Influence of the Gap on the Acoustic Response of the Trumpet

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This study explores diverse approaches to studying the influence of the gap—the space between the mouthpiece and the beginning of the trumpet's leadpipe —on the acoustic response of the trumpet. Currently, from both a musical and an instrument manufacturing perspective, no consensus or standardization exists regarding the impact of the gap. Different manufacturers have made varying statements, yet no recent research has reported scientific evidence underlying gap-related physical phenomena.

Related to this area of study is a thesis by Dennis Fleisher (Fleisher, 1980). Recent studies confirm that slight changes in the initial area of the mouthpiece-trumpet bore can significantly impact its acoustics behaviour (Bertsch, 2003) (Resch et al, 2016).

To control the gap systematically, a modular receiver was designed, allowing the user to vary from 0 to 8 mm longitudinally within 2 mm increments for a specific mouthpiece.

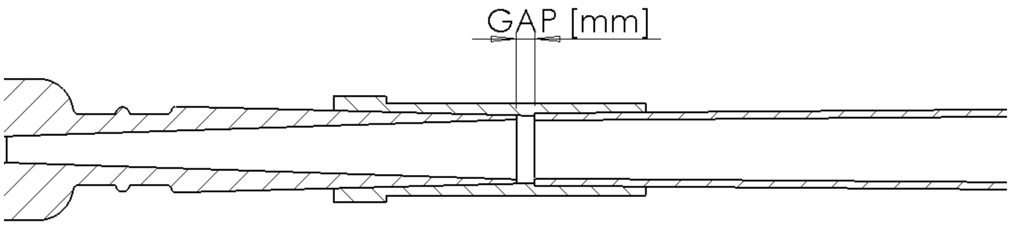

Fig. 1. Gap longitudinal dimension

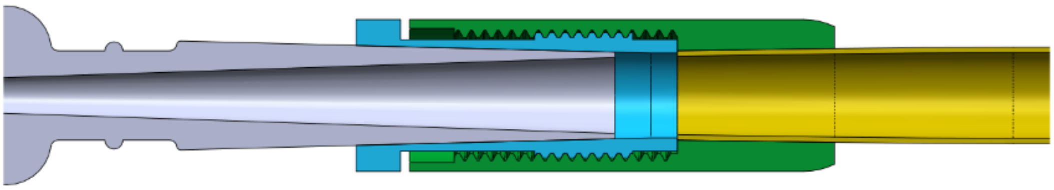

Fig. 2. Modular gap receiver design

Fig. 3. Receiver system mounted on the test trumpet

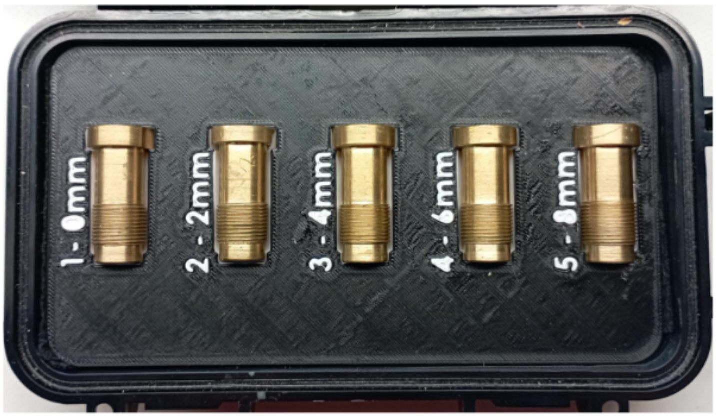

Fig. 4. Insert number - gap distance.

Experimental measurements of acoustic properties, **numerical simulations**, and **sensory perception evaluations** from musicians were conducted for every gap number. Acoustic measurements were performed in the anechoic chamber of the MdW, using the BIAS system, obtaining data for input acoustic impedance, pulse response, and pulse response factor.

