The Saxophonist's Vocal Tract

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Part 1: Introduction, Problem, Research, and Results

Introduction

There are many opinions in the saxophone world concerning pedagogical techniques in the area of tone production. This is a good thing, for people learn and understand in many different ways. A variety of teaching techniques is necessary in order to accommodate these learning variances. In the same way, it is valuable for a teacher to know factual information regarding the mechanics of saxophone tone production so that methodologies can be designed for the individual.

Often the word science in the context of art worries artists with thoughts of rigidity and loss of creativity or uniqueness. Richard Miller, a well-known vocal pedagogue and author, commented to this writer, "there are always reactionary forces who assume that the magic of art will disappear if it can be analyzed or its principles codified." Vocalists have utilized the most up-to-date equipment available since the late 1800s to discover the elements of singing that are otherwise hidden from view. Subsequent books on vocal pedagogy include explanations of anatomy, descriptions of acoustic functions, and analysis of how they work together. With this scientific information, they have developed successful teaching techniques.

Concerning the use of science in teaching, Higo Titze, vocal physicist and author, stated to this writer,

It is true that there is no clear way to prove that scientific approaches have helped vocal pedagogy. But that doesn't mean that there are not strong arguments in its favor. One of the best is to equate scientific approaches to instrument playing with exercise science. Does anybody still doubt that exercise scientists have helped athletes?

As with vocal technique, knowing the physical and acoustical functions of the internal mechanisms utilized for saxophone tone production is necessary. Science provides a knowledge base that can be adapted to answer basic questions about various aspects of saxophone sound production. These might include: how overtones are produced, why altissimo can still be difficult even with a "correct" embouchure, why some teachers use vowels with positive results, how inherently out-of-tune notes can be placed in tune without embouchure adjustment, how a professional player can

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make a student instrument sound good, or why one player can play low notes at a soft
dynamic (with no embouchure adjustment) while another has to resort to subtones
(with embouchure adjustment). Saxophonists share basic fingerings and have a reserve
of alternates for dynamics, intonation, timbre, alissimo, technique and special effects.
It is the same with the fundamentals of vocal tract theory and practice. There are
certain universal standards and a plethora of variances that are individually unique.
Investigating internal mechanisms does not threaten art; it facilitates learning. After
years of using scientific discoveries to improve vocal pedagogy, have vocalists begun to
all sound the same? No, nor will science destroy art for saxophonists.

Sometimes a teacher may answer a student's question by saying, "I think I'm
doing this." Another teacher may have an entirely different explanation, yet also be
producing a professional sound. The two may be doing exactly the same thing, at least
in a general sense, but state the principle, or even believe it to be achieved, in an
entirely different manner. What is really going on? Would one not be more able to
customize instruction, or develop effective teaching techniques, if one knew exactly
what was happening in the vocal tract and why?

This author has found it most useful to concentrate on the similarities
between performers, the general principles, and the large-scale formations. The
following analogy is often helpful when introducing vocal tract theory to students.
Imagine that you have just entered the United States from Mexico or Canada. At the
border you were instructed to make your way to Carnegie Hall in New York City. That
is your goal. Unfortunately, you have never been to the U.S. and you have not been
given a road map. Eventually, through trial and error, you make it to Los Angeles,
whereupon a wise citizen points you in the direction of the East Coast. Your progress
brings you to Chicago. A well-intended citizen points you in another direction of
travel. Trustingly you move "forward" only to find yourself in Dallas. Eventually,
through many years of hard work, some good and some bad advice, and a little
personal inspiration you make it to the city limits of New York. You still have to find
your way to Carnegie Hall. Now, imagine the same scenario with one alteration. At
the border of the United States you are given a map. It does not show Carnegie Hall
nor does it include a city map, but it does get you to the city limits. It requires hard
work in travel and some instruction on map reading, but you have saved a great deal
of time. Once in New York City you have to find your way to Carnegie Hall, which
you do by asking locals, listening, reading signs, trying out different avenues, etc. Your
route was likely unique.

Likened the pedagogy of saxophone tone production to the above situation.
Understanding the science of the internal mechanisms is like getting a map that shows
you the location of New York City. If your goal is to reach Carnegie Hall, the map can
save you a great deal of time by keeping you from wandering around the country. It
helps the student with what this writer calls macro-movements. These large-scale,
general shapes and movements are the basis of a good beginning technique. (A
foundation of correct saxophone playing that, regrettably, many students miss
entirely.) The micro-movements (from the border of New York City to Carnegie Hall)
concern the uniqueness of the individual and equipment. Raymond Wheeler, one of the first researchers to utilize fluoroscopy (explained below), concurs:

Individual differences would be in response to idiosyncrasies of individual instruments. Slight variations in tongue positions would be necessary, then, as each player adjusted to intonation deficiencies, or differences of blowing resistance for tones within his personal instrument. The amount of variation would be in proportion to the degree of deficiency for tones of individual instruments.³

These micro-movements are learned through listening and emulation, through exercise and experimentation, through effort over time. The macro movements include largerscale positions of the tongue and larynx, for example, that seem to be universally practiced by proficient players whether or not they can describe what they are doing. The research sets forth principles that can be used to confidently guide any student if the teacher understands the concepts sufficiently to customize them to individual differences.

The preceding paragraphs have been included to help the reader understand three concepts. First, there is great value to the performer and teacher in understanding the mechanisms of saxophone tone production. Second, science is useful in learning these mechanisms accurately. Third, it is the commonalities among saxophonists that are most useful pedagogically. The discussion that follows is not designed to force a right or wrong way of teaching, but to show information that has been discovered through research, to explain why some of these findings might occur, and to offer suggestions on the use of this information.

