with moderately loud masking noise.

1. THE EXPERIMENTAL SETUP

1.1. Data acquisition

An S. E. Shires symphonic tenor trombone was played by two players with two different bells. The trombone is constructed in a modular fashion, so that it was possible to interchange bells with no other alterations to the instrument. One bell was made of red brass (90% Cu, 10% Zn), the other of yellow brass (70% Cu, 30% Zn). In addition, the red brass bell was made of thicker metal.

Both players used a Vincent Bach 5G mouthpiece. Sound pressure within the mouthpiece was monitored with an Endevco 8510 B-2 piezoresistive pressure transducer mounted flush with the interior surface of the mouthpiece cup.

Sound pressure external to the trombone was measured with an electret microphone positioned on the bell axis 75 cm from the plane of the bell rim. The external microphone was mounted on an aluminum rod attached to the hand slide, so that its position relative to the trombone was fixed as long as the slide was kept in the same position (all measurements were made with the slide fully retracted, that is, in first position).

After passing through a preamplifier (built by the author), the two signals were digitized by a USB sound card (M-Audio Transit) whose output was recorded on a MacBook Pro computer at a 44.1 kHz sample rate and 16-bit resolution using the Amadeus Pro sound editing program.

The recordings were made in a moderately dead room (but by no means anechoic). However, the external microphone was close enough to the trombone that the direct sound very strongly dominated the reverberant field. Moving the playing position within the room produced no discernible change in the recorded signal.

A skilled brass player can exercise a good deal of control over timbre, except perhaps at the extremes of the dynamic range [2]. In order to estimate this effect, for half the tests the players performed normally, while for the other half they listened to moderately loud pink noise through MP3 player ear buds worn beneath sound-isolating earmuffs. The masking noise level was high enough that vocal communication, even at shouting level, was not possible. Both players found the masking noise quite disconcerting, but were eventually able to adapt to it. However, their control of the playing pitch was somewhat impaired by the masking noise.

1.2. Data analysis technique

Four pitches were recorded: $B\flat_2$, F_3, $B\flat_3$, and F_4 (the second, third, fourth, and sixth harmonics of the trombone with the slide in first position).

Both players had stated in advance the Bach 5G mouthpiece was sufficiently similar to their normal mouthpieces that they would be quite comfortable playing on it, but this proved not to be true. Both players had difficulty controlling $B\flat_2$; results for that pitch are more scattered than for the higher pitches.

The analysis software was written in Python and was inspired by parts of Beauchamp's SNDAN package [3]. Every two periods of the fundamental frequency of the analyzed note, the program analyzes a window four periods wide and finds the signal level and a number of parameters derived from the spectrum.

The parameter used here to characterize the radiated spectrum is the *average frequency* [4], defined as

$$f_{av} = \frac{\sum_{k=1}^{N} f_k |A_k|^2}{\sum_{k=1}^{N} |A_k|^2} \qquad (1)$$

where f_k and A_k are the frequency and Fourier coefficient of the kth harmonic of the windowed signal, f_1 being the fundamental frequency[1]. This calculation included harmonics up to 90% of the Nyquist frequency; that is, $f_N = N f_1 \simeq 0.9 f_{Nyquist}$.

A higher value of f_{av} means stronger higher harmonics, and corresponds to a brighter or brassier timbre.

2. RESULTS

All of the results shown here are taken from slow diminuendos over the full dynamic range. Thus, they represent essentially steady tones.

The conventional wisdom among players is that the light-weight yellow brass bell produces a brighter sound than the heavy-weight red brass bell, presumably corresponding to a higher f_{av}.

All the figures below show f_{av} vs. sound pressure, both quantities measured by the external microphone.

Figures 1 and 2 compare the two bells for the note $B\flat_2$, played by player G. At high levels, there is considerable scatter, but this was the pitch where both players felt most strongly the departure from their normal mouthpieces.

