Mouthpieces for Brasswinds in the Writings of Victor-Charles Mahillon: A Historical and Analytical Review[1]

Hannes Vereecke and Stewart Carter

Victor-Charles Mahillon (1841–1924; see Figure 1) left his mark on the musical instrument field in several ways. As an instrument maker he managed one of the largest manufacturing concerns of its type in Europe.[2] As a museum curator he was instrumental in founding and systematizing one of the most important collections of instruments in the world, now known as the Brussels Musical Instruments Museum.[3] As an organologist he developed a system of classification for musical instruments that, though it was modified by Sachs and Hornbostel in 1914, remains viable to a large extent even in the twenty-first century. Mahillon wrote extensively on the acoustics of musical instruments. While his writings on this topic are largely of historical interest today, instrument makers as well as scholars can still learn from his observations.[4] Mahillon was, after all, a highly successful manufacturer whose firm in its heyday produced thousands of musical instruments each year. The musical instrument business was as competitive in his time as it is today, so Mahillon had to innovate in order to survive in an intense economic environment. Moreover, the trade fairs held frequently in various European cities made him keenly aware of the need to keep abreast of his competitors' newest products.

Figure 1: Victor-Charles Mahillon (1841–1924).
Photo reproduced courtesy of Les Amis de Musique.

DOI: 10.2153/0120110011001

Éléments d'acoustique musicale & instrumentale (1874) is by far the most comprehensive of Mahillon's several publications on musical acoustics.[5] He published many smaller studies as well, including a series of articles in *Zeitschrift für Instrumentenbau* and also in *L'echo musicale*, a periodical he founded and edited himself. Throughout his life Mahillon exhibited a keen interest in scientific matters as they relate to musical instruments. Looking first at his practical side, he was after all the son of an instrument maker, Charles Borromée Mahillon, who, after training in England, established an instrument-making firm in Brussels in 1836 in partnership with his brother-in-law, G.C. Bachmann.[6] By the mid-1850s the Mahillon factory was the largest producer of brasswind and woodwind instruments in Belgium, with a branch in London. Victor-Charles joined the firm in 1865.

The son's interest in acoustics may have been inspired by his father, who certainly had a keen interest in the practical side of the discipline. Victor-Charles tells of an experiment his father devised, sometime around 1864, in an effort to prove "to some of his leading adversaries" that the material of which a wind instrument is constructed has no effect on its timbre.[7] The elder Mahillon and his associates made a replica, in wood, of a brass cavalry trumpet. According to Victor-Charles, the experiment proved his father's point, yet it failed to convince his "adversaries," who "refused to believe their ears" ("n'ont pas voulu en croire leurs oreilles"). At least three of Charles-Borromée's wooden trumpets, stamped with the trademark of the Mahillon firm, still survive.[8]

In addition to the practical side, there was also a scholarly slant to Victor-Charles's interest in acoustics. We know little about his early education, but his 1874 book bespeaks an extensive knowledge of the subject. He often cites earlier sources—writers such as John Tyndall,[9] Claude Pouillet,[10] Charles Delezenne,[11] Theobald Boehm,[12] and Hermann von Helmholtz.[13] Mahillon's debt to Helmholtz, whose *Lehre von der Tonempfindung* appeared just eleven years before *Éléments d'acoustique*, is particularly obvious—sometimes painfully so, since Mahillion copied a few illustrations directly from Helmholtz without indication of attribution.[14] The younger Mahillon's scientific bent is further revealed in the many mathematical formulas and tables he included in his book. Here he was more careful in acknowledging his debt to earlier authors—notably Delezenne, twelve pages of whose logarithmic tables he reproduced as an aid to the calculation of intervals.[15]

The scientific interests of Victor-Charles were inspired both by advances in instrument design in the nineteenth-century and by persistent questions relating to instrument construction. One of these questions, which continues to have considerable relevance today, concerns the acoustical significance of the shape of brasswind mouthpieces. Mahillon kept copious notes on his practical and empirical experiences and observations on mouthpiece design. The objectives of this study are to shed light on Mahillon's ideas on this topic and to consider these concepts in the context of today's knowledge of the acoustics of mouthpieces.

Historical developments in mouthpiece design

The mouthpiece is an extremely important component of an instrument's acoustical system; small changes in its geometry can produce significant alterations in the instrument's response. In the historical development of trombone mouthpiece design, roughly three main phases can be identified.[16] The first phase is characterized by mouthpieces made in three parts—a cup, a stem, and a ferrule to cover the joint between them. Typically the cup is bowl-shaped with a relatively sharp-shouldered throat and a backbore that was not conical (see Figure 2). Such a design is particularly characteristic of sixteenth- and early seventeenth-century mouthpieces. [17]

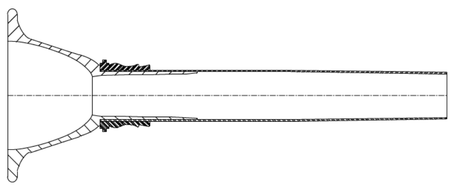

Figure 2: Mouthpiece associated with the tenor trombone made by Anton Schnitzer the Elder in 1579, preserved at the Accademia Filarmonica, Verona. Drawing by Hannes Vereecke.

During the second phase, in the early nineteenth century, the treatises of Joseph Fröhlich (1813 and 1829) and Andreas Nemetz (1827) show mouthpieces that clearly have a straight conical backbore, as seen in modern mouthpieces (see Figure 3; Nemetz's mouthpiece for tenor trombone is essentially identical to Fröhlich's 1813 illustration).[18] All the mouthpieces depicted in the works of these authors (except those for the horn) feature a conical tapered segment leading from the smallest diameter at the throat of the mouthpiece to the widest diameter at its end. This feature of nineteenth-century mouthpieces provided a smooth transition from the mouthpiece proper to the main bore of the instrument and is of decisive acoustical significance.

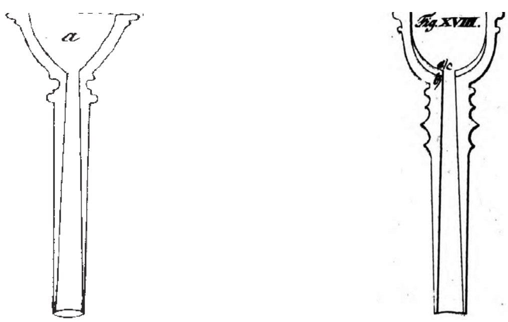

Figure 3: **a (left):** Tenor trombone mouthpiece, from Joseph Fröhlich, *Vollständige theoretisch-pracktische Musikschule* (1813). **b (right):** Mouthpiece for tenor (shallower cup) and bass (deeper cup) trombones, from idem, *Systematischer Unterricht in den vorzüglichsten Orchester-Instrumenten* (Würzburg, 1829), vol. 2: plate 68. Reproduced courtesy of Bayerische Staatsbibliothek, Munich.