Problem

As a student, this researcher studied the available resources on saxophone playing somewhat intensely, including books, periodicals, video (and pre-video), lectures, master classes, and so forth. When so-called “traditional” concepts were applied to his saxophone playing, some worked quite well while others aggravated the problem. For example, at one point this researcher had an acceptable low register sound and response on the classical tenor saxophone. Always trying to improve, he applied a traditional (to some ways of thinking) vocal tract concept and achieved the formation. (The accuracy of the formation is known because of subsequent x-ray filming.) However, the application of this technique resulted in a tone that became reedy (rich in high harmonics, a slight buzz to the tone) as it descended and somewhat bright (an overabundance of high frequency strength) with an increased perceived dynamic level. It became practically impossible to achieve a pianissimo low D without subtone, and low notes could not be started from silence. Much more air volume was necessary to

produce low-register tones and their "classical" nature migrated to a sound more indicative of contemporary jazz. Because of how deeply this traditional vocal tract concept became ingrained in this writer's mind, it was difficult to let it go and reclaim his old non-traditional way that earlier had been producing a uniform classical tone and acceptable response. Likewise, there were concepts in the higher registers that aggravated the production of good tone. This led to doubts as to whether or not performers really knew what they were doing within the vocal tract or if, instead, they were applying what they were told (supposition) to what they felt (sensation) and assuming it was reality.

Research

The need to know brought on the research. The writer found that several individuals have used fluoroscopy and endoscopy to view motion in the vocal tract of saxophonists in much the same way vocalists have done since the technology came available. Fluoroscopy is an x-ray technique that allows motion, rather than still images, to be filmed. When connected to a video recorder with suitable microphones, sound can be recorded simultaneously with the x-ray film. For filming saxophone playing, the profile view tends to give the clearest picture. Endoscopy involves the use of a lens at the end of a flexible or non-flexible tube connected to a camera by optic fibers. The lens can be inserted into places that were inaccessible by previous technology.

Saxophone and/or clarinet vocal tract movement by means of fluoroscopy, endoscopy, or other technologies has been documented in at least eight dissertations and five articles (see Appendix). The clarinet studies (Anfinson, Brown and Hocjke, Clinch, Compagnone, Johnston et al., Mooney, Pappone, and parts of Carr and Wheeler) are significant to the saxophone because, if the findings are the same or similar, they add credence. They are collaborative; something about the formations must be important. Mooney comments, "The adjustment of the tongue for the change of registers on the clarinet raises the question of whether or not they occur for the other wind instruments in which a reed protrudes into the oral cavity." Carr recognizes the significance of the relationship as he uses it as the assumption for findings in his dissertation. His summary of clarinet research will suffice for the purposes of this paper.

In the earlier cinefluorographic investigations the position of the tongue and throat was clearly defined for the soprano clarinet as to: (1) register change, (2) articulation, (3) syllabic vowel formations in tone production. Using these findings the following assumptions were made in relationship to the clarinet: (1) low register production—tongue in a high arched back position; (2) high register production—gradual movement to a flatter arched, tip forward and

James Edward, Mooney, "The Effect of the Oral Cavity on the Tone Quality of the Clarinet?" (Ph.D. diss., Brigham Young University, 1968), 79.
down position; (3) vowel formations aid in tone production, [u] as in “boot” for the low register, [ʌ] as in “under,” and [ɔ] as in “father” are indicated as best for the high register tones; (4) tongue position affects tone quality and pitch. Air pressure, point of damping, and lip pressure have the greatest effect on tone quality and pitch. The tongue, however, has a subtle but necessary effect on the end result.5

The saxophone projects (Carr, Clinch et al., Patnode, Peters, and Wheeler) will be summarized below by project description, conclusions, and recommendations. In the interest of space, only those aspects that concern themselves with the present study are included. (Where information is formatted into lists, numbers are added or adjusted by the writer.)


Project Description:

Five subjects for each of the major woodwinds were randomly selected from Los Angeles area professionals. The saxophone group included Gary Foster, a well-known saxophonist in some circles. The study took place at the University of Southern California in 1978. Carr used fluoroscopy to examine influences of the vocal tract on dynamics, ascending and descending scales, syllables, articulation, harmonics, articulation, pitch changes, and vibrato. Carr gives suggestions for pedagogical application.

Conclusions:

Dynamics: The overall variance between the soft and loud dynamic tasks indicated an expansion of the tongue and throat dimensions when increasing the volume level.

Ascending and descending scales: The flute, oboe, clarinet, bassoon, and saxophone groups displayed an increase in the vertical and horizontal supralaryngeal dimensions as the range was extended upward and a decrease in the dimensions as the range was lowered.

Syllables: As the subjects extended their range into the upper registers, the vertical tongue position became larger and the horizontal throat dimension opened. ... The position of the tongue

for wind playing was similar to the tongue positions displayed in the singing and speaking syllable usage studies.

Harmonics: The saxophone group raised the tongue to play the middle and high register harmonics and sharply dropped the tongue to produce the extreme harmonic tone.

Articulation: The vertical aperture became larger as the range was extended. When playing staccato, the tongue displayed less motion and there was less variance in its position from the lower to the upper registers than when playing legato. The tip of the tongue was more forward and closer to the point of attack for the staccato tasks than the legato tasks. The oboe, bassoon, and saxophone groups opened their throats when staccato notes were articulated. . . . The tip was observed to move with a shorter stroke and remain closer to the point of attack for the faster articulation.

Pitch: For most groups the tongue and throat aperture was smaller when playing a tone flat than when playing a tone sharp.

Vibrato: The clarinet and saxophone groups raised the tongue to produce a vibrato tone. . . . The lip and jaw motion was distinguishable for those subjects who used this technique when producing vibrato, however, it did not cause the tongue and throat position to move.\(^6\)

Recommendations:

1. The videofluorographic process did not clearly outline the fine movement of the reed because the density of the cane was not sufficient enough. A new method should be explored in order to be able to view the reed while playing.
2. The formant frequency and its influence on tone quality and response when the jaw, tongue body and tip are changed should be investigated.
3. The intensity of the air column and its influence on dynamics, tone quality, and harmonics should be investigated.
4. The tip of the tongue was not clearly observable. Additional investigation into the role of the tongue tip in relation to the point of attack and release would be extremely important to the player and teacher.