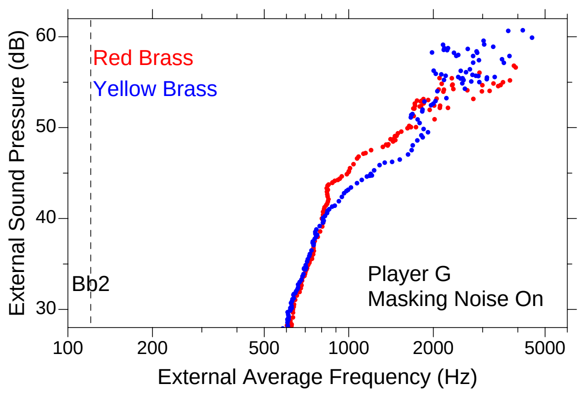

Figure 1: Player G, with masking noise. The vertical dashed line shows the fundamental frequency of the note played, in this case $B\flat_2$.

Although player G was the one who did not appear to be correcting the timbre by altering his embouchure, it is clear that he does so unconsciously. With the masking noise (Figure 1), f_{av} for the yellow brass bell is noticeably higher than for the red brass bell in the middle of the dynamic range, as expected. This is not so without the masking noise (Figure 2).

The next two figures show the corresponding data for player W. Again, with the masking noise (Figure 3), the yellow brass bell is the brighter, this time over more of the dynamic range. Without the masking noise (Figure 4), the difference largely disappears.

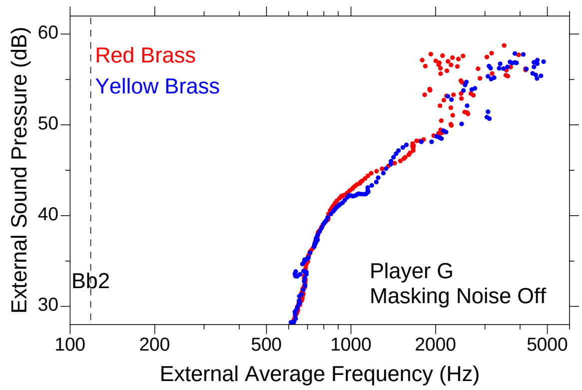

Figure 2: Player G, without masking noise, $B\flat_2$.

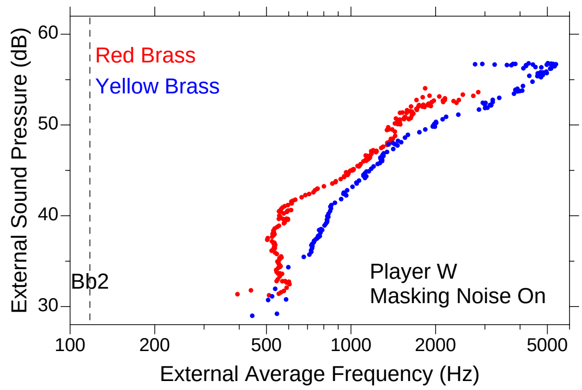

Figure 3: Player W, with masking noise, $B\flat_2$.

But this is not the end of the story. Figures 5 through 8 show similar plots for F_3, the note a fifth higher.

This time, the presence of the masking noise does not exaggerate the difference between the bells. In fact, player W, who normally seems to be able to control the timbre quite well, shows a large difference without the masking noise and almost none when the masking noise was present. For him, the yellow brass bell has the higher f_{av}, as expected.

For player G, on the other hand, the red brass bell has the higher f_{av}, with or without masking noise.

Finally, Figures 9 through 12 show the results for $B\flat_3$. For this note, as for $B\flat_2$, the absence of masking noise seems to allow both players to produce a more consistent timbre on both bells.

[1]The average frequency is the center of gravity of the *power spectrum*; it is a close cousin of spectral centroid as defined by Beauchamp, which is the center of gravity of the *amplitude* of the spectrum.

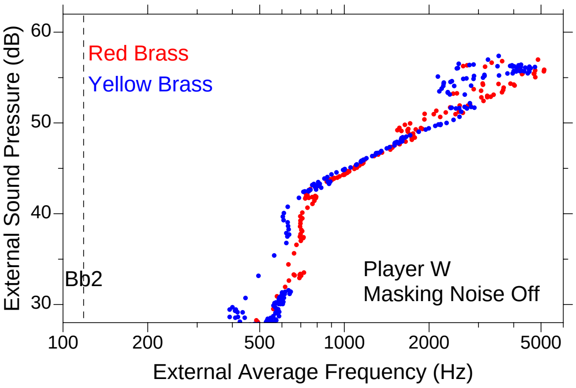

Figure 4: Player W, without masking noise, $B\flat_2$.

