Humming and Singing While Playing in Clarinet Performance: An Evidence Based Method for Performers and Resource for Composers

by

Jeremy Larkham Ruth

A Research Paper Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Musical Arts

Approved April 2019 by the
Graduate Supervisory Committee:

Joshua T. Gardner, Co-Chair
Robert Spring, Co-Chair
Peter Schmelz
Juliet Weinhold

ARIZONA STATE UNIVERSITY

May 2019

ABSTRACT

Two different techniques utilizing vocalization in clarinet performance were examined through a research study in which one subject (the author) played several tasks utilizing each technique with different played pitches, vocalized pitches, and dynamic levels for each task. The first technique was *singing* while playing, which is also sometimes referred to as growling. This technique is produced by engaging the vocal folds during regular clarinet performance to create a second vocalized pitch that resonates in the oral cavity and exits through the mouthpiece as part of the same air stream as that used by the vibrating reed. The second technique studied was a much more recently pioneered technique that the author has labelled *humming* while playing due to its similarity to traditional humming in vocal pedagogy. This technique is produced by filling the oral cavity with air, sealing it off from the rest of the vocal tract using the tongue and soft palate, and humming through the nasal cavity. The cheeks are simultaneously used to squeeze air into the mouthpiece to maintain the clarinet pitch, much like in the technique of circular breathing.

For the study, audio, nasalance, and intraoral pressure data were collected and analyzed. Audio was analyzed using spectrograms and root mean square measurements of sound pressure for intensity (I_{RMS}). Analysis of the nasalance data confirmed the description of the physiological mechanisms used to generate the humming while playing technique, with nasalance values for this technique far exceeding those for both singing while playing and regular playing. Intraoral pressure data showed significant spikes in pressure during the transitions from the regular air stream to air stored in the oral cavity when humming while playing. Audio analysis showed that the dynamic range of each

technique is similar to that of regular playing, and that each technique produces very different and distinct aural effects.

This information was then used to help create a method to assist performers in learning how to produce both singing and humming while playing and a resource to help educate composers about the possibilities and limitations of each technique.

ACKNOWLEDGEMENTS

I would like to thank Joshua Gardner and Robert Spring for everything that they have done to help, guide, and support me throughout not only this project, but all of my graduate studies. Nobody is better at fostering an environment of exploration and creativity than they are, and I am truly grateful for everything that they do. I would also like to thank the other two members of my committee, Peter Schmelz and Juliet Weinhold, for all of their help with this project.

I would also like to express my gratitude to the other members of The Ambassador Trio, Patrick Englert and Jack Liang, for continuously pushing boundaries and exploring new musical frontiers. I couldn't hope for better colleagues or friends, and with them, I hope to continue to boldly go where no clarinet trio has gone before!

I would like to thank Leslie Moreau for all that she did to push me to the next level in my studies. She is an exceptional teacher, and I never would have made it this far without her guidance and support.

I would also like to thank all of the other great teachers I have had throughout my musical studies. There are far too many to list, but Marcellus Brown, Michael Hall, and Barbara Walker all deserve mention for their great teaching and guidance.

Finally, I would like to thank my parents and my brother for all of their love and support over the years.

TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

CHAPTER 1

INTRODUCTION

While research has been done on clarinet multiphonics achieved through special fingerings and voicing manipulation, very few resources address an alternative technique for producing multiple sounds in clarinet performance—singing while playing. Singing while playing has been researched more extensively in brass pedagogy, but the few resources that address this technique in clarinet performance, such as Ronald Caravan's *Preliminary Exercises and Etudes in Contemporary Techniques for Clarinet*, are limited in scope, and no research has examined the separate, but closely related technique of humming while playing.[1] Both singing and humming while playing utilize the vocal folds to produce a second sounding pitch but differ in how the airstream is used and the chamber in which the vocalized pitches resonate.

The first purpose of this paper is to explain the physiological differences in the production mechanisms for these two techniques and to describe how each technique produces a unique aural effect. Nasalance and intraoral pressure were recorded from one subject (the author) performing several tasks demonstrating each technique. The quantitative data were used to help explain the physiological differences between singing and humming while playing, while spectrograms and root mean square measurements of sound pressure for intensity (I_{RMS}) were taken from the recorded audio of the tasks and examined to help describe how each technique produces a distinct acoustic effect.

[1] Matthew William Haislet, "The Art of Multiphonics: A Progressive Method for Trombone" (DA diss., University of Northern Colorado, 2015), 6; Ronald Caravan, *Preliminary Exercises and Etudes in Contemporary Techniques for Clarinet* (Oswego, NY: Ethos Publications, 1979), 30.

The second purpose of this paper is to utilize the information gathered to create a method that can be used by clarinetists to learn how to produce each technique in performance, in addition to a resource for composers who want to know the technical limitations and acoustic differences between each technique. Since humming while playing is such a new and unexplored technique, particular emphasis is placed on the compositional possibilities and limitations relating to it, along with potential areas of future exploration. By studying these techniques in depth and creating a method and resource, the ultimate goal of this paper is to educate performers and composers alike about the potential acoustic possibilities available to them when using vocalized pitches in clarinet performance.

CHAPTER 2

HISTORY

Vocalized pitches have been used in clarinet performance since at least the early 1920s, although at this time, they were used primarily by jazz clarinetists such as Sidney Bechet, Benny Goodman, and Pee Wee Russell, rather than by prominent Western classical players. These jazz musicians would commonly refer to the technique of singing while playing as "growling," and players who were influenced by the Uptown New Orleans style of jazz made frequent use of it.[2] Bechet was one such player, and his 1923 recording of *Wild Cat Blues* shows an example of his early use of this technique.[3] Other prominent jazz clarinetists such as Goodman and Russell would continue to make use of the technique in the following years, with Russell being particularly noted and sometimes disparaged by critics for using it so heavily.[4]

Although singing while playing was common for jazz clarinetists in the first half of the twentieth century, this technique was rarely used by Western classical players prior to the 1960s. In the 1960s and beyond, however, when experimentation with various clarinet extended techniques became far more common, composers such as William O. Smith and Ronald Caravan began writing works that required the clarinetist to utilize this technique. Smith has written several works for solo clarinet that require singing while

---

[2] Jonathan Robert Hunt, "On the Shoulders of Giants: Bechet, Noone, Goodman and the Efflorescence of Jazz Clarinet and the Improvised Solo" (PhD diss., The University of Adelaide, 2014), 11, https://digital.library.adelaide.edu.au/dspace/bitstream/2440/101783/2/02whole.pdf.

[3] Ibid., 11-13.

[4] Ibid., 40; Robert Hilbert, *Pee Wee Russell: The Life of a Jazzman* (New York: Oxford University Press, 1993), 63.

playing, such as *Fancies for Clarinet Alone*, *Variants for Solo Clarinet*, *Jazz Set for Solo Clarinet*, and *Musing for Three Clarinets*.[5] Caravan has also composed several works that utilize singing while playing, some of which are intended to be used as pedagogical tools to help performers learn the technique. These works, including *Five Duets for One Clarinetist*, *Polychromatic Diversions for Clarinet*, and *Preliminary Exercises and Etudes in Contemporary Techniques for Clarinet* all use the technique of singing while playing to various degrees.[6]

Increased utilization of singing while playing by contemporary classical composers did not, however, lead to a uniformly accepted nomenclature or standard way of notating the technique. One of the most common ways of notating singing while playing is to simply write a second staff and indicate that one staff is the played pitch and the other is the sung pitch, as in Smith's *Variants for Solo Clarinet* and Caravan's *Five Duets for One Clarinetist*, which is shown in Figure 2.1.[7]

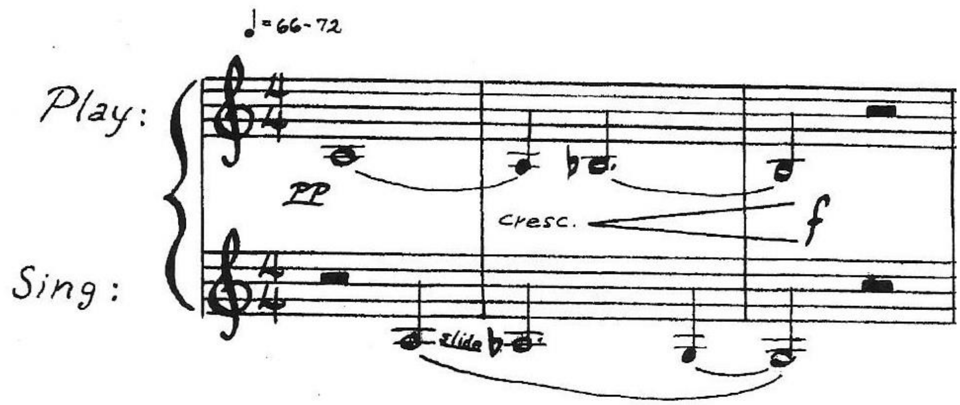
---

[5] William O. Smith, *Fancies for Clarinet Alone* (New York: MJQ, 1972), 5; William O. Smith, *Variants for Solo Clarinet* (London: Universal Edition, 1967), 1; William O. Smith, *Jazz Set for Solo Clarinet* (Rochester, NY: SHALL-u-mo Publications, 1981), 5; William O. Smith, *Musing for Three Clarinets* (Rome: EDI-PAN, 1990), 5.

[6] Ronald Caravan, *Five Duets for One Clarinetist* (Verona, NJ: Seesaw Music, 1976), 1; Ronald Caravan, *Polychromatic Diversions for Clarinet* (Oswego, NY: Ethos Publications, 1979), 11; Caravan, *Preliminary Exercises*, 30.

