

# The Flute Inside-Out: Tracking Internal Movements in Flute Playing

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A thesis submitted in partial fulfilment of requirements for the degree of Doctor of Musical Arts Sydney Conservatorium of Music University of Sydney 2017

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

# Acknowledgements

I would like to acknowledge:

My flute teachers: Sirlei, Helcio Latorre, Rogerio Wolf, Eva Amsler, Mary Stolper, Aldo Baerten, Emma Sholl and James Kortum. Thank you for believing in me and my flute playing.

My sister Andrea Cardoso, who was the main responsible for me to pursue this research in the first place, and who continues to inspire me day by day. Thank you also to my niece and my brother in law: Nicole and Tio Nelo. I love you!

The love of my life Jaqueline Santos, who was beside me through the difficult times, and kept supporting me day after day.

My mom and dad who did not let me look back or give up. Thank you for teaching me what the word love means.

My supervisors: Cate Madill, Anna Reid, Rowena Cowley and Dr. Novakovic for never giving up on me and giving me always the right advice.

The experts Dr. Daniel Novakovic and Dr. Cate Madill for the tremendous support with the endoscopies and analysis.

All the participants. Without you, this research would not exist. Thank you for trusting me and believing in the project.

# Abstract

Analyses in the past have revealed that flute sound production is a complex procedure involving internal movements of the body. The larynx and pharynx in particular play a crucial role. Some authors, advocate for the abdominal muscles, while others, draw attention to the lips and the oral cavity. However, despite the various studies, the physiology of flute playing is limited by lack of empiricallyderived information about what happens when a player carries out musical tasks.

The present study is an empirical investigation of the role of the larynx and pharynx in flute playing from the perspective of a flute specialist. Specifically, the study aims to determine vocal fold involvement in vibrato, epiglottis movements, arytenoids and epiglottis involvement in articulation, and glottal aperture in tone and dynamics production (soft to loud, loud to soft). A detailed analysis of the relationship between standard flute techniques and the larynx and pharynx mechanisms is presented, making a significant contribution to the flute pedagogical literature.

Two male and three female experienced players (referred to in the study as "the participants") participated in a video-nasendoscopy procedure. The behaviour of the participants' larynxes and pharynxes while playing a performance protocol specifically designed for this research was observed by a qualified speech pathologist. Specifically, the observer analysed true vocal fold adduction, false vocal fold adduction, laryngeal height, pharyngeal space, epiglottis movement, and arytenoid adduction.

This study reveals that laryngeal/pharyngeal participation in flute playing is not limited to vibrato production or specific techniques, such as singing and playing

or flutter tongue (tongue rolling effect while playing). The larynx plays a major role in producing flute tone and dynamics and should be considered by pedagogues, performers and health specialists.

These findings can assist flute professionals in their daily practice, performances and teaching. Knowing the role of the larynx in vibrato, articulation, pitch control, and dynamics control, reveals a new tool for flute players to use with assurance when preparing any piece of the standard repertoire, or teaching a student.

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# Preface

As a flute student, I had never been able to comprehend fully the origin of vibrato, or the internal processes involved in changing dynamics on the flute (*crescendo, decrescendo*). Questions always surged in my head every time I was supposed to perform a high note *diminuendo* on a chamber piece, or an extremely loud passage in orchestra. Just what happens inside me when I create sound on my flute? With teaching, these questions became stronger as the most popular method for teachers to deliver these techniques involves the apprentice imitating the teacher. Although I could make a sound on the flute, I simply did not know what physical processes took place. Imitating my teachers produced an acceptable result but I still did not know *how* I was able to do it.

When I started to investigate this problem, I realised that the internal mechanics of sound production on the flute is an area of very sparse investigation. With this project, I hope to uncover empirical evidence that will enable student and professional flutists to understand the different facts about the internal mechanisms of what body in relation to the basic sound production techniques on the flute. This

Moreover, I hope this study will inspire my colleagues to use these facts in their pedagogical publications (methods, articles, books). As a result, I am sure we will have more well-informed professionals, and lessons and master-classes will generate interesting factual-based discussions on the internal mechanisms involved in flute playing.

### **Teaching the flute**

This section is a survey of many of the existing method books and resources commonly used to study the flute. It will be possible to observe the language of each resource as well as the different approaches to the topics studied by the present research (pitch, vibrato, articulation and dynamics).

#### The language of flute methods

In regards to teaching the flute, the standard flute methods use descriptive language to explain the basic techniques of the instrument (Taffanel, 1958; Rockstro, 1967; Altes, 1956; Krell 1973; Toff, 1996; Dick 1987). Pitch, vibrato, dynamics and articulation are all presented based on personal experience and previous sources. Topics such as breathing, posture, and body mapping appear to be published in more recent texts, and not in regular methods, but in books and articles (Dick, 1987; Pearson, 2006, Debost, 2002; Wilkins, 1963).

#### Pitch

Many flute methods and books use the word "intonation" when referring to pitch. In addition, several texts include pitch under the topics of tone or sound (Taffanel, 1958; Rockstro, 1967; Altes, 1956; Krell 1973; Toff, 1996; Dick 1987). One of the few sources to dedicate a whole section on pitch (using that specific term) is Galway's *Flute* (1982). The author describes pitch as not something to be only thought of as a "technique", such as vibrato, finger movements, or dynamics. For Galway, it is crucial that the flautist develops a sense of pitch by listening and singing. Although Galway does not go into specific details as to how the pitch should

be produced or controlled (physiologically speaking), he does acknowledge that air control and jaw movements directly affect pitch (Galway, 1982).

Krell (1973) discusses pitch-related questions under the topic of tone. Krell agrees with Galway (1982) when he defends that the flautist needs to develop a pitch sense in order to produce good pitches. Krell goes further and states, "Each pitch has its own placement which achieved brings a maximum response from the instrument" (p. 8). Although Krell strongly associates pitch production with the acoustics of the instrument, he does highlight that pitch control is directly associated to the volume and direction of air implemented across the hole (Krell, 1973).

Diverging from Krell and Galway, Toff (1996) divides her chapter on tone into various subsections including tone production and intonation. The author places greater emphasis on body awareness. According to Toff, the air assumes the main role in producing a good tone; therefore, every little detail in the body can affect the air column and subsequently the tone quality:

The body must be relaxed, with arms held sufficiently away from the body so that the air can travel from lungs to flute without obstruction. The head should be held up, with the bottom of the chin more or less parallel to the floor. Lowering the head too much will crimp the neck muscles and constrict the throat, and raising it is impractical (p. 91).

Toff asserts that constriction of the throat significantly affects tone production. She lists the size of oral cavity as one of the important factors on tone quality achievement (Toff, 1996). The author acknowledges the important contribution of physiological aspects by stating that intonation and tone are tied together due to the physiology. In other words, a well-produced tone will result in a well-tuned sound as well.

Toff gives detailed instructions on how to change pitch. However, none of the guidelines includes internal physiological factors (Toff, 1996). Although Toff does not mention these factors in this source, in her earlier text *The Development of the Modern Flute* (Toff, 1979) she is much more comprehensive. She describes pitch and timbre changes as follows:

Indeed, the throat, lips, tongue and diaphragm are capable of quite sophisticated alteration of pitch and timbre with no assistance from the fingers, the principal variables being breath pressure, which affects the pitch, tonal focus or intensity (p. 212).

The degree of involvement of the throat or the larynx is never specifically mentioned; however, Toff is clear when she includes the throat as a key mechanism in the process of pitch production or alteration.

Underwood (2012) acknowledges the crucial impact of the physiology on tone production. For him, the flute player needs to sing the phrase without the flute before he or she actually plays it. During this blowing exercise, the player actually places the tongue in between the teeth to create resistance (Underwood, 2012). The idea is to observe the oral cavity and organise the air without worrying about holding the instrument, or fingering notes.

According to Underwood (2012), air control establishes a critical role in tone production. George (2011), on the other hand, lists oral chamber openness as the first rule to achieve a good tone. George asserts that air direction is usually an overseen topic, and that flautists frequently are not aware of the difference air direction, speed and volume can have on their tone.

Unlike George and Underwood, some flute pedagogues with students at beginner level advocate using the lips to develop tone. A good example of this, Ridd (2013) develops a case for the shape of the lips. However, she also mentions the throat to describe how to produce a good resonant sound:

Students can be encouraged to create as much resonating space inside the mouth as possible by keeping the teeth/jaws apart and tongue down. Keeping the throat open and relaxed is another key component (p. 56).

Other important factors for Ridd (2013) are the air direction and the support muscles. Ridd does not refer to specific physiology when describing the techniques. It is interesting, however, that the author dedicates a whole sub-section to intonation:

Variables of air speed and direction affect pitch. Not knowing this, or not being able to control these variables, can hamper a student's ability to play in tune (p. 57).

Clearly, the use of air is important for the author; however, she does not elaborate on the elements involved in air control and changes in air speed.

A case study by Neszhad (2012) tried to answer the question of mechanics of flute tone production by observing and interviewing flute players. Recognising tone as a major topic of discussion from Quantz to the present day, Neszhad asserts that the main factors of flute tone are primal sound (basics of human sound production), air column, and physiological components (abdominal muscle support, breathing apparatus).

Neszhad (2012) dedicates the last section of his article to the physiological approach in tone pedagogy:

This kind of physiological approach leads to a better understanding of the core components of tone pedagogy (support, centre of gravity, air column and primal sound), and other determinant aspects, including technique, artistic perception, style, and resonance. Utilizing this approach will gradually lead the learner to a self-reliance in learning as they develop a manner and technique of tone production that emanates from their own anatomical and physiological properties (p. 41).

Although he takes an approach based more on feeling and hearing, the comparison with Hohauser-Nizza (2013) is inevitable. Both authors advocate the importance of physiology in flute pedagogy; however, one focuses on visual description, while the other places greater emphasis on the sensations.

Several sources discuss the role of the throat specifically on sound, tone production, and intonation, including Robert Dick's "throat tuning" concept (Dick, 1987). According to Dick, the voice needs to be "tuned" with the flute pitches. Furthermore, the pitches should be produced on the flute exactly the same way as if they were to be sung; however, without making any voice sound (Dick, 1987). When explaining extended techniques (singing and playing), Dick proposes an exercise where the flautist plays a few notes, sings the same sequence, and finally brings both together singing and playing at the same time.

#### Vibrato

Toff (1996) gives a clearer idea from the physiological viewpoint as to how vibrato should be produced. According to Toff, there are three schools of thought.

The first one believes vibrato is organic, and that it should not be taught; the second says that the vibrato should be well mastered by the performer and should therefore be taught; the third explains that for some players it could be organic, but others need to learn step-by-step how to produce it.

Toff (1996) describes the different types of vibrato in an unusual way. According to Toff, vibrato can be produced in the diaphragm, in the throat or in the jaw and lips. Describing throat vibrato, she says:

Throat vibrato is produced by action of the rearmost portion of the tongue against the throat. It is similar to the repetition of the syllable "ah" without voice, accompanied by a definite closing of the throat at the end of such syllable. It is a variation in the constriction of the trachea or wind-pipe as the air passes through it. Throat vibrato is a potentially dangerous technique, however, because it is a major cause of tension in the throat, and tension is something to be avoided at all costs because it usually results in a smaller sound. Moreover, it is easy to overdo throat vibrato, and it may be audible as a physical action-particularly the vocalization of "ah". Throat vibrato is the type most likely to turn into a goat imitation (p.108).

Toff (1996) states that she is in favour of the school of thought that vibrato should be taught. She goes on to explain the ways of practising the different vibratos. In regards to throat vibrato, Toff (1996) gives a simple exercise where the student is to "cough lightly" four times per second, with and without the flute, increasing to six then eight times per second.

According to Debost (2008), there are two major ideas present in the flute community in regards to vibrato teaching: one is that vibrato is produced by the muscles around the diaphragm, and the other is that vibrato is produced in the area of

the vocal folds. Debost (2008) asserts that vibrato in flute playing should be produced in the larynx. This assumption is based on sources that deal with vibrato for singers, which Debost applies to flute players (Debost, 2008). He states:

To me, vibrato is produced in the area of the vocal cords. This is what singers

do, and our best artistic endeavour is to inspire ourselves from them (p. 2). Debost is incisive about not using diaphragmatic vibrato when he explains, "It is impractical to consciously shake and sustain diaphragm muscles for any length of time" (Debost, 2008); however, he does not elaborate on how the vocal folds should work, or if there are any other laryngeal muscles or mechanisms involved.

Unlike Debost, Gilbert (1987) does not try to explain the origin of vibrato, or where it is produced. For him, vibrato is a natural skill that needs to be practised at different speeds (Gilbert, 1987). Gilbert does not provide a physiological description and neither Debost (2008) nor Gilbert (1987) clarifies the mechanisms involved in the vibrato production in detail. Although Debost is more definite (mentioning the vocal cords), he does not describe which muscles are stimulated and how the process is realised from beginning to end from a physiological point of view.

Angelita Floyd (2004) suggests that a muscle opens and closes the glottis in so-called "throat vibrato". She goes even further and describes the process:

This muscle controls the size of the opening called glottis. The glottis acts as a valve, opening to permit the air column coming from the lungs to pass freely, or constricting and closing off the air supply (p. 91–92).

According to Floyd, James Galway defends the concept that vibrato can be better controlled in the throat (Floyd, 2004).

One of the first flute performers and pedagogues to explicitly advocate for vibrato being produced in the larynx was Frederick Wilkins (1963). Although his flute

guide was published before Debost or Floyd's works, Wilkins thoroughly describes the vibrato question:

Flutists are often at odds about the mechanics of vibrato production. Some describe it as emanating from the diaphragm. This is not altogether true, although we must remember that all the flutists' sounds must be supported by the diaphragm or a weak sound will result ... The control point is not the diaphragm, but the constrictor – located in the throat. The constrictor is in simple words, the muscle used to constrict the windpipe as in coughing (p. 37).

Wilkins (1963) is very precise about the mechanisms of vibrato playing. The "constrictor" for him is most likely the vocal folds. An article by Bayley (2006), which is along the same lines, explains the vital importance of teaching vibrato, especially in order to make the vibrato more flexible. Although Bayley acknowledges the existence of a "lower" vibrato, he clearly advocates for a throat vibrato by citing Kincaid's thoughts (Bayley, 2006). Furthermore, he explains how the vibrato technique should be taught:

Say ha-ha-ha. That gives you the pulsations which make the throat staccato. At first you will not hear a good flute tone but rather a whisper, perhaps with a slight whistle, indicating that your throat is open and relaxed. Start on C2 and play 4 pulsations to a beat, 4 beats to a bar, 16 pulsations on the same note, with the metronome (mm = 72) (p. 31).

Bayley expands his "throat pulsations" idea, explaining that the object of the exercise is to guide the student towards a more controlled and flexible vibrato, with vibrato ultimately becoming a natural part of the student's music life (Bayley, 2006).

Sparks (2013) clearly states that these pulsations are based on the diaphragm, and that the throat should merely be "open and relaxed". Although the main focus of the article is not specifically the vibrato physiological construction, Sparks does give a clear idea of the organs involved in the process. According to him, flautists should use the "panting" exercise in the same way as vocalists:

Skilled vocalists tend to be skilled at a panting exercise that is common in vocal pedagogy as it strengthens the diaphragm muscle. This can work for flautists as well, as it helps with rapidly pulsing air, a skill needed for the production of vibrato ... Without the flute, stand or sit comfortably. Pant with the mouth open or closed, although it is easier with heavy panting to keep the mouth open. It may be best to do this when alone as it can inspire unsavoury comments from others. Make firm little puffs of air as if saying a silent *ha*. With no articulated throat or grunt. Once this is comfortable, add the flute. The goal is to pulse the tone simultaneously with the attack of the air column, so remove the tongue from the equation at first (p. 9).

Sparks clearly advocates a "pulsation" that comes from the diaphragm, an idea that differs from several authors (Debost, 2008; Floyd, 2004; Wilkins, 1963; Toff, 1996). Bayley also talks about "throat pulsations" using the "ha, ha, ha" exercise which activate the same muscles. Sparks is incisive regarding the throat role stating that this part of the body should be stable, without any particular movement.

Krell (1973) dedicates a small section of his text *Kincadiana* to the topic of vibrato. Although he does not support the idea of full participation of the larynx, he does not completely agree with the concept of diaphragm only:

The consensus, however, is that it should be a shallow, controlled, and even undulation of sound, avoiding the nervous, automatic and uneven type of shaking. It is most probably produced by a combination of the delicate vibration of the throat and the elastic reinforcement of the diaphragm, acting together and sympathetically (p. 15).

Later in the text, Krell acknowledges that vibrato is made up of pulsations; however, he does not elaborate on the concept enough for the reader to understand where these pulsations come from, or how the flautist should produce them.