\(^6\)Ibid., 75-79.
5. The vocal folds and larynx area should be investigated as the subject produces vibrato tones. Angles other than the lateral position would have to be used.

6. The researcher should explore other means to view the musician while playing. The cine- or videofluorographic method, because of the amount of radiation exposure endurance, limits the duration that one can study an individual.\(^7\)

This writer found similar results; however, the comments on teaching vary. Carr’s use of vowels is contradictory to the sources referenced and filming by this researcher. For example, he describes the [u], as in you, vowel as creating an open vocal tract when, in fact, it is a high posterior tongue formation.\(^8\)


Project Description:

Clinch, et al. filmed professional performers of clarinet, soprano saxophone, and recorder utilizing fluoroscopy to determine vocal tract movement and shapes. They conducted internal and external spectrum analyses, compared male and female vocal tracts, made vowel shape comparisons, and investigated formant influences. The studies were completed at Melbourne State College, Carlton, Victoria, Australia and Monash University, Clayton, Victoria, Australia in 1982.

Conclusions:

X-ray fluoroscopic examinations have been made of the changes in shape of the vocal tract involved in playing the clarinet, soprano saxophone and recorder. In the case of the clarinet and soprano saxophone, the tongue movements parallel those used in forming speech vowels. Sound spectra of the clarinet taken both inside the mouth and close to the “bell” of the instrument show that the quality of the note is strongly dependent on vocal tract shape. It is concluded that vocal tract resonant frequencies must match the frequency of the required notes in clarinet and saxophone performance.

\(^7\)Ibid., 81-82.

... the resonant frequency of the vocal tract is increased intuitively by
the performer to match the increasing pitch of the instrument.

... when the pitch rises in the higher registers of the clarinet and the
soprano saxophone, the tongue (which is more forward in the mouth
than for the lower register, ... ) and the larynx are lowered.

It will be seen that the pharyngeal shaping which raises the first
formant is closely paralleled by the shaping for the pitch raising in the
higher registers of the clarinet and saxophone.

X-ray fluoroscopic examination of the vocal tract shapes used in
playing notes of good quality on woodwind instruments has shown
qualitatively that the length and shape of the vocal tract are altered to
suit the pitch of the note being played. In the case of the high
registers of the clarinet and soprano saxophone, the tongue plays a
very important part, and the shapes are closely akin to those used for
forming vowels; further, as the pitch rises, the tongue shape alters in
a similar fashion to that necessary to raise the first formant. When
poor quality notes are played, the spectra inside and outside the vocal
tract remain identical. It is therefore clear that the formants or
resonant frequencies of the vocal tract are important not only in
actually obtaining the required pitch, but also in controlling the
quality of the note played.9

In a later article, co-written by R. Johnston and G. J. Troup, Clinch’s previous work is
summarized.10

1. Large systematic oral tract shape changes, largely regulated by the
position of the tongue, occurred for players of the clarinet and
soprano saxophone when the scale was ascended.

2. For a given note, the shapes were very similar for different players
if they were players of high caliber, and were very similar for notes
of the same pitch on the two instruments, despite the acoustically
important differences in bore geometry.

3. The change was from a rearward position of the tongue, which
created a large mouth cavity and small larynx cavity, for low
notes, to a forward tongue position creating the opposite volume
distribution for high notes (essentially the same as for the
baroque trumpet).

9P. G. Clinch, G. J. Troup and L. Harris, “The Importance of Vocal Tract Resonance in Clarinet and

4. Movement of the tongue from the “normal” position, if slight, was found to alter the spectral components in the radiated sound, and if large, to cause changes of pitch (again, similar to the baroque trumpet) or “multiphonic” notes.

5. Similar, but smaller changes were found in players of the recorder and oboe.

6. . . . the players of these instruments were intuitively matching a resonance of the vocal tract to the pitch of the note that was being played. The resonance being matched was usually the lowest but could be a higher resonance when the very high instrument registers were being played.

No recommendations for further study were made.


Project Description:

A fiber optic scope was used to film nine graduate and post-graduate students executing assignments in the saxophone’s altissimo register. A significant purpose of the study was to determine if performers could describe their tongue positions. Three woodwind pedagogues made evaluation of the video. The study was conducted at Arizona State University, Tempe, Arizona in 1999.

Conclusions:

1. The saxophonists who participated in this study could more accurately determine a change in their tongue positions when performing examples from octave to octave than they could when performing chromatic examples.

2. Subjects’ tongues tend to move downward when playing the extreme high register chromatic examples . . . , although many sense an upward tongue motion.

3. Saxophonists are mostly unaware of their own tongue manipulations in this register.¹¹

No recommendations for further study were made; however, the study inadvertently demonstrates the need to view the vocal tract with more than one

system. Profile through fluoroscope images adds significant understanding to the perceptions of Patnode's study. In his conclusion he states,

> From the results of this study it can be determined that each of the nine subjects utilized many different tongue positions (among players) to execute both octave and chromatic examples. Each individual saxophonist, consciously or subconsciously, employs the necessary tongue placement to facilitate production of these tones.\textsuperscript{12}

Wheeler, quoted above, mentions the necessity of formation variance because of the differences in equipment (and physiology). In the introduction to the present paper, a distinction was made between macro- and micro-movements. Viewing both fiber optic and fluoroscope images shows differences in micro-movement but major similarities in macro-movement. More details will be presented in the discussions to follow.