[7] Smith, *Variants*, 1; Caravan, *Five Duets*, 1.

Figure 2.1. Ronald Caravan, *Five Duets for One Clarinetist*, I., mm. 1-3.



Alternatively, the sung pitch can be notated on the same staff as the played pitch with a label to differentiate the two, as in the third movement of Smith's *Musing for Three Clarinets*, shown in Figure 2.2.[8]

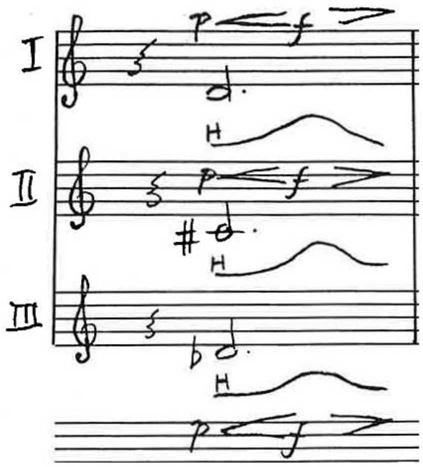
Figure 2.2. William O. Smith, *Musing for Three Clarinets*, III. "Raspy," mm. 1-2.

In both cases, depending on the specific effect the composer wishes to achieve, the sung pitches can be written as specific pitches on the staff or as inexact, graphically notated

[8] Smith, *Musing*, 5.

pitches, such as Smith's graphic notation later on in the third movement of *Musing for Three Clarinets*, shown in Figure 2.3.[9]

Figure 2.3. William O. Smith, *Musing for Three Clarinets*, III. "Raspy," m. 10.



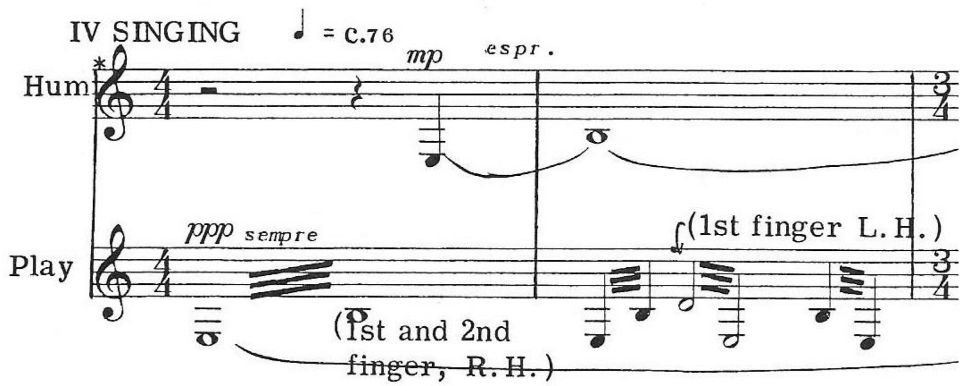
The nomenclature used to refer to this technique has also varied between "singing," "humming," "growling," and simply "voice." In most of Caravan's works that use the technique, such as *Five Duets for One Clarinetist*, he uses a second staff to notate the sung pitches, along with the word "sing" as a label, as shown in Figure 2.1.[10] Smith will often use the same notation standard as Caravan, writing the sung pitch on a second staff, but labeling it "hum," despite wanting the same effect as in Caravan's works. An example of this is found in the fourth movement of Smith's *Jazz Set for Solo Clarinet*, shown in Figure 2.4.

---

[9] Ibid.

[10] Caravan, *Five Duets*, 1.

Figure 2.4. William O. Smith, *Jazz Set for Solo Clarinet,* IV. "Singing," mm. 1-2.



Other composers, such as F. Gerard Errante, use the same dual-staff notation system, but with yet another label, as in *Another Look at October for Solo Clarinet,* where he simply labels the second staff "voice," as shown in Figure 2.5.[11]

Figure 2.5. F. Gerard Errante, *Another Look at Octorber for Solo Clarinet,* mm. 12-13.

Until recently, the lack of nomenclature uniformity when referencing singing while playing had very little room for potential confusion among performers because this was the only known technique that utilized vocalized pitches during clarinet performance. However, a clear distinction must now be made between the traditional technique of singing while playing and the much more recently pioneered technique of humming while playing. To this end, any time *singing* while playing is mentioned in this paper, it

[11] F. Gerard Errante, *Another Look at October for Solo Clarinet* (Verona, NJ: Seesaw Music, 1986), 2.

will refer to the traditional technique of using the same airstream to sing and play simultaneously, regardless of whether or not the composer notates it as a hummed or voice pitch. Any time *humming* while playing is mentioned in this paper, it will refer to the newer technique of humming a pitch using a second, separate airstream to produce an entirely different effect. The reasons behind these particular choices in nomenclature relate directly to the physiological mechanisms for producing each technique, and will be elaborated upon in Chapter 3.

The main reason humming while playing does not already have an established nomenclature is because it was invented so recently that very few performers or composers are aware of it or have developed the ability to produce it. Interestingly, just as clarinet-specific singing while playing has its roots in jazz, the first known mention of the technique of humming while playing comes from jazz trombonist Dick Griffin, who referred to it as "circularphonics," since the technique is similar to the technique of circular breathing.[12] The first clarinetist to utilize the technique of humming while playing is the Swedish virtuoso Martin Fröst. In reference to discovering this technique, Fröst stated:

> I experiment […] the whole time with pushing limits with techniques. I'm switching the […] circular breathing in three steps so I will release my vocal cords, [and] I then can sing normally. This was totally [a] mistake when I realized it. Now, maybe people start to learn it, but when I realized it was possible, no one did it. Of course, people can sing and play by just making sound, but then you destroy the sound and you sound funny. But this was a way [to] separate them totally.[13]

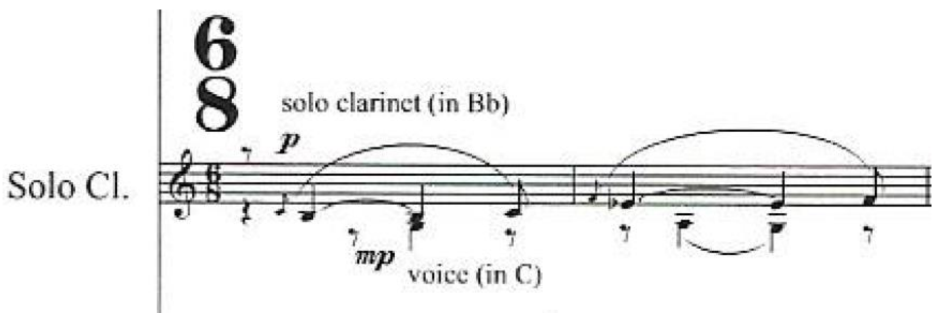
---

[12] Bob Bernotas, "Masterclass with Dick Griffin: Multiphonics on the Trombone," *Online Trombone Journal* (1999): http://trombone.org/articles/library/viewarticles.asp?ArtID=85.

[13] Martin Fröst, interview by Stephen Hetherington, *The OHMI Trust: An Interview with Martin Frost*, November 26, 2011, https://vimeo.com/34971609.

Fröst has played transcriptions utilizing the technique of humming while playing, such as the excerpt from Johann Sebastian Bach's cantata, BWV 156, that he plays in the aforementioned interview, in addition to premiering an original work that requires the technique.[14] While almost no repertoire utilizes humming while playing, Rolf Martinsson's *Concert Fantastique* for clarinet and orchestra is one of the rare examples.[15] Written for Fröst, the work contains three cadenzas for the solo clarinet, the second of which calls for humming while playing.[16] Martinsson uses some of the same notation and nomenclature practices that composers like Errante and Smith use in their writing. He notates the played pitches and the hummed pitches on the same staff, and labels the hummed sections as "voice," as shown in Figure 2.6.

Figure 2.6. Rolf Martinsson, *Concert Fantastique,* mm. 257-258.



Interestingly, in Martinsson's truncated *Suite Fantastique for Clarinet and Piano,* which takes all of its musical content from *Concert Fantastique,* the composer notates the

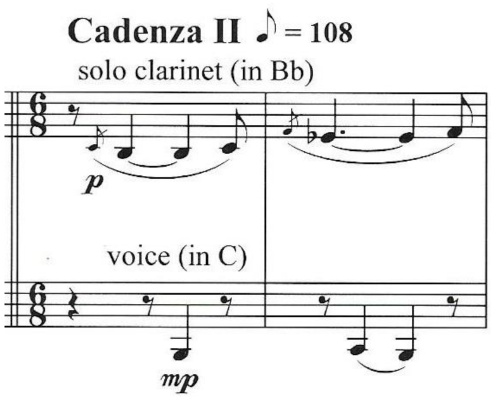
[14] Ibid; Rolf Martinsson, *Concert Fantastique: Clarinet Concerto No. 1, Op. 86* (Stockholm: Gehrmans Musikförlag, 2010), 2.

[15] Ibid.

[16] Ibid., 36.

same section of humming and playing from the second cadenza using dual-staff notation, as shown in Figure 2.7, rather than writing both parts on the same staff.[17]

Figure 2.7. Rolf Martinsson, *Suite Fantastique for Clarinet and Piano*, mm. 117-118.



This similarity in notation and nomenclature between works that incorporate humming while playing and works that utilize singing while playing shows why there is a need to establish standard practices in each area to avoid confusion on the part of the performer, which will be addressed further in Chapter 9.