Authors therefore support the idea of vibrato production based on air pulsations (Bayley 2006; Sparks 2013) On the other hand, several authors suggest vocalisation without the flute. A good example of this approach is the article by Louke (2012). The author discusses Underwood's thoughts on the topic:

First the flutist used the syllable yu-yu-yu (pronounced you) to simulate 4 vibratos per beat, as he vocalized the phrase. This exercise also develops rhythmic subdivision skills. Flutists can experiment with other speeds of vibrato, such as 2, 3, 4, 5 or 6 per beat, or different vowel sounds such as yo-yo-yo to change the character of the vibrato. The jaw should be kept still during these exercises (p.26).

After the first two vocalisation exercises, Louke demonstrates another example given by Underwood where the student uses the f consonant, adding the air factor to the vocalisation proposed earlier.

Wye (2003) is one of the few authors to mention throat, larynx, and diaphragm. According to Wye there should be a combination of the larynx and the diaphragm:

The exercises which follow will train you in the use of vibrato between 4 and 7 wobbles per second. There are three basic ways of producing a fluctuation in pitch:

- (a) By moving the lips or jaw by alternately compressing and relaxing the lips
- (b) By opening and shutting the throat
- (c) By using the larynx
- (d) By fluctuating the air speed and therefore the air pressure with the diaphragm.

(c) and (d) are jointly the method most common used and are recommended because:

(i) it allows the lips solely to perform the function of forming the embouchure.

(ii) it allows the throat to remain open and relaxed – probably the most  $% \left( \frac{1}{2} \right) = 0$ 

important single factor in tone production.

(iii) it encourages the correct use of the diaphragm for tonal support (p. 19).

Wye differs from Krell (1973) in that Wye separates the larynx and the throat. Because Wye is not specific about to which organs he is referring with the term "throat", it is not clear which mechanisms he wishes to remain still, and which are to be engaged. According to Fain (2009) the larynx participates actively in the sound process by changing the air as it goes through the mechanism. The parallel between flute playing and voice or speech is noticeable for Fain (2009) who treats the larynx as the "voice box", and the main organ, when it comes to vibrato production:

Since the diaphragm, an involuntary muscle designed to move with the speed of breathing, is incapable of rapid repetitions heard in the sound of a flutist's vibrate tone, it would seem to be a reasonable inference that the spinning vibrato so valued by flutists as an integral ingredient of their sound is produced by the rapid fluctuations of the vocal folds. These folds are clearly under voluntary control, and since they were trained to produce speech and singing, they can be also trained to produce vibrato (p. 265–266).

Although Fain clearly agrees with various authors about the vibrato origin (Wilkins, 1963; Pearson, 2006; Toff, 1996; Debost, 2002), she adds that another option of vibrato producing could be using the cheek muscles (Fain, 2009). She goes on to say that although this is possible it is not the most efficient way to achieve results. Even though Fain scrutinises the larynx and the pharynx organs, she does not relate these findings to flute technique other than vibrato, breathing and airflow.

#### Articulation

Similar discussions occur on the topic of articulation. Several authors discuss the role of the tongue in the process (Wye, 1999; Toff, 1996; Dick, 1987). However, most sources omit the involvement of the larynx.

One of the few sources to touch on the role of the throat in articulation is a work by Esposito (2014). According to Esposito, the placement of the tongue is

crucial, especially because this placement may affect the overall tone quality. The author explains:

For native English speakers, the natural position of T and D is usually with the flat part directly above the tip of the tongue touching somewhere on the fleshy ridge above the top teeth. A placement of the tongue that hinders sound quality by blocking throat, or a position that rests the tongue consistently on the lower lip, causes problems with tone quality and embouchure flexibility (p. 18).

Esposito bases her theory on the fact that, depending on the player's native language, the tongue position will differ. Her argument is that some people will feel more comfortable with the tongue slightly forward because that is the position used to speak that particular language. The author appears interested in finding positions and shapes for articulation that will ensure the larynx area is "free of blocking" in order to keep the airflow smooth and continuous.

Because of this idea of tone quality preservation in articulation, Esposito suggests different types of vowels that will consequently produce different shapes. She says, "In the ah position, the jaw is naturally open at its hinge point and the tongue is lower, allowing for more resonance in the throat and oral cavity" (p.19). The author does not mention muscles or movements in the larynx or pharynx area associated with these proposed shapes and articulations.

As previously stated, the authors of the various flute methods are consistently descriptive in presenting the techniques to a student (Quantz, 2001; Taffanel and Gaubert, 1958; Wye, 1999; Wilkins, 1963). Articulation is probably one of the most descriptive topics. Taffanel and Gaubert's method (1958) dedicates a good portion of its text to articulation, divided into single, double and triple tonguing. It is a detailed

and specific guide for beginners in that it gives a step-by-step approach to produce a good single, double and triple articulation attack. The beginning of the articulation section states: "This articulation [single tonguing] must be rough; to obtain this the tongue is stiffened. It will then beat with force a little above the teeth" (p.90).

Toff (1996) describes the single tonguing phenomenon in slightly greater detail:

[Single tonguing] is done quite simply, by pulling the tongue away from the back of the teeth, just at the point where the tip of the tongue touches the roof of the mouth when the mouth is shut (p. 117).

Although Toff is less ambiguous, there is no mention of larynx or pharynx involvement. Trevor Wye (1999) offers a similar approach to Gaubert and Taffanel (1958) and Toff (1996). Wye demonstrates a precise and thorough manner of describing where the tongue should be in the mouth, where it should touch, and how it should rest while it is not being used.

Although these authors all closely examine the relationship between tongue, teeth and oral cavity in general, Floyd (2004) gives a broader perspective. Floyd listed three major areas to be considered on articulation: embouchure, placement of the tongue and support of the diaphragm and throat aperture (Floyd, 2004). Furthermore, she provides an important quote by Gilbert from one of his lessons: "Tonguing requires a tremendous back pressure" (p. 104). For Gilbert, this proves there is much more involved in tonguing than merely tongue placement.

Following the same line of thought as Gilbert, Debost (2002) explains the real source of articulation:

An attack is not percussion, but the venting of an aperture. Prepare the blowing before the attack. Don't take a huge breath if you don't need to; it causes bad attacks. Use discrete finger movement to set the air column in motion. Time your delicate attacks (p. 34).

Debost advocates for tone production bases when it comes to articulation. He asserts that the air column is the most important feature in tonguing in particular and in flute playing generally. Not only is Debost's idea of thinking further than the tongue's placement interesting, but also how he proves his point. According to Debost, when tonguing, the flautist should think more about the vowel than the consonant. This is because it is only the vowel that carries the sound, while the consonant is merely a detail (Debost, 2002). By using this analogy, Debost is saying that the air (and what is vital for its production) is the most important component for the flautist.

Various other sources discuss the articulation using the consonant and vowel analogy. In his *Flutist's Guide*, the famous flute pedagogue Wilkins (1963) states:

Now place the tongue on the gum above the upper front teeth and pronounce the syllable Doo ... For general purposes, the Doo articulation is more satisfactory since there is less danger of blurring the note. Furthermore, the oral cavity is in vowel formation (round) which is a basis for a good sound production (p. 46).

Less assertive than Debost, Wilkins (1963) observes that the vowel is more important than the consonant as the vowel leaves the air free, whereas the consonant is likely to affect the air if it becomes too aggressive (Wilkins, 1963). Even though

neither Debost, Wilkins nor Gilbert explicitly mention the vocal tract, they all consider the air to be vital in articulation. Therefore, it is clear that the breathing apparatus (including the vocal tract) assumes the main role for these authors.

The question of articulation presents discrepancies between the scholars not only because of their different concepts, but also because of their language (Valette, 2010). According to the author, the flute pedagogues of the so-called French School of flute playing can manage the articulation process differently due to the way they speak. Moreover, Valette (2010) draws a parallel between French and the English speakers' articulation mechanisms. He explains the exact differences:

In French, the column of air (*colonne d'air*) originating in the lungs is transformed into a "blade" of air (*lame d'air*) as it is focused on the flute embouchure. English-speaking students emit a more diffuse column of air that fans somewhat outward over the flute embouchure. If condensation occurs on the mouthpiece, it is disseminated and barely visible (p. 24).

Valette explains that the air column of the French flautist is different due to the tension of the lips and forward position of the tongue forming a "triangle" of condensation. In other words, it is a more focused embouchure, while the American version is more "diffuse" (Valette, 2010).

Besides the embouchure shape, another topic highlighted by the author is the tongue position. Again, she applies this to air direction. A good example is the comparison of the English "too" and the French "tu". The French version is lighter and allows the air to run smoothly (Valette, 2010). Valette stresses that in French, most of the vowels are produced closer to the front part of the mouth, and therefore the shape of the oral cavity changes.

The crucial part of this comparison is the importance given by the author to the whole mechanism of articulation from its origin (breathing) to its end (lips). Even though she does not mention any mechanisms in the middle of the process (i.e. larynx, pharynx and vocal folds), she clearly acknowledges the vital importance of the change in air direction caused by the oral cavity's shapes of the different flautists.

In accordance with Valette's study, Sullivan (2006) conducted a study with 66 high school students on the effects of using a multi-syllabic versus a single-syllabic articulation approach. The results clearly indicated that using various syllables is more effective. In her study, the author used sight-reading exercises as well as rehearsed passages. Again, the multi-syllabic method showed better results.

Sullivan (2006) also highlights that the students enjoyed using the different syllables more, which helped the ensemble directors transmit the musical ideas. Sullivan's findings do mention the effects of the different articulations on the airstream. Although the author does not go further into the question of oral cavity, or tongue placement, one of the exercises includes the syllable "tut". This is a sound that can be easily compared to the French "tu". Both Valette (2010) and Sullivan (2006) agree that this creates an air direction change.

The idea of using different syllables when teaching various types of articulation has been proposed by several flute masters (Toff 1996; Dick 1987; Taffanel and Gaubert 1958). Furthermore, one of the oldest flute methods by Quantz (2011) proposes two very specific syllables:

Since some notes must be tipped firmly, and others gently, it is important to remember that *ti* is used for short, equal, lively, and quick notes. *Di*, on the contrary, must be used when melody is slow, and even when it is gay,

provided that it is still pleasing and sustained. In the Adagio *di* always used except in dotted notes, which require *ti* (pp. 71–72).

#### **Dynamics**

The topic of dynamics involves great discussion amongst flute pedagogues. In her text about Gilbert, Floyd asserts the dynamics contrast should be executed mainly by the lips (Floyd, 2004). According to Floyd, Gilbert taught dynamics along with tone colour and intonation. She reports that because of the instrument's acoustics, Gilbert detailed how a *forte* embouchure should be and how a *piano* embouchure should be. Based on Gilbert's principals, Floyd (2004) describes a *forte* embouchure:

The forte embouchure should be approached from the front. Start with the top lip over the bottom lip (covering-directing the air stream down) and bring note into focus (p. 82).

One of the most important flute methods of all times, *La Sonorité* (Moyse, 1934) also covers the topic of dynamics from the point of view of the lips and jaw area. Moyse explains that the jaw muscles should be constricted when a soft dynamic is desired, and relaxed when a louder dynamic is the goal (Moyse, 1934).

Toff (1996) provides a contrasting idea of what should be included in flute tone production. According to the author, fingers are at most 50% of the total flute playing production. The major part is administered by the breathing mechanism and the pharyngeal cavity. According to Toff (1996), the throat, lips and tongue all form part of the pharyngeal cavity. Moreover, Toff suggests that both mechanisms can control most flute techniques including dynamic changes.

In contrast to Floyd (2004), Toff suggests that these two mechanisms (breathing and pharyngeal) are the most important features in flute playing. One

common point between the two in terms of dynamics, is that the flute is acoustically limited and therefore greater physical effort is needed to achieve good results.

Unlike Toff (1996) and Floyd (2004), Dick (1987) asserts that "breath pressure" is exclusively responsible for dynamic changing in flute playing:

The intensity of breath pressure, which is controlled from the diaphragm, determines the dynamic level of a note. Ideally, the breath pressure used to play at a given dynamic level is constant throughout the entire range of the flute. Thus, the same breath pressure is used to play both B3 and B6 *ppp*. The intensity of breath pressure is directly proportional to the dynamic level (p. 46).

It is important to note that Dick does not mention larynx or pharynx when talking about dynamics. However, he does mention the "throat" when explaining the singing and playing technique as we observed earlier.

#### **Breathing for flute pedagogues**

Breathing is a topic of great importance for flute players. It is perhaps the most frequently investigated subject regarding internal body mechanisms (Debost, 2002; Floyd, 2004; Toff, 1996; Krell 1973). However, the analysis of breathing is rarely accompanied by an analysis of the air's path between onset and the actual tone. Vauthrin et al. (2015) states that flute players do engage the breathing muscles differently when preparing for a difficult musical passage. Cossette et al. (2010) draws a very comprehensive study on the relationship between the pulmonary capacity and the lip management in flute playing. Although the findings are relevant, especially when it talks about the lip engagement in controlling dynamics versus intonation, it does not include anything about the larynx, pharynx or vocal tract.

While it is relatively easy to find literature on breathing techniques, it is not so easy to find literature on airflow quality and internal elements that can alter or control the air. It is this aspect of air control where an investigation of the role of the larynx and pharynx in flute playing needs to begin. The same way breath control is crucial for a good sound production, an in-depth understanding of the larynx and pharynx is important for students, colleagues, and professors.

#### The role of the larynx

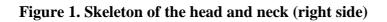
One of the laryngeal functions is to protect the airway from having foreign elements, such as food, going into the lungs. This protection is completely involuntary and reflexive. The pharyngeal stage of swallowing not only involves the pharynx, but also the tongue and the larynx (Pitts, 2014). Initially, when the food is in the mouth, the tongue pulls back and moves posteriorly, directing the food straight to the pharynx. While the tongue moves, there is a closure of the velopharyngeal port. This closure helps a pressure accumulation in the pharynx that will help propelling the food to the oesophagus.

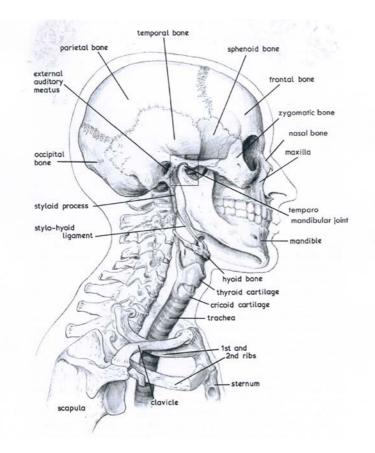
A group of muscles help move the hyoid bone and the larynx superiorly and anteriorly under the base of the tongue. During the movement of the larynx, the vocal folds adduct (close), and the epiglottis folds over the glottal space (space between the vocal folds) forming another area of protection (Pitts, 2014). This laryngeal movement also opens the upper oesophagus sphincter (the barrier between the digestive tract and the pharynx).

The secondary function of the larynx is to close in order to build up intraabdominal pressure for the purposes of evacuating the bowels and bladder, coughing and during physical exertion (Simonyan, K & Horwitz, H, 2011). Finally, the larynx is used to make sound, a function that is innate for emotional vocalisation but learnt in the case of vocalisation for speech and singing (Simonyan, K & Horwitz, H, 2011).

#### Physiology

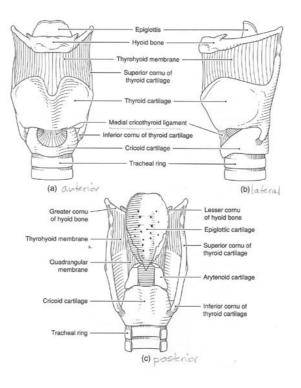
In order to understand the movements of the larynx and vocal tract during flute playing, it is necessary to clearly define the components, functions and biomechanics of the larynx and pharynx. The larynx is positioned in the front of the neck (reference), anterior to the spinal cord. It is slung from the base of the skull and connected to the top of the trachea via membranous connection between the cricothyroid cartilage and the first ring of the trachea (see Figure 1). The larynx is comprised of five cartilages, five intrinsic muscles, five extrinsic muscles, two pairs of joints, four intrinsic membranes and ligaments and four extrinsic membranes and ligaments.





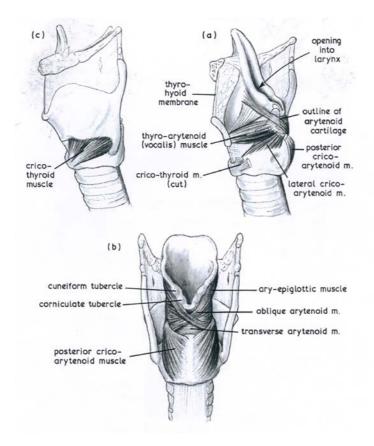
Source: Dayme (2009, p. 91)

Figure 2. . Larynx framework (anterior, posterior, lateral)



Source:Titze, (1994, p. 5)

#### Figure 3. Intrinsic muscles of the larynx



Source: Dayme (2009, p. 95)

The larynx has both biological and non-biological functions. Its biological function is mainly to prevent foreign substances from entering the vocal tract (Titze, 1994). The non-biological function is primarily vocalisation. Both functions are dependent on the true vocal folds.