Project Description:

“The purpose of this study was to investigate laryngeal movements in selected performance situations on alto saxophone.”\textsuperscript{13} Three alto saxophonists of equal level (does not state aptitude of performer, professional or student) were filmed with the aid of a fiberoptic laryngoscope. Research problems included: (1) various pitch ranges and registers, (2) \textit{fortissimo} and \textit{pianissimo} dynamic levels, (3) \textit{crescendo} and \textit{decrescendo}, (4) long tones with vibrato, and (5) legato and staccato styles of articulation. Peters defines the term \textit{glottis} as the region of laryngeal cavity at the level of the vocal folds. The term \textit{laryngeal movements} refers to both lateral movements in the glottis and the vertical movements of the whole larynx. The study was held at North Texas State University, Denton, Texas in 1984.

Conclusions:

1. \ldots in the C\textsuperscript{2} to D\textsuperscript{2} register change some movement of the larynx could be observed. This movement was either a vertical laryngeal lunge or a lateral widening of the glottis.
2. The only pitch range within a register to produce consistent observable movement was during the pitches A\textsuperscript{3}, B\textsuperscript{3}, and C\textsuperscript{4} in

\textsuperscript{12}ibid., 142-143.

\textsuperscript{13}Jeffrey T. Peters, “An Exploratory Study of Laryngeal Movements During Performance on Alto Saxophone” (Masters thesis, North Texas State University, 1984), abstract.
the altissimo register, in which all three subjects evidenced a slight rise in laryngeal elevation.

3. . . . the pianissimo performance appeared to require greater muscular effort than the same pitches at a fortissimo dynamic level. The increased muscular effort seemed to be consistent throughout all of the pitch ranges and registers tested.

4. . . . the crescendo-decrescendo brought about two types of movements which coincided with the crescendo-decrescendo: (A) a dropping and rising of laryngeal elevation, and (B) a lateral widening and narrowing of the vocal folds.

5. . . . there was no apparent glottal reaction to, or influence on the production of vibrato on alto saxophone.

6. . . . there was no glottal activity observed in music performed with legato articulation. With staccato articulation, however, there was a marked pumping action of the glottis.

7. Laryngeal movements appeared to be most prevalent and consistent in two performance situations: (1) when variations in dynamic level were required, especially in pianissimo performance, and (2) in situations where the resistance of the instrument changed quickly, i.e., the stopping and starting of the tone in staccato performance and the C^2-D^2 register change.

8. The glottis does appear to be used as an expiratory airflow constrictor during performance on alto saxophone, especially during pianissimo performance, and to some extent, on higher register tones.\(^{14}\)

Recommendations:

Peters suggests that more use of the laryngoscope be made to investigate the larynx and that other woodwind instruments be included.

Correlation of Peters' findings to other projects can be clearly seen with brief explanation. He notes a drop in laryngeal elevation between the C^2-D^2 register changes. The other researchers note an increase in vocal tract vertical dimension as pitches rise. Posterior tongue elevation and laryngeal height are related. Peters mentions a rise in laryngeal position during the pitches A^3, B^3, and C^4 in the altissimo register. These may be considered micro-movements as the overall vocal tract space as compared to lower notes is still considerably larger and the laryngeal position lower. The macro-movement is consistent with the other projects. The use of the glottis as an airflow constrictor is consistent with Carr and Wheeler (below). It should be noted that Peters' observation of vibrato is probably that of jaw or lip vibrato as opposed to air vibrato. Carr noted no laryngeal involvement with jaw vibrato but did

\(^{14}\text{Ibid., 65-68.}\)
observe movement when an air vibrato was produced. Comments relating Peters' articulation observations will be made in Part 2.


Project Description:

A fluoroscope was used to film a single subject, Ray Wheeler, on clarinet, alto saxophone, oboe, and bassoon for three separate tests. Excerpts included intervals, scales, articulation, dynamics, and syllable singing. Illustrations are included and an extensive discussion regarding pedagogical applications for the clarinet are made. The experiments took place in Ellensburg, Washington in 1967, 1971, and 1972.

Conclusions:

Findings related to vocal tract formations are similar to those cited above. Wheeler emphasizes the principle that the shapes are requisite for instrument performance.

... single and double reed instruments required performers to use specific tongue positions in order for those instruments to respond in their intended manner.

... a specific shape cannot be altered to improve tone quality for any given tone, assuming that tone has been reasonably stabilized. If the shape were to be changed, a clarinet or saxophone tone, for example, would either deteriorate or be forced to jump to an overtone or an undertone.

... for ascending scales that began in the lowest register (chalumeau) and proceeded through the middle (clarion) and into the high register (altissimo) of the clarinet, the tongue progressed gradually from a high and rearward position to a lower and forward position. During ascending intervals... the tongue shifted instantly from one position to another, positioning itself at high, middle, and low levels as it moved forward on a descending diagonal for the respective three tones. These tongue positions resulted in "small" throat openings for low tones and "large" openings for high tones—certainly a contradiction of present teaching theories. ... X-ray images of alto
saxophone performance examples showed similar vertical and horizontal tongue movements for scales ascending from low register tones to those well above the staff (including harmonic tones which extend the range above high F).\textsuperscript{15}

Comparisons to vowel formations are similar to the findings of this researcher but Wheeler views them as less useful pedagogically.

\ldots x-ray images of vowel or syllable vocalizations ("taw," "toe," "tie," "too," "tch," and "teh") showed these syllables to have tongue positions not entirely adequate for shaping the air stream correctly for the clarinetist. The difficulty lies in the fact that for low tones "taw" or "toe" correctly decreases the area behind the tongue, but they lower the top of the tongue far too much. Similarly, while tch opens the throat correctly for high tones, the top of the tongue is positioned too high. \ldots Less extreme syllables ("tie," "too," and "tch") have the same difficulty, but to a lesser degree.

Of further interest was the fact that ascending and descending pitch vocalizations on each syllable did not alter the shape of the tongue, nor should it have, since the lower vocal folds control pitch, not the tongue's shape.\textsuperscript{16}

Significant comments are made regarding intonation adjustments, specifically, the raising of the tongue to lower pitches and the lowering of the tongue to raise pitches.