Compared to the more widespread technique of singing while playing, the relative dearth of repertoire that calls for humming while playing would suggest that this is a technique that requires more research if it is to become more widely used. One of the primary goals of this paper is to provide information that can be used by composers who wish to effectively incorporate this technique into their writing, along with the more common technique of singing while playing.

[17] Rolf Martinsson, *Suite Fantastique for Clarinet and Piano* (Stockholm: Gehrmans Musikförlag, 2011), 11.

CHAPTER 3

PHYSIOLOGICAL MECHANISMS

Overview of Selected Vocal Tract Anatomy

In order to create a method for performers to learn how to sing and hum while playing, it is useful to first explain the underlying physiological mechanisms used in the production of each technique. The main physiological differences between standard clarinet playing, singing while playing, and humming while playing relate to the different resonating chambers used in the vocal tract and whether or not the vocal folds are vibrating. Figure 3.1 shows a sagittal diagram of the human vocal tract for reference.

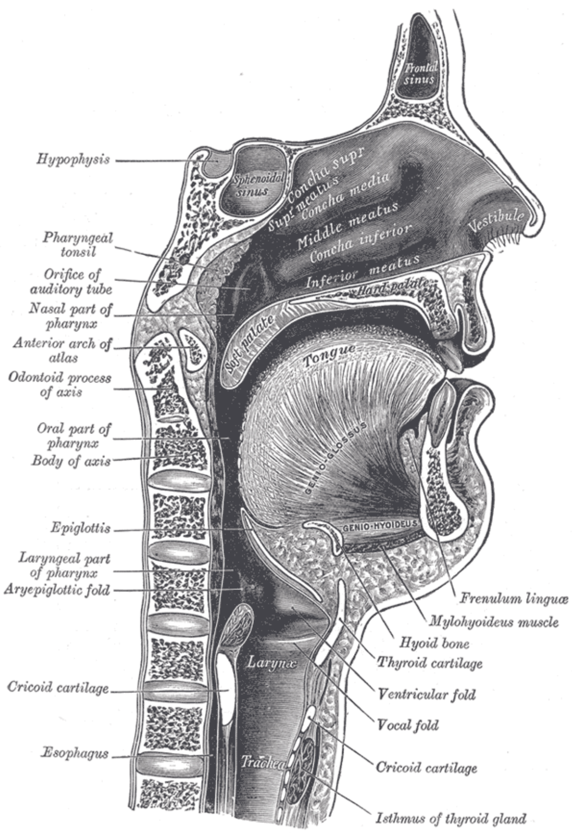


Figure 3.1. Sagittal diagram of the vocal tract.[18]

---

[18] Henry Gray, *Anatomy of the Human Body*, 20th ed., edited by Warren H. Lewis (Philadelphia: Lea & Febiger, 1918), Figure 994.

The primary physiological structures that are relevant for this paper are the oral cavity, the nasal cavity, the pharyngeal cavity, the velum, the velopharyngeal port, the tongue, the larynx, and the vocal folds. The inferiormost of these structures is the larynx, a cartilaginous area that contains the vocal folds, which are bands of muscular and epithelial tissue that extend into the airway and can vibrate when force is placed upon them, producing phonation.[19]

Superior to the vocal folds is the pharynx, or pharyngeal cavity, which is a vertical tube stretching up to the area posterior to the nasal cavity.[20] The pharyngeal cavity is comprised of three sections, each of which is named according to the surrounding structures.[21] The inferiormost section of the pharyngeal cavity is the laryngopharynx, which is superior to the esophagus and posterior to the epiglottis.[22] Directly superior to the laryngopharynx is the oropharynx, which is closest to the oral cavity and bounded on the upper end by the velum and on the lower end by the hyoid bone.[23] The final section of the pharyngeal cavity is the nasopharynx, which is superior to the oropharynx and closest to the nasal cavity.

The nasal cavity is the space that extends horizontally from the nostrils to the nasal choanae, which connect the cavity to the nasopharynx.[24] Similarly, the oral cavity is

---

[19] J. Anthony Seikel, Douglas W. King, and David G. Drumright, *Anatomy and Physiology for Speech, Language, and Hearing,* 3rd ed. (Clifton Park, NY: Thomson Delmar Learning, 2005), 224-229.

[20] Ibid., 317.

[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Ibid., 318.

the space that extends horizontally from the mouth to the faucial pillars and connects to the oropharynx.[25] The superior boundary of the oral cavity is the hard palate in front and the velum in back.[26] The velum is a muscular structure that moves to seal off the oral and nasal cavities from each other.[27] The space posterior to the velum is the velopharyngeal port, which is considered closed when the velum and the pharyngeal walls form a seal, separating the nasal cavity from the rest of the vocal tract.[28] The velum can also form a seal with the tongue to isolate the oral cavity from the rest of the vocal tract.[29]

Mechanics of Clarinet Playing

Closure of the velopharyngeal port is a common occurrence in everyday speech. In fact, /m/, /n/, and /ŋ/ are the only sounds in the English language that are formed using an open velopharyngeal port.[30] The /ŋ/ sound is produced by placing the back of the tongue on the soft palate as if making a /g/ sound, but making the air go through the nose. As in most speech sound production, standard clarinet playing typically utilizes a closed velopharyngeal port to direct all of the air through the oral cavity and into the instrument.[31] Generally, there are only two exceptions to this. The first would be if a

[25] Ibid., 315.

[26] Ibid., 315-316.

[27] Ibid., 316.

[28] Jamie L. Perry, "Anatomy and Physiology of the Velopharyngeal Mechanism," *Seminars in Speech and Language* 32, no. 2 (2011): 84.

[29] Joshua T. Gardner and Eric C. Hansen, *Extreme Clarinet* (Cedartown, GA: Potenza Music, 2012), 10.

[30] Perry, 84.

[31] Christopher Allan Gibson, "The Soft Palate Air Leak in Clarinetists: A Multiple Case Study of Stress Velopharyngeal Insufficiency" (DMA diss., University of Missouri, Kansas City, 1995), 6.

clarinetist is unable to close the velopharyngeal port, allowing air to escape through the nasal cavity in addition to the oral cavity. This air leak is known as velopharyngeal insufficiency, and is a condition that can negatively affect some clarinetists and other wind musicians.[32]

Unlike velopharyngeal insufficiency, however, the second possible instance in which the velopharyngeal port is opened in clarinet performance is an intentional technical choice. This technique is the practice of circular breathing, in which air is stored in the oral cavity while the velum and the tongue come together to seal it from the rest of the vocal tract.[33] By synchronizing the inhalation of air through the nasal cavity with the simultaneous expulsion of the air stored in the oral cavity into the instrument, a clarinetist can inhale while still generating a continuous clarinet sound.[34]

Mechanics of Singing While Playing

The technique of singing while playing utilizes a closed velopharyngeal port, just as in standard clarinet playing. The primary physiological difference between standard playing and singing while playing is simply that the vocal folds are allowed to vibrate in singing while playing. The additional vocal sound generated by the vocal folds then resonates in and exits through the oral cavity, as the nasal cavity is sealed by the closed velopharyngeal port. The energy required to produce this technique, however, is greater

[32] Ibid., 2-3.

[33] Gardner and Hansen, 10.

[34] Ibid.

than with standard clarinet playing—it is very similar to the lip and tongue trills utilized in vocal pedagogy because it requires two sound sources to utilize the same air stream.[35]

With vocal lip and tongue trills, both the vocal folds and the lips or tongue must receive enough air pressure to vibrate properly and produce sound, meaning that the vocalist must learn to balance the pressure allocation so that one is not vibrating at the expense of the other.[36] In the singing while playing technique, the principle remains the same, but the reed takes the place of the lips or tongue as one of the two vibrating sound sources. The clarinetist must similarly learn how to allocate enough air pressure using one air stream to cause both the reed and the vocal folds to vibrate and produce sound.

In addition to this pressure allocation problem, it is also likely that simply inducing vocal fold vibration in singing while playing is more difficult than in normal phonation. This is due to the fact that while subglottal pressure levels in phonation are typically between 0.49 kilopascals (kPa) and 0.98 kPa when excluding atmospheric pressure, the intraoral pressure levels present in standard clarinet playing can be up to six times higher than the upper end of this range, as Chapter 6 will show.[37] This means that not only must the clarinetist allocate enough pressure to cause both the reed and the vocal folds to vibrate, but s/he must also learn to produce vocalized pitches within a much higher-pressure environment than s/he would in normal phonation.

---

[35] Ingo Titze, “Voice Research: Lip and Tongue Trills—What Do They Do for Us?,” *Journal of Singing* 52, no. 3 (January/February 1996): 51.

[36] Ibid.

[37] Kenneth N. Stevens, *Acoustic Phonetics* (Cambridge, MA: The MIT Press, 1998), 35.

The singing while playing technique shares another limitation with vocal lip or tongue trills in that the possible vocal range for these techniques should theoretically be smaller than if the performer was singing without a second sound source. This is due to the phonation threshold pressure—the minimum amount of pressure needed to phonate—needing to be higher as the sung pitch increases.[38] This means that not only must the clarinetist use more air pressure than in standard playing to ensure that both sound sources can vibrate, but s/he must also be prepared to add additional air pressure to account for the higher pressure demands of higher sung pitches.[39] Because of this relationship between higher pitches and increased phonation threshold pressure, the upper end of a performer's vocal range should theoretically be smaller when dividing air pressure between multiple vibrating sound sources, as in singing while playing, than when simply using the air stream to induce vocal fold vibration alone.