Throughout much of the nineteenth-century, mouthpieces for trumpet and trombone continued to be constructed with a relatively sharp shoulder at the throat. The third phase of development in mouthpiece design took place during the working life of Victor-Charles Mahillon and completed a transition from the sharp-edged throat to a smoother throat-edge and curvilinear cup-shape (see Figure 4). However, trombone mouthpieces with sharp-edged throats were used by some orchestral musicians up to the middle of the twentieth century.[19]

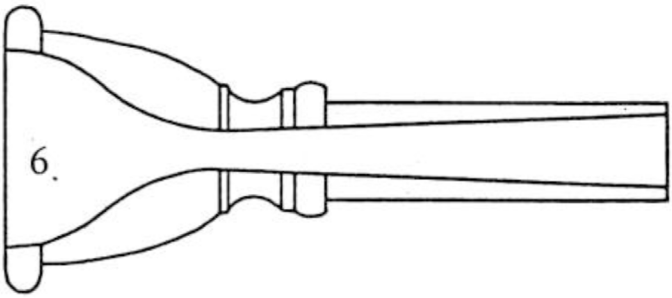

Figure 4: Mouthpiece for tenor trombone depicted in Mahillon, *Éléments d'acoustique,* 2nd edn. (1984), based on Mahillon's typescript revisions of 1916. Reproduced by permission of Les Amis de la Musique, Brussels.

Mahillon on mouthpieces

In the 1874 edition of *Éléments d'acoustique* Mahillon provided cutaway drawings of six different mouthpieces (Figure 5). In 1916 he drafted extensive revisions to his treatise, apparently with the objective of publishing a second edition that unfortunately did not come to fruition until long after his death. Many of these revisions are in the form of handwritten annotations and corrections he made to pages of text and drawings he extracted from the 1874 edition; he also added nearly 300 newly typewritten pages and some fifty new illustrations to his draft. Daniel Bariaux adopted much of the 1916 compilation in preparing a second edition of *Éléments d'acoustique,* published in 1984.[20]

In 1874 and also in 1916, Mahillon's discussion of mouthpieces and their construction is almost exclusively empirical. Here the practical man—Mahillon the maker of musical instruments—summarizes his theories of mouthpiece design. The following quotation follows the author's first edition of 1874, with substantive revisions from Mahillon's 1916 typescript (as published in 1984) in italic type. The complete text of both versions can be found in Appendices A and B, respectively.

> The shape of a mouthpiece exerts a great influence on the timbre [of an instrument]. A curved cup [i.e., not necessarily a curvilinear throat] makes the tone brighter in proportion to the closeness of the [player's] lips to the

throat [of the mouthpiece]. The part of the interior of the mouthpiece that is the most constricted is called the throat, through which vibrations formed in the cup are communicated to the column of air, either breaking against a sharp corner to produce brightness or gliding along a rounded corner to produce a sweet [tone]. *A mouthpiece with a deep cup facilitates the low tones; a shallower one aids the production of high harmonics. A middle route is the best choice.*

[Mouthpiece no. 5 in Figure 5] represents the cup of a mouthpiece for the *trompette d'harmonie,* the timbre of which should be of a moderate brightness. Making the bowl shallower results in a mouthpiece with a brighter timbre, like that produced by a cavalry trumpet.

A cup in conical form is necessary for instruments with sweet and velvety sounds, among which the horn holds the highest rank. This is the brass instrument whose tone approaches most closely the sweet sonority of the woodwind instruments, with which it combines admirably…. [I]ts [mouthpiece] is the deepest of all; the throat is so open that there is little difference between [the throat] and the lower extremity.

[Mouthpiece no. 6 in Figure 5] shows the cup of a trombone mouthpiece; its bowl is easily distinguished from that of the deeper mouthpiece of the tuba, which has walls that are more incurved…. The former contributes to the brightness of the trombone [while] the latter is necessary for the sweetness of the timbre of the tuba and for the production of [tones in] its low register.

The cornet has a brighter sound than the contralto bugle in B♭. [Nos. 2 and 3 in Figure 5 in this article] show their respective mouthpieces. The former approaches curvilinear form; the latter has a straighter form.

All of the [members of the] bugle family have mouthpieces in which the less incurved cup aids the formation of the sweet timbre that is characteristic of these instruments.

It is easy to understand the influence that the form of the cup exerts on the formation of timbre if one considers that the sound waves are born in the cup. Also we cannot advise artists strongly enough to make use of no mouthpiece other than that which the long experience of [instrument] makers has shown to be the most suitable for the sound of the associated instrument….

There is nothing more disadvantageous for an artist than changing the mouthpiece. The only means of achieving good [results] consists in habituating oneself, through study and exercise, to the mouthpiece that one has judiciously chosen. *The lips will thus acquire a perfect flexibility and elasticity that they cannot otherwise obtain.*[21]

Mahillon's 1916 sketches show alterations to the mouthpieces for tuba, trumpet, and trombone (Figure 6, nos. 4, 5, and 6; refined for publication in 1984 in Figure 7, nos. 4, 5, and 6). In the upper-left-hand corner of this same page he jotted a note that appears to say "redo this plate according to the application given and according to those calibrations actually in use" ("refaire cette planche d'apres l'aplication [*sic*] données et d'apres [*sic*] les calibrations actuellement en usage").[22] In light of the phrase "actually in use," which possibly refers to changes in specifications for machines at Mahillon's factory, the transition in mouthpiece design between 1874 and 1916 is clearly demonstrated by comparing the three versions—1874, 1916, and 1984—of the tenor trombone mouthpiece (Figure 8).