#### **True vocal folds**

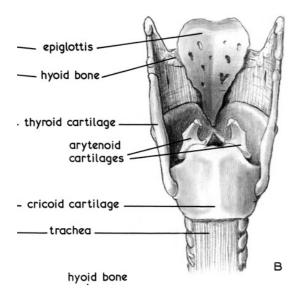
The true vocal folds consist of the thyroarytenoid muscle with layers known as lamina propria (deep and superficial) covered by a skin (epithelium). The deep layer is composed of collagen fibres, while the superficial layer is made up of elastin fibre. The epithelium layers comprise a softer tissue, enclosed by an elastic membrane. The true vocal folds are positioned just underneath the laryngeal ventricle and the false vocal folds. The true vocal folds open (abduct) and close (adduct) to allow air into and out of the trachea.

In adduction (bringing the folds together) the lateral crico-arytenoid muscles and the intra-arytenoid muscles are involved. In abduction (moving the folds apart), the posterior crico-arytenoid muscles contract to provoke the opening. Lengthening of the true vocal folds is created by contraction of the crico-thyroid muscles and simultaneous relaxation of the thyro-aryntenoid muscles. Crico-thyroid muscle contraction results in the stretching of the folds, most commonly resulting in an increase in vibration rate of the true vocal folds and perception of pitch (Titze, 1994).

#### **Epiglottis**

The epiglottis is positioned in front of the larynx and is connected to the back of the larynx by the thyro-epiglottic ligament. Its sides are connected to the arytenoid cartilages by the aryepiglottic folds. The epiglottis is also connected to the base of the tongue superiorly. The surface of the epiglottis is covered by mucosa (see Figure 3).

#### Figure 4. The epiglottis



Source: Dayme (2009, p. 94)

#### Arytenoids

This pair of cartilages sits on top of the cricoid cartilage at the back of the larynx. The thyroarytenoid ligament (and subsequently the thyroarynoid muscle) are attached anteriorly to the thyroid cartilage and posteriorly to the arytenoid cartilages. The arytenoids are held in place by the interarytenoid, thyroarytenoid, lateral and posterior crico-arytemoid muscles (forming the crico-arytenoid joint). As this joint is not an articulating (interlocking) joint, the arytenoids can adduct, abduct, rotate or even glide. Since the crico-arytenoid muscles along with the inter-arytenoid muscles are the ones responsible for the vocal fold adduction and abduction, the arytenoids enable positioning of the vocal folds both medio-laterally (side to side) and on the vertical plane (Drake et al., 2015).

#### **False vocal folds**

The false vocal folds (also called vestibular folds) sit above the true vocal folds. They consist of glandular tissue to help lubricate the true vocal folds (Drake et al.,2015). Their lower part is attached to the epiglottic cartilage, and the back of them is connected to the anterolateral surface of the arytenoid cartilage.

#### **Thyroid cartilage**

This cartilage consists of two plates joined in the middle. Looking from a posterior or an anterior angle it is possible to visualise a gap. From each plate of the cartilage it is possible to see two knobs that start at the posterior edges of the cartilages. The higher knob is known as the superior horn, the lower knob the inferior horn. This projection is connected to the cricoid cartilage, and the superior horn is linked to the hyoid bone by a ligament (Titze, 1994).

#### **Cricoid cartilage**

This cartilage is positioned below the thyroid cartilage and is, in effect, the top ring of the trachea. Shaped like a signet ring, the posterior aspect has a wider area than the anterior facet. Laterally, the little corners of the circle are also called the cricothyroid articular facets. This is the place where the inferior horn of the thyroid is attached, developing the cricothyroid joint. On the top part of this cartilage are little smooth areas known as cricoarytenoid articular facets, where the arytenoids are connected.

#### **Pharyngeal wall**

The pharynx is a 12 to 14cm tube that extends from the base of the cranium to the lower border of the cricoid cartilage and on to the oesophagus. The pharynx is situated behind the mouth, larynx and nasal cavities. From above, the larynx borders the posterior part of the sphenoid body and the base of the occipital bone; below it extends to the oesophagus; behind, its connective tissue segregates it from the cervical part of the vertebral column and prevertebral fascia. The frontal part of the pharynx opens into the nasal cavity, mouth and larynx.

Because of its extension, the pharynx is attached on each side to the medial pterygoid plate, pterygomandibular raphe mandible, tongue, hyoid bone, and thyroid and cricoid cartilages. The lateral part of the pharynx connects to the tympanic cavities by the pharyngotympanic tubes (Drake et al., 2015). The laryngeal part of the pharynx goes from the upper part of the epiglottis to the lower part of the cricoid cartilage. The pharyngeal wall consists of several layers including muscles, fibres, and mucosa.

#### The biomechanical links in the larynx

The true and the false vocal folds are linked by a ventricle. The ventricle's primary function is to lubricate the larynx. Because of the existence of this ventricle, the two pairs of folds can move separately and independently (Dayme, 2009). This explains how normally during phonation, the true vocal folds are retracted, not contributing to the sound production.

The true vocal folds and the arytenoids are connected via the vocal process. This is the point where the vocal ligament (part of the vocal folds) attaches to the anterior base of the arytenoids (Titze, 1994). In the posterior side, there is another projection called muscular process. Both processes can be positioned in several manners to allow the adduction and abduction of the true vocal folds.

As it could be seen in the physiology section, the arytenoids are also attached to the epiglottis via the aryepiglottic folds, and the epiglottis attaches to the base of the tongue via the glosso-epigottic folds. During deglutition, the aryepiglottic folds adduct and the arytenoids elevate, also helping the larynx's protection. At the same time, the epiglottis moves down, propelling the food downwards, also impeding the larynx from receiving foreign substances (Dayme, 2009).

#### Physiological studies of wind instrumentalists

A few studies on the laryngeal involvement in wind instrument playing have been produced. Mukai (1989) presents a case study on the role of the vocal tract in wind instrument playing. It is one of the few sources that discusses laryngeal movements during wind instrument playing, and one of the first to involve observation through a fiberscope. Mukai found that wind instrumentalists do adduct the vocal folds during the tone production, and that vibrato was produced by the vocal folds adduction and abduction.

Eckley (2006) aimed to clarify the phonatory mechanism's behaviour in order to treat vocal deficit in wind players rather than to achieve optimal flute sound production. The author clearly explains, however, observations of the larynx movements and its consequences during playing. Eckley (2006) studied ten adult wind players' laryngeal movements via flexible videolaryngoscopy. According to the author, wind instrumentalists could be included in the group classified as voice professionals due to the extensive usage of the vocal tract and the larynx during their performances. It is clear that Eckley's approach is specific to clinical issues; however,

it does highlight that there is much more to be discovered in the larynxes of wind instrument players.

Gallivan and Eitnier (2006) claimed voice disorders cannot be related directly to wind instrument playing in their study in which they investigated one participant who was a voice trained person, as well as a wind band conductor, to analyse the laryngeal activity via videolaryngoscopy. The focus of the study is at the vocal fold level, more specifically, the potential risk of vocal fold polyp in wind players.

As the authors explain, the misunderstanding is where the greatest level of air and muscle usage happens. For singers, it is at the laryngeal level and for instrumentalists it is at the embouchure level. By using video laryngoscopy with and without stroboscopy, the researchers asked the study participant to sing, then play the saxophone followed by the French horn. The researchers found that when playing the saxophone and French horn, the participant did not activate the strobe when it was placed on their neck during performance. This led the researchers to conclude that wind players could not harm their vocal folds.

It is crucial to clarify that the participant only played a reed and a brass instrument, two timbres that require lip pressure. No flute playing was analysed or considered and consequently the fact that flute players do not use vibration at the lip level was overlooked in this study. Furthermore, two different skills were analysed (singing and wind playing) using only one participant. It is understandable that having one participant professionally trained in both areas can answer the question of where the damage is happening on him or her. However, wind instrument playing involves a large number of different sound productions and techniques. More participants are therefore needed to reach a more definite conclusion.

Although the results have differences, Eckley's (2006) and Gallivan and Eitner (2006) do agree on the matter that wind instrumentalists share laryngeal and pharyngeal functions and shapes with singers. Gallivan and Eitner (2006) highlight that both singers and wind instrumentalists use the larynx to control the airflow. The difference is that singers rely completely on the larynx for this job, whereas wind players use the embouchure more to realise the operation.

Although Eckley comes to this same conclusion, she goes further and suggests that wind instrumentalists are closely related to voice professionals. Kahane, et al. (2006) also draw this parallel between singers and wind instrumentalists. In this case study, however, the researchers restrict their arguments specifically to vocal tract usage of wind instrumentalists and the differences between singing and wind playing at the vocal fold level. Kahane et al. (2006) perform a very detailed analysis of the internal muscular activity of the larynx describing arytenoid movements, epiglottis displacements as well as supraglottic pressure.

The study produced by Kahane, et al. (2006) reveals a more comprehensive approach to the interaction between vocal tract and specific instrument techniques. Using fiber-optic laryngeal endoscopy, the researchers aimed to evaluate the upper airway and the larynx activities of four adult male professional bassoonists as they performed the instrument. The results identified changes in pitch and dynamics were linked with pharyngeal widening, and the vocal folds displacements appeared to change the airflow. Another important conclusion from the study is that epiglottic movements from tongue base activity affected the vibrato. In contrast with King et al. (1988), in this case the researchers used the musical parameters (vibrato, dynamics, articulation) as the main points of analysis, investigating the direct influence of physiological mechanisms (vocal folds, glottis) on musical techniques (vibrato,

dynamics). The authors did not describe the performance protocol. It is therefore unknown what exactly was performed for each of the techniques.

Unlike Eckley's work, King, et al. (1988) discuss exclusively laryngeal and pharyngeal involvement during woodwind playing. The authors found consistent vocal fold adduction across the different wind instruments, with more significant results for flute and saxophone .The analysis was organised separating the participants into four different categories: single reeds (clarinet, saxophone), double reeds (oboe, bassoon, English horn) and air reed (flute). In regards to pitch, they found that the larynx acts as a "cavity resonator" to the tone production, being able to change the sound eventually.

In the case of brass instruments, the analysis is slightly different. King et al., (1989) observed this group of instrumentalists using nasendoscopy with a video camera attached (same as the previous study). However, the participants performed several different techniques, such as tonguing and dynamics. As a result, the vibrato attracted more attention and received special consideration during the analysis. According to the results, the vibrato was produced as a collaborative work between larynx, diaphragm and tongue.

Although the observations were still described in terms of the physiological aspects, it is noticeable that the different musical techniques produced by the different instruments intrigued the researchers.

Gillespie (2016) also conducted an experiment focused on the laryngeal function on a brass instrument, this time specifically the horn. The author used real time imaging video (MRI) as a tool to capture the images. Although Gillespie did not use a real horn because no metal is allowed near the MRI scanner, the results do show a significant participation of the larynx in controlling dynamics (arytenoids

movements and vocal folds aperture). The author used six participants and assessed the data herself. In contrast to King et al. (1988), vibrato was not part of the protocol, but the findings indicate that the arytenoids and the glottis aperture do change as the player change dynamics, play staccato passages and ascending and descending scales.

Along with flautists and oboists, bassoonists are the group of players who most use vibrato as a consistent tool. Due to the popularity of vibrato amongst bassoonists, several studies explore the technique.

Kahame et al. (2006) expose the subtle but consistent involvement of the vocal tract as well as the larynx across the different procedures. This supports Eckley's and Mukai's consideration of wind players' constant use of the vocal tract and the larynx when performing.

A broader approach to the comparison between wind players and singers can also elicit different questions. Weikert and Schlomicher-Thier (1999) demonstrate the relationship between wind players and singers. When analysing saxophone players' larynx and pharynx the authors found that the vocal folds adducted partially during the entire performance period. In regards to the comparison between singers and wind players, the researchers emphasise that while the breathing mechanisms may be the same, the sound origin is different. To observe the larynx, the researchers used videolaryngoscopy, and to observe breathing, the researchers used fluoroscopy. Only two participants were involved, which somewhat limited the results' considerations.

Similarly to Kahane et al. (2006), in this case, physiological aspects defined the musical protocol parameters (vibrato, articulation). It is therefore unknown what exactly was performed for each of the items analysed.

While Kahane, et al. (2006) noted constant action of the larynx in producing vibrato for the bassoonists, Weikert and Schlomicher-Thier (1999) found that during

vibrato it was possible to observe vibrations of the deep hypopharynx and the lateral walls of the pharynx. Besides these small differences in the conclusion, they do agree that small movements in the larynx could be noticed during the performance. Due to the parallel drawn between singers and wind players in general, it is noticeable in this study, that the sound source is crucial for the authors.

Clearly, the source of the sound is a major difference between singers and wind players, since the singers do produce sound in the larynx by the vocal folds vibrations, whereas the wind players do not. In the Mukai (1989), Eckley (2006) or King et al., (1989) studies, the origin of the tone has not been a topic of major discussion. Instead, the researchers decided to focus on the process of tone production and control, where major similarities between singing and wind playing can be seen.

Neither Weikert and Schlomicher's study (1999) nor the study by Kahane, et al. (2006) specifies the protocol used by the instrumentalists. This raises the question as to whether the participants performed everything technically possible to explore all the techniques and their possible physiological stimulations.

In stark contrast to the previous study's findings, Wolfe et al. (2015) aimed to explain the interactions between the wind instruments and players. According to the reports, the woodwind instruments are the ones that use the least amount of air pressure if compared to brass instruments. In regards to flute vibrato, Wolfe et al. (2015) presents his findings:

In professional flute playing, vibrato is normally produced by oscillation in the pressure in the mouth, and it is found that these oscillations have an effect mainly upon the amplitude of high harmonics and thus on the timbre of the sound. There is very little effect on sounding frequency and so little or no

pitch vibrato [20]. Other parameters that can be varied include the shape of the aperture between the lips and the mouth cavity volume ... (p. 214)

Although Wolfe et al (2015) express that the change in mouth pressure is the usual method to produce vibrato on the flute, the reports do acknowledge that the larynx and the air pressure may be involved (Wolfe et al., 2015).

Scavone et al. (2008) aimed to explain specifically the vocal tract influences in saxophone playing. This was assessed by placing two microphones on the mouthpiece measuring the pressure on the upstream and downstream of the mouthpiece. Asking them to concentrate on the larynx only, the researchers asked the participants to perform timbre changes, pitch changes as well as multiphonics without moving the embouchure (lips).

The results achieved by Scavone et al. (2008) concluded that the larynx performs an important role in saxophone playing; however, the influence is not continuous. In other words, the larynx mechanisms do not participate continuously on saxophone playing. On the other hand, tasks such as timbre variations and extended range playing do inevitably involve laryngeal features.

Scavone et al. (2008) decided to focus on the sound results. In the case of the present research, the physiological phenomena resulted from specific musical techniques (vibrato, dynamics, articulation).

Among the few empirical sources produced by music pedagogues and performers that treat the question of vibrato, Rydell et al. (1996) present significant findings involving flute players. Although voice disorders were the starting point here, as with most of the investigations produced by several health specialists, some of the findings involved internal mechanisms more extensively. Of the six participants, two were flute players.

In one of the two flute players the vocal folds were mainly active during the protocol, whereas on the second participant the researchers observed extensive participation of the epiglottis (Rydell et al., 1996). These results show a broader approach to the role of the larynx and pharynx in the analysis. In this case, not only the epiglottis participation was observed, but the base of the tongue as well.

Several doctoral theses discuss throat function in woodwind instrument playing. Three good examples, that have slightly different methods, are the dissertations by Walter Carr (1978), Huwang-Shim (2005) and Pool (2004). Pool used a laryngoscopic test on five professional bassoonists to clarify that bassoonists produce vibrato in the larynx with substantial involvement of the vocal folds (Pool, 2004). Carr (1978) carried out a videofluorographic investigation on all woodwind instruments to observe how the tongue and throat positions performed.

Carr (1978) elaborated on a performance protocol that included dynamics (soft to loud and loud to soft), articulation (single tonguing, slurs, double tonguing), vibrato, pitch, and harmonics. On the topic of dynamics, Carr observed that the flautists used a wider glottis for both exercises (soft to loud, loud to soft). When performing the *crescendo* (soft to loud) the researchers observed that the flute group had the widest throat dimension across all woodwind instrument groups. In one of the pitch exercises where the participants performed an ascending scale, the author verified that the flute group showed a slight closing of the glottis. During the descending scales performance, however, the opposite was observed. The glottis expanded as the instrumentalist played lower.

The same phenomenon occurred with the legato articulation exercise. Carr found that the flautist group presented the largest glottal aperture. On the other hand,

no significant throat aperture differences were observed on staccato and double tonguing.