Mechanics of Humming While Playing

Humming while playing is physiologically closely related to singing while playing in one significant way: both humming and singing while playing require the vocal folds to vibrate and act as a second sound source in addition to that made by the vibrating reed. Beyond this, the physiological mechanisms used to produce the humming while playing technique share much more in common with circular breathing than with singing while playing. As in circular breathing, humming while playing utilizes an open velopharyngeal port, with the tongue and velum coming together to store air in the oral

[38] Ibid.

[39] Ibid.

cavity and seal it off from the rest of the vocal tract. Similarly, the air stored in the cheeks is then used as the air source to generate the clarinet sound while the rest of the vocal tract is free to operate independently of the oral cavity. As Gardner and Hansen point out, the most challenging part of circular breathing is smoothing the transition from using a regular air stream, as in standard playing, to using air stored in the oral cavity.[40] When the clarinetist has mastered this transition, s/he can then generate a continuous clarinet sound without any perceptible breaks when switching between air supplies.

Humming while playing is identical to circular breathing up to this point, but differs in how it uses the rest of the vocal tract after the tongue and velum seal off the oral cavity. In circular breathing, the clarinetist inhales fresh air through the nasal cavity while expelling the stored air in the oral cavity through the instrument to maintain reed vibration. In humming while playing, the clarinetist does not inhale while the air in the oral cavity is expelled, but instead pushes air out through the nasal cavity while placing enough air pressure on the vocal folds to induce vibration. The result is a hummed pitch that resonates in and exits through the nasal cavity.

One notable difference in theoretical limitations between humming while playing and singing while playing relates to the possible vocal range available for each technique. As previously stated, singing while playing requires the clarinetist to divide the total air pressure in one air stream between two vibrating sound sources, thereby limiting the upper vocal range since the higher pitches require increasingly more pressure. Because humming while playing separates the air source used to generate the clarinet sound from the air source used to generate the vocal sound, the clarinetist can devote all of the

[40] Gardner and Hansen, 10.

available air pressure from the latter source to producing vocal pitches. This means that humming while playing should theoretically offer a higher upper vocal range limit than singing while playing.

Discussion of Nomenclature

The author chose "humming while playing" as the preferred nomenclature for this technique for multiple reasons, but this choice was primarily based on the physiological mechanisms described in this chapter. The only prior mention of this technique that seeks to establish a nomenclature to differentiate it from singing while playing is Dick Griffin's coined term "circularphonics."[41] This is clearly a reference to the similarity between this technique and circular breathing. While this similarity is certainly strong, any term that incorporates the word "circular" has the potential to confuse performers attempting to learn the technique. It is likely that without detailed instructions, performers hearing a word such as "circularphonics" would attempt to generate vocal sounds while inhaling through the nasal cavity and simultaneously expelling air from the sealed off oral cavity, as in circular breathing. To avoid this possible confusion, another term was chosen, which relates both to the physiological mechanisms used to produce it and to existing vocal pedagogy.

As Richard Miller points out, the term "humming" can be used to refer to any "vocal sounds emitted through the nose, rather than through the mouth," which includes the /m/, /n/, and /ŋ/ sounds previously noted as the only sounds in the English language

[41] Bernotas, "Masterclass with Dick Griffin."

that are formed with an open velopharyngeal port.[42] The /ŋ/ sound is particularly relevant here, since production of it entails sealing the oral cavity from the pharyngeal cavity with the velum and tongue, using the nasal cavity as a resonating chamber, and utilizing the nostrils as the exit portals for the vocal sound.[43] This description of humming with a /ŋ/ sound aligns perfectly with the vocal sound production element of humming while playing. The only difference between the two relates to the additional clarinet sound production, as additional air is stored in the cheeks and expelled into the instrument during the act of humming.

Because of the striking similarity in physiological mechanics between this technique and /ŋ/ humming in vocal pedagogy, "humming while playing" was chosen as the preferred nomenclature. The label also creates a clear distinction between this technique and "singing while playing," which is far more similar to traditional singing since it uses the oral cavity as a resonating chamber and allows the vocal sound to exit through the mouth. It should be noted that if these two terms become accepted as the standard nomenclature for the corresponding techniques, performers could potentially be confused about earlier works that call for singing while playing but do not adhere to current standards of nomenclature. Because various works already use "hum," "sing," and "voice" to refer to both the same and different techniques as detailed in Chapter 2, this potential problem would likely arise no matter what standard nomenclature is chosen.

---

[42] Richard Miller, "Sotto Voce: What Does Humming Accomplish," *Journal of Singing* 52, no. 3 (January/February 1996): 49; Perry, 84.

[43] Miller, "Sotto Voce," 49.

Therefore, the author has chosen to simply use labels that physiologically correspond most closely to established techniques in vocal pedagogy.

CHAPTER 4

OVERVIEW OF RESEARCH STUDY

Purpose of Study

The primary objective of this research study is to gather data that can be used to help create a method for performers who wish to learn the techniques studied and a set of guidelines for composers who wish to utilize these techniques in their compositions. Additional data were gathered with the intention of providing evidence to help describe some of the differences in physiological mechanisms between the two techniques, as elaborated upon in Chapter 3.

To these ends, each parameter was chosen for one of two reasons. The first reason was to gather quantitative data that would provide evidence of specific physiological similarities or differences between the techniques. This could then be used to help explain the mechanics of the two techniques and guide the composition of the method for performers. This data would also be of potential benefit in the resource for composers, since it could help define some of the possibilities and limitations inherent in each technique.

The second reason to choose a particular parameter was to analyze the different acoustic effects produced by each technique. This information was primarily intended to be utilized in the set of guidelines for composers, since it would help composers decide what technique to use when they want a particular acoustic effect. Some of the parameters overlapped concerning the reasons why they were chosen, since they might contribute to more than one area. However, every parameter was chosen because it would potentially provide useful information in at least one of these two areas.

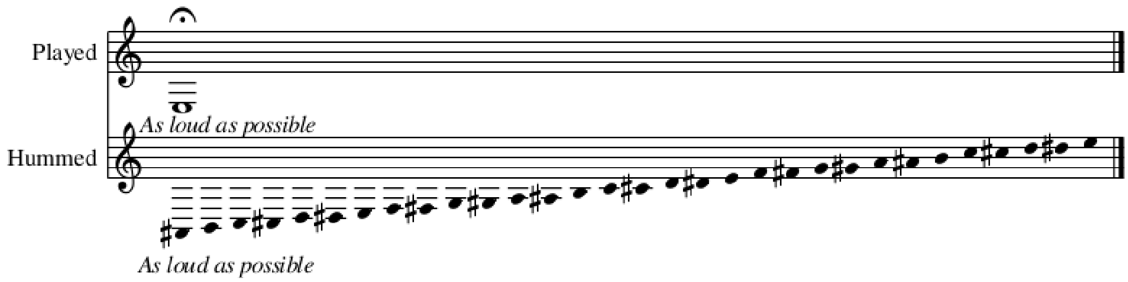
Method and Equipment for Research Study

This research study consisted of one professional clarinetist (the author of this study) performing fifty-nine performance tasks, during which intraoral pressure, nasalance, defined as the ratio of nasal acoustic energy to total acoustic energy, and audio data were recorded simultaneously. Since very few players currently practice the humming while playing technique, only one subject was examined in this study. The first three performance tasks contained no vocalized pitches, but only the following played pitches: E_3, G_4, B_4, C_6, E_6, G_6, and C_7.[44] These tasks were used as a baseline against which all subsequent tasks could be compared. The three tasks were played at soft, medium, and loud dynamics, respectively.

The remaining fifty-six tasks were divided into eight groups of seven tasks each. Every group contained one task for each of the played notes listed above, and each task consisted of the subject playing and holding only one note on the clarinet. In the first group, the subject played as loudly as possible while attempting to hum a chromatic scale as loudly as possible from the lowest to the highest possible hummed notes in his vocal range. Figure 4.1 notates the first task from this group performed by the subject.

[44] Unless otherwise noted, all pitches in this paper, including sung and hummed pitches, are transposed up a major second to correspond to written B-flat clarinet pitches.

Figure 4.1. Performance task for loudly humming while loudly playing E_3.



While the played pitch, vocalized pitch range, vocalized pitch type, and dynamics varied from task to task, Figure 4.1 shows the basic template used for all performance tasks.

The second group used the same outline as the first, but with the subject now humming the notes as softly as possible. The next two groups were identical to the first two, but with the subject playing every task as softly as possible while humming either as loudly or as softly as possible. The final four groups followed the same layout as the first four, with the only difference being that instead of humming while playing, the subject was now singing while playing. The task groups can be visually organized as shown in Table 4.1.

Table 4.1. Performance task groups.

Played Pitches:	Hummed/Sung Pitches:	Task Group:
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Loud, Hum Loud
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Loud, Hum Soft
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Soft, Hum Loud
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Soft, Hum Soft
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Loud, Sing Loud
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Loud, Sing Soft
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Soft, Sing Loud
E_3, G_4, B_4, C_6, E_6, G_6, C_7	Lowest to Highest Possible	Play Soft, Sing Soft

The subject performed the tasks on a Buffet Crampon R13 Greenline B-flat clarinet with a Paulus & Schuler adjustable length, 64 to 67 millimeter (mm) Zoom barrel, a Yamaha 4C mouthpiece, a Yamaha YAC-1601 ligature, and a Gonzalez GD 3¼ strength reed. The mouthpiece was modified by embedding a 1.3 mm (inner diameter; 1.5 mm outer diameter) stainless steel tube in a thin layer of epoxy resin on top of the beak of the mouthpiece, as shown in Figure 4.1.