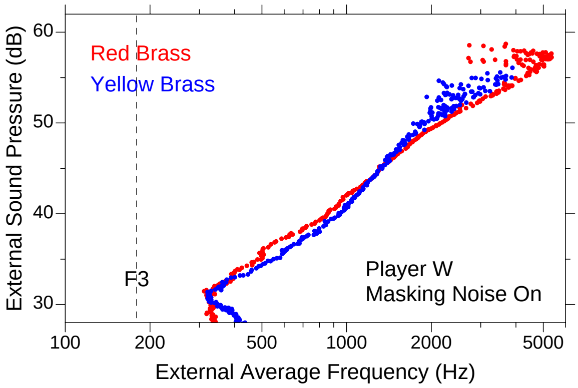

Figure 7: Player W, with masking noise, $F3$.

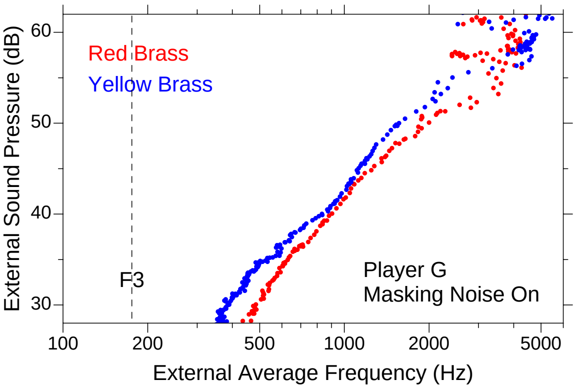

Figure 5: Player G, with masking noise, F_3.

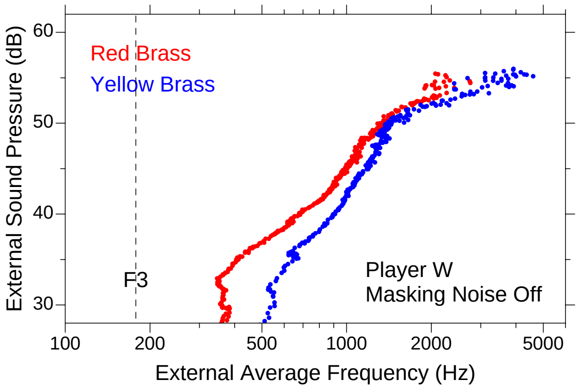

Figure 8: Player W, without masking noise, F_3.

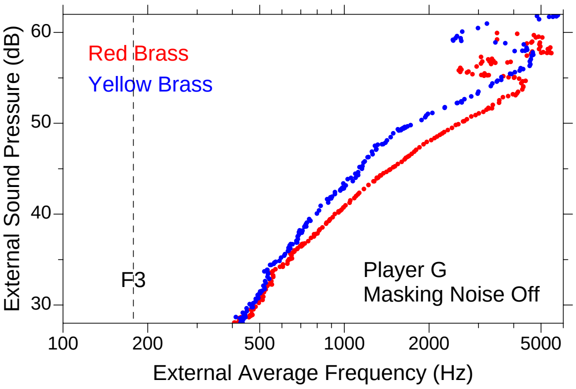

Figure 6: Player G, without masking noise, $F3$.

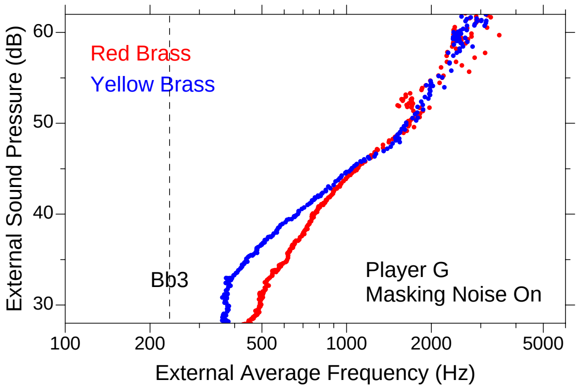

Figure 9: Player G, with masking noise, $B\flat_3$.