The vibrato was the one task that Carr (1978) did not observe relevant changes in the flute group. The author described the results:

The throat enlarged as the oboe group used vibrato, while smaller apertures were prevalent for the clarinet, bassoon and saxophone groups. The flute group did not change either dimension. Even though the positioning changes for most groups when playing tones with and without vibrato, there was not a measurable amount of movement in the tongue or throat that could be deciphered while vibrato was being executed. What movement that did take place was too isolated (p. 69).

An important finding in Carr's work is that in comparing the groups he observed, the flute and bassoon participants had similar glottal aperture variances in most tasks. In accordance with Walter Carr's verification about the similarities between flute and bassoon's glottis, and also the article by Kahane et al. (2006) already discussed, the thesis by Christopher Pool (2004) shows larynx's behaviours in bassoonists similar to those dedicated to the flute. Although Pool chose to study only vibrato technique, it is clear that he was interested in analysing data originated by the different laryngeal shaping evident during vibrato. Pool states his opinion about larynx participation in vibrato based on his findings as follows:

One could see the movement of the vocal folds open and close in correspondence with the vibrato heard. Since this excerpt was to be performed without vibrato, the majority of the video showed no movement of the folds during the performance other than the movement involved in swallowing or taking large breaths ... When the performer would accidentally allow vibrato

to occur, as outlined in Table 3.1.2, the change from open position to a closed position of the vocal folds could immediately be seen in the video data. This was an important observation supporting the idea that vibrato originates and is controlled primarily in the larynx (pp. 46–47).

Also in accordance with other authors who studied the bassoon vibrato such as Kahane et al. (2006), this statement by Pool shows the tremendous importance of the vocal folds in vibrato production.

Brown (1973) recruited five participants to perform three vibrato exercises using cinefluorographic filming. He concluded the arytenoids and vocal folds are extensively involved. However, he observed the vocal folds' movement only because of participation of evident aryepigllottic folds (Brown, 1973).

#### Physiological studies of flute players

A more specific approach to the larynx in flute playing is the study carried by Hwang-Shim (2005). The author dedicated her research to the study of the larynx in flute playing, drawing a parallel between the larynx and the lips. She measured the glottal aperture and the lip aperture of the participants playing specific tasks and compared the measurements (lips and glottis). Although the author did not include any articulation exercise in the performance protocol, the findings regarding dynamics are significant. Looking at the results, Hwang-Shim found that most participants had a wide glottis aperture in loud playing, while a more narrowed configuration was observed in soft playing. Regarding pitch, the author observed that in most participants the glottis configuration was narrowed by the lengthening and the approximation (adduction) of the vocal folds.

Another important conclusion was the participation of the epiglottis in high playing; Shim highlighted that at times, the epiglottis movement covered the clear vision of the glottis. According to her, most participants narrowed the glottis aperture in the high register.

A very important piece of evidence stressed by Hwang-Shim (2005) was the participation of the arytenoid cartilages in pitch adjustment. She observed a sudden abduction of the arytenoids just before the preparation for the pitch change on descending intervals. In agreement with previously discussed authors, Shim concluded that all participants adducted and abducted the vocal folds during vibrato.

The interesting lip configuration analysis designed by Hwang-Shim showed that the lips do change across the tasks; however, she concluded that these movements did not cause the main changes:

During vibrato the lips displayed small fluctuating movements with sound for loud playing during task 6 [vibrato playing] in all participants. These were very small movements which appeared to be more sympathetic to changes in the mouth pressure rather than being responsible for the sound fluctuations (p. 96).

Although pedagogy was not part of the research aim, the author exposes her point of view on diaphragm involvement in the teaching of flute playing teaching. According to the author, pedagogues have a misconception about the role of the diaphragm. Based on her research, she concludes that the diaphragm is probably not the primary source in controlling the expiration process (Hwang-Shim, 2005).

Another important study that also used two different parameters for comparison is the thesis by Compagno (1990). The author used the flute and the clarinet as the main objects of the research comparing larynx behaviours across eight participants for each instrument. Slightly more specific than Shim, he proposed not

only sustained notes in the performance protocol, but also included articulation exercises (single tonguing, double tonguing, legato).

Compagno (1990) found that the larynx ascended as the register increased, with the epiglottis actively participating in changing the pitch. Regarding articulation, the author observed no considerable movement in the glottal area across tasks amongst the participants participants, concluding that the majority of the articulation techniques were produced by the tip of the tongue. Concerning dynamics, Compagno asserted that the participants who did use laryngeal mechanisms to produce the change, were not able to keep a stable pitch:

It was observed that the participants with the greatest degree of throat movements were not able to keep the pitch (intonation) from changing throughout the crescendo and decrescendo. Subjects with little movement of the glottis during the task were able to play the notes without any fluctuation in pitch. The results indicated that for the dynamic task, three of the five subjects abducted the glottis slightly during the crescendo and adducted the glottis during crescendo. Subjects who were able to produce the least amount of glottal movement were able to maintain a consistent pitch at low and high volumes (p. 110).

Concerning vibrato, Compagno (1990) found that most participants moved the arytenoids as well as the aryepliglottic folds, resulting in true vocal folds adduction and abduction.

Jochen Gartner (1981) investigated flute player's larynxes, abdominal muscles, thoracic muscles and diaphragm. According to his results the laryngeal vibrato has the widest range of variation compared to all other kinds of vibrato. Although Gartner could confirm abdominal muscles activity in some players, the

author did not observe any diaphragmatic participation (Gartner, 1981). Regarding the laryngeal participation Gartner stated:

In every case the larynx is actively participating with muscular activity, even at low frequencies and in the martelatto. Thus the thoraco-abdominal vibrato is always a mixed type. The degree of laryngeal involvement can vary (p.126)

Gartner is very specific to establish that the larynx participates continuously when the vibrato is in action. Although he did not measure the degree of each laryngeal element's participation, it is clear in the text that the larynx is a crucial factor in producing vibrato. (Gartner, 1981)

#### **Hypothesis**

The hypothesis of this study is that the involvement of the larynx and pharynx is essential for flute players in sound production. As flute players do not have any physical resistance at the lip level (such as reeds and mouth pieces) it is probable that the larynx and the pharynx contribute to flute tone production more substantially.

#### Aim

The present study is an empirical investigation of the role of the larynx and pharynx in flute playing from the perspective of a flute specialist. Specifically, the study aims to determine vocal fold involvement in vibrato, epiglottis movements, arytenoids and epiglottis involvement in articulation, and glottal aperture in tone and dynamics production (soft to loud, loud to soft). A detailed analysis of the relationship between standard flute techniques and the larynx and pharynx mechanisms is presented, hopefully making a contribution to the flute pedagogical literature.

The research will extend the knowledge of existing studies by observing and analysing movements in specified areas in the larynx and pharynx during a performed videotaped protocol. The research aims to measure muscular activity in the larynx during the demonstration using an electromyography (EMG) nasendoscope to generate detailed data. Performers selected for the study will be expert flautists (flute players with significant experience).

Specifically, this study relates musical concepts of vibrato, pitch, range and articulation on the flute to activity of the larynx and pharynx (arytenoid activity, epiglottis movement, vocal folds adduction, pharyngeal wall, and laryngeal height). In particular, the research will investigate the glottal activity during tonguing, explaining the physiological process of the different types of tonguing. Unlike previous studies, this study will also expose participants to a performance-based protocol with musical parameters which will clarify what is being played and why.

# Method

The larynx and the pharynx have major factors of involvement in flute playing. However, investigating this involvement becomes challenging because the moving larynx and vocal tract are difficult to observe and measure. The most frequently used method of observing larynx and pharynx behaviours in the playing of musical instruments is the video nasendoscopy, where a flexible fiberoptic cable is introduced through the nose and captures video images (Titze, 1994).

Videostroboscopy has also been used to capture the vocal fold vibration when playing the saxophone (Weikert et al., 1999). The examination needs to be performed

by a professional otolaryngologist, and in most cases the usage of topical anaesthesia to the nasal cavity is recommended.

#### **Participants**

Five professional flautists were recruited for the study, 2 males and 3 females. Participants were aged between 22 and 26 (mean age). The flautists were either professional or advanced students (recent graduates and post-graduates). They were recruited via personal contacts and professional suggestions. The number of years' experience, type of training and amount of professional playing is presented in Table 1.

Gender	Age	Years of experience	Years of professional playing
Female	26	13	9
Female	24	10	8
Male	65	55	45
Female	30	18	12
Male	30	17	11

Table 1. Study participants according to gender age and experience

#### Procedure

The participants underwent video-nasendoscopy administrated by a fully qualified and experienced otolaryngologist. Topical anaesthesia (Lignocaine hydrochloride 5% + Phenylepherine hydrochloride 0.5%) to the nasal cavity was offered to and accepted by all participants. The participants had an introductory familiarisation with the equipment as well as the opportunity to play the instrument with the endoscope introduced before the official protocol started.

A Pentax Flexible video endoscope VNL-1170K or VNL-1190STK attached to a Pentax 9310HD computer was introduced into the nasal cavity and positioned above the epiglottis. Once the participant was comfortable with the scope inserted, they were instructed to play the musical piece they had practised prior to the scope insertion (see appendix B).

Participants were instructed move their head or neck as little as possible while playing and the otolaryngologist ensured that the position of the scope did not move during the playing of the piece.

The complete musical protocol was recorded and the entire examination, from administration of anaesthesia to conclusion, took approximately twenty minutes.

#### **Performance protocol**

This protocol included four specific categories for assessment: Pitch, Vibrato, Dynamics and Articulation. These major techniques were selected because of the potentially substantial data. Each of the categories included a few tasks. The following list describes the exercises in detail:

Pitch:

- 1. Sustained C4 in mf
- 2. Sustained A5 in mf
- 3. Sustained D4 in mf

Vibrato:

- 4. Sustained G5 in *mf* with no vibrato (straight tone)
- 5. Sustained G4 in *mf* with no vibrato (straight tone)

- 6. Sustained G5 in *mf* with vibrato
- 7. Sustained G4 in mf with vibrato

Articulation:

- 8. Rapid semi-quaver groups (double tonguing)
- 9. Two groups of single notes- crotchets (single tonguing)
- 10. Two groups of quavers (legato)

Dynamics:

- 11. Crescendo from *pp* to *ff* on A5
- 12. Decrescendo from *ff* to *pp* on D5
- 13. Decrescendo from *ff* to *pp* on E4

Each one of the participants was advised to take as long as needed in between the tasks, so the movements of respiration could be fully captured with detail as well.

#### **Preparation of video samples**

The videos were originally categorised by participants. Subsequently, they were edited in short clips of ten seconds. Lastly, each one of the exercises from the protocol was separated and the clips of all participants went through a randomisation process.

#### **Rating procedure**

Nasensdoscopy rating of laryngeal images commonly occurs in voice research, where researchers recognise possible subjective factors when rating sound and function. It was assumed that these factors would also apply in rating laryngeal images during flute playing. These factors include the experience of the rater, the provision of external anchors for comparison, the nature of the task, rating multiple dimensions, the provision of definitions and training in the rating tool (Iwarsson & Petersen, 2012).

To address these challenges of reliability, a fully qualified speech pathologist with 16 years' experience in the field, viewed and rated the video samples to identify the movements of the laryngeal parameters. This professional had previously assessed nasendoscopy footage in both clinical and research settings.

To assess intra-judge reliability, eight of the samples were presented to the rater twice. Repetitions included all types of tasks to ensure analysis of reliability of ratings across tasks. This resulted in a total of 66 clips being prepared for rating by the speech pathologist.

A rating form was devised for use by the speech pathologist that enabled each laryngeal parameter to be assessed with an individual rating on both a visual analogue scale and by providing comments as required to describe the movement (see Appendix A). The rating tool design was based on the Functional Parameters for Voice rating scale (FVP) by Madill et al. (2010). The FVP was developed as a tool for identifying and quantifying the amount of movement of laryngeal structures using videonasendoscopy with accompanying audio recording to assist in interpretation of the visual images.

Rosen (2005) has noted the importance of the quantification in the perceptual rating of laryngoscopic images. Therefore, the method of registering those observations becomes as important as the actual observation. The rating tool must contain reliable parameters and be simple (Rosen, 2005).

A visual analogue scale (VAS) was selected based on the findings of Yu et al. (2002) which concluded that the VAS is more effective than the ordinal scale when considering the correlation between objective and perceptual judgements. The VAS

permits the rater to demonstrate the observations better, especially if there are various parameters involved (Yu et al., 2005) and provides the rater with the possibility of a more subjective and detailed judgment (Wuyts et al., 1999).

Using the rating form provided, the speech pathologist rated a total of 66 clips. As it can be seen on the form, the rater had the opportunity to add comments to each parameter, when appropriate. There were three rating sessions of three hours each. There were six parameters rated: true vocal folds, false vocal folds, laryngeal height, pharyngeal space, epiglottis movement, arytenoids adduction. All these parameters were rated using the visual analogue scale (see Appendix A).

Subsequently, all the visual analogue scale markings were converted into a ten-centimetre scale. According to this conversion, the parameters will be organised as seen in Table 2.

Visual analogue scale		Measurement points
TVFA	True vocal folds	Complete-10/Partial-5/None-0
FVFA	False vocal folds	Complete-10/Partial-5/None-0
LH	Laryngeal height	High 5/Neutral-0/Low-5
PS	Pharyngeal space	Wide open-10/Partial closure-5/Closed-0
EM	Epiglottis movement	Anterior-5/Stationary 0/Posterior 5
AA	Arytenoids adduction	Complete 10/Partial 5/None-0

Table 2. Visual analogue scale (VAS) measurement points definitions

Each of these measurements were organised on a table divided by musical aspect (High pitch, Low pitch, Middle pitch, No Vib 1, No Vib 2, Vib 1, Vib 2, Dynamics 1, Dynamics , Dynamics 3, Double tonguing, Single tonguing, Legato). Measurements totalled 390.

#### Data analysis

Data from the rating forms was extracted by measuring the mark on the line and converting this into a value of centimetres. These values were entered into a spreadsheet and analysed using descriptive statistics. The values were divided into the different musical tasks (pitch, vibrato, dynamics, and so on). Each musical task had all the laryngeal features' values for each participant. Means and standard deviation was calculated for each of the laryngeal parameters values.

## **Results**

Both quantitative and qualitative results are reported in this section. Results include specifically descriptive ordinal data from the VAS ratings as well as comments made by the rater when a special movement was observed, or if something that could not be rated on the visual analogue scale was observed.

Each of the participants performed the set of exercises following the musical aspects order in the protocol (pitch, no vibrato, vibrato, dynamics and articulation). All results are reported here and specific detail is provided for findings that are common across parameters.

None of the participants reported any major difficulty performing any of the tasks while undergoing the nasendoscopy procedure. Ninety per cent of participants performed a different laryngeal configuration for the onset (preparation before the note) compared to the actual note start. Due to the limitation of the visual analogue scale, all these cases were reported in the comments section by the rater.

## **Intra-rater reliability**

Approximately 10% of the samples were repeated during the rating for reliability. These repeated samples were randomly distributed during the rating sessions. The graphs on the following page (Figures 5 to 11) illustrate the comparison between the core values and the repeated values.

#### Figure 5

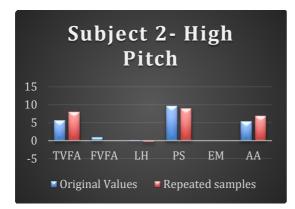
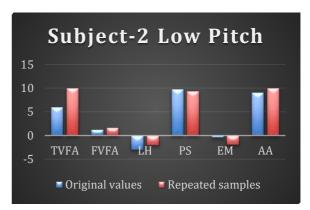
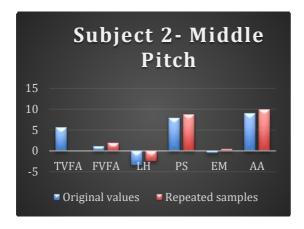


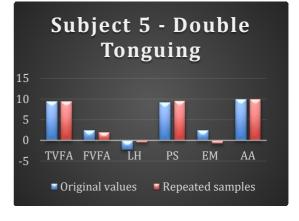
Figure 7





#### Figure 8





#### Figure 9

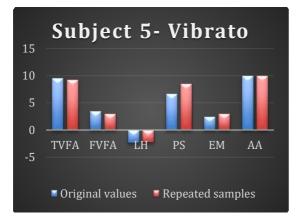
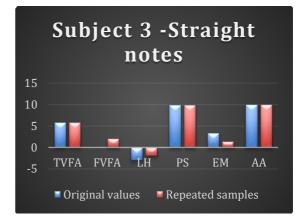


Figure 10



#### Figure 11

Subject 4 Straight notes				
15				
10				
5				
0				
-5	TVFA FVFA LH PS EM AA			
	Original values Repeated samples			

As it can be observed, the rater was highly consistent across tasks and participants; 90% of the ratings show approximately the same ratings, 5% are significantly different, and 5% are slightly different.