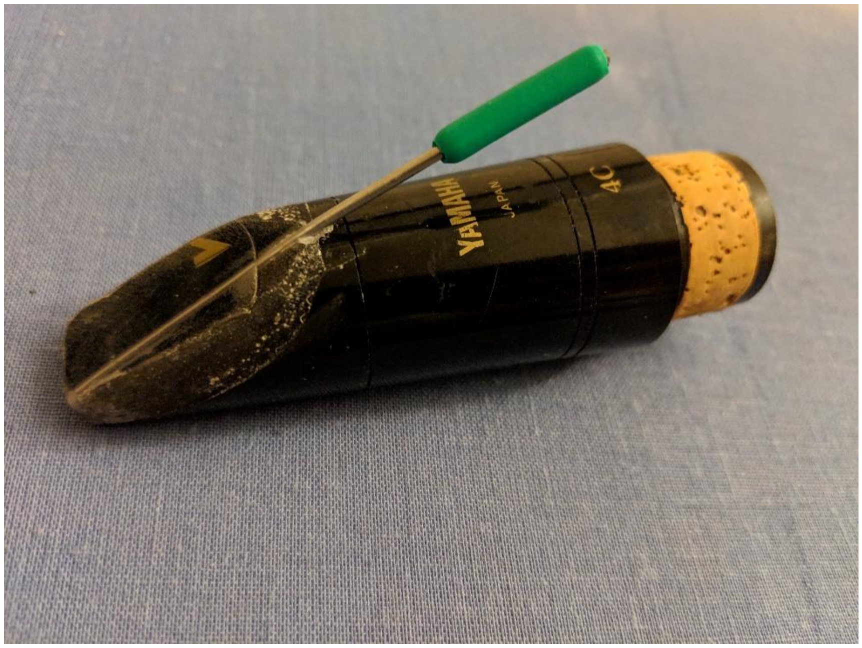


Figure 4.2. Mouthpiece with stainless steel tube embedded in epoxy.

The steel tube was then connected to a Vernier Gas Pressure Sensor connected to a Vernier LabQuest interface. The interface was connected to a MS Windows laptop, and intraoral pressure changes were recorded in kilopascals (kPa) at 1 millisecond (ms) intervals for the duration of every performance task using Vernier's Logger Pro software, which is intended to be used for data collection and analysis with many of Vernier's sensors.[45] After each task was recorded, the intraoral pressure data were exported as comma-separated values (CSV) files for analysis.

Nasalance data were collected using a KayPENTAX Nasometer II 6450 headset strapped to the subject's head, as shown in Figure 4.2.

[45] Vernier Software and Technology (2019), Logger Pro (Computer program), Version 3.9, retrieved February 9, 2019, https://www.vernier.com/products/software/lp/.

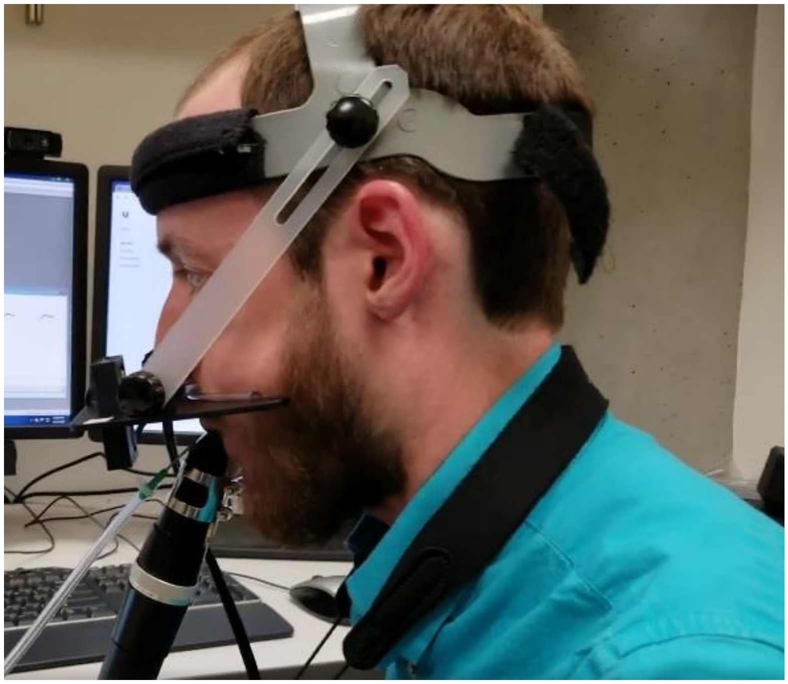


Figure 4.3. Subject wearing the Nasometer headset used in the study.

The data were recorded using Nasometer II software, and changes in nasalance were recorded at 8 ms intervals for every performance task. Nasalance data were exported as text files and converted to CSV files for analysis following the recording of each task.

Audio was recorded through an Earthworks M30 measurement microphone with a Sound Devices USBPre 2 audio interface connected to a MS Windows laptop. The open-source speech and audio analysis application Praat was used to record and export the audio from the performance tasks at 48 kilohertz (kHz) at 16 bits.[46] The audio files were exported as waveform audio (WAV) files for analysis.

Each task began with the subject playing a short D3 loud enough to appear as a distinct event in every parameter. The D3 served as a time stamp marker to synchronize

[46] Paul Boersma and David Weenink, Praat: Doing Phonetics by Computer (Computer program), Version 6.0.47, retrieved February 10, 2019, http://www.praat.org/.

nasalance, intraoral pressure, and audio data. Due to the nasalance data being collected at 8 ms intervals, rather than the 1 ms intervals used in the collection of the intraoral pressure data, there is a margin of error of ± 7 ms for the synchronization of the two parameters.

After synchronizing the data, the author aurally analyzed the audio from each task to identify each hummed or sung pitch in the study. Using the spectrogram view of the audio recording and editing application, Audacity, the starting and ending times of each pitch were then noted for each task.[47] Any repeated hummed or sung pitches and performance errors were removed from all tasks, along with any extended periods of silence, in an effort to keep the visual analyses of the data succinct and focused on the elements discussed in this paper.

Once each parameter was trimmed and labeled, line graphs were generated for each performance task, showing nasalance, intraoral pressure, and all hummed or sung pitches performed during the task. Screenshots of the spectrograms and waveform dB analyses taken from Audacity were then generated and labeled with the aurally identified hummed and sung pitches in each task. The spectrograms were created using a window size of 2048 and a Blackman-Harris window. All of these visual representations of the data gathered are analyzed and discussed in the following chapters. Audacity was also used to extract the root mean square measurements of sound pressure for intensity (I_{RMS}) for certain sections from the audio files of several tasks for analysis. These, rather than the waveform dB analyses, were the basis for the intensity analysis done in Chapter 7.

[47] Audacity Team (2018), Audacity: Free Audio Editor and Recorder (Computer program), Version 2.2.2, retrieved February 10, 2019, https://audacityteam.org.

The waveform dB images were still included in Appendix C as a visual reference, however, as they generally correspond to the more accurate I_{RMS} measurements.

CHAPTER 5

ANALYSIS OF NASALANCE DATA

Purpose of Measuring Nasalance

Nasalance is defined as the ratio of nasal acoustic energy to total nasal and oral acoustic energy, and is expressed as a percentage.[48] This is calculated by dividing the nasal acoustic energy by the sum of the nasal and oral acoustic energy, then multiplying the quotient by 100.[49] Nasalance data are typically used by speech pathologists, otolaryngologists, and plastic surgeons and can help evaluate various velopharyngeal disorders.[50]

In this study, however, nasalance data were collected for the primary purpose of identifying the differences in physiological mechanics between the techniques of humming while playing and singing while playing, as elaborated upon in Chapter 3. Since one of the primary perceived differences between the two techniques relates to the resonating chambers used for the vocalized sounds, it would logically follow that a device capable of measuring nasalance would provide quantitative evidence as to whether or not each of these techniques uses the nasal cavity as a resonating chamber. All of the nasalance data referenced in this chapter are taken from the graphs found in Appendix A, encompassing Figures A.1 through A.59.

---

[48] *Nasometer II: Model 6450*, Informational brochure (Lincoln Park, NJ: KayPENTAX), 2.

[49] Gillian de Boer and Tim Bressmann, "Comparison of Nasalance Scores Obtained With the Nasometers 6200 and 6450," *The Cleft Palate-Craniofacial Journal* 51, no. 1 (January 2014): 90.

[50] *Nasometer II*, Informational brochure (Montvale, NJ: PENTAX Medical, 2016), 2.

Potential Difficulties with Nasalance Data

Two issues need to be considered when analyzing the nasalance data collected in this study. First, the Nasometer experienced recording errors during three of the fifty-nine performance tasks. One of these tasks, in which the subject played a C_7 as softly as possible and hummed as loudly as possible, as shown in Figure A.24, did not record any nasalance data. The other two tasks with recording errors are found in Figure A.23 and Figure A.30. In Figure A.23, the subject played a G_6 as softly as possible and hummed as loudly as possible, while in Figure A.30, the subject played a G_6 as softly as possible and hummed as softly as possible. Nasalance data for these two tasks did not begin to record until partway through the performance tasks and could not be synchronized using the same D_3 synchronization note as in every other task. However, the nasalance data for these two tasks did appear to align with the pressure data when they were synchronized using the point where pressure returned to atmospheric levels and nasalance dropped to zero for the last time. Because of this, nasalance data for these two tasks are still included in the graphs, although they will not be utilized in this paper.