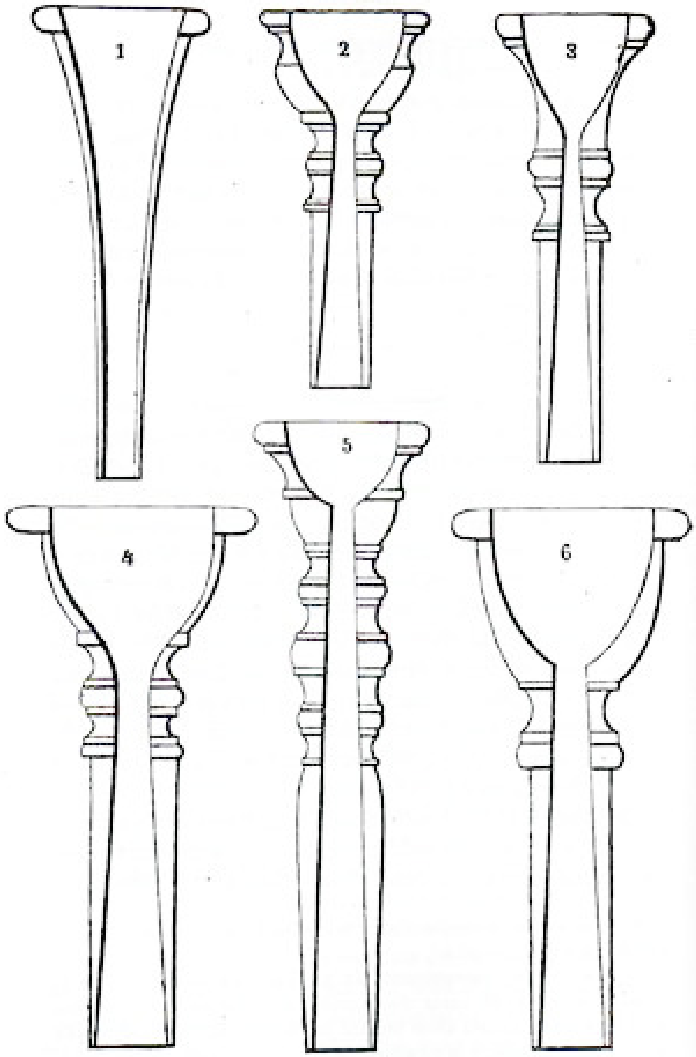

Figure 5: Mouthpieces from Mahillon's *Éléments d'acoustique* (1874), 96. No. 1, horn; no. 2, cornet; no. 3, bugle; no. 4, tuba; no. 5 trumpet; no. 6, trombone.

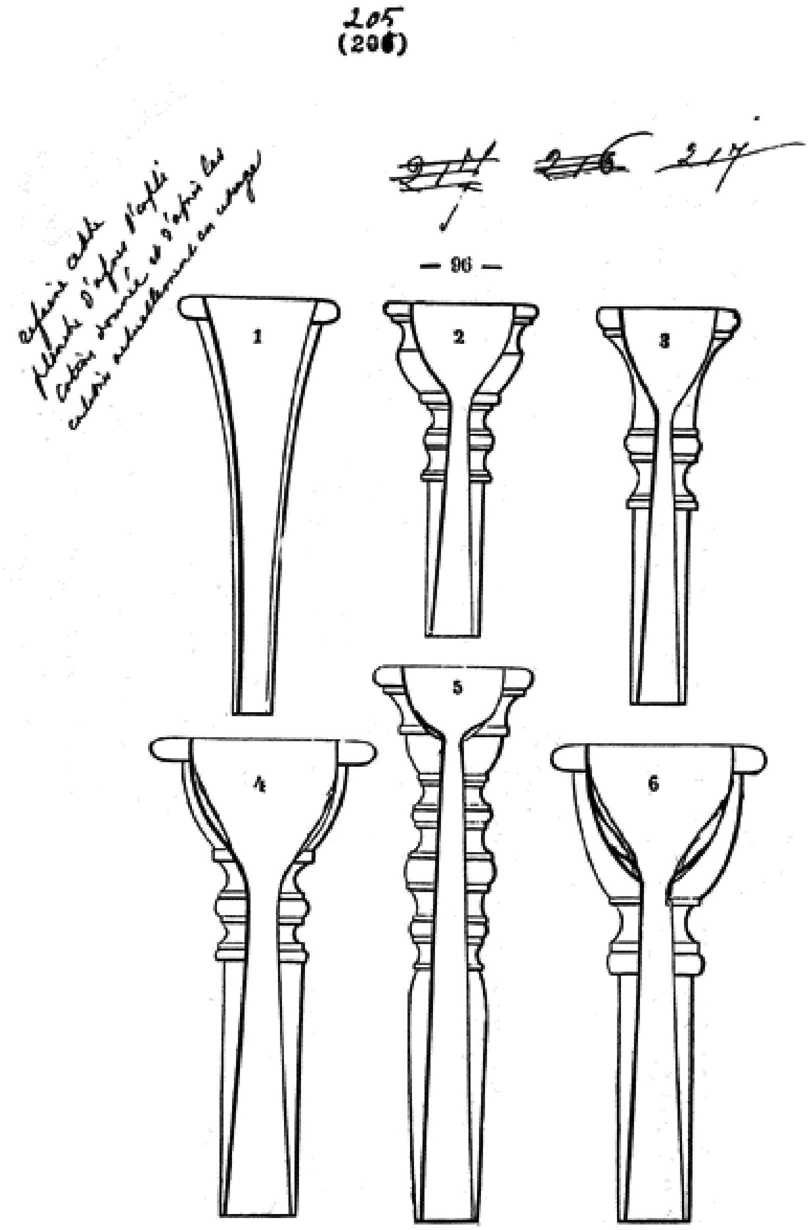

Figure 6: Mahillon's 1916 sketches for revisions to his 1874 mouthpiece drawings, from his *Éléments d'acoustique,* 2nd edn. (1984), 344.
Reproduced by permission of Les Amis de Musique.