# Rater observations of specific laryngeal parameters across all participants

The larynx as a whole was rated to be active across all participants during all tasks according to the VAS ratings. Table 3 shows the mean VAS ratings for each parameter.

Parameter	High pitch mean (range)	Low pitch mean (range)	Middle pitch mean (range)	No vibrato 1 mean (range)	No vibrato 2 mean (range)	Vibrato 1 mean (range)	Vibrato 2 mean (range)	Dynamics 1 mean (range)	Dynamics 2 mean (range)	Dynamics 3 Mean (range)	Double tonguing Mean (range)	Single tonguing Mean (range)	Legato Mean (range)
TVFA	6.78 (5.7-7.7)	5.78 (0-8.8)	6.88 (5.4-8.7)	5.88 (3.7-8.5)	6.26 (5.5-8.2)	7.16 (5.3-9.5)	8.26 (5-10)	8.76 (6.7-9.7)	8.56 (7-9)	8.7 (7.2-9.5)	8.92 (6.3-9.6)	8.3 (7-9.7)	8.1 (6.1-9.3)
	SD= 1.14	SD=3.4	SD=1.75	SD=1.70	SD=1.09	SD=2.07	SD=1.93	SD=1.13	SD=1.24	SD=0.88	SD=1.46	SD=1.07	SD=1.2
FVFA	0.98 (1-1.7)	1.74 (1-3.2)	10.8 (1.2-4)	0 (0-0)	0.72 (0-2.5)	1.5 (0-4)	2.3 (1-6)	2.4 (1-4.3)	1.9 (0-3.4)	2.32 (2-3.5)	1.46 (0-2.5)	1.96 (0-5.6)	1.76 (0-2.4)
	SD=0.33	SD=0.97	SD=1.15	SD=0	SD=1.10	SD=2.06	SD=2.10	SD=1.2	SD=1.86	SD=0.63	SD=1.33	SD=2.29	SD=1.76
LH	-2.46 (0-3.8)	-1.04 (-3.7-1.7)	-1.58 (-3.4-0)	-2.54 (-3.6-1.5)	-2.52 (-25-1.3)	-2.18 (-3-0.9)	-1.48 (-3.6-0_	-0.88 (-2.3-0)	-0.58 (-3-1.3)	-0.98 (-2.3-0.5)	-1.1 (-2.3-0.5)	-1.06 (-2.3-0.7)	-1.58 (-3.2-0)
	SD=1.71	SD=2.26	SD=1.44	SD=0.79	SD=0.94	SD=0.91	SD=1.39	SD=1.01	SD=0.37	SD=1.10	SD=1.38	SD=1.2	SD=1.22
PS	9.58 (8.1-10)	9.2 (8.4-9.8)	9.32 (8-10)	9.1 (6.7-10)	9.06 (6.5-10)	8.28 (6.7-9.5)	9.04 (8.5-10)	9.48 (9.4-9.6)	9.42 (9-10)	8.94 (8.2-9.2)	9.5 (9.2-9.8)	7.26 (8.1-9.5)	9.04 (8-10)
	SD=0.83	SD=0.6	SD=0.77	SD=1.36	SD=1.48	SD=1.29	SD=0.59	SD=0.08	SD=0.37	SD=0.42	SD=0.29-	SD=0.66	SD=0.73
EM	0.56 (-0.5-1.5)	-0.26 (-2.4-2.4)	0.62 (-0.6-1.6)	-1.84 (-4.7-3.3)	0.28 (-4-2.7)	1.08 (-0.4-3)	1.04 (-3.2-3.6)	-0.68 (-4.7-2.3)	-2.22 (-3.8-0.8)	-4.3 (-4.3-1.5)	-0.2 (-3.2-2.5)	0.72 (-3-2.1)	0.65 (-0.5-2.3)
	SD=0.86	SD=1.71	SD=1.14	SD=3.73	SD=2.81	SD=2.17	SD=2.77	SD=3.25	SD=1.89	SD=2.75	SD=2.93	SD=2.16	SD=1.17
AA	6.84 (5.4-9)	7.26 (5.4-9)	8.28 (5.8-9)	8.16 (5.2-10)	9.1 (5.5-10)	8.08 (4.5-10)	8.6 (7.5-10)	10 (10-10)	9.1 (7.9-10)	9.8 (9-10_	9.86 (9.6-10)	9.7 (8.5-10)	8.96(6.7- 10)
	SD=1.83	SD=1.80	SD=1.39	SD=2.52	SD=2.01	SD=2.24	SD=0.97	SD=0	SD=1.01	SD=0.44	SD=0.19	SD=0.67	SD=1.50

## Table 3. Involvement of each physiological aspect for each parameter per task

Key	Range reference
TVFA: True vocal folds	Complete-10/Partial-5/None-0
FVFA: False vocal folds	Complete-10/Partial-5/None-0
LH: Laryngeal height	High 5/Neutral-0/ Low-5
PS: Pharyngeal space	Wide open-10/Partial closure-5/closed-0
EM: Epiglottis movement	Anterior-5/ Stationary 0/ Posterior 5
AA: Arytenoids adduction	Complete 10/ Partial 5/ None-0

These results show that there was more consistent movement of the three parameters TVFA, EM and AA across all participants and all tasks. While the VAS score on the other parameters indicates that there was movement of these structures, there was no consistent movement patterns across all participants.

#### True vocal fold adduction

The means, range and standard deviation values of the true vocal folds adduction as rated on the VAS scale demonstrate that this element varied across participants and tasks from partial to complete closure configuration according to the results (see Table 3). Figure 12 details the true vocal folds activity for each participant across the tasks.

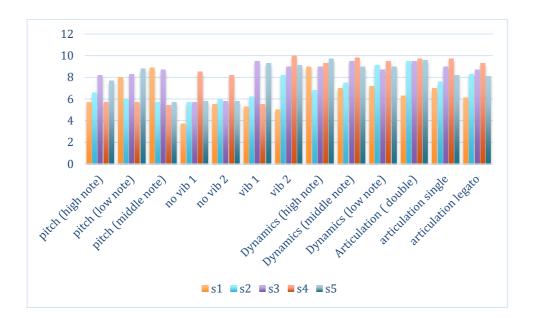


Figure 12. True vocal fold activity for each activity across tasks

The true vocal folds graph shows that all participants adducted the folds to some extent in across tasks. Looking at the results 67% of the participants demonstrated a complete adduction shape (8–10 in the scale) and 33% a partial adduction (4–6 in the scale).

The comments provided by the rater describe the crucial participation of the vocal folds in performing the tasks across participants. The rater included a comment on a total of 34 samples, showing that approximately 50% of the videos included some kind of movement. Again, the two vibrato tasks demonstrated a high number of movements. According to the ratings, all the participants showed some kind of movement. Table 4 describes the comments on vibrato tasks movements by the rater.

 Table 4. Rater observations of vocal folds during vibrato tasks

Participant	Vibrato Task 1	Vibrato Task 2
1	"Vocal folds posteriorly adduct at onset, then abduction during the note. There is abduction or adduction (partially)in true vocal folds with vibrato."	"Abduction and adduction during vibrato."
2	"Vocal folds abduction and adduction in true vocal folds with vibrato but with a partially open position."	"Bowed configuration."
3	"Left vocal fold abducts and adducts in true vocal folds with vibrato."	"Bowed configuration"
4	"Abduction and adduction during vibrato."	"Adduction and abduction in true vocal folds with vibrato. Right vocal fold moves then left does."
5	"Most adduction (not closed) happens at onset then abduction and adduction with vibrato."	"Abduction of right fold during vibrato."

The true vocal folds appear to move constantly during vibrato. Although the abduction/adduction movement is consistently present, it is also noticeable that the true vocal folds adduct at the onset of two participants (S1 and S5) in the first task, demonstrating the movement of the true vocal folds before and during the task. On the

other hand, this onset configuration (adduction) is not as significant as in in the samples involving arytenoid movement.

Another task that showed great involvement of true vocal folds movements was the dynamics task. According to the ratings, there were movements by participants in all sub-tasks (1, 2 and 3). Table 5 details the comments by the rater involving the three dynamics tasks.

 Table 5. Rater observations of true vocal fold movements during three dynamics tasks

Participant	Dynamics Task 1	Dynamics Task 2	Dynamics Task 3
1		"Most adduction(not closed) happens at onset then abduction then abduction and adduction with vibrato."	"Can't see fully to describe."
2			"Slight abduction as note gets louder."
3	"Abduction of right fold during vibrato."	"Abduction and adduction of right vocal fold on vibrato."	"Abduction/adduction of right vocal fold on vibrato."
4	"Abduction of interarytenoid space at loudest point during the note. Abduction and adduction on vibrato."	"Slight abduction towards the end of the note."	"Slight abduction towards the end of the note."
5	"Abduction as note gets louder. Abduction and adduction during vibrato."	"Sudden abduction then adduction."	

It is important to consider that the participants made use of the vibrato during the dynamics tasks, as it is a common practice to do so. However, the rater was very specific in detailing these moments. Without taking abduction and adduction motions (during vibrato) into account, it is possible to observe that the vocal folds adducted at onset and abducted at the end for Participant 1 on the second task and Participant 4 on the third task. This demonstrates the participation of the true vocal folds in controlling the airflow.

#### Arytenoids activity

The arytenoids also participated actively across participants and tasks. Here is a detailed graph with all the participants' results regarding only the arytenoids: **Figure 13. Arytenoid adduction activity across tasks and all participants** 



All participants adducted the arytenoids across all tasks; 50% of the participants presented a complete adduction configuration (8–10 in the scale), 10 % partial adduction (4–6 in the scale) and 40% in between (6–8 in the scale). The movements of the arytenoids were dynamic rather than static during the production of vibrato. Table 6 reports the comments by the rater where these movements are described in detail. The two columns represent each of the vibrato tasks for each participant.

Participant	Vibrato Task 1	Vibrato Task 2
1	"Arytenoids adduct at onset, then abduct slightly. They then 'wobble' in true vocal folds with vibrato."	"Arytenoids adduct at onset, then slightly abducts in true vocal folds with vibrato. Left arytenoid moves than right arytenoid moves."
2	"Arytenoids wobble (no adduction or abduction) during vibrato."	"Wobble with vibrato (no abduction/adduction)."
3	"Abduction or adduction with vibrato. Right side moving, left vocal fold hardly moving."	"Right arytenoid abduction or adduction (wobbles) with vibrato."
4	"Nearly adducts by end of note but not quite."	"Arytenoids wobble with vibrato."
5	"Abduction or adduction (with no full closure) during vibrato."	"Arytenoids abduction or adduction during vibrato."

#### Table 6. Rater comments on arytenoids movements

All the participants showed movements in both vibrato tasks. The "wobbling" cited by the rater demonstrates the significant participation of the arytenoids in producing vibrato. Another task that presented a significant participation of the arytenoids was the two articulation tasks that involve tonguing (single and double). The comments by the rater also describe the movements (Table 7).

Participant	Vibrato Task 1	Vibrato Task 2
1	"Slight movement during tonguing."	"Right arytenoid abducts slightly between the notes."
2	"Slight abduction in between notes."	"Slight movement with note change."
3	"Slight abduction as notes change."	
4	"Nearly adducts by end of note but not quite."	
5	"Arytenoids abduct after note and stay partially closed."	

 Table 7. Rater comments on arytenoids movements (tonguing)

The comments highlight the abduction movement of the arytenoids when the

tonguing is being performed. The third sub-task (legato) was not included.

#### **Epiglottis movement**

Along with the arytenoids and the true vocal folds, the epiglottis parameter showed posterior (55%) and anterior (40%) configurations across participants and tasks. In total, 95% of the participants demonstrated one of the two shapes. Figure 14 shows the detailed activity of the epiglottis movements throughout the tasks (anterior 0/-5 and posterior 0-5)

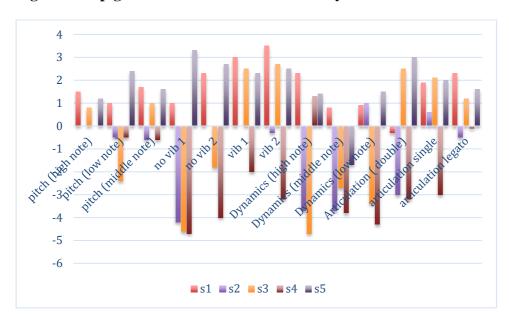


Figure 14. Epiglottis movement detailed activity across tasks

As it can be seen, approximately 50% of the participants presented an anterior configuration across tasks, and approximately 45% posterior shapes. The comments by the rater describe with much detail how the movements happens. Table 8 demonstrates these comments in all three dynamics tasks:

Participant	Dynamics Task 1	Dynamics Task 2	Dynamics Task 3
1	"Epiglottis moves more posteriorly over the course of the note."	"Epiglottis moves posteriorly through vibrato then anteriorly at the end of the note."	"Epiglottis moves posteriorly during note until nearly completely covered."
2	"Slight movement anteriorly."	"Slight movement anteriorly during the note."	"Epiglottis is initially positioned anteriorly then moves more posteriorly as the notes gets louder."
3		"Only the base of the tongue bumps in."	"Base of the tongue moves posteriorly."
4	"Big anterior movement at onset then moves posteriorly as notes gets louder."	"Epiglottis moves anteriorly during the note."	"More anterior movement during the note."
5	"More posterior movement during the note."	"Anterior movement towards end of the note."	"Slight movement posteriorly."

The comments are consistent with a pattern of movements related to task. In the two tasks that included *crescendo* (Tasks 1 and 3) the rater reports a predominance of posterior movements, whereas in the second task (*decrescendo*) the rater reported an anterior motion on 55% of occasions. With the exception of one sample (Participant 3, dynamics task 1) all the other dynamics clips demonstrated the presence of epiglottis movements in performing dynamics changes in flute playing.

Similarly to the dynamics tasks, the articulation exercises also demonstrated a consistent presence of epiglottic movement. However, in this case the movements were more diverse. The comments detail these phenomena across the three articulation tasks.

Participant	Articulation Task 1	Articulation Task 2	Articulation Task 3
1	"Anterior to posterior movements during tonguing but not covering glottis."		
2			"Slight posterior movement over the note sequence."
3	"Posterior and anterior movement during tonguing."	"Epiglottis moves more posteriorly with each note."	"Epiglottis initially moves anteriorly then moves posteriorly over sequence of notes."
4	"Movement of tongue base during tonguing."	"Movement of tongue base during tongue."	"More anterior movement during the note."
5	"Slight instability and movement during tonguing."	"Slight instability and movement during tonguing."	"Slight movement posteriorly as note progresses."

Looking at the comments, it is possible to see varied movements (posterior/anterior) during tonguing. It is possible to observe epiglottic motions in four of the participants on the legato task (the third one), showing that the epiglottis participates with and without tonguing presence.

Although there were no oscillations during the task performances, it is important to highlight the shape of the epiglottis during the straight tones task (no vibrato). Half of the participants demonstrated extreme posterior shapes during the tasks. Although there was no movement because there was no vibrato, dynamic changes or articulation, the epiglottis was significantly present controlling the air-flow and producing the tone.

#### **Musical activities highlights**

The movements of each laryngeal parameter associated with individual musical tasks was also analysed. This analysis revealed that, the many laryngeal parameters, not just TVFA (true vocal folds), AA (arytenoids activity) and EM (epiglottis movement), were active in specific tasks.

#### Pitch

The pitch results indicate that the larynx participated actively across all participants. As it can be seen on the performance protocol, there were three tasks to be performed; one with a low register note, one with a middle register, and one with a high register pitch. Tables 10, 11 and 12 show the VAS results of the three pitch tasks.

Participan t	TVFA	FVFA	LH	PS	EM	AA
1	5.7	1.7	-3.8	8.1	1.5	5.6
2	6.6	1	-3.3	10	0	8.7
3	8.2	1.2	-2	10	0.8	9
4	5.7	1	0	9.8	0	5.4
5	7.7	Х	-3.4	10	1.2	5.5

Table 10. VAS results for Pitch Task 1 (high pitch)

Table 11. VAS results for Pitch Task 2 (low pitch)

Participan t	TVFA	FVFA	LH	PS	EM	AA
1	0	2.3	-3.7	9	1	7.5
2	6	1.2	-3	9.8	-0.5	9
3	8.3	1	-0.5	9.8	-2.4	9
4	5.7	1	1.7	9	-0.5	5.4
5	8.8	3.2	0	8.4	2.4	5.4

Participan t	TVFA	FVFA	LH	PS	EM	AA
1	8.9	1.5	-2.7	9.4	1.7	8.6
2	5.7	1.2	-3.4	8	-0.6	9
3	8.7	1.5	-1	9.5	1	9
4	5.4	4	-1	10	-0.6	5.8
5	5.7	2.6	0.2	9.7	1.6	9

For the low register frequency, it could be observed that across all participants the true vocal folds and the arytenoids were partially adducted. In the low register note, both true vocal folds and arytenoids were closer to a complete adduction on most of the participants. The middle register pitch showed three participants closer to partial adduction of the true vocal folds and three participants with a complete adduction of the arytenoids. Considering the means of the results of all participants on the pitch task, it is possible to highlight that the true vocal folds and the arytenoids participate very actively on the process. The true vocal folds move towards the partial adduction across participants and tasks, and the arytenoids closer to a full adduction across participants in two tasks (low and high pitches). The larynx was kept slightly lower across participant and tasks. The epiglottis was kept still and the pharyngeal wall wide open across tasks and participants.