The second potential difficulty when analyzing the nasalance data relates to how the Nasometer collects data. The Nasometer headset utilizes a large plate that divides the oral cavity from the nasal cavity and contains microphones on either side that are used to measure oral and nasal acoustic energy.[51] Since the Nasometer is designed for use with speech and not clarinet playing, the acoustic energy generated from the played clarinet pitches can potentially be greater than the device was designed to measure. Therefore, when certain tasks are played particularly loudly or sound exits the clarinet through tone

---

[51] *Nasometer II: Model 6450*, 2.

holes closer to the headset, the upper nasal microphone could potentially pick up the clarinet sound, which would produce a higher nasalance value than is actually being produced by nasal acoustic energy. Tasks that did not have any acoustic energy emanating from the nasal cavity could still appear to have some low-level nasalance readings due to this contamination from the clarinet sound.

A similar problem may occur when sound exits the clarinet at a greater distance from the microphone or when particularly soft tasks are played in combination with high levels of nasal acoustic energy. The nasal microphone would pick up the nasal acoustic energy as it normally would in speech analysis, but the oral microphone might not capture the clarinet sound as accurately as it would a speech sound. This could potentially result in tasks with high nasalance ratios appearing to be even higher than they actually are. While this means that the nasalance measurements may not be precise ratios of the actual nasal acoustic energy to the total acoustic energy, the nasalance data should still show clear differences between tasks with generally high nasalance levels and tasks with generally low nasalance levels. This distinction alone can be extremely useful in showing relative nasalance levels between tasks utilizing the same played pitch and in showing any overarching trends between task groups, even without precisely accurate nasalance measurements.

Analysis of Nasalance Data

The nasalance analysis will focus on the average nasalance values recorded while singing or humming pitches in each task. Even with the potential errors discussed in the previous section, averaging the nasalance values recorded in each task should show if there are any large trends that can help differentiate humming while playing from singing while playing.

The first three tasks, shown in Figures 5.1 through 5.3, consisted of only pitches played on the clarinet at loud, medium, and soft dynamics, respectively. Since standard clarinet playing should not produce any nasal acoustic energy, the nasalance readings from the played pitches in these three tasks serve as a baseline against which all subsequent tasks are compared. Any readings above 0% can be attributed to nasal microphone contamination, as outlined in the previous section.

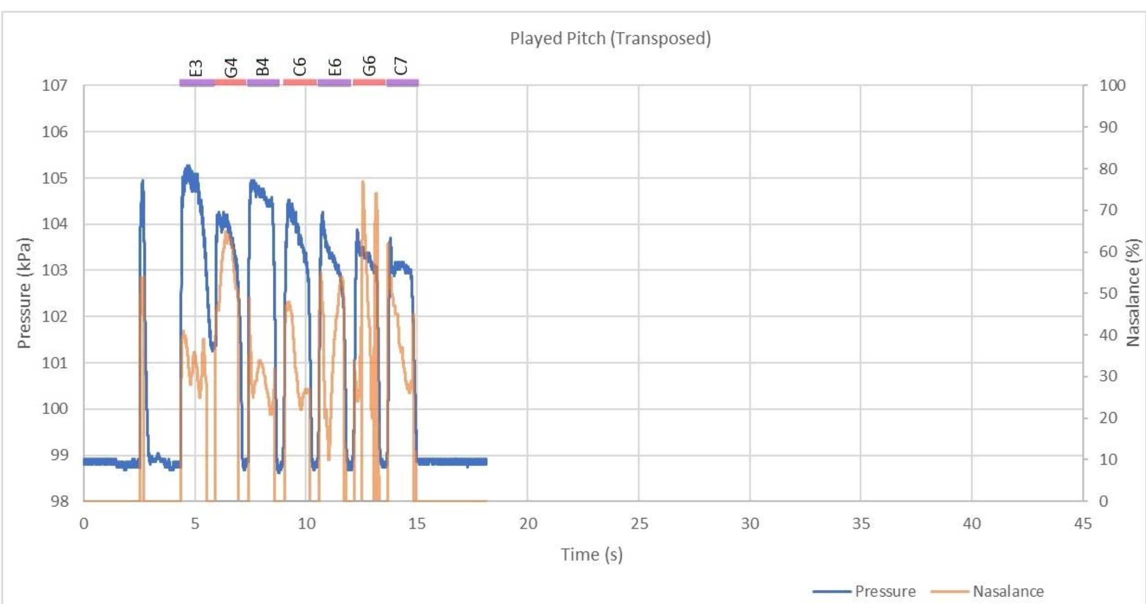


Figure 5.1. Pressure and nasalance graph, play loud, no vocalization, all pitches.

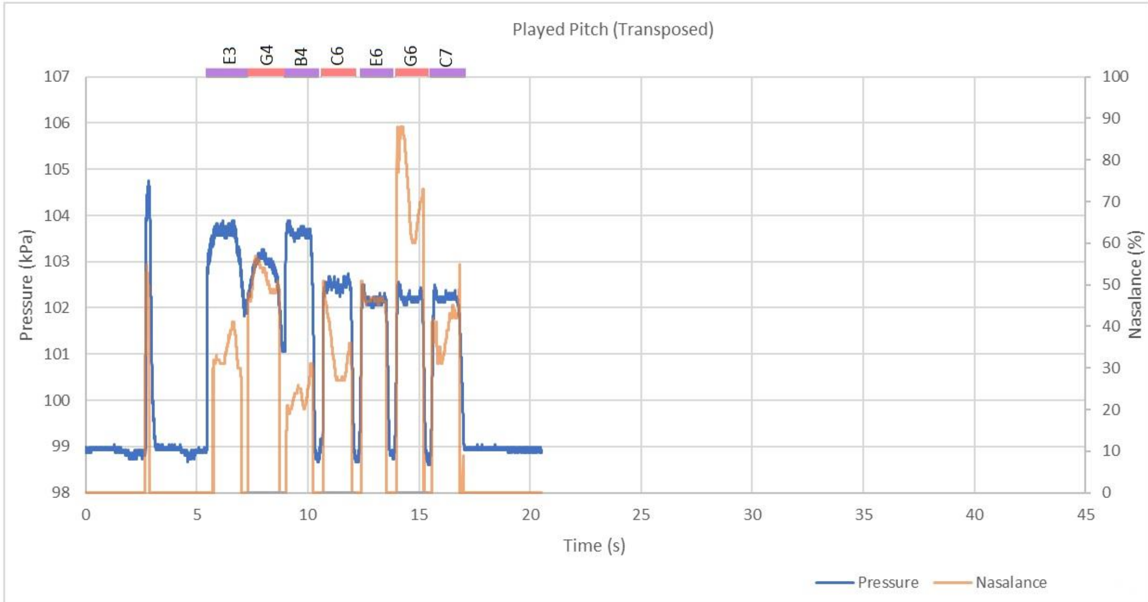


Figure 5.2. Pressure and nasalance graph, play medium, no vocalization, all pitches.

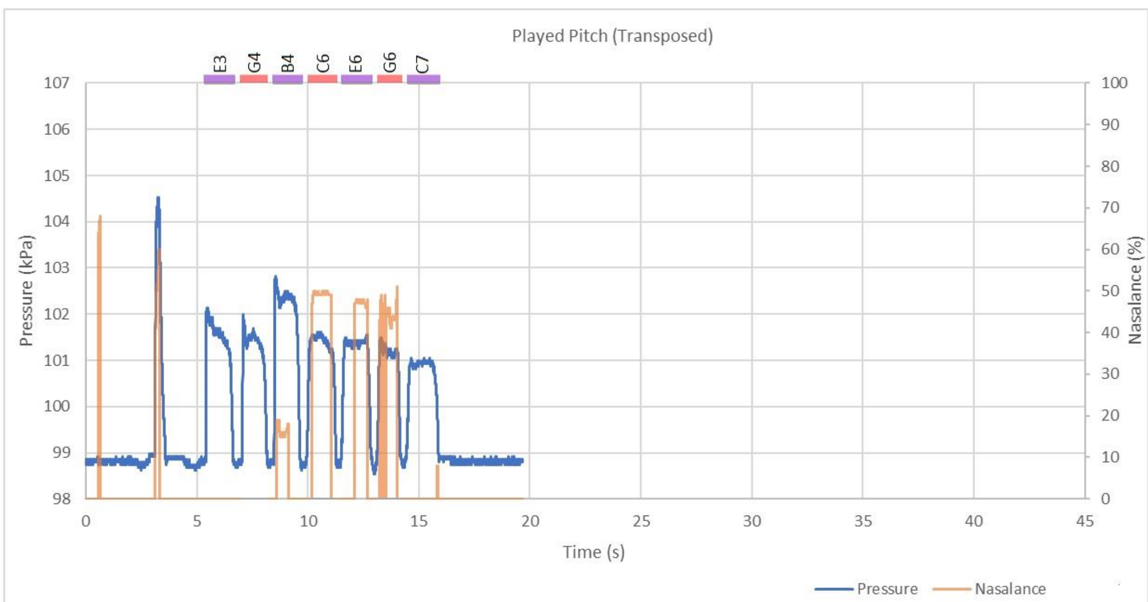


Figure 5.3. Pressure and nasalance graph, play soft, no vocalization, all pitches.