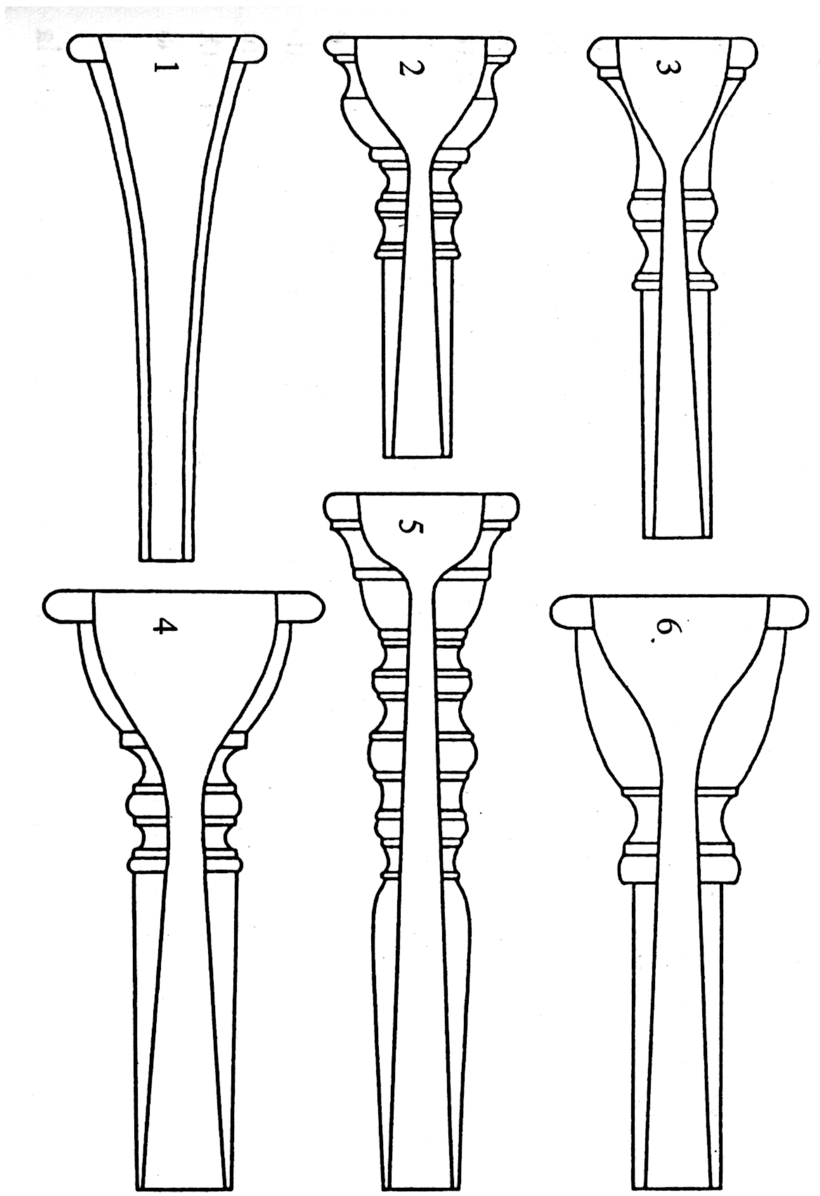

Figure 7: Mahillon's mouthpiece drawings, as revised by Daniel Bariaux for the second edition of *Éléments d'acoustique* (1984), p. 147, based on Mahillon's sketches of 1916. Reproduced by permission of Les Amis de la Musique. (Identification of specific mouthpieces as in Figure 5.)

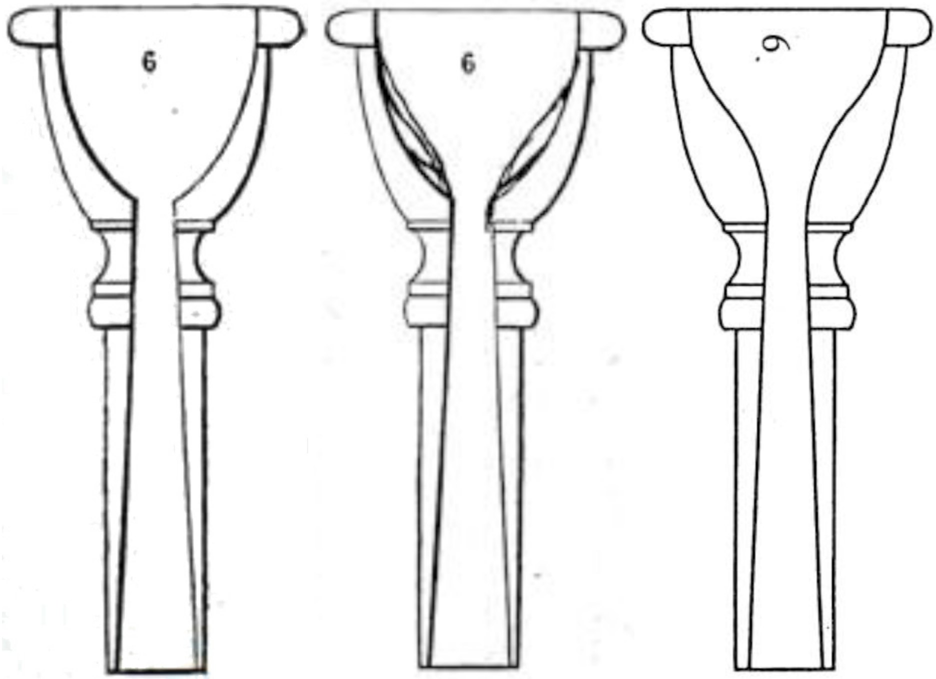

Figure 8: Comparison of Mahillon's drawings of mouthpieces for tenor trombone. Left: *Éléments d'acoustique* (1874); center: handwritten corrections by Mahillon (1916); right: Bariaux's edition (1984). Center and right drawings reproduced by permission of Les Amis de la Musique.

As can be seen in Figure 8, the most significant aspect of this modification is the change in the shape of the cup: the sharp shoulders separating cup and throat in the mouthpieces for trombone reveal a more curvilinear design and a considerable decrease in cup volume. (A similar modification can be observed in the mouthpieces for trumpet by comparing the different versions of item no. 5 in Figures 5, 6, and 7.) We must ask: What is the significance of this modification, and why did Mahillon specify this change in design? In spite of Mahillon's scientific approach to many aspects of musical instruments, his approach to mouthpieces was primarily empirical, as we have seen above. In the following section of this essay, we will investigate these changes in design from an acoustical as well as an empirical standpoint.

Mouthpiece acoustics

The scientific study of brasswind acoustics is a highly interdisciplinary field of research, drawing on inseparable aspects of material science, acoustics, and psychoacoustics. Because the mouthpiece of a brasswind instrument is considered by musicians to be such a critical component of the instrument, the study of the influence of the mouthpiece on overall acoustical behavior is a topic of considerable interest for today's brasswind scholars. The advent of computer-powered diagnostic equipment and computational physics has done much to facilitate in-depth understanding of mouthpiece design since Mahillon's time, though many questions still remain. Since lip shape, dental configuration, and mouth-cavity volume vary considerably from one musician to another, each individual player has his/her own unique *timbre*. Moreover, performers' musical perceptions and assessments are highly subjective in nature. Diagnostic equipment and computational methods, including statistical algorithms, can capture only part of the picture,[23] so subjective assessments remain essential to the scholar. [24] Thus very little on this topic can be stated categorically, since the player's interaction with the mouthpiece is of crucial significance; musicians' opinions remain indispensable.[25]

In recent years, input impedance, a technique used to calculate the ratio between acoustical pressure and acoustical flow, has proved to be extremely useful in mouthpiece research. The acoustical pulse in input impedance measurements is provided by a sine wave at moderate sound-pressure levels, produced by a loudspeaker. This pulse differs considerably from the pulse provided by a playing musician. Such measurements therefore provide an objective but unfortunately also an incomplete picture. One of the principal open questions in musical acoustics continues to be how closely such input-impedance curves are related to the actual musical properties of a specific instrument.[26]

The mouthpiece has two particular acoustical functions: it lowers the instrument's high resonances and boosts its resonances in the area of the mouthpiece's own resonance. Klaus Wogram concluded that the lower the main resonance, or *eigenfrequency*, of the mouthpiece, the better its acoustical properties.[27] The *eigenfrequency* of the mouthpiece has an important influence on intonation as well as response, since it affects the alignment and amplitude of the resonances.

From an acoustical standpoint, the most crucial parts of the mouthpiece are the cup, the throat, and the backbore. A long history of trial-and-error has shown that cup volume is an acoustically decisive parameter. This volume is of course influenced by the intrusion of the lips into the cup, and is therefore dependent on the physical characteristics of the lips. Cup volume affects both tone quality and pitch, and can alter the latter by as much as 35 cents.[28] Enlarging the throat diameter has the same acoustical effect as decreasing the volume of the mouthpiece: it raises the resonance frequencies. The field-tested general state of knowledge on the acoustical significance of cup, throat, and backbore can be summarized as follows:[29]

> *Cup:* affects tone, intonation, and attack. A deep cup darkens the sound and lower notes are subsequently easier to play. In the present instance, the decrease in cup volume between Mahillon's 1874 drawing of a trombone mouthpiece and his 1916 revisions = an increase in resonance frequency.
> *Throat/backbore:* affects tone, resistance, and intonation. A larger bore results in a mellower sound.