#### **Straight tones (no vibrato)**

The participants performed two tasks without any vibrato. One was a middle G and the other one was a low G. The epiglottis participated actively in all participants. Three of the participants presented posterior movements, while two moved the epiglottis anteriorly. In most participants (four out of five), the true vocal folds were partially adducted, however the arytenoids were reported fully adducted in three participants. Following the same behaviour as the one demonstrated on the pitch task, the larynx was slightly lower across participants, and the pharyngeal wall was wide open.

According to the rater, the false vocal folds were not able to be rated due to the difficulty in visualisation. Tables 13 and 14 represent all the results for straight notes across participants and tasks.

Participant s	TVFA	FVFA	LH	PS	EM	AA
1	3.7	0	-2.2	10	1	5.2
2	5.7	0	-3.6	6.7	-9.2	10
3	5.7	0	-2.4	9.4	-9.6	10
4	8.5	0	-1.5	9.6	-9.7	5.6
5	5.8	0	-3	9.8	3.3	10

Table 13. VAS results for straight notes (Task 1)

Table 14. VAS results for straight notes (Task 2)

Participants	TVFA	FVFA	LH	PS	EM	AA
1	5.5	0	-3.5	9	2.3	10
2	6	0	-2.7	6.5	-0.6	10
3	5.8	1.1	-1.8	10	-1.8	10
4	8.2	0	-1.3	10	-4	5.5
5	5.8	2.5	-3.3	9.8	2.7	10

Looking at the straight tones results, it is possible to observe extensive participation of the true vocal folds, the arytenoids and the epiglottis. One important note by the rater here is about the different onset, where the respiration happens. According to the report, the true vocal folds, and the epiglottis participated in the process of execution during the course of the note. The folds were partially adducted and the epiglottis moved anteriorly in one of the participants.

#### Vibrato

The vibrato results show again extensive participation of the true vocal folds, epiglottis movements, and arytenoids adduction. However, in this case greater movements can be observed. Therefore there are additional comments describing the phenomena (as it was previously discussed).

According to reports, the true vocal folds stay partially adducted across participants; however, there is an adduction/abduction movement correspondent to the sound fluctuation produced. The arytenoids follow the same pattern with a slight difference. In this case, the results show a complete adduction position, despite the abduction/adduction movements during the vibrato across participants.

Regarding the epiglottis movements, the reports show different movements between participants. Three presented posterior movements, whereas two moved it anteriorly during the note. Tables 13 and 14 show two vibrato tasks with all parameters results.

Participants	TVFA	FVFA	LH	PS	EM	AA
1	5.3	0	-3	8.5	3	8
2	6.2	0	-3	9.5	0	10
3	9.5	3.5	-2.4	6.7	2.5	10
4	5.5	0	-0.9	9.5	-2	4.5
5	9.3	4	-1.6	7.2	2.3	7.9

Table 13 VAS results for Vibrato Task 1

Participants	TVFA	FVFA	LH	PS	EM	AA
1	5	1.5	-3.6	8.5	3.5	7.5
2	8.2	1	-2	9.1	-0.3	10
3	9	2	-0.5	8.6	2.7	9.1
4	10	1	-0.3	10	-3.2	8
5	9.1	6	-1.3	9	2.5	8.4

#### Table 14 VAS results for Vibrato Task 2

When compared to all other musical aspects, the vibrato was the one that showed greatest participation of the larynx. Although the epiglottis, true vocal folds and the arytenoids had the strongest participation, the pharyngeal wall observations also showed slightly narrowing in three of the participants on both notes.

The larynx height also presented some significant results. In three of the participants it showed a significant low position, and in one the larynx moved slightly up and down during vibrato. The false vocal folds showed a slight adduction/abduction following the true vocal folds movements in one of the participants. For two of the participants, it was not possible to completely assess the false vocal folds due to the epiglottis movements blocking the view.

# **Dynamics**

Three tasks involved dynamics. The first was a middle A (A5) *crescendo*, the second a middle D (D5) *decrescendo*, the third and last a low E (E4) *crescendo*. On the first note, the participants presented similar laryngeal configuration to the vibrato task. This is because they used the vibrato as a tool to increase the volume. However, there are some important differences.

Participants	TVFA	FVFA	LH	PS	EM	AA
1	9	2.2	-1.1	9.6	2.3	10
2	6.8	2.5	-2.3	9.4	-3.7	10
3	9	2	0.2	9.5	-4.7	10
4	9.3	1	-1.2	9.4	1.3	10
5	9.7	4.3	0	9.5	1.4	10

Table 15. All results for Dynamics Task 1 (high note)

Table 16. All results for Dynamics Task 2 (middle note)

Participants	TVFA	FVFA	LH	PS	EM	AA
1	7	0	1.3	9.7	0.8	9.7
2	7.5	3.4	-3	9	-3.7	10
3	9.5	2.1	-0.5	9.3	-2.7	9.8
4	9.8	0	-1	9.2	-3.8	7.9
5	9	4	0.3	9.9	-1.7	8.1

Participants	TVFA	FVFA	LH	PS	EM	AA
1	7.2	3	0.5	8.2	0.9	10
2	9.1	2	-2.3	9	1	10
3	8.7	2.1	-1.8	9.2	-3.4	10
4	9.5	3.5	-0.5	9.1	-4.3	9
5	9	2.8	-0.8	9.2	1.5	10

Table 17. All results for Dynamics Task 3 (low note)

According to the observations, three participants slightly narrowed the pharyngeal space by moving the pharyngeal wall anteriorly and/or posteriorly during the *crescendo*. In addition, one of the participants moved the larynx slightly upwards. Similarly to the vibrato results, the true vocal folds moved during the *crescendo*. However, in this case, the overall configuration of the folds was completely adducted across the participants. In other words, the folds abducted and adducted as the note became louder with a wider vibrato. In addition, the arytenoids did not move during the *crescendo*. According to the reports, only at the loudest point was it possible to see a slight abduction. Otherwise, there was a complete adduction configuration across participants with very particular epiglottis movements. At onset (breathing) the epiglottis moved anteriorly; as the note became louder, the epiglottis moved seven to the seven the adduction. This movement was evident in three of the participants, with only one showing slight anterior movement.

The second dynamic task was the *diminuendo*. Here the participants also used the vibrato as a tool. However, the laryngeal configuration changed significantly in this task. In four of the participants, the epiglottis maintained a posterior configuration and moved slightly anteriorly as the note became softer. Only one participant presented an anterior configuration with posterior movements.

In contrast to the first task, the participants used the arytenoids during the decrescendo rather than the pharyngeal wall. According to the report, the arytenoids abducted as the note became softer along with the vibrato. The true vocal folds showed a complete adduction configuration with opening and closing movements along the softening process. In this case, the pharyngeal wall did not move, and in one of the participants it was not possible to clearly see it. The false vocal folds kept a slight adduction configuration across participants, but there were no movements. The larynx remained slightly lower, with evidence of one participant only moving it slightly upwards.

### Articulation

The articulation task was divided in three sub-tasks: double tonguing, single tonguing and legato.

Participants	TVFA	FVFA	LH	PS	EM	AA
1	6.3	2.3	-1.8	9.3	-0.3	9.6
2	9.5	0	-2.2	Х	-3	10
3	9.5	2.5	-2.3	9.2	2.5	10
4	9.7	0	0.5	9.7	-3.2	10
5	9.6	2.5	0.3	9.8	3	9.7

**Table 18. Articulation – double tonguing** 

Participants	TVFA	FVFA	LH	PS	EM	AA
1	7	5.6	-2.3	9.2	1.9	10
2	7.6	0	-2	Х	0.6	10
3	9	2.2	-1.2	8.1	2.1	10
4	9.7	0	-0.5	9.5	-3	8.5
5	8.2	2	0.7	9.5	2	10

**Table 19. Articulation – single tonguing** 

Table 20. Articulation – legato

Participants	TVFA	FVFA	LH	PS	EM	AA
1	6.1	0	-3.2	9.9	2.3	6.7
2	8.3	2	-2	8	-0.5	10
3	8.7	2.4	-1.8	8.7	1.2	10
4	9.3	2.4	0	9.1	0	10
5	8.1	2	-1	9.5	1.6	8.1

The double-tonguing task showed extensive participation of the epiglottis across participants. As the tongue was moving rapidly to produce the effect, the epiglottis moved in different directions. In two participants, the epiglottis had an anterior to posterior motion; in the other two participants the epiglottis moved anteriorly from a posterior shape. One participant showed an anterior positioning without movements.

The other laryngeal parameters did not register extensive participation in this process, except for a slight movement of the pharyngeal wall in one participant and a slight up-and-down movement of the larynx in another participant. The true vocal folds and the arytenoids maintained a complete adduction position across participants;

the false vocal folds registered a slight adduction in three participants, but no movement.

Similar to the double-tonguing, the single tonguing task demonstrated crucial participation of the epiglottis. However, in this case, only three participants actually moved the epiglottis. Two participants moved it posteriorly and one anteriorly. The others kept it slightly forward, but with no movement. Similar to the double-tonguing results, the other parameters did not show significant changes during the process, except for a false vocal folds movement in one participant. According to the reports, the false folds adducted on onset and retracted immediately.

The other parameter that had a single-case engagement was the laryngeal height. According to the rater, there was an upwards movement between the notes, and an immediate lower motion. Once again, the true vocal folds and the arytenoids kept an almost complete adduction shape across participants. The reports also show a slight narrowing of the pharyngeal space in two participants; one at onset and one during the note.

The legato task was the last exercise performed by the participants. Because tonguing in legato is not predominant, larynx behaviour changes. The results show a significant participation of the true vocal folds, pharyngeal wall and epiglottis. According to the report, two participants abducted the folds as the notes changed, and one slightly adducted during the process. The pharyngeal wall was engaged in three participants. Two participants presented a slight constriction as the notes changed; one moved the left wall constricting the space only slightly. Although the epiglottis was not the most dominant parameter engaged in legato, three participants presented changes; two moved the epiglottis slightly posteriorly as the pitches changed, and one moved it anteriorly first and then posteriorly. The arytenoids showed a complete

adduction shape across participants. Participants kept the larynx slightly lower and the false folds presented a modest adduction across participants.

# Discussion

This section will discuss the results of this investigation with the literature presented earlier and includes possible pedagogical applications as well as future research ideas. This way, the findings of this research will not only serve as empirical evidence, but also as a pedagogical tool for teachers and performers in their future projects.

The flute differs from other woodwind and brass instruments because the embouchure is free from any resistance. King et al. (1988) use the term "air reed" to classify the only flute participant used in their experiment. This term not only describes clearly the idea of not having an actual reed or mouthpiece, but also proposes that the air works as the flautist's "reed". It is possible to infer from this that the air is clearly treated differently in flute playing. The videos presented in the appendix show how the "air reed" actually works, and the term may be a useful metaphor for understanding the complex activity inside the throat. Flutists rely on the larynx more than any other instrumentalists as the lips do not present any resistance, where other wind instruments have devices that do.

The common pedagogical methods, concepts and exercises involving the larynx and pharynx, will also form part of this section's discussion as they show the current material available to flute teachers. The results of this thesis will enrich those concepts with the aim of helping performers and teachers come to a new understanding of the relationship between traditional practices and this new

knowledge about the larynx. Researchers of sound production for the flute will be initiate new projects in the pedagogical area.

### Vibrato

Vibrato is one of the most discussed topics in the flute pedagogical literature and is present in empirical works by pedagogues (Pool, 2010; Campagno 2003), as well as purely pedagogical methods and articles (Debost, 2008; Floyd, 2004; Galway, 1982). However, before the vibrato findings are analysed and compared to the literature, it is crucial to consider another aspect of this research: the straight notes.

Looking at the straight notes results it is possible not only to understand the vibrato results better, but also the flute tone production in general. As it has been mentioned in the results section, the epiglottis and the true vocal folds showed a significant participation in the straight tones tasks. According to the rater comments 60 % of the participants moved their epiglottis posteriorly, while 40 % of them moved it anteriorly. However, more important than the actual shape during the note is the onset.

The rater notes that the true vocal folds abduct before the note and adduct during the course of the note. This fact proves that the larynx participates actively in changing the air flow, as abducting the true vocal folds narrows the glottal aperture, changing the flow and pressure of the expiratory air. This is a voluntary act as the flautist comes to think about the notes that are to be played. Just becoming aware that this is an action that occurs with the thought associated with playing a note, can revolutionise the way that teachers can communicate the idea to students. To be able to play, this thought to embodied action simply occurs and affects both straight notes and those with vibrato as they come from the same initial physical action.

Studies such as Toff (1996), Bayley (2006), Sparks (2013) and Krell (1973) do defend vibrato as being produced in the abdominal area. The present research did not investigate respiratory muscle movements. However, not only the vibrato task, but also all other tasks, showed the unquestionable participation of the true vocal folds, the arytenoids and the epiglottis in producing the flute tone. According to the comments by the rater, both arytenoids and true vocal folds showed consistent oscillatory movements (also described as "wobble") across participants in the vibrato task. Many teachers suggest that the diaphragm and abdomen are the source for vibrato, but this research has shown that the true vocal folds have an important part to play.

The results demonstrate an active control of vibrato at the laryngeal level which corroborates the assertions of several authors (Wilkins, 1963; Floyd, 2004; Galway, 1983; Debost, 2008). Unlike the assertions, the material explored in this thesis provide more direct evidence for the influence of true vocal cords to the actual practice of sound production. Wilkins (1963) for example, explains the vibrato in his method by mentioning a "constrictor" (p. 67). Although this is an unclear term, the results of this research regarding the true vocal folds and the arytenoids do corroborate the concept. Debost (2008) gives his personal opinion by stating that the vibrato is produced in the "vocal cords" (p.68), as does Floyd (2004) that also comes in agreement with the present findings regarding true vocal folds adduction. According to the author, Gilbert used to teach his students that the "glottis" is the element that controls vibrato. Although the glottis is not a proper muscle, but an aperture, it is possible to infer that he was referring to the true folds or the arytenoids. It is understandable that the proper physiology terminology is in some cases

complicated and it is more helpful for students to assimilate the concept if the specific physiological terms were available to them.

Using vibrato in performance is both ubiquitous and contested. Vibrato can be used to enhance the meaning of music through its swift or slow presentation. Essentially, vibrato subtly changes the speed and pitch of a note. Understanding the manner in which the true vocal folds change between straight notes and also the variation found in notes with vibrato, has the very practical outcome of making the music meaningful. It is important to reinforce that this research is restricted to the laryngeal/pharyngeal involvement. It is not the aim of this research to exclude any other physiological involvement possibly present in vibrato.

## **Dynamics**

The results regarding dynamics show the importance of the involvement of the epiglottis along with true vocal folds and arytenoids to change dynamic levels. The research findings identified anterior movements by the epiglottis (mostly at onsets) and posterior movements (during the course of the note) across participants and tasks. The true vocal folds presented complete adduction shapes throughout tasks and participants, and the arytenoids activity also showed complete adduction shapes throughout. According to the rater comments, both true vocal folds and arytenoids presented the consistent oscillatory movements across the tasks. In other words, the epiglottis, true vocal folds and arytenoids are working as a system to produce dynamics.

These results are very similar to the vibrato findings as most players use vibrato as a tool to increase the frequency volume due to the instrument playing characteristics. The use of vibrato in dynamics was already expected as this is a

natural tool used by performers and indicates how important vibrato is for flute players and consequently the larynx elements.

Floyd (2004) explains that Gilbert advocates that dynamics are produced in the lip region. Hwang-Shim (2005) conducted empirical research on the comparison between glottal aperture and lips aperture, and found that the lips do participate in changing dynamics along with the glottal aperture. Although participation of the lips has been proved to be part of the process of producing dynamics by these authors, this research did not investigate this feature further as the focus was rather on the means of creating airflow. This study focused on the whole laryngeal/pharyngeal apparatus engagement in producing *crescendo* and *decrescendo*. Breathing is the beginning of sound production where the lips are the last stage of the process.

Dick (1987) agrees as he asserts that "breath support" is the responsible for controlling dynamic changes. Toff (1996) notes that the "pharyngeal cavity" is the main factor in increasing volume. This last concept is the one that comes closest to the findings of the present research. Although Hwang-Shim (2005) investigated thoroughly the glottal influence in flute playing, the author does not mention anything about the epiglottis participation in dynamics. On the other hand, as can be seen from the results of this study, the epiglottis is one of the main factors in *crescendo* and *decrescendo* production.