All of the pitches played in Figures 5.1 and 5.2 produced nasalance values above 0%, while only four of the seven pitches played in Figure 5.3 produced nasalance values over 0% for an extended duration. The majority of the pitches played in Figure 5.1 have very similar nasalance value averages to those played in Figure 5.2, while almost every corresponding pitch in Figure 5.3 is much lower than the first two. This is easily explained by the idea that loudly played pitches produce more microphone contamination than softly played pitches, likely causing the softly played tasks to produce more accurate nasal acoustic energy measurements than the loudly played tasks. Additionally, different pitches produced significantly different nasalance values across dynamic ranges, showing that certain notes, such as G_6, were either picked up more easily by the nasal microphone or were simply played louder than others by the subject. Figure 5.4 shows the average nasalance values for every pitch recorded in Figures 5.1, 5.2, and 5.3.

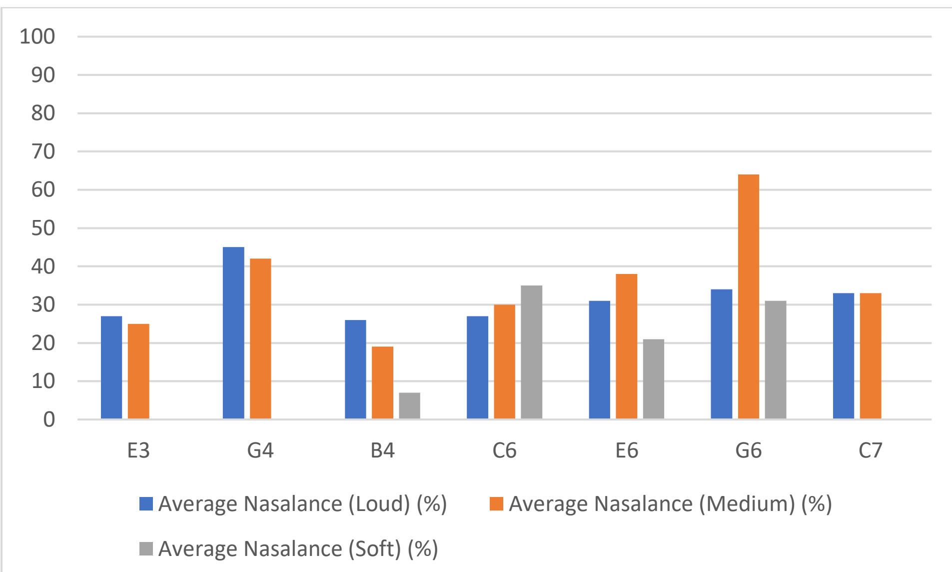


Figure 5.4. Average nasalance values for played pitches.[52]

The next four task groups, shown in Figures A.4 through A.31, all use the humming while playing technique. Due to the physiological mechanics of this technique, the average nasalance values for these tasks should be significantly greater than the

[52] E_3, G_4, and C_7 all produced average nasalance values of 0%.

average values for standard playing that will act as the baseline for comparison. Figure 5.5 shows the average nasalance values during humming for every played pitch in Figures A.4 through A.32.

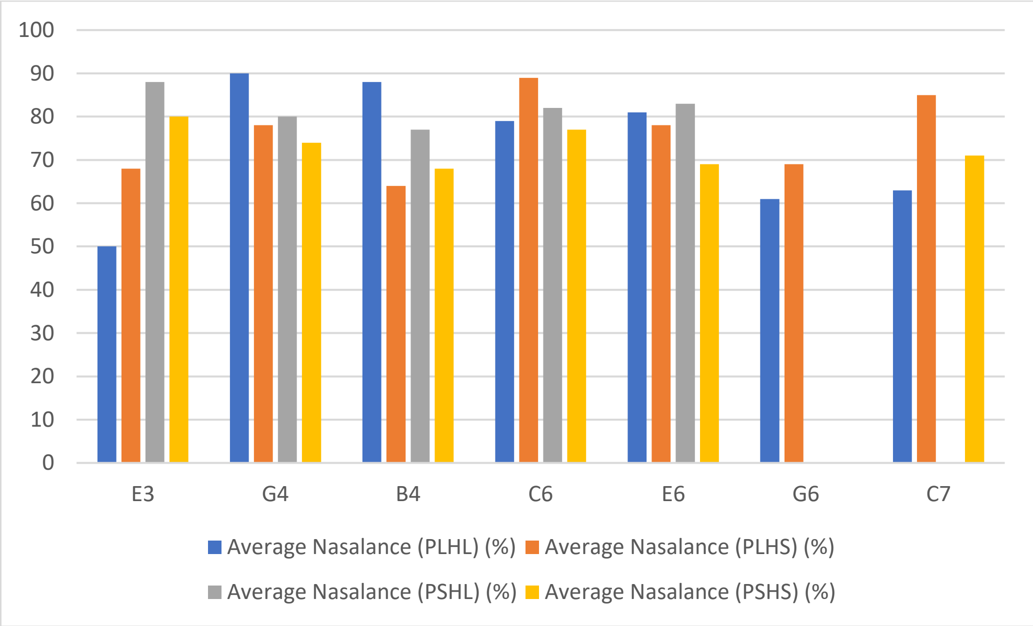


Figure 5.5. Average nasalance during humming while playing. [53]

As expected, nearly every task utilizing humming while playing shows a greater average nasalance value than any of the corresponding tasks with the same played pitch without vocalization. Even when comparing the hummed task with the lowest average nasalance value on a given note to the baseline task with the highest average nasalance value on a given note, all but one task show a difference of at least 23%. The one exception is the group of hummed G_6 tasks, which are much closer to the G_6 task played without vocalization at a medium dynamic. The 64% average nasalance value in the latter

[53] Tasks are abbreviated to PLHL for play loud, hum loud, PLHS for play soft, hum soft, PSHL for play soft, hum loud, and PSHS for play soft, hum soft; Nasalance values for PSHL and PSHS for G_6 and PSHL for C_7 are omitted due to the recording errors outlined in the previous section.

task is an outlier, however, since it is the only played pitch out of the twenty-one pitches recorded without vocalization that produced an average nasalance value greater than 45%.

The next four task groups examined were the tasks utilizing the singing while playing technique, shown in Figures A.32 through A.59. Since the physiological mechanisms behind singing while playing do not utilize the nasal cavity and should not generate any nasal acoustic energy, the average nasalance values for these tasks should closely match the average nasalance values for the corresponding pitches played in the tasks used for baseline comparisons. Figure 5.6 shows the average nasalance values during singing for every played pitch in Figures A.32 through A.59.

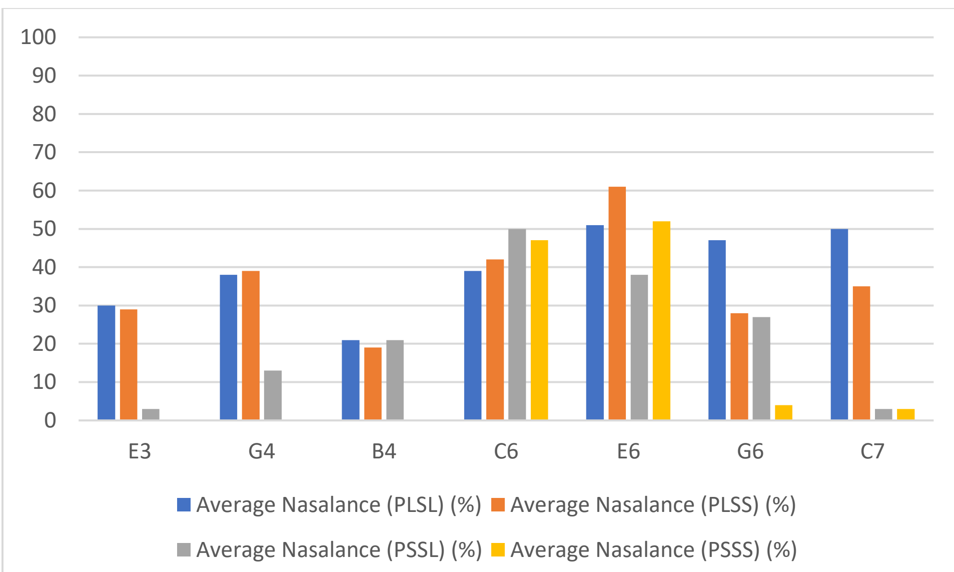


Figure 5.6. Average nasalance during singing while playing. [54]

[54] Tasks are abbreviated to PLSL for play loud, sing loud, PLSS for play loud, sing soft, PSSL for play soft, sing loud, and PSSS for play soft, sing soft; E_3, G_4, and B_4 all produced average nasalance values of 0% for PSSS.

The majority of average nasalance values during singing while playing align with the expected results, matching closely with the baseline measurements from Figure 5.4. Five of the seven pitches from the tasks utilizing singing while playing have results that are within 20% of the corresponding average nasalance values from the baseline pitches at similar dynamic levels, and many of these are within 10%. The outliers in the singing while playing task groups are E_6 and G_6, which deviate from their corresponding baseline pitches by a maximum of 31% and 36%, respectively. These wider differences could be attributed to outliers like the medium dynamic G_6 from Figure 5.4 skewing the results. In an effort to minimize the impact of these outliers, the nasalance values from all of the tasks were grouped together based on pitch and technique used, and then averaged to create an overall average, as shown in Figure 5.7.