Experimental assessments

In order to gain further insight into the acoustical differences between the trombone mouthpiece depicted by Mahillon in the 1874 edition and the changes he made in the 1916 drawing, an experimental study of mouthpiece *eigenfrequencies* was conducted. By scaling Mahillon's 1874 and 1916 drawings of tenor trombone mouthpieces by means of digital image processing with *Matlab* and *Autocad* and the dimensions extracted from a similar surviving example made by the Mahillon factory, approximate bore profiles could be determined. Subsequently, the fundamental resonances of the mouthpieces were calculated, using the input-impedance simulation software *BIAS*.[30] Figure 9 indicates that the main resonance of the 1874 mouthpiece is much lower in frequency and amplitude than that of the 1916 mouthpiece.

The input impedance curves displayed in Figure 9 show that with decreasing cup volume the *eigenfrequency* of the mouthpiece will increase in amplitude and frequency. The shift in frequency means that higher harmonics are amplified, resulting in a brighter sound. The positive shift in amplitude results in improved response, especially in the higher register.

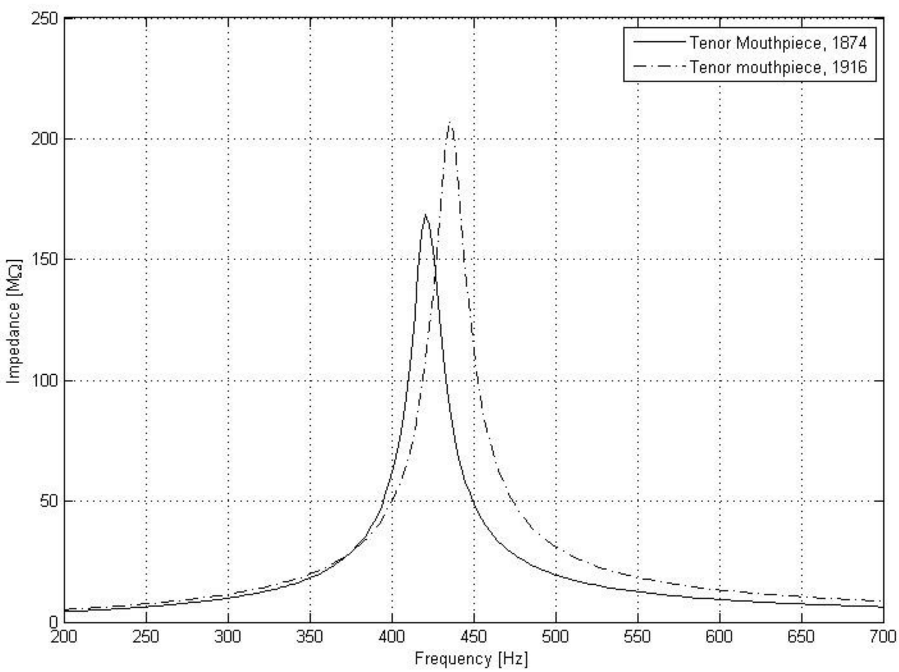

Figure 9: Primary resonances of the two tenor trombone mouthpieces.

Aero-acoustics and mouthpiece design

The study of the flow of air in mouthpieces and leadpipes is an integral part of brasswind engineering.[31] In order to interpret Mahillon's statement relating to the significance of a sharp-shouldered throat of the mouthpiece and to gain further insight into the acoustical meaning of the changes Mahillon made in 1916 to his 1874 mouthpiece design, a consideration of fluid-dynamical processes in mouthpieces is essential.

Based on the practical experiences of one of the authors,[32] a mouthpiece with a sharp-edged throat is generally perceived by performers as being more difficult to play, since it is more difficult to "lock into" the desired note. On the other hand such mouthpieces are assessed as providing more flexibility in timbral contrast in comparison to a mouthpiece with a more curvilinear/smooth throat design. Furthermore, musicians state that a sharp-edged throat results in improved accuracy of attack in the higher register and allows for a more "centered" playing behavior and tone, though it is also responsible for some unwanted noise in the radiated sound. Musicians note in particular that a chamfered throat-edge makes the playing characteristics more equal in all registers.

From an aero-acoustical standpoint, the sharp-edged throat encourages a flow separation at the throat. The study of flow separation in woodwind instruments is well established,[33] but very little has been done with regard to brasswind mouthpieces since modern mouthpieces do not feature sharp throat edges. If the air flows from the cup into the throat, which represents a sudden contraction in pipe diameter, a contraction occurs in the jet stream, which in the field of fluid dynamics is called a *vena contracta*. The preconditions for a *vena contracta* are a sharp edge and a sufficiently high flow rate, causing the flow to separate from the wall approximately at the throat. The jet reaches its maximum contraction at a point slightly downstream from the sharp-edged throat, where the jet becomes parallel and constant. Farther downstream from this point the jet reattaches to the wall.

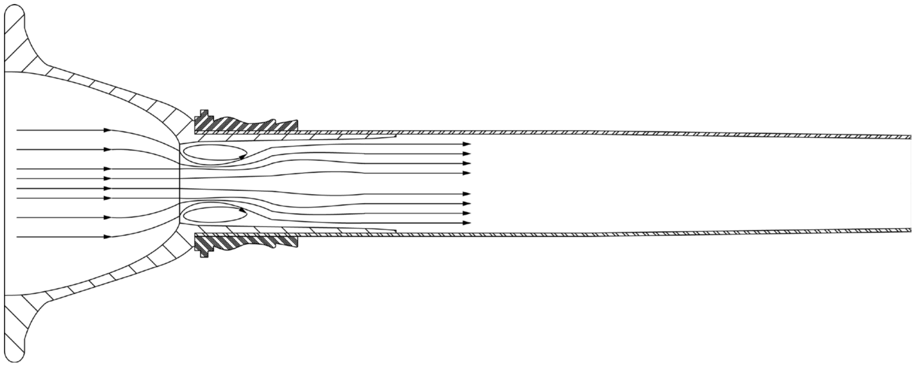

Figure 10: Schematic depiction of flow separation caused by a sharp-edged mouthpiece throat. Drawing by Hannes Vereecke.

Figure 10 shows that at the maximum point of jet contraction the effective cross-section of the bore is narrower than the geometrical diameter. Consequently, if one wants to achieve in a mouthpiece with a sharp-edged throat the same effective cross-section as one with a more curvilinear mouthpiece design, the bore must be enlarged. In the area of flow separation near the throat, between the jet and the wall of the stem—the "dead-spots"—vortices are generated.