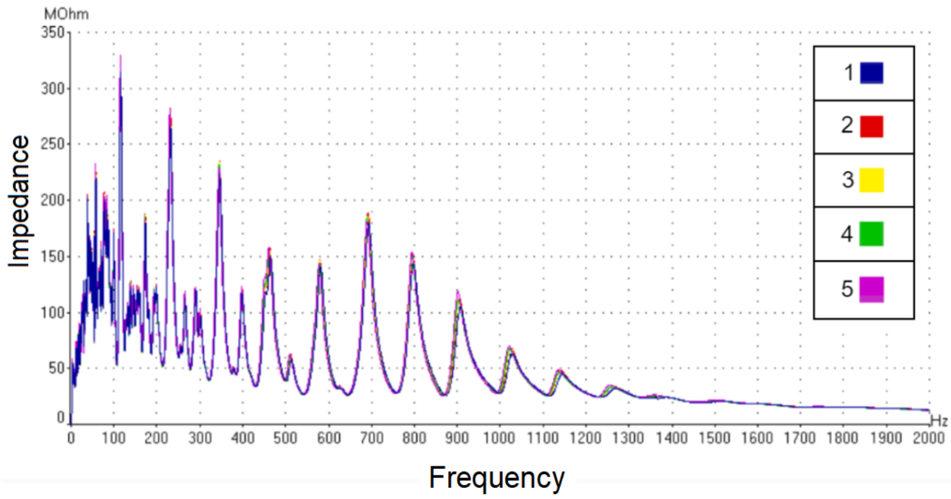

Fig. 5. Standard weighted representation of measured impedances

Color		Partial	2	3	4	5	6	7	8
		GAP 2 Impedance **REF** (MOhm)	282	235	157	146	188	152	113
		GAP 3 Impedance (MOhm)	278	233	157	146	185	151	110
		GAP 3 over REF (%)	0,0	-0,9	0,0	0,0	-1,6	-0,7	-2,7
		GAP 4 Impedance (MOhm)	277	232	156	144	185	150	110
		GAP 4 over REF REF (%)	-1,8	-1,3	-0,6	-1,4	-1,6	-1,3	-2,7
		GAP 5 Impedance (MOhm)	281	229	158	144	180	154	119
		GAP 5 over REF (%)	-0,4	-2,6	0,6	-1,4	-4,3	1,3	5,3

Table 1. Quantified weighted partial peaks for the measured impedances

*Gap number 1 presented anomalies (as expected), not shown in this table

Numerical simulations were calculated by the Transfer Matrix Method (TMM) in the BIAS software for the properties measured in the laboratory.

Partial	2	3	4	5	6	7	8
GAP 1 Impedance (MOhm)	165	143	172,5	161	120,5	68	36,5
GAP 1 over REF	0,0	-0,3	0,3	0,6	-0,4	-1,4	0,0
GAP 2 Impedance **REF** (MOhm)	165	143,5	172	160	121	69	36,5
GAP 3 Impedance (MOhm)	165,5	143,5	171	159	121	69,5	37
GAP 3 over REF (%)	0,3	0,0	-0,6	-0,6	0,0	0,7	1,4
GAP 4 Impedance (MOhm)	165,5	144	170	158,5	121,5	70	37,5
GAP 4 over REF REF (%)	0,3	0,3	-1,2	-0,9	0,4	1,4	2,7
GAP 5 Impedance (MOhm)	166	144	169,5	158	122	71	38
GAP 5 over REF (%)	0,6	0,3	-1,5	-1,3	0,8	2,9	4,1

Table 2. Calculated weighted impedances

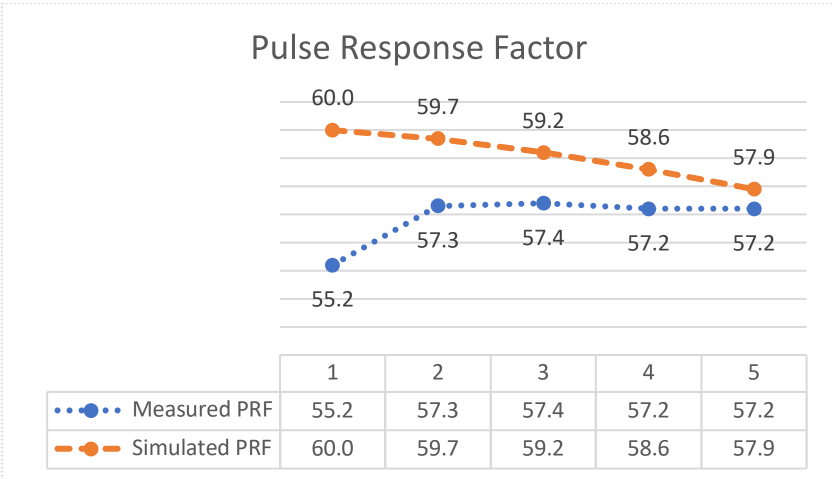

Fig. 6. Pulse response factor

The results suggest small differences in behaviour, numerical simulations effectively predict measured parameters. Additionally, it can be deduced that, in the case of an effective null gap receiver, it would not necessarily improve acoustic parameters.

Sensory evaluation tests took place in London, Vienna, and Madrid, conducted by five highly established trumpet professionals with great expertise in trumpet development. A questionnaire based on (Bertsch, 2003) collected data on the instrument's response. The tests were conducted in random order, and trumpet players did not know the gap was being used in every test. Scoring responds to the scale:

>0 Optimal response

=0 Sufficient response

<0 Poor response

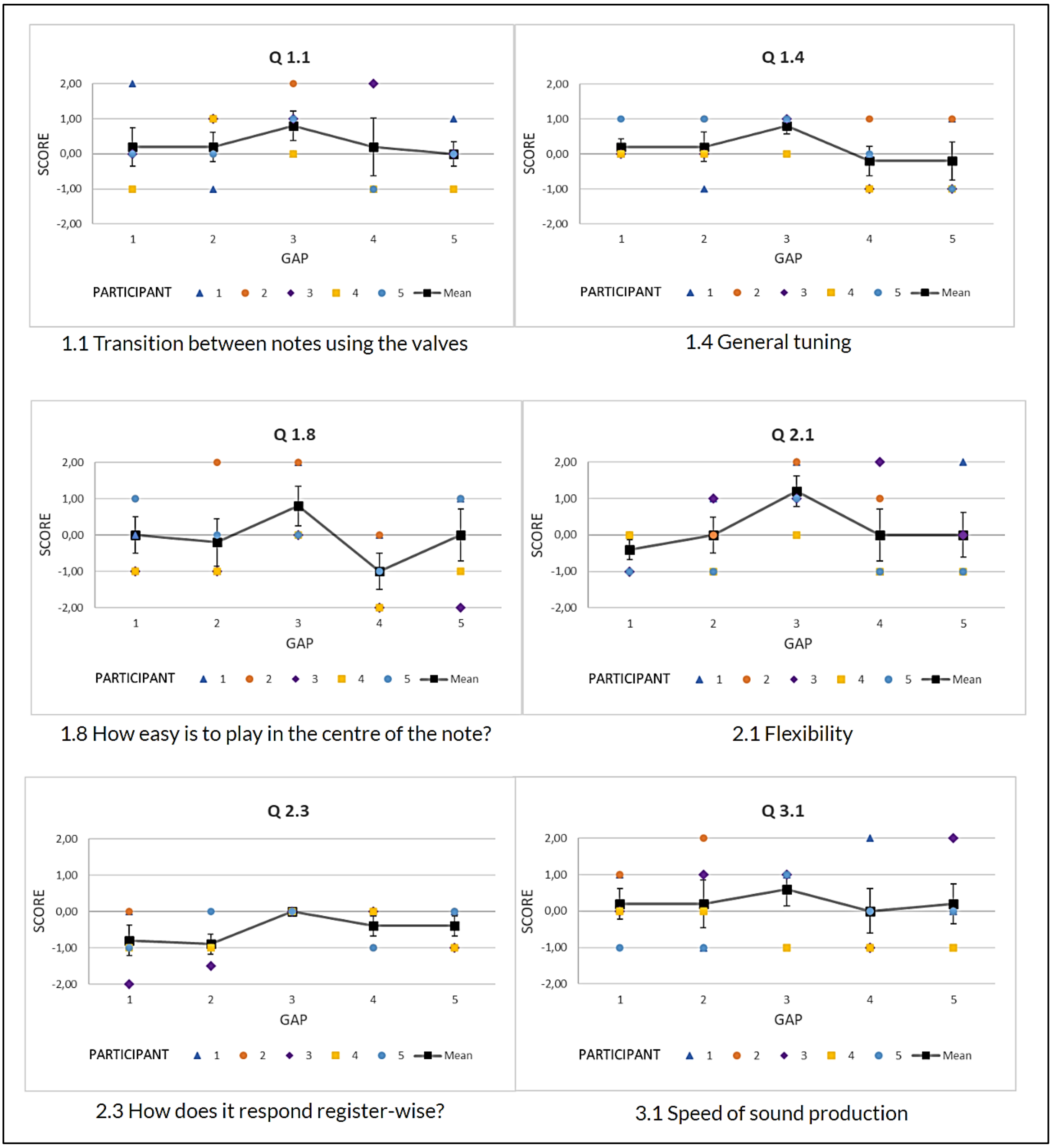

Fig. 7. Representation of some of the most important values of the acoustic response in the sensory evaluation

The qualitative analysis indicates that gap number 3 (4 mm) shows better performance overall, with a lower standard deviation than the other gap numbers.

After analysing the results from these three approaches, the gathered evidence is consolidated to draw the conclusions:

- Achieving a zero gap with the pressure-based system used by the industry and the accepted tolerances in brass instrument manufacturing is not feasible. Additionally, a zero gap might not yield acoustic benefits.
- A gap around 4 mm is a suitable general solution.
- Standardized norms for dimensions on the receiver would benefit the industry.
- Small differences in acoustic impedance parameters and pulse response are not correlated with expected effects on sensory perception.
- More advanced tools for study and analysis are needed to gain a deeper understanding of the phenomena underlying the initial zone of the instrument.
- Precisely determining the relationships between sensory perception and acoustic parameters is essential for advancing the study of acoustics and the technological development of brass wind instruments.

References:

- Fleisher, D. An acoustical study of the trumpet annulus. University of Rochester. 1980.
- Bertsch, Matthias. Bridging instrument control aspects of brass instruments with physics-based parameters. 2003
- Resch, J., Krivodonova, L., & Vanderkooy, J. Three-dimensional simulations of sound propagation in a trumpet with accurate mouthpiece shank geometry. 2016