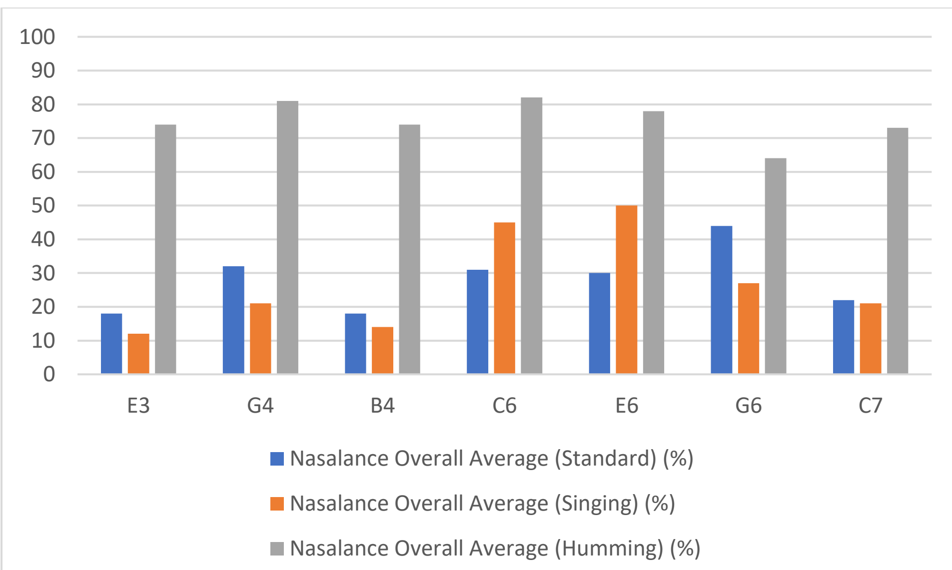


Figure 5.7. Overall average of nasalance values.

The results in Figure 5.7 come much closer to showing the expected relationship in nasalance values between the three playing techniques. Standard playing and singing while playing are very closely related, since the difference in average nasalance values between the two techniques varies from 1% to 20% by played pitch. In contrast, humming while playing generally has far greater nasalance values than the other two techniques. The average nasalance value for hummed pitches exceeds the average nasalance value for the corresponding played pitches without vocalization by anywhere from 22% to 57%, depending on the played pitch. When making the same comparison between hummed and sung pitches, the hummed pitches exceed the sung pitches by anywhere from 20% to 56%.

Finally, mean nasalance for each technique across all pitches are 27% for standard playing, 27% for singing while playing, and 76% for humming while playing, as shown in Figure 5.8.

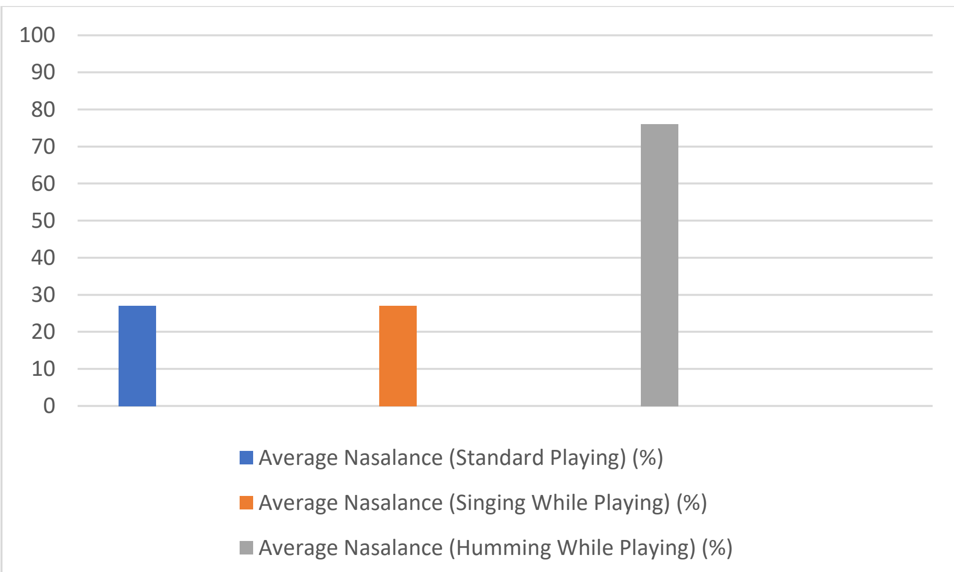


Figure 5.8. Overall average of nasalance values for all pitches.

This is perhaps the clearest evidence that humming while playing uses nasal acoustic energy to produce the hummed pitch, exceeding the baseline average nasalance value for standard playing by 49%. In contrast, singing while playing produced identical average nasalance values to standard playing. This shows that the singing while playing technique does not generate any nasal acoustic energy and helps to confirm the explanation of the physiological mechanisms behind each technique elaborated upon in Chapter 3.

CHAPTER 6

ANALYSIS OF INTRAORAL PRESSURE DATA

Purpose of Measuring Intraoral Pressure

Intraoral pressure is defined as the "quantifiable measure of force exerted on the surface area of the oral cavity" and can be altered by adjusting the volume of air used or by changing the resistance to the air stream exiting the mouth.[55] Intraoral pressure during woodwind and brass playing have been measured by researchers such as Micah Bowling, Jonathan Kruger, Mark Kruger, and James McLean, although none of these studies have included measurements taken during singing or humming while playing.[56]

Because different played pitches on the clarinet can offer different levels of resistance, the intraoral pressure levels are expected to shift somewhat from one pitch to another. By examining intraoral pressure across techniques on the same played pitch, some of the differences and difficulties involved with the production of each technique can become more apparent. The pressure data can be analyzed both throughout the played range of the instrument and throughout the hummed or sung vocal range of the performer.

Of particular interest in this study are any notable changes in intraoral pressure during humming while playing. Any time the clarinetist transitions from the primary air stream, as in standard playing, to the air stored in the oral cavity, as is typically used in

---

[55] Micah Bowling, "Intraoral Pressure and Sound Pressure During Woodwind Performance" (DMA diss., University of North Texas, 2016), 7.

[56] Ibid; Jonathan Kruger, James McLean, and Mark Kruger, "More Air, Less Air, What Is Air?" *ITG Journal* 36, no. 3 (March 2012): 12.

the circular breathing technique, likely produces an intraoral pressure change. Since smoothly making this transition is often regarded as the most difficult element of circular breathing to master, any data gathered showing changes in intraoral pressure during humming while playing should help explain possible changes the performer should make to aid in the execution of the technique on different played notes throughout the range of the clarinet.[57] All of the intraoral pressure data referenced in this chapter are taken from the graphs found in Appendix A, encompassing Figures A.1 through A.59.

Analysis of Intraoral Pressure Data

The analysis of the intraoral pressure data will focus on both the average and peak intraoral pressure levels produced in kilopascals (kPa) during humming or singing while playing for each task from Figures A.4 through A.59. These levels will be compared against the baseline measurements taken from Figures A.1 through A.3, in which each pitch was played without vocalization. By examining average intraoral pressure levels, the goal for this analysis is to determine whether the overall pressure levels change or remain relatively constant across techniques.

Additionally, peak intraoral pressure levels will be examined to determine if there are spikes in intraoral pressure, particularly during humming while playing. Figures 6.1 and 6.2 show the average and peak intraoral pressure levels during standard clarinet playing at various dynamic levels and will be used as the baseline against which all subsequent pressure measurements will be compared. Atmospheric pressure levels

[57] Gardner and Hansen, 10.

recorded at a nearby weather station in Phoenix, Arizona on the date of the study have also been included in Figures 6.1 and 6.2 for reference. [58]

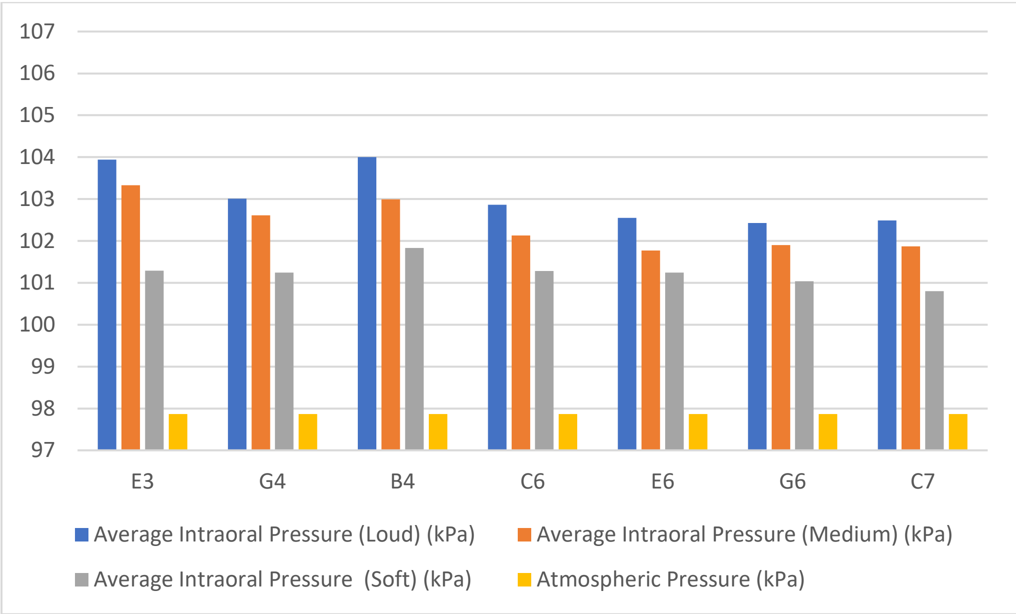


Figure 6.1. Average intraoral pressure levels for played pitches.