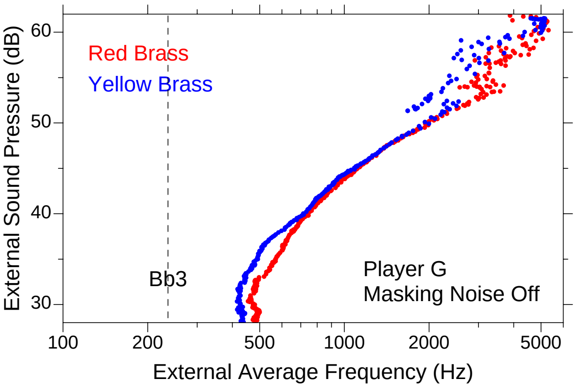

Figure 10: Player G, without masking noise, $B\flat_3$.

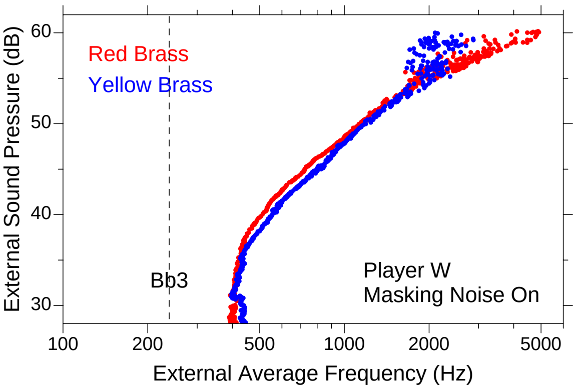

Figure 11: Player W, with masking noise, $B\flat_3$.

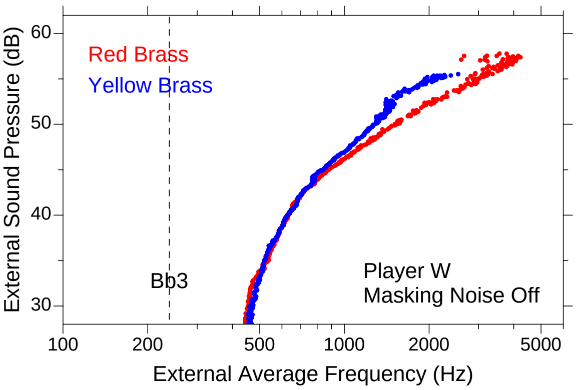

Figure 12: Player W, without masking noise, $B\flat_3$.

For player G the red brass bell has the higher f_{av}, at least at the softer playing levels (Figures 9 and 10).

This contrasts with player W, for whom yellow brass produced a (very slightly) higher f_{av} in the presence of masking noise (Figure 11). Without the masking noise, red brass had the higher f_{av}, but only at the loudest playing levels (where player control is least). At lower dynamics, there was minimal difference (Figure 12).

3. CONCLUSIONS

Without the masking noise, both trombonists control the timbre to some extent, whether consciously or not. With the masking noise, differences in timbre, presumably due to the different bell alloys, are more pronounced. The prediction that the yellow brass bell will produce a brighter timbre than the red brass bell was not observed at all pitches, nor was it consistent between the two players.

It is very likely that players' perception of tone quality is based on the entire gamut of pitches, not just three or four notes, and that attack transients also play a role. It is widely thought that red brass bells are characterized by a "softer" attack than yellow brass. This could mean that the higher harmonics build up more slowly for a red brass bell.

It appears that more experiments would be helpful.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Pyle, R., "Does a brass-instrument's timbre depend on the alloy from which it is made?", J. Acoust. Soc. Am., Vol. 125, No. 4, Pt. 2, April 2009, p 2597(A).

[2] Norman, L., Chick, J.P., Campbell, D.M., Myers, A., and Gilbert, J., "Player control of 'brassiness' at intermediate dynamic levels in brass instruments", Acta Acustica united with Acustica, **96**(4), pp. 614-621.

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[4] Cohen, L., Time-Frequency Analysis, Prentice-Hall, Upper Saddle River, New Jersey, 1995 (ISBN 0-13-594532-1).