#### Articulation

Several authors mention the importance of the vowel in articulation (Debost, 2002; Floyd, 2004; Wilkins, 1963; Valette, 2010; and Esposito, 2014) pointing out that this is due to the air stream. Vowels change the shape of the inside of the mouth due to changing positions of the tongue and the epiglottis. According to the authors, the air stream should be well controlled so the articulation result is satisfactory. The

articulation results of the present research show a great involvement of the epiglottis across articulation tasks. As the tongue sits in different positions in different vowels (Dayme, 2009), moving the tongue would likely affect epiglottis movement due to the biomechanical linkage between the tongue and the epiglottis.

Although this research did not measure air flow directly, the epiglottis movements do show what it appears to be an air flow control from a possible tongue base movement, which is the same result that Kahane (2006) found on his study with bassoonists. It was not the specific objective of this research to investigate the vowel shapes relationship to the laryngeal physiology, however the epiglottis movements during the legato task (no tonguing) appear to be related to tongue base movements and shapes as well. Therefore, it is important for flute teachers and performers to consider in the future mentioning the specific laryngeal factors when discussing articulation. Understanding the link between the epiglottis and the tongue in constructing vowel shapes is a precursor to a deep consideration of the sound that will ultimately be produced.

#### **Pitch control**

There were three tasks involved in the pitch control element of the research, legato, single tonguing, and double tonguing. The findings show strong evidence of true vocal folds adduction and arytenoid adduction in pitch control. However, when it comes to pitch, writers on flute playing do not agree amongst themselves. Toff (1996) is one of the few who support the idea of pitch being internally controlled in what she calls the "size of the oral cavity". This indicates recognition of the parameter of pharyngeal space. As the pharyngeal wall moves the space at the back of the throat gets wider – naturally this impacts on the possible pitches that are available for a flutist to produce on the instrument.

There are other factors outside of the current study's scope at work in pitch control. Some of these are indicated in the work of Debost (2002) and Bastani-Nezhad (2012), who discuss the role of the whole breathing apparatus and lung capacity. Undoubtedly, the flute itself is a major controller of pitch.

Nevertheless, the current study found evidence of laryngeal parameters directly involved in controlling pitch. Some authors (Dick, 1987; Eckley, 1996) propose that pitch controls in flute use the same mechanisms as singers, who moderate pitch with a combination of vocal fold length and thickness and acoustic factors (Dayme, 2009). Eckley (1996) goes further and proposes that flute players should be called "voice professionals" (p. 13). Those statements cannot be completely validated as the research in this thesis shows that flute players have some necessary differences to singers and this study was not totally comparative to the environment of singers. Just because the larynx is used for singing and for flute playing, flutists are not actually making the sound of a note as singers do, rather it is the means of creating air flow that will produce the note on an instrument. There are significant differences between singers' and flute players' techniques.

# **Pedagogical implications**

This research project has found some elements that can now be incorporated into contemporary flute pedagogy. As it could be seen, a number of flute pedagogues used descriptive language to organise ideas for flute students (Taffanel & Gaubert, 1958; Altes 1954; Wye, 1999). This language can now incorporate the findings of this research. Understanding how physical things work will enable teachers a greater range of information and metaphor for use with students. Undoubtedly the traditional flute methods books will continue to be used, however this research now adds a richness to the discussion through its empirical findings. The frustrations I found of

knowing how sound is actually produced are addressed by the research findings. Importantly, the visual element provided in the attached videos will enable teachers to see what is happening rather than using the traditional methods of hearing and imitation. The research also dispels some myths relating to the primacy of the abdomen for control of vibrato, and the role of the tongue for pitch and articulation.

The role of the larynx in pitch, vibrato, dynamics and articulation can be incorporated into one-on-one lessons. The video footage (appended to his thesis) can be used to demonstrate how these features work, and how the student should proceed. Instead of only using modeling as a tool, the teacher can use the visual stimulus.

#### **Teaching vibrato**

This research shows that the vocal folds and the arytenoids are major elements in producing vibrato. Toff (1996) suggests the students could "cough lightly"(p.19) when starting to learn vibrato. The video recordings can provide the right reference for the student with the videos directly associating movements and sound oscillation.

Wilkins (1963) wrote in his method:

I have known a number of accomplished flutists who could not explain the mechanics of vibrato, yet they produced one of a nice, singing quality. They did this naturally and by instinct fell into the correct production. How much better it would be if they knew and were able to explain the mechanics of vibrato the less fortunate students (p. 45).

The results of the present research not only elucidate the mechanics of vibrato questioned by Wilkins, but also provide references (video footage) for the students to use and understand the concept better.

As vibrato is a crucial tool for flute players, the flute repertoire comprises various pieces that can serve as an example of vibrato application. However, understanding how the continuous "wobbling" (cited by the rater in this research) occurs between vocal folds and arytenoids becomes an easier task if vibrato and straight tone (where there is no movement) are shown.

One of the most famous orchestral pieces by Claude Debussy entitled *Afternoon of a Faun* (Figure 15), starts with a flute solo highly debated among flute specialists. There are several difficulties in this solo. Maintaining a stable tone without vibrating continuously is one of the most challenging tasks. Undoubtedly, both the vibrato and straight tone videos would be of great value for the students to help them fully understand what is moving and what is not when he or she is vibrating.





Source: Baxtresser (1995, p.13)

#### **Teaching articulation**

As we could observe from the earlier discussion of language in standard of flute methods, most use description as the main tool to explain these techniques with articulation appearing to receive the most detailed presentation. This is likely because of the different types of articulation.

According to the research results, the epiglottis moves significantly during articulation exercises. The rater comments showed there were movements in both directions (anterior-posterior and posterior-anterior) especially in double-tonguing. Having this level of detail of what happens inside assists with complex technical issues such as double tonging. Knowing how the system behind the lips works provides a deeper appreciation on how flute technique can develop to foster clear articulation.

Teaching tonguing is one of the most difficult tasks for a teacher, since there are so many variations, and it is never easy to tell from the outside what exactly is the student doing. The videos produced by the present results can also assist by providing the students the actual true visual reference of movements related directly to the sound production, giving visual and auditory models at the same time. Moreover, the confirmed participation of the larynx shows that there is more to articulation than just tongue participation, and this visualization through the videos (appended to this thesis) can clarify this to both student and teacher.

The first movement of the *Partita in A-Minor* by J.S. Bach (Figure 16) requires consistent single tonguing articulation from beginning to end. As we have discussed before, the significant epiglottis participation in tonguing appears to be related to the tongue base movements. From start to finish there are no rests which means that the flutist has to work with a constant tongue repetition. From a traditional

standpoint a teacher would be thinking about how the tip of the tongue could work. Consequently, the student will be thinking about the tip of the tongue which will also get somewhat tired through the rehearsal of the work. Knowing that the tongue is part of a system where the epiglottis also contributes to tongue movement, as well as the air flow associated with the other throat actions, changes the way that the student can consider their approach to the musical problem. Like an athlete who will rest their muscles in motion, the flutist will be able to think their body into action when specific techniques are called for. Simply thinking about the system, and then about the tip of the tongue, and then about the system, will perhaps physically change their approach to the interpretation of the passage. This form of thinking will also enable the student to vary their approach, articulation, breath control and hence enable a musical performance that is artistic rather than repetitive. In other works, students may use double tonguing which uses both the tip and the middle of the tongue thereby putting several systems into play at once where the most important element is the air flow.

Figure 16. J.S. Bach, Partita in A-Minor



Source: Bach (1963, p. 2)

#### **Teaching dynamics and pitch control**

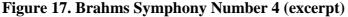
A frequent challenge faced by flute students when learning dynamics is to alter the pitch when trying to produce a *decrescendo* or a *crescendo* which is also related to air flow. As we could see from the results, the epiglottis moves anteriorly during *decrescendo*, and posteriorly during *crescendo*. Although this research did not measure air flow (ie the *amount and speed* of air that passes through the throat) these movements appear to indicate a modification in air flow. Therefore, one should not discuss dynamics and pitch control without including the role of the larynx. The videos of the present research include high and low pitches played in both directions (*crescendo* and *decrescendo*) and may therefore be very useful for teachers and students.

Orchestral excerpts are perfect examples of how the footage can be used in one-on-one teaching of dynamics and pitch control. There are numerous musical examples that could be given. However, perhaps one of the most significant ones is the flute solo of the last movement of the Brahms' Symphony Number 4 (Figure 15). It contains all the elements discussed earlier regarding pitch control and dynamics. The *pianissimo* start in the high register and the constant *crescendos* and *decrescendos* throughout the piece can be directly related to the videos presented in the present research, giving the students another important resource when facing the performance challenges.

When working with a student on this orchestral excerpt the teacher could draw attention to the laryngeal elements present in producing dynamic changes. For instance the feel an idea of the larynx when producing the *pp dim* from measure 92 will be distinctly different when attempting the crescendo/decrescendo moments in

bar 95 at the start of the solo. These same bars can be more secure regarding pitch control as awareness of the adducted vocal folds will change the focus from the lips – again, a concept of embodiment of the theory of system based air flow.





Source: Durichen, C. & Siegfried, K. (1991, p.6)

## **Performance implications (based on recital preparations)**

During the preparation of my three solo recitals, the discoveries of the present research altered drastically my way of executing these techniques. Especially being present at all the tests and watching the videos gave me a clear reference point.

For the second recital, I prepared extremely contrasting pieces. One was *La Folie de Espagne* by Marin Marais (1656–1728) and the other was *La Merle Noir* by Olivier Messiaen (1908–1992). While on the first piece I was striving for a more delicate sound, with little vibrato, on the other I was aiming for wide vibrato on loud and high notes, with very abrupt dynamic changes between low/soft notes and high/loud notes. Instead of the old sound result-based method, I used the laryngeal

videos of flute playing as my reference, with the vocal fold and arytenoid consistent movements as my base images.

My last recital (appended to this thesis) also contained contrasting works. This time, I performed significantly longer and technically demanding pieces. Two examples are the *Chaconne* by Sigfrid Karg-Elert and the *Sonata* by Yuko Uebayashi. While the first called for a consistent sound, with richness and power in the low register, the second required loud playing, soft playing, delicacy, agility all at once.

However, there was one technical factor in common, that made me refer directly to the video footage for clear understanding; the vibrato. Both pieces required a consistent sound throughout, and especially the extreme moments called some times for very fast and wide vibrato, sometimes for slow and narrow or fast and narrow (*pianissimo* passages). Being able to relate my playing directly to the video images made me execute those sections much more easily than before. The arytenoid activity images in particular clarified the vibrato production for me.

Observing the video of the final performance will not *show* what is happening, but listening to the difference between the straight notes (found in the Marais) compared to the vibrato found in the *Chaconne*, demonstrates the power of the research findings. Traditional ways of thinking about support being related to the abdominal muscles can now be extended. Vibrato is not related directly to support (abdominal muscles), but rather to vocal folds and arytenoids adduction and this made a change in the way in which I approached those passages.

The findings of this research make a direct impact on the idea of embodiment in performance. Traditional thinking about sound production has focused on the lips and abdomen, but understanding the complex environment in the larynx also enables me to *change* what happens there deliberately.

#### The hypothesis and aims in relation to performance

The hypothesis and aims of this research included relating musical concepts of vibrato, pitch, range and articulation on the flute to activity of the larynx and pharynx (arytenoid activity, epiglottis movement, vocal folds adduction, pharyngeal wall, and laryngeal height). The goal was to clarify the physiological activity present in flute performing, if any.

Based on the results, it is more than clear that these musical parameters and physiological aspects have much in common. As it has been observed, the vibrato question demonstrates a popular topic of discussion among flute players; however, the other basic parameters involved in flute playing also are crucial in flute performance.

#### **Articulation results: implications**

As it was possible to observe, the epiglottis presented a significant participation in all articulation exercises from the protocol. These epiglottis movements may be caused by the base of the tongue motion, present in tonguing. As it was explained in the pedagogical section, only the fact that there is more to tonguing than only tip of the tongue articulation and air, will already change the performer's view on how to approach the technique.

Looking at the recitals I gave throughout my D.M.A degree it is possible to find several good articulation examples. However, the *Chaconne's* variation XII is probably the most emblematic one (Figure 18).

#### Figure 18. Chaconne variation XII



This short, but challenging variation requires extremely accurate articulation skills. Usually, performers worry about the evenness of the execution, and this is commonly related to the tongue movement; however most of the time only the tip of the tongue is considered. Based on the results and video footage present in this research, the performers should consider the base of the tongue movements the same way they do with the tip/middle of the tongue.

This *Chaconne* variation (figure 18) requires double tonguing. Different from the piece analysed in the pedagogical section (Partita in A-minor by J.S. Bach), this one is much shorter and with double tonguing throughout the whole variation. Although in this case clearly there are more movements than only the tip of the tongue ones, flute players commonly account only for the front (tip) and back (middle) movements.

The results of the present research do show an active and constant participation of the epiglottis throughout the double tonguing exercises, proving that tonguing is in some level related to the larynx. Moreover, it proves that a performer should consider the laryngeal factors when practising and performing purely articulated passages.

#### **Dynamics and pitch results: implications**

As we could see in the pedagogical and results section, it was not the aim of this research to measure air flow. However, from the results presented it appears that the epiglottis anterior and posterior movements during *decrescendo* and *crescendo*  indicate some air flow management. Different from the articulation exercises, in this case it is possible to see a more gradual movement from the epiglottis. Therefore it becomes crucial for the performers to include laryngeal factors into their routines.

The best performance example of pitch and dynamics control from the last recital I gave is the slow movement of Yuko Uebayashi's Sonata for Flute and piano (figure 18). The movement requires great endurance as well as extremely good management of dynamics/pitch, so the *piano* dynamic of the beginning does not sound flat in intonation.



The results of the dynamics exercises did show participation of vocal folds, epiglottis and arytenoids throughout the tasks. When involving soft dynamics, it was possible to observe the epiglottis maintained a posterior configuration and moved slightly anteriorly as the note became softer, the arytenoids abducted as the note became softer along with the vibrato, and the vocal folds presented a completed adduction configuration.

In conclusion, it is vital for performers to become aware of the great participation of the larynx and pharynx in producing dynamics and pitch control techniques during performance. Although these elements cannot easily be observed, there are empirical investigations, such as the present one and the ones cited earlier in the text that can provide performers very useful information on how these processes may occur.

# Conclusion

This research responds to the scarcity of empirically-derived investigative research in flute playing literature. The idea was to create information that may be used as a source for performers and teachers to use as basis for teaching methods, courses, syllabi, and articles. The findings of the research confirm the important involvement of the larynx and pharynx in flute playing, opening the topic to further possible investigations and comparison. The focus of this research was the larynx, not including other possible factors that can contribute to the basic techniques production. Therefore, the investigation may lead into several future studies, for example:

- Similarities and differences between flute players' and the singers' vocal tracts
- The abdominal muscles and the laryngeal movements in flute playing
- The differences and similarities between flute players and bassoon players at the laryngeal level.

There are other possibilities to be investigated, as the internal movements in flute playing are clearly more present than the external ones. Therefore, it is hoped that these unexplored elements receive attention from future researchers to complement the present project towards the full discovery of the body internal movements in flute playing.

The limitations of this research were the inability to see vocal fold activity whilst playing the highest notes due to the epiglottis movement that covered the camera's view. The study did not look at the rate of air flow nor at the moment of the abdominal muscles. Examining these two elements as part of the overall breathing system for flutists would increase understanding of embodied practice. While it is possible to consider how the results of this research may be used for pedagogy, the indications given above are speculative at this stage and based on my own experience of learning and performance. There is opportunity here for further studies relating to pedagogies that may adopt these findings.

The major finding of this research is the way in which the larynx and pharynx work as a system to produce sound through the flute.