Applying this concept to the case of brasswind mouthpieces is speculative, however, since in reality we have an oscillating flow rather as a continuous one.[34] Moreover, it should be noted that flow separation already occurs at the point where the air jet emerges from the lips.[35] Partially due to the sharp edge, turbulences also occur that are experienced subjectively by musicians as resistance and noise. It is however unclear how these turbulences interact with the emerging jet and amplify or absorb energy.

Conclusions

The information presented here, including the subjective assessments collected from various professional musicians, has important implications for players of brasswind instruments. Mouthpieces with sharp-edged throats are appropriate for use on reproductions of early trombones (and trumpets); horn mouthpieces are altogether different, since they are more conical. These sharp-edged throats may be less comfortable for the player, but they permit greater flexibility of tone. Theoretically this should provide a particular advantage for players of reproductions of early trombones, who often are required to be "switch-hitters," playing forcefully with the shawms in an *alta* band, but at other times softly in order to blend with voices.

Mouthpieces with curvilinear throats are appropriate for modern players because they make it easier to lock into a tone, facilitate evenness of tone throughout the instrument, and provide greater playing comfort. The curvilinear throat should therefore appeal to orchestral players, but perhaps also to military bandsmen. It should be remembered that military contracts were highly sought-after by makers of wind instruments throughout the nineteenth century and into the early twentieth. Military musicians often had to play while marching or while riding on horseback. Enhanced ability to lock into a tone was thus a considerable advantage for such players. Greater evenness of tone, improved playing comfort, and enhanced ability to lock into a tone, then, quite likely are the principal reasons for Mahillon's 1916 revisions to his 1874 mouthpiece designs.

Again it must be noted that Mahillon's acoustical theories are today largely of historical interest. We have seen his learned side, reflected in his logarithmic tables, but we have also seen his practical side, revealed particularly in his discussion of mouthpieces. When it came to designing mouthpieces for brasswinds, practical considerations clearly dominated his thinking, but he was widely regarded as an instrument maker with a solid understanding of the physics of sound. In other words, he had a reputation for "bridging the gaps"[36] between acoustical science and practical instrument-making.

Acknowledgements
The authors wish to thank Günther Hett and Friedemann Lutz for allowing us access to Mahillon mouthpieces in their care, and to Murray Campbell, Abraham Hirchberg, and Robert Pyle for sharing thoughts on the aero-acoustics of mouthpieces. Special thanks also to Ignace De Keyser and Howard Weiner.

Hannes Vereecke is Scientific Associate at the Institute for Musical Acoustics, University of Music and Performing Arts, Vienna. Since receiving his master's degree in musical instrument making from the Royal Conservatory in Ghent, Belgium, he has specialized in the technical study of brasswind instruments. In 2012 he was appointed Lecturer at the Vocational College of Musical Instrument Making in Ludwigsburg, Germany. He received the Ph.D. degree in Musical Acoustics from the University for of Music and Performing Arts, Vienna, in 2014 with a dissertation on the construction of sixteenth-century trombones.

Stewart Carter is Editor of the Historic Brass Society Journal. *Recently he published* The Renaissance Trombone: A History in Pictures and Documents *(Pendragon, 2012),* A Performer's Guide to Seventeenth-Century Music, *2nd edn., revised and expanded by Jeffery Kite-Powell (Indiana University Press, 2012), and* Instruments, Ensembles, and Repertory, 1300–1600: Essays in Honor of Keith Polk, *ed. Timothy J. McGee and Stewart Carter (Brepols, 2013). He is President of the Society for Seventeenth-Century Music and Past-President of the American Musical Instrument Society. He currently serves as chair of the Department of Music at Wake Forest University in Winston-Salem, North Carolina, where he holds an endowed professorship.*

APPENDIX A
Victor-Charles Mahillon, *Éléments d'acoustique musicale & instrumentale* (Brussels, 1874), 97–99, remarks on mouthpieces for brasswinds (original French text; references to "figures" in Appendix A refer to illustrations in this edition of Mahillon's book, not to figures in the essay above).

La forme de l'embouchure exerce aussi une grande influence sur le timbre. Un bassin de forme curviligne engendre des sons d'autant plus éclatants que le grain est plus rapproché des lèvres. On appelle *grain* la partie la plus rétrécie de l'intérieur de l'embouchure, par laquelle les vibrations formées dans le bassin se communiquent à la colonne d'air, soit en se brisant contre un angle pour produire l'éclat, soit en glissant sur l'angle arrondi pour produire la douceur.

Ainsi la figure 5 de la planche qui précède représente la coupe d'une embouchure de trompette d'harmonie dont le son doit avoir un éclat modéré; il suffit de donner moins de profondeur au bassin pour obtenir l'embouchure qui convient au timbre strident de la trompette de cavalerie.

Le bassin de forme conique est nécessaire aux instruments à sons doux et veloutés, parmi lesquels le *cor* se place au premier rang. C'est l'instrument de cuivre dont le timbre se rapproche le plus de la douce sonorité des instruments de bois avec lesquels qu'il s'allie admirablement. Voyez son embouchure (fig. 1), c'est la plus profonde de toutes, le grain est si écarté qu'il se confond même avec l'ouverture de l'extrémité inférieure.

La figure 6 donne la coupe d'une embouchure du trombone; la forme curviligne est exactement observée et se distingue facilement du bassin adopté pour l'embouchure du tuba (fig. 4). La première de ces embouchures contribue à l'éclat du trombone, la seconde est nécessaire à la douceur de timbre du tuba.

Le cornet a le son plus éclatant que le bugle contralto en *si♭;* les figures 2 et 3 représentent leurs embouchures respectives. La première se rapproche de la forme curviligne, la seconde de la forme conique.

Toute la famille des bugles emploie des embouchures dont le bassin, de forme conique, aide à la formation du timbre doux qui caractérise ces instruments.

Il est facile de comprendre l'influence que la forme du bassin exerce sur la formation du timbre si l'on veut bien se rendre compte que c'est dans le bassin que les ondes sonores prennent naissance. Aussi ne pouvons-nous assez conseiller aux artistes de ne pas se servir d'autre embouchure que celle qu'une longue expérience a désignée aux facteurs, comme la seule convenable au timbre de l'instrument qu'elle accompagne, Nous voyons souvent des artistes jouant du cornet et du bugle en *si♭*, se servir de la même embouchure, sans se douter que la différence de timbre de ces deux instruments exige des embouchures possédant des bassins de forms opposées. La même observation s'adresse aux artistes jouant du trombone et du tuba. L'emploi de la même embouchure pour les deux instruments doit amener inévitablement l'altération de l'un des deux timbres.