One exception occurred to break the smooth tongue pattern of shifting forward and slightly downward for the ascending scale. As the scale moved through fourth-line D, the top-middle of the tongue reversed its direction and [rose] nearly to the palate for D. However, after two more tones, the tongue had lowered to a position more in keeping with its gradual progression forward and downward.

There is a satisfactory explanation for that unexpected tongue elevation. That tone is inherently a sharp pitch on all saxophones, and competent players have learned to "humor" the pitch to a lower and better pitch level. Obviously, the tongue raised to make the adjustment, extreme though it was, when compared to adjacent tones and their tongue position requirements. Embouchure adjustment was not necessary or desirable; to have done so would have changed the tone quality of D from that of adjacent tones.\textsuperscript{17}

\textsuperscript{15}Raymond L. Wheeler, "Tongue Registration," 4-5.
\textsuperscript{16}Ibid., 4-5.
\textsuperscript{17}Ibid., 6.
Wheeler makes observations regarding the vocal tract functioning to regulate air pressure.

Clearly, the back and top of the tongue adjusts the throat aperture and oral channel through which air flows, functioning, in effect, as a pressure valve to regulate the air supply provided continually by rib intersections with abdominal muscle contractions during forced expiration."^{18}

Comments on articulation include legato and staccato. It is apparent that he prefers tongue-stopped staccato (a return of the tongue is used to stop the note). No differentiation is made between this type and air-stopped staccato (note ended with air cessation) and his description most resembles the former.

During legato tonguing of moderate length tones, the tongue action very much resembled that of a boxing glove "pulling" its punch, so to speak, as it quickly touched and withdrew from the reed. For short staccato tones, however, the front of the tongue withdrew only slightly before touching again, the sensation being that of remaining against the reed and lip all the time. The difference between staccato and legato articulation was merely a matter of time (how long the tongue remained on or off the reed), not which part of the tongue touched which part of the reed.^{19}

Recommendations:

Wheeler expresses the need for further research using scientific devices for the purpose of developing more accurate teaching techniques. He comments on the need for a front view and on the fact that he could not see the tip of the tongue well during his articulation exercises. These problems are remedied by the use of fiberoptic scopes and modern fluoroscope machines. Only the alto saxophone was involved in Wheeler's study. He recommends that the rest of the family be filmed. He states, "it appears that tongue positions do not change if crescendo and diminuendo are accomplished with steady pitch control," but suggests that this be studied.^{20} While discussing the necessity of filming subjects of different sizes, Wheeler speculates, "The author's hypothesis would be that air space or air capacity near the critical area of the uvula would be the same for both subjects."^{21} Other recommendations include: examining performers playing on different mouthpiece, reed, and ligature combinations, and placing a pad on the mouthpiece to increase vocal tract size.

^{18}Ibid.
^{19}Ibid., 10.
^{21}Ibid.
Viewed together, the existing research seems to be asking and trying to answer the same questions proffered at the conclusion of the introduction above. What happens in the vocal tract when playing the saxophone? Why do these things occur? How can the performer and teacher utilize this information? Some of the specific goals of this researcher’s projects and subsequent analysis are to:

1. Increase the subject base
2. Substantiate or disprove other researcher’s findings and respond to their recommendations, including:
   a. Determine if saxophone tendencies are similar to clarinet
   b. Observe elements that were previously not possible such as a front view and the tip of the tongue
   c. Investigate formant frequencies and their relation to saxophone vocal tract formations
   d. Film the vocal folds and surmise their involvement regarding dynamic, range, vibrato, and tone
   e. Explore other means to film internal mechanisms
   f. Use scientific devices for the purpose of developing more accurate teaching techniques
   g. Expand the research to include all standard saxophone types (soprano, alto, tenor, baritone)
   h. Note vocal tract (tongue shape and larynx position as opposed to vocal fold involvement) stability or change with variances of dynamic
   i. Document player size considerations
   j. Check the consistency of vocal tract principles when varied performance equipment is utilized
3. Sift through performer differences and find the similarities
4. Find viable pedagogical applications
5. Help establish a codified standard if possible
6. Add credence to a cause and effect philosophy: if one does this, this will happen
7. Explain why vocal tract formations occur
8. Learn through first-hand observation
9. Assess influences of the embouchure on the vocal tract
10. Investigate tongue movement and tongue length considerations for articulation
11. Determine whether or not there are significant differences between jazz and classical vocal tract formations
12. Check specific tone studies for variances to standard playing
13. Compare mouthpiece pitches with those played on the saxophone
14. Relate air pressure readings with tongue formations
15. Observe internal and external spectrum changes for high and low tongue positions on the same pitch
These goals relate to each other in varying degrees and are not accomplished in equal measure. Some are simply a cursory, exploratory examination. Because of the relation of one principle to another, several aspects of research often need to be discussed together. This makes it impossible to report the research goals and objectives in order; therefore, no attempt is made to do so.

The first step after reviewing the literature is to add to the subject base. The demography, according to statistical theory, is best if it includes a large, randomly selected, sample population. Because of the difficulty using fluoroscopy, this has not been possible. Consequently, this researcher's subject base was selected to emphasize diversity, to mimic the random concept and to fill the needs posed by previous projects.

Parameters included: lineage (teachers of subjects), equipment, geographic locations, styles (jazz and classical), saxophone types (soprano, alto, tenor, baritone), and physical size. Frederick Hemke suggested the idea of lineage in a conversation with the writer. He felt that one might discern differences by studying the students of major teachers. A total of sixteen subjects were obtained, nine professionals and seven advanced students. The teachers (lineage) of the subjects include: Burnette Green, James Hill, Trent Kynaston, Patrick Meighan, C. Raymond Smith, James Umble, John Sampen, Jean-Marie Londeix, Eugene Rousseau, Yushi Ishiwata, Daniel Deffayet, Mark Watkins, and Mark Fly. Two were self-taught. Instrument, mouthpiece, and reed usage was random; performers used their personal equipment. This included twelve different saxophone brands or models, thirteen varied mouthpieces, and five reed brands or types with varying strengths. Geographic locations include where the performers were currently located at the time of the projects and where they studied (lineage): Bordeaux, France; Paris, France; Florida, Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, Ohio, Tokyo, Japan; Utah. Styles include five jazz and eleven classical. Saxophone types include: two soprano, five alto, six tenor, and three baritone. A fairly even distribution of physical size ranged from 5'3" to 6'5".