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# Appendix A

<u>Frue Vocal Fold Adduction</u>		
	<u>on</u>	
Complete	Partial	None
Movement during the no	ote (circle):Stationary? Yes	/No
f yes, please describe:		
False Vocal Fold Adducti	on	
Complete	Partial	None (Retracted)
		+
Movement during the no	ote (circle):Stationary? Yes	/No
	te (encle).stationary. res	/10
f yes, please describe:		
Larvngeal Height		
High	Neutral	Low
	Neutrai	
Movement during the no	ote (circle):Stationary? Yes	/No
f yes, please describe:		

Wide Open	Partial Closure	Nearly Closed	Closed
·			
Movement during the note (	circle):Stationary? }	Yes/No	
If yes, please describe:			
<u>Epiglottis Movement</u>			
Anterior	Stationar	y Poste	rior (covered)
Movement during the note (	circle):Stationary? \	Yes/No	
If yes, please describe:			
Arytenoid Adduction			
Complete	Partial	No	one
		7 /NT	
Movement during the note (o	circleJ:Stationary	res/no	
If yes, please describe:			

# **Appendix B**



# **Appendix C**

# Pitch Task 1

https://youtu.be/7pi\_erikQqk https://youtu.be/k5SkOW4x5fI https://youtu.be/-0yIBi9KPKg https://youtu.be/tdT7p6P463s https://youtu.be/4e6Sdw65x14

# Pitch Task 2

https://www.youtube.com/watch?v=6YCVk2DQrHY https://www.youtube.com/watch?v=gDkwa0lSHfc https://www.youtube.com/watch?v=8aL5kgPWCXY https://www.youtube.com/watch?v=mQwXMUNR2TQ https://www.youtube.com/watch?v=4KJiCC-Fz1c

# Pitch Task 3

https://www.youtube.com/watch?v=RaccK\_dTN0 https://youtu.be/bbgIBOBq5Jk https://www.youtube.com/watch?v=fCBZAi2sBIY https://www.youtube.com/watch?v=P\_VfqCD0fTY

# Vibrato Task 1 (straight tones)

https://www.youtube.com/watch?v=E3xFWM0\_D\_g https://www.youtube.com/watch?v=YMLwMWxj3Is https://www.youtube.com/watch?v=Qq00WG1FzyM https://www.youtube.com/watch?v=iXQB0DexnwI https://www.youtube.com/watch?v=jKO0q14Ft5E

Vibrato Task 2 (straight tones)

https://www.youtube.com/watch?v=jzz9kaliLoU https://www.youtube.com/watch?v=gaGbnoCx114 https://www.youtube.com/watch?v=gZGlcKaPyig https://www.youtube.com/watch?v=IEzEgLL68qU https://www.youtube.com/watch?v=HpKWlIxGYZg

# Vibrato Task 3

https://www.youtube.com/watch?v=RJ-ZRK\_oHBI https://www.youtube.com/watch?v=yeX63BIZjUs https://www.youtube.com/watch?v=r20qZml1d\_I https://www.youtube.com/watch?v=ULNz5mG0jUU https://www.youtube.com/watch?v=Gn1EkTPTmLM

#### Vibrato Task 4

https://www.youtube.com/watch?v=Woq9eAvyg9c https://www.youtube.com/watch?v=AOEUoikT9og https://www.youtube.com/watch?v=1M1eMTvCdMY https://www.youtube.com/watch?v=dUny1oeOTn0 https://www.youtube.com/watch?v=oW66n\_rL7eg

#### Dynamics Task 1

https://www.youtube.com/watch?v=Pn1sWjmmi\_s https://www.youtube.com/watch?v=0u61F2RAQ30 https://www.youtube.com/watch?v=jHVivRJBReU https://www.youtube.com/watch?v=pwOrRY8N6\_4 https://www.youtube.com/watch?v=TncJQ\_6ITXs

#### Dynamics Task 2

https://www.youtube.com/watch?v=wRqH\_Qc9hTM https://www.youtube.com/watch?v=Jyp\_MmQ11Ww https://www.youtube.com/watch?v=2tvQEBSZDuw https://www.youtube.com/watch?v=Sg\_tJc1hlq0 https://www.youtube.com/watch?v=qhBPknSKMmo

# Dynamics Task 3

https://www.youtube.com/watch?v=q0Ql1q66Gfc https://www.youtube.com/watch?v=wkYhQzK4Rho https://www.youtube.com/watch?v=cPb8C3yqEI8 https://www.youtube.com/watch?v=ghKsHPNI068 https://www.youtube.com/watch?v=4bF\_wnku3vk

# Articulation Task 1

https://www.youtube.com/watch?v=6235GrQOEyM https://www.youtube.com/watch?v=Z2La-zlK9BA https://www.youtube.com/watch?v=2ebuOLCcvMY https://www.youtube.com/watch?v=kmYJg5Y2rNY https://www.youtube.com/watch?v=jYekk7iznpU

# Articulation Task 2

https://www.youtube.com/watch?v=DrvCTBrHXw8 https://www.youtube.com/watch?v=1vUSyUYpPRw https://www.youtube.com/watch?v=X1\_Qsvx0-rA https://www.youtube.com/watch?v=chgw9hGbvAY https://www.youtube.com/watch?v=FXX-70g98yk

# Articulation Task 3

https://www.youtube.com/watch?v=9VCrTYstHAk https://www.youtube.com/watch?v=G8cSs74MpU0 https://www.youtube.com/watch?v=uRBh0C0w-80 https://www.youtube.com/watch?v=PsTEt90ifR0 https://www.youtube.com/watch?v=0KyIEVqioCE

# **Appendix D**



Research Integrity Human Research Ethics Committee

Friday, 29 May 2015

Dr Rowena Cowley

Vocal Studies and Opera Unit; Sydney Conservatorium of Music Email: rowena.cowley@sydney.edu.au

#### Dear Rowena

I am pleased to inform you that the University of Sydney Human Research Ethics Committee (HREC) has approved your project entitled "**The flute inside out: Tracking internal movements in performers**".

Details of the approval are as follows:

# Project No.: 2015/360

#### **Approval Date: 28 May**

2015 First Annual Report

Due: 28 May 2016

#### Authorised Personnel: Cowley Rowena; dos Santos Junior Osvaldo Gomes; Madill Catherine; Novakovic D;

#### **Documents Approved:**

Date Uploaded	Туре	Document Name
26/05/2015	Participant Consent Form	PCF
26/05/2015	Participant Info Statement	PIS
26/05/2015	Advertisements/Flyer	Recruitment Flyer
26/05/2015	Safety Protocol	Safety Protocol
19/04/2015	Recruitment Letter/Email	E-mail to participants
19/04/2015	Study Protocol	Playing Protocol

19/04/2015	Study Protocol	Rating form
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HREC approval is valid for four (4) years from the approval date stated in this letter and is granted pending the following conditions being met:

#### **Condition/s of Approval**

- Continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans.
- Provision of an annual report on this research to the Human Research Ethics Committee from the approval date and at the completion of the study. Failure to submit reports will result in withdrawal of ethics approval for the project.
  - All serious and unexpected adverse events should be reported to the HREC within 72 hours.
  - All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.
  - Any changes to the project including changes to research personnel must be approved by the HREC before the research project can proceed.
  - Note that for student research projects, a copy of this letter must be included in the candidate's thesis.

#### **Chief Investigator / Supervisor's responsibilities:**

- 1. You must retain copies of all signed Consent Forms (if applicable) and provide these to the HREC on request.
- 2. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

R.L. Sharkel

# **Associate Profess Rita Shackel Chair**

Human Research Ethics Committee

This HREC is constituted and operates in accordance with the National Health and

Medical Research Council's (NHMRC) National Statement on Ethical Conduct in

# **Appendix E**

# **CRITICAL NOTES**

My last DMA recital will present pieces by C.P.E Bach, Sigfrid Karg-Elert, Louis Ganne, and Yuko Uebayashi. Along with my recital, my research entitled "The flute inside-out: Tracking internal movements in flute playing", has been completed and will soon be submitted. The research investigated laryngeal/pharyngeal movements in flute playing.

Six laryngeal parameters have been studied: true vocal folds, false vocal folds, laryngeal height, pharyngeal space, epiglottis movements, arytenoids adduction. Five flute players preformed a protocol that included the following musical features: pitch, straight notes, vibrato, dynamics and articulation. The findings demonstrated that the larynx participates actively in controlling the air-flow and managing the production of all techniques in flute playing. Although this empirical study does not relate specifically to any composer, stylistic period, or school; the findings of the research did contribute significantly to how the works were prepared. The strong evidences of the laryngeal movements in flute playing gave not only another important reference, but also a different method of approaching the technical requirements of the different pieces.

C.P.E BACH (1714–1788) Sonata in D major for flute and continuo (Wq 126)

I. Largo II. Allegro III. Vivace Carl Philipp's musical style of composition was clearly influenced by the aesthetic style called *Empfindsamkeit* or *Empfindsamer Stil* (Brown, 1980), a musical language based on the sensibility and emotion expression. This characteristic is very easily noticed in Bach's works by the use of contrasting dynamics, and articulations written by the composer. While the contemporary baroque style of the time was still based on the thought of "Each movement has one emotion", Bach's works were going in the opposite direction by having several emotions in one movement.

C.P.E Bach himself wrote a fragment exposing this idea in the Preface to the *Musikalisches Mancherley*, which includes the A Minor Sonata for flute solo. The text goes: "Music serves either the connoisseur, be he more naturally inclined or more schorlarly ... or it is the language of feeling" (Nastasi, 1983). C.P.E Bach not only incorporated the new style, but he used his previous knowledge to contribute to the new language. It is noticeable how the oratorical style is present in his works. Matching speaking and musical phrases was a common practice by the composers of those days (baroque style). This was one of the attributes that C.P.E Bach brought to his composition style.

The D major sonata was composed in 1738 in Berlin. It is part of a set of six sonatas with *basso continuo*; however, it is the only one with a theme and variations format as the third movement. The first movement is a *Largo* with great participation of the flute in establishing the harmonies through arpeggios, trills and scales. Furthermore, the harmonies of this sonata are not as complex as the ones in later flute works by C.P.E Bach, for example, the two solo sonatas Wq 132 and Wq 134. On the other hand, the ornaments in this first movement in particular are prevalent in both trills and *appoggiatura* forms.

The second movement is a brisk allegro. It presents challenging aspects in different ways. Firstly, the sets of continuous semiquaver and demisemiquaver runs for five or more bars present a breathing challenge for the player. Secondly, the fast pace and the small subdivisions, demand highly technical control as well as precise articulation.

The third movement is extremely demanding from the technical execution point of view. This movement is in a theme and variations format where the flute leads the first variation, and the obbligato in the second. There is a series of semiquaver triplets and regular semi-quavers, demonstrating one more time the similarities between this sonata and later solo sonatas (Wq 132–134).

One aspect of the findings of the laryngeal study applies to the execution of this Sonata. According to the findings, there was a significant presence of laryngeal movements (glottal aperture and epiglottis) across participants in performing straight tones. Furthermore, especially the first movement requires the usage of no vibrato on long notes according to the stylistic characteristics (Quantz, 1966). Therefore, when teaching this piece the tutor will find these results a great tool to explain the mechanics of straight notes production and control.

# YUKO UEBAYASHI Sonata for flute and piano (1958)

I. Lento II.Presto III. Calmato IV. Allegro

The Japanese composer Yuko Uebayashi started her career in Kyoto (Japan). She went to the Kyoto City University of arts and studied with Ryohei Hirose and Komei Abe. However, it was after her university experience that she fell in love with the flute. She worked as an arranger for a Japanese flute orchestra called "Umebueno-Kai"(Chiu, 2016). During a rehearsal of the group, she also was introduced to Nobutaka Shimizu (principal flute of the Kyoto Symphony). By knowing Shimizu, Uebayashi eventually met the French composer and pianist Jean Michel Damase, who was responsible for bringing the Japanese composer to Paris. Uebayashi composed a few pieces for Damase and Shimitsu to perform in Kyoto and Paris, and after those concerts she decided to move to Paris with her family.

It was during her time in France that Uebayashi composed the Sonata for flute and Piano for Jean Ferrandis (French flute player). The piece was composed in 2002 and the premiere was in 2003 in Paris (Chiu, 2016)

The first movement *Lento-Allegro Moderato* follows a typical sonata form with an introduction-exposition-development- recapitulation structure. The start of the piece demands great dynamic control by the flute player as soft and delicate playing is requested. The transition between introduction and exposition(letter B-bar 20) is the perfect example of the dynamic control required:

# Figure 1. mm. 17–21



The *pianissimo* needs to be maintained through the high notes passage in bar 18 before the *crescendo* starts in bar 19 with the tempo change.

The abrupt tempo change in the middle of the development section, presents a highly demanding technical passage for both flute and piano players. While the right hand of the piano holds the melody of the first theme, the flute presents a countermelody based on triplets:

#### Figure 2. mm. 108–111



The second movement of the Sonata is a *scherzo* in a binary form. Here, the challenge is keeping the beat steady between the two instrumentalists. The ensemble factor is also a challenge not only because of the fast pace, but also the interaction between flute and piano parts; the beginning of the movement demonstrates this synchronizing challenge. The piano starts with the first quaver, and the flute plays only the second quaver of the first two bars (off-beats), requiring great ensemble communication:

# Figure 3. mm. 1–5



The third movement is the only genuine slow movement. However, the 6/4 meter and the tempo marking (crochet=96) do not implicate necessarily a slow pace. On the other hand, Uebayashi herself suggested that this tempo could be slower, as long as the feel of "two" is preserved (Chiu, 2016). There are no significant technical challenges on this movement; the difficulty here is the endurance. The dynamic control on high notes is again a factor; however, it is maintaining those long notes with colour and intonation throughout the movement that makes this movement a challenge (see Figure 4).



In total, the movement is six minutes long. The long duration with few breaks is also a significant aspect when it comes to difficulties. The intonation can certainly be affected by the long soft high notes (due to breathing issues), but it can also be affected by the slow pace (endurance).

The last movement starts after eighteen minutes of playing. According to Ueabayashi the first idea was to have an *attaca* transition between third and fourth movement, but Ferrandis (who she wrote the piece for) suggested a small introduction to get himself ready for such an intensive movement (Chiu, 2016). The movement is written in 4/4, in A major and presents a genuine Rondo form (ABACA). The piano presents a complex part from the rhythmical point of view. This makes it harder for the flute player to follow; especially because of the syncopations in the bass part (see Figure 5).

Figure 5. mm. 37–40



# SIGFRID KARG-ELERT Chaconne for Solo Flute (1877-1933)

The majority of Karg-Elert compositions were dedicated to the organ and the harmonium. Sigfird Krg-Elert was born in 1877, and his compositions travel between tonal and atonal works. The interest in writing for the flute came from a period he spent playing oboe in a band during the First World War (diMauro, 2014). Seven out of the eight flute works were composed during this time, including the *Chaconne*. The piece is the last selection of a compilation of thirty caprices and it was written between 1917–1918.

The Chaconne is written in F minor and the form is theme and variations. The theme follows a typical baroque *chaconne* format in 3/4 with four dotted minims as the motif (see Figure 6)





Although the piece starts with a simple melody (reminding of a baroque Chaconne) the variations soon start to show the twentieth century influence with syncopated rhythms, complex harmonic progressions and sudden tempo changes. As the variations increase in number, the technical difficulty increases for the player. Double tonguing, triple tonguing are required in some of the variations:

#### **Figure 7. Variation XI**



**Figure 8. Variation XII** 



Karg-Elert indicates different tempos throughout the variations, demonstrating the intentional change of tempo throughout the piece. The later variations present series of fast notes, requiring extremely high level of execution by the flute player. Moreover, the last variations require the flute player not only to play fast passages but also extremely high notes (C#5 and D5), which makes the ending even more technically demanding for the player.

Because of the intensive dynamics required for the Chaconne, vibrato appears to be an extremely useful tool for the player. The findings of the research (The flute inside-out: Tracking Internal Movements in Flute Playing) on the topic can definitely help in the execution. According to the results, the true vocal folds and the arytenoids adduct and abduct intensively during vibrato. Therefore, to control the intensity and speed of vibrato, it is useful and important to understand this laryngeal participation.

# LOUIS GANNE Andante et scherzo for flute and piano (1862-1923)

Louis Ganne studied with Cesar Franck and Theodore Dubois at the Paris Conservatoire in the end of the XIX century. Besides his composition studies, he worked as a conductor in France. The *Andante et Scherzo* was a piece commissioned to be the *Solo de Concours* for that year of the flute class at the Paris Consertavoire. The *Solo de Concours* pieces were especially commissioned by the Paris Conservatoire teachers to give the students an original work for their final examination of the year. It was required by the teachers that the piece should be challenging and difficult (Cook, 1991).

*Andante et Scherzo* follows the rule of challenge and difficulty very well. It starts with a simple melody as the first theme, but it evolves to more complex motifs and a cadenza at the end of the first movement. This cadenza exposes the flute player to almost all difficulties on the instrument, *pianissimo* ascending arpeggios, fast arpeggios on the second octave and a range that almost covers the whole range of the instrument (C#3 – Bb5).

If the first movement phrasing and cadenza are technically demanding, the second movement demonstrates an even more challenging section. A *scherzo* that starts with the piano, with the flute coming in six bars later. The first theme of the *Scherzo* requires extremely precise articulation to execute the *stacattos* scales and arpeggios. Fast double tonguing is required for this performance. The only tempo change marked at bar 111 (*Un Peu Retenu*), instructing the players to slow down, especially to perform the section a few bars later, where the piano takes over the main

melody and the flute accompanies it by playing variations in the form of demisemiquavers. The section before the recapitulation shows how controlled and secure the flute player needs to be in order to perform it with success. A series of semiquaver arpeggios from third to second octaves alternate between piano and flute without breaks.

The ending of the piece shows the high level of rhythmical precision that is required. Three semiquaver triplet passages from first to third octave on the flute, leading to two quaver chords on the piano all three times, demonstrating also how well synchronized the two players need to be.

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