Les vibrations des lèvres obtenues par la pression des bords de l'embouchure, sont d'autant plus rapides que l'instrument est plus aigu, puisque les lèvres vibrent à l'unisson des longueurs d'ondes de la colonne d'air. Les lèvres minces sont donc beaucoup plus avantageuses pour le jeu des petits instruments que les lèvres grosses dont la conformation est plus en rapport avec les instruments basses de grande longueur, dont le son est le résultat de vibrations moins rapides (*).

Rien n'est plus désavantageux pour l'artiste que le changement d'embouchure; le seul moyen d'en posséder une bonne consiste à s'habituer, par l'étude et l'exercice, à celle que l'on possède; de cette façon les lèvres vibrant sous l'action d'une pression obtenue par des bords de forme et de diameter invariables, acquièrent une flexibilité et un élasticité qu'elles ne peuvent obtenir par des embouchures différentes modifiant, à chaque changement, le contour des parties vibrantes.

(*) Le diamètre de l'embouchure augmente en raison de la gravité de l'instrument.

APPENDIX B

Victor-Charles Mahillon, *Éléments d'acoustique musicale & instrumentale*, 2nd edn., ed. Daniel Bariaux (incorporating Mahillon's typescript revisions of 1916) (Brussels: Les Amis de Musique, 1984), 147–49, remarks on mouthpieces for brasswinds (original French text; references to "figures" in Appendix B refer to illustrations in this edition of Mahillon's book, not to figures in the essay above).

La forme de l'embouchure exerce aussi une certaine influence sur le timbre. Un bassin de forme curviligne engendre des sons d'autant plus éclatants que le grain est plus rappoché des lèvres; une embouchure à bassin profond facilite les sons graves, une moindre profondeur aide la production des harmoniques aigus. Il y a un juste milieu à choisir.

La figure 5 de la planche qui précede représente la coupe d'une embouchure de trompette d'harmonie dont le timbre doit avoir un éclat modéré: il suffit de donner moins de profondeur au bassin pour obtenir une embouchure telle que le timbre plus éclatant de la trompette de cavalerie se produise.

Le bassin de forme droite non-incurvée est nécessaire aux instruments à sons doux et veloutés parmi lesquels le *cor* se place au premier rang. C'est celui des instruments à embouchure dont le timbre se rapproche le plus de la douce sonorité des flûtes, clarinettes et bassons auxquels il s'allie admirablement. Voyez son embouchure (fig. 1), c'est la plus profonde de toutes; le grain est si écarté des bords qu'il se confond avec l'ouverture de l'extrémité inférieure.

La figure 6 donne la coupe d'une embouchure de trombone et son bassin se distingue facilement de celui de l'embouchure du tuba plus profonde et dont les parois sont moins incurvées (fig. 4). La première contribute à l'éclat du trombone, la seconde est nécessaire à la douceur de timbre du tuba et à la production de son registre grave.

Le cornet a le son plus éclatant que le bugle contralto en *si♭;* les figures 2 et 3 représentent leurs embouchures respectives. La première se rapproche de la forme curviligne, la seconde de la forme droite.

Toute la famille des bugles emploie des embouchures dont le bassin moins incurvé aide à la formation du timbre doux qui caractérise ces instruments.

Ils est facile de comprendre l'influence que la forme du bassin exerce sur la formation du timbre lorsque l'on sait que c'est dans le bassin que les ondes sonores prennent naissance. Aussi ne pouvons-nous assez conseiller aux artistes de ne pas se server d'autre embouchure que celle qu'une longue expérience a désignée comme la plus convenable au timbre de leur instrument. Nous voyons souvent des artistes jouant du cornet, du bugle en *si♭,* et même de la trompette, se servir de la même embouchure sans se préoccuper de l'importance que la forme du bassin exerce sur le timbre. Une même observation s'addresse aux artistes jouant du trombone et du tuba. L'emploi de la même embouchure pour les deux instruments amène inévitablement l'altération des timbres.

Les vibrations des lèvres obtenues par leur pression sur les bords de l'embouchure sont d'autant plus rapides que l'instrument est plus aigu. Les lèvres minces sont donc beaucoup plus avantageuses pour le jeu des petits instruments que les lèvres épaisses qui conviennent aux instruments basses dont le son est produit par des vibrations moins rapides.(*)

Rien n é st plus désavantageux pour l'insturmentiste que de fréquents changements d'embouchure; le seul moyen d'en acquérir et de conserver la sûreté dans l'émission du son c'est de s'habituer par l'étude et l'exercice à l'embouchure que l'on aura judicieusement choisie; les lèvres acquièrent ainsi une flexibilité et une élasticité parfaits qu'elles ne pourraient jamais obtenir autrement.

(*) Le diamètre des bords ou du bassin de l'embouchure est proportionnel à la longueur de l'instrument.

Notes

[1] An earlier version of this essay, lacking the scientific input of Hannes Vereecke, appears in Stewart Carter, "Victor-Charles Mahillon's Theories on the Construction of Mouthpieces for Brasswinds," in *Proceedings of the Second Vienna Talk on Musical Acoustics,* ed. Werner Goebl (Vienna: Institute of Musical Acoustics [Wiener Klangstil], 2010). viennatalk.mdw .ac.at/?page_id= 14000

[2] The most comprehensive study of Victor-Charles Mahillon and the Mahillon instrument-manufacturing concern is Igance De Keyser, "De geschiedenis van de Brusselse muziekinstrumentenbouwers en de rol van Victor-Charles Mahillon in het ontwikkelen van het historisch en organologisch discours omtrent het muziekinstrument" (Ph.D. diss., University of Ghent, 1996).

[3] Victor-Charles Mahillon, *Catalogue descriptif & analytique du Musée Instrumental du Conservatoire Royal de Musique de Bruxelles,* 5 vols., 2nd edn. (Brussels: Les Amis de la Musique, 1978), 1–89.

[4] Regarding Mahillon's writings on the acoustics of woodwind instruments, see Friederich August Drechsel, *Kompendium zur Akustik der Blasinstrumente nach Victor-Charles Mahillon* (Celle: Moeck, 1979).

[5] Victor-Charles Mahillon, *Éléments d'acoustique musicale & instrumentale* (Brussels: C. Mahillon, 1874) [hereafter Mahillon (1874)], 64.

[6] William Waterhouse, *The New Langwill Index: A Dictionary of Musical Wind-Instrument Makers and Inventors* (London: Tony Bingham, 1993), 49–50.

[7] Mahillon (1874), 64.

[8] One instrument is preserved at the Musical Instruments Museum in Brussels (inv. No. 572). Two further instruments survive, one at the Galleria dell'Accademia, Dipartimento degli strumenti Musicali, Florence (inv. no. 1988/179 Cherubini) and one at the Museum of Music in the Sheremetev Palace, St. Petersburg. The instrument in Saint Petersburg was once part of the collection of César C. Snoeck in Ghent.

[9] John Tyndall, *Sound: A Course of Eight Lectures Delivered at the Royal Institution of Great Britain* (London: Longmans, Green, 1867).

[10] Claude Pouillet, *Éléments de physique expérimentale et de météorologie,* 2 vols. (Paris: Béchet jeune, 1827–30).
[11] Charles Delezenne, *Table de logarithmes acoustiques, depuis 1 jusqu'a 1200, précédée d'une instruction élémentaire* (Lille: L. Danel, 1857).
[12] Theobald Boehm, *Über den Flötenbau und die neuesten Verbesserungen desselben* (Mainz: B. Schott's Söhne, 1847). Boehm's innovations were in part the result of his collaboration with C.E. Schafhäutl; see C.E. Pellisor (Schafhäutl), "Berichtigung eines Fundamentalsatzes der Akustik und Beiträge zur Theorie einiger akustischen Instrumente," *Neues Jahrbuch der Chemie und Physik* 5 (1833): 227–49.
[13] Hermann von Helmholtz, *Die Lehre den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (Braunschweig: F. Viewig und Sohn, 1863), transl. John Alexander Ellis as *On the Sensations of Tone as a Physiological Basis for the Theory of Music,* 2nd edn. (1885; rept., New York: Dover, 1954).
[14] Compare, for example, Helmholtz's drawing of a reed pipe of an organ (Ellis, *On the Sensations of Tone*, 96) with Mahillon's (1874), 84.
[15] Mahillon (1874), 252–63.
[16] See Dale Olson, "Chronology of Innovation: the Trumpet Mouthpiece," *International Trumpet Guild Journal* 34, no. 2 (2010): 63–70 (part 1); and no. 3 (2010): 63–70 (part 2).
[17] See Sabine K. Klaus and Stewart Carter, "The Jamestown Mouthpiece: an Analytical and Historical Study," *Journal of the American Musical Instrument Society* 37 (2011): 19–44; Hannes Vereecke, "The Sixteenth-Century Trombone: Dimensions, Materials and Techniques," Ph.D. diss., Institute of Musical Acoustics (Wiener Klangstil), University of Music and Performing Arts, Vienna, 2014; and Eric Halfpenny, "Early British Trumpet Mouthpieces," *Galpin Society Journal* 20 (1967): 76–88.
[18] See Joseph Fröhlich, *Vollständige theoretisch-pracktische Musikschule*, 4 vols. (Bonn, 1813), 27–35; idem, *Systematischer Unterricht in den vorzüglichsten Orchester-Instrumenten* (Würzburg, 1829), 1:267–285; 2: plates 67–68. The authors thank Howard Weiner for providing information on Fröhlich's 1829 publication, and for providing copies of the images in Figures 3a and 3b, from the same sources. For further information on mouthpiece designs of both Fröhlich and Nemetz, see Weiner, "Andreas Nemetz's *Neueste Posaun-Schule:* An Early Viennese Trombone Method," *Historic Brass Society Journal* 7 (1995): 12–34, here 13–15. In this article Weiner further notes that both Fröhlich's 1813 publication and Nemetz's *Allgemeine Trompeten-Schule* (Vienna, 1827) demonstrate that the mouthpiece for an alto trombone was essentially the same as that for a trumpet, but with a slightly deeper cup. In a personal communication of September 2014, Weiner reports that Fröhlich's 1829 publication confirms this relationship between mouthpieces for trumpet and alto trombone.
[19] Sebastian Krause, personal communication, July 2014.
[20] Mahillon, *Éléments d'acoustique musicale & instrumentale,* 2nd edn., ed. Daniel Bariaux (Brussels: Les Amis de la Musique, 1984) [hereafter Mahillon (1984)].
[21] Complete texts of Mahillon's remarks on mouthpieces, from both 1874 and 1916/1984, can be found in Appendices A and B, respectively.
[22] The authors thank Ignace DeKeyser for his assistance in deciphering this annotation.
[23] Gunter Ziegenhals, *Beurteilung von Metallblasinstrumenten auf der Basis messtechnisch gewonnener Merkmale, Studientexte zur Sprachkommunikation,* vol. 64 (Dresden: TUDpress, 2012).
[24] Gunter Ziegenhals, *Subjektive und objektive Beurteilung von Musikinstrumenten: eine Untersuchung anhand von Fallstudien* (Dresden: TUDpress, 2010).

[25] Andrew Brown and Matthias Bertsch, "The Paradox of Musical Acoustics: Objectifying the Essentially Subjective," in *Proceedings of the 1st Conference of Interdisciplinary Musicology* (Graz: Universität Graz, 2004).
[26] See, for example, George Plitnik and Bruce Lawson, "An Investigation of Correlations between Geometry, Acoustic Variables, and Psychoacoustic Parameters for French Horn Mouthpieces," *Journal of the Acoustical Society of America* 106, no. 2 (1999): 1111–25.
[27] Klaus Wogram, "Die Bedeutung des Mundstückes bei Blechblasinstrumenten," *Instrumentenbau-Zeitschrift*, 46/6 (1992): 53–58.
[28] Paul Anglmayer, "Computermodellgestützte Untersuchungen über den Einfluss unterschiedlicher Mundstücksformen auf die Eingangsimpedanz von Trompeten unter besonderer Berücksichtigung von Wiener Mundstücken," in *Tagungsprogramm zur Jahrestagung der Österreichischen Physikalischen Gesellschaft ÖPG* (1998).
[29] Jody Hall, "The Proper Selection of Cup Mouthpieces," *Conn Educational Series* (Elkhart: Conn-Selmer, 1963). See also Vincent Bach, *Mouthpiece Manual* (Elkhart: Conn-Selmer, 2012).
[30] Wilfried Kausel, "Optimization of Brasswind Instruments and its Application in Bore Reconstruction," *Journal of New Music Research* 30, no. 1 (2001), 69–82.
[31] Abraham Hirschberg, "Aero-acoustics of Wind Instruments," in *Mechanics of Musical Instruments*, ed. A. Hirschberg, J. Kergomard, and G. Weinreich, (Berlin: Springer, 1995).
[32] Vereecke, "The Sixteenth-Century Trombone," 101–13.
[33] Jean Pierre Dalmont, Joël Gilbert, S. Ollivier, and M. Blondet, "Non-linear Characteristics of Single Reed Instruments: Quasi-static Volume Flow and Reed Opening Measurements," *Journal of the Acoustical Society of America* 114 (2003): 2253–62.
[34] Andrey R. da Silva, Yong Shi, and Gary Sacvone [*sic*], "Computational Analysis of the Dynamic Flow in Single Reed Woodwind Instruments," *Acoustical Society of America, Proceedings of Meetings on Acoustics* 19 (2013), no. 035043 (http://dx.doi.org/10.1121/1.4799627).
[35] Neville H. Fletcher, "Autonomous Vibration of Simple Pressure-controlled Valves in Gas Flows," *Journal of the Acoustical Society of America* 93 (1993): 2172–80.
[36] "Bridging the Gaps" was the theme of the second Vienna Talk in 2010; see n. 1.