Adding the subjects from previous studies would increase all areas to include Gary Foster, other L.A. studio musicians and Peter Clinch as subjects; Joseph Wytko and other well-known instructors to the lineage; California, Arizona, Texas, and Washington to the geography; and increase the variety of equipment, styles, and saxophone types. For future projects, adding age, gender and ethnic background to the sample population is recommended.

The number of subjects is always a concern when trying to prove a principle. This researcher consulted with two statisticians regarding the present projects. Several principles were emphasized. First, statistics do not prove; they say that something is very consistent or gives strong evidence. Second, some types of information can be determined by a sample population of twenty-five but the present study parameters suggest a randomly selected sample population in the hundreds as being more proper. Third, the practicality of filming hundreds of subjects with the requisite equipment is very low. Fourth, the relationship between clarinet and saxophone results is significant and adds to the statistical foundation. Fifth, sixty-seven subjects is sufficient to give strong evidence. Previous research represents eighteen saxophonists and thirty-one clarinetists. Add these to the sixteen saxophonists and two clarinetists that this
researcher filmed and the subject base becomes sufficient to make reasonable assumptions. Sixth, more people should be filmed. Seventh, the researcher is not saying, "we have proven," but rather, "Wow! Look at this."

It is by the accumulation and comparison of knowledge from past research and publications, other disciplines, and present methods and technology that one continues to progress towards the truth. Musical examples were based on the goals listed above, the excerpts included in Walter Carr's dissertation, and those sent to this writer by Ray Wheeler. A description of this researcher's projects follows:

Project #1: Salt Lake City, Utah (February 1998)

Fluoroscopy and endoscopy were utilized for this project and included the saxophone professors from Brigham Young University (Dr. C. Raymond Smith), the University of Utah (Dr. Mark Ely), and Weber State University (Dr. David Feller) along with their top students and professional performers from the region, totaling eleven subjects. Fluoroscopic images were taken in profile while the subjects played samples including octave slurs, scales, arpeggios, altissimo, overtones, mouthpiece pitches, vibrato, articulation, vowel pronunciation with and without the mouthpiece, movements of the larynx and vocal folds, and other tone studies and excerpts. All subjects in this study were also filmed with the endoscope to determine front contours in relation to the profile contours obtained from the fluoroscope.

Project #2: Moorhead, Minnesota (January 1999)

A comparison of sound waves recorded within the vocal tract to those recorded externally was done to help understand the significance of vocal tract formations and the relationship between vocal tract and instrument. The microphone probe used for this experiment was several inches long and syringe-like measuring .5 mm wide and could be inserted along the side of the mouthpiece with very little discomfort to the performer. During the same appointment a water manometer was used to determine air pressure when playing the various ranges of the saxophone. A water manometer is a flexible tube connected to a U-shaped glass tube partially filled with water. When one blows into the open end of the flexible tube it displaces the water level of the U-shaped glass tube. This displacement of water can then be measured to determine variances in air pressure. The open end of the flexible tube was placed within the oral cavity by inserting it alongside the mouthpiece. Dr. Walt Worman, professor of physics at Moorhead State University, and Dr. Wayne Dorothy of North Dakota State University assisted with the project. This researcher served as the sole subject for this project.

Project #3: Fargo, North Dakota (June 1999)

A second fluoroscope study was conducted in Fargo, North Dakota and included the saxophone professors from North Dakota State University (this researcher) and
Concordia College (Russell Peterson) along with a few top students and the Hard-Bop Saxophone Quartet. In addition to filming these saxophonists, two professional clarinetists and one professional vocalist were filmed. The clarinetists were filmed to assess similarities in the vocal tract between saxophone and clarinet. The vocalist was filmed to document International Phonetic Alphabet vowel formations, relationships between sung and spoken vowels, and to determine any vocal tract similarities between sung pitches and pitches played on the saxophone. A second probe microphone and water manometer project, also with the help of Dr. Worman, took place in conjunction with the second fluoroscope project. The probe microphone and water manometer were inserted during the fluoroscope performances in order to relate their readings to the movements within the vocal tract and to increase the subject base of the first experiment.

*Project #4: Provo, Utah (March 2000)*

This project was held to clarify questions related to articulation, embouchure, and mouthpiece pitch. Subjects included the same saxophone professors from Brigham Young University (BYU), Weber State University, and one of the professional musicians from the first project above plus four students from BYU, one from Brigham Young University-Idaho, and this researcher. Technology included an endoscope and a pressure gauge. In regards to the articulation aspect of the project, the endoscope was used to examine tongue-to-reed contact points. Performer tongue lengths were measured to compare length to contact point. The endoscope was then used to measure internal bottom lip placement on the reed while playing. External measurements were also taken. The purpose of these measurements was to obtain information as to lip thickness, reed exposure in the oral cavity, and embouchure placement on the mouthpiece. The pressure gauge was used to determine lip pressure changes over the full range of the saxophone (low B-flat to altissimo F) during normal playing (no special effects). The mouthpiece pitch element of this study was conducted to find the actual mouthpiece pitches (mouthpiece alone, without the body or neck of the saxophone) that saxophonists were producing during performance. This was done by sanding the cork on the instrument so that the mouthpiece could seal but easily slide off of the neck. One performer then held the instrument while another held the mouthpiece firmly and blew the tone. The first performer would quickly pull the horn away leaving the second performer holding the mouthpiece and blowing a mouthpiece pitch. These pitches were recorded for all notes of the full range of the saxophone from low B-flat to altissimo F.

*Project #5: Rexburg, Idaho (June 2001, April 2002)*

Research involved the use of an analog spectrum analyzer and was conducted at BYU-I with the assistance of Brian Pyper from the physics department. Initial readings were taken of Fourier frequencies (overtones) to determine whether or not the saxophone functioned on Relative Pitch Theory (similar strengths and weaknesses of overtones
for each note of the instrument) or Formant Theory (areas of strong influence on overtones) or a combination of the two. A follow-up study was conducted later using a fast Fourier transform computer program that gave a more accurate reading of the entire spectrum.

Results

Perhaps the most significant finding from this researcher's projects is the position of the tongue, larynx, and soft palate for playing the various registers of the saxophone. The researcher used translucent paper pressed against a monitor screen to trace selected still images from the video documentation. Figure 1 is a key to understand these tracings.

Figure 1. X-Ray Profile.

Figure 2 shows a profile of vocal tract positions for four octaves of written C on alto and tenor saxophones taken from this researcher's projects (1 and 3). Notice that the tongue starts with a high posterior position for C\(^1\) and progresses downward as the pitch ascends from octave to octave with the lowest posterior position found on C\(^4\). The anterior of the tongue progresses slightly forward and minimally upward until the altissimo register, where the anterior tongue continues forward but moves down to create even more space within the vocal tract.
Figure 2. Saxophone Vocal Tract Formations.

[Diagram showing saxophone mouthpieces and vocal tract formations for alto and tenor saxophones]
The position of the hyoid bone, anatomically located just above the larynx and easily seen on the x-ray film, is indicated in Figure 2 and represents laryngeal placement. The larynx remains fairly stable until C\(^3\), where it drops slightly, and C\(^4\), where it drops more significantly. As the posterior tongue drops to achieve the higher registers, the soft palate, or vellum (represented by the dotted line in Figure 2), rises. This helps to enlarge the vocal tract. Likewise, when the notes descend the soft palate descends, decreasing the space. These findings concur with previous studies.

There are minor differences amongst the saxophone types. For example, the tenor maintains more anterior space and slightly less posterior space than the alto. Jazz and classical formations show little, if any, variance except in the lowest register where the posterior vocal tract is occasionally more open for jazz. When the variance occurs it is accompanied by a timbre change and will be discussed in more detail later. The consistency of findings is rather remarkable and should not be treated lightly. Many of the above reports included illustrations removing any doubt as to what they were describing.

Clarinet and saxophone tendencies appear to be similar, with one marked exception regarding the larynx position. Compagno states, “It was observed that the larynx ascended during the production of the upper register tones and descended for the change to the low register tones on clarinet and flute.”\(^{22}\) Peters and Wheeler found a similar tendency. Upon examination of this researcher’s film of clarinetists, he also found this movement. The larynx rises between chalumeau D and clarion D-sharp. The saxophonists studied did not make this adjustment.

Ray Wheeler stated that a front view would be needed along with the profile obtained from the fluoroscope in order to understand the formations accurately.

The writer has one minor concern, however. Motion picture x-ray images show only the outline of the tongue. It may be that some lateral “spreading” or “valleys” of significance occur within the outline. It was suspected that only front views of subjects would show those movements. Consequently, front exposure views were attempted during pre-tests using the writer and the assisting medical doctors (who were amateur clarinetists) as subjects. Image prominence of spinal bones of the neck obscured the outline of the soft tissue of the tongue so that further front exposures were not made.\(^{23}\)

At the time of his research, the ability to film a front view was not available. This can now be done with an endoscope. Patnode, limited to endoscopy, found inconsistency in the analysis of his research. One reason he gives is as follows,

\(^{22}\)Nicholas A. Compagno, “Laryngeal Movements Observed During Clarinet and Flute Performance” (Ph.D. diss., University of North Texas, 1990), 115.

Since the scope was placed at the front of the subject’s mouth, tongue movement may have been more difficult to see when the tongue moved toward the camera, away from it, or in the event that it did not move at all. This effect can be compared to seeing a car on the road from a distance and not knowing if it is moving toward you, away from you, or is merely parked.²⁴

Some of these difficulties can be understood more fully when a front view (endoscopy) and a side view (fluoroscopy) are analyzed in conjunction with each other. With this probe lens, the researcher can place the fiber optic tube alongside the mouthpiece and view the forward part of the vocal tract clearly and discern front view tongue shapes among other things. Results of this procedure show that the contour does change from low register to high and markedly from player to player. Figure 3 shows the shape formed by one of the subjects (typical of the eleven filmed). As the note ascends, an increase in the valley or channel of the tongue can be seen. One can also see the tongue moving forward. The amount of channeling done by each performer depends greatly on individual physiology. This may influence the extent to which the shapes shown in Figure 2 are formed. If a saxophonist makes a deep channel, then the profile image might show a higher overall tongue position. If a saxophonist cannot form a deep channel, then a lower overall tongue position might be seen.

Figure 3. Front View.

![Diagram of tongue shapes](image)

There are many factors that cause differences from player to player: the front contour of the tongue being one, the size of the performer being another. These differences may be one of the reasons for so much variation in opinion as to vocal tract shape and/or volume. For example, two professional alto saxophonists in this writer’s Fargo project contrasted in size considerably: one approximately 5'8" and the other 6'4". A third performer, a tenor saxophonist (6'3"), is also included in the comparison.
A small metal rod was placed on the mouthpiece in order to obtain accurate measurements by ratio from the video (figure 4). Distance in millimeters was determined between the tongue and the tip of the mouthpiece (1), tongue and hard palate (2 and 3), tongue and soft palate (4), and tongue and the pharynx wall (5). The fluoroscope view and the vertical measurements appear to indicate that the larger performer preferred to form a smaller overall vocal tract air chamber. Subject 3, a tenor saxophonist, also tall, showed larger dimensions than Subject 2 but smaller at some points than Subject 1. Three additional perspectives are missing: 1) average vocal tract length, 2) average vocal tract width, and 3) the above-mentioned front view tongue contour or valleys. Length was measured from the top teeth along the roof of the mouth to the jaw (A to B). Figure 4 shows that the taller saxophonists have longer vocal tracts making the perceived tongue height deceptive in relation to actual space. Considering the probable greater width and possible valleys, it is hypothesized that the three performers, particularly the two alto saxophonists, utilize a similar total vocal tract volume but have to raise or lower the tongue different degrees to achieve optimum resonance and/or air pressure.

The reader will notice that the general contour remains the same. (See Figure 2, alto column, for a sketch of Subject 1 and the tenor column for Subject 3.) It is the general contour that is of value to saxophone pedagogy. Teaching inconsistencies arise when performers teach vocal tract theory based on their own size. The smaller performer might teach an overall more open vocal tract than the larger performer. If the larger performer were to open proportionally as much as the smaller saxophonist, an undesirable sound and response would result (to be discussed further in Part 2). A problem would also result if the smaller player attempted the same feel as the larger player. A similar situation might arise if one player had a larger tongue mass as compared to available vocal tract volume. However, the concept as outlined in Figure 2 remains valid. The teacher simply has to recognize these possibilities and instruct accordingly.

These findings may contradict traditional concepts. Gustav Langenus stated, “to get the high notes, contract the throat a little more than for the lower notes.” Based on the available information in 1923, when this statement was printed, his conclusions were logical; for, if one is only able to view anterior tongue positions, this is probably what one would conclude. Fluoroscopy has provided us with a full view, however, that sheds further light on the subject. To restate Johnston, et al. from above, “The change was from a rearward position of the tongue, which created a large mouth cavity and small larynx cavity, for low notes, to a forward tongue position creating the opposite volume distribution for high notes.” (Italics added.) Additionally, there are other factors involved. For example, if one recognizes that large chambers aid in low tone production and vice versa (like a tuba and a piccolo), then Langenus’ statement gains strength; but what about nodes, antinodes, and formants?

Without science or with superficial knowledge, writings have been contradictory. Carr states,

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26Johnston, et al., 67.
Figure 4. Performer Vocal Tract Dimension.

**Average Vocal Tract Length**

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<tr>
<th>Subject</th>
<th>A to B</th>
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<tbody>
<tr>
<td>1 (5'8'')</td>
<td>106.15</td>
</tr>
<tr>
<td>2 (6'4'')</td>
<td>117.73</td>
</tr>
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<td>3 (6'3'')</td>
<td>127.53</td>
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**Vertical Dimension**

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<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (5'8'')</td>
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<td>3.8</td>
<td>3.2</td>
<td>4.6</td>
<td>3.6</td>
</tr>
<tr>
<td>2 (6'4'')</td>
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<td>7.3</td>
<td>4.3</td>
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<td>3.3</td>
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<tr>
<td>3 (6'3'')</td>
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<td>15.8</td>
<td>8.6</td>
<td>4.3</td>
<td>6.3</td>
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<td>12.0</td>
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<td>11.6</td>
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<td>17.2</td>
<td>10.9</td>
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Theories about the physiological aspects of the tongue and throat positions during performance, as expressed in numerous writings, have been mostly contradictory and ambiguous. Woodwind teaching theories have been based mainly on external evaluation and supposition.\(^{27}\)

Mooney, in his dissertation, comments similarly, “Most of the theories mentioned previously by clarinet teachers and players have been the result of external evaluation and supposition.”\(^{28}\)

Another cause for the inconsistency of opinion regarding vocal tract formations is that it is difficult to associate what one feels to what is actually happening. Walter Carr mentions, “The area that the performers had the most difficulty describing in their questionnaire responses was the throat aperture.”\(^{29}\) Wheeler said, “While advanced players do have deliberate control of the rear portion of the tongue, it seems clear that even they are not able to discern the spatial placement of the rear portion of their tongues, else we surely could not have been misled in those tone production matters.”\(^{30}\) Matt Patnode’s conclusions clearly state that his subjects “were not able to determine their actual tongue positions.” He later comments in regard to the experts that reviewed his video tapes that, “the individual training of the panel may have influenced the judgment of each panelist.”\(^{31}\)

Sometimes preconceived notions influence our perspective.

There are numerous explanations regarding the internal mechanisms involved with saxophone performance. These, along with more study results and details, will be outlined and explained in Part 2. Let the writer conclude this section by again quoting Ray Wheeler.

...for reasons which are unknown, woodwind teachers and performers have been less successful [than brass and voice teachers] in analyzing their technics, at least in regard to describing tongue placement for tones in various registers. ... Throughout this article readers will have noticed information that conflicts with woodwind pedagogical concepts, and will realize that those concepts need modification. It seems almost urgent that further projects be undertaken, using x-ray equipment or other reliable research apparatus to test basic teaching concepts that possibly are detrimental to efficient progress for woodwind students.\(^{32}\)

Since the time that this statement was made there have been many projects conducted heeding Wheeler’s advice. The general concepts discovered have been uniform. All

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\(^{27}\) Carr, 1.
\(^{28}\) Mooney, 10.
\(^{29}\) Carr, 81.
\(^{31}\) Patnode, 144, 147.
have noticed similar large-scale formations and noted a vast amount of variances on the smaller scale. These small-scale differences must be so because of the unique characteristics of the individual and the differences in performance equipment. The large-scale characteristics should be similar because saxophone construction and human anatomy are similar.
Appendix

Research of Saxophone and/or Clarinet Vocal Tract Movement Utilizing Fluoroscopy, Endoscopy, or Other Technologies

Dissertations


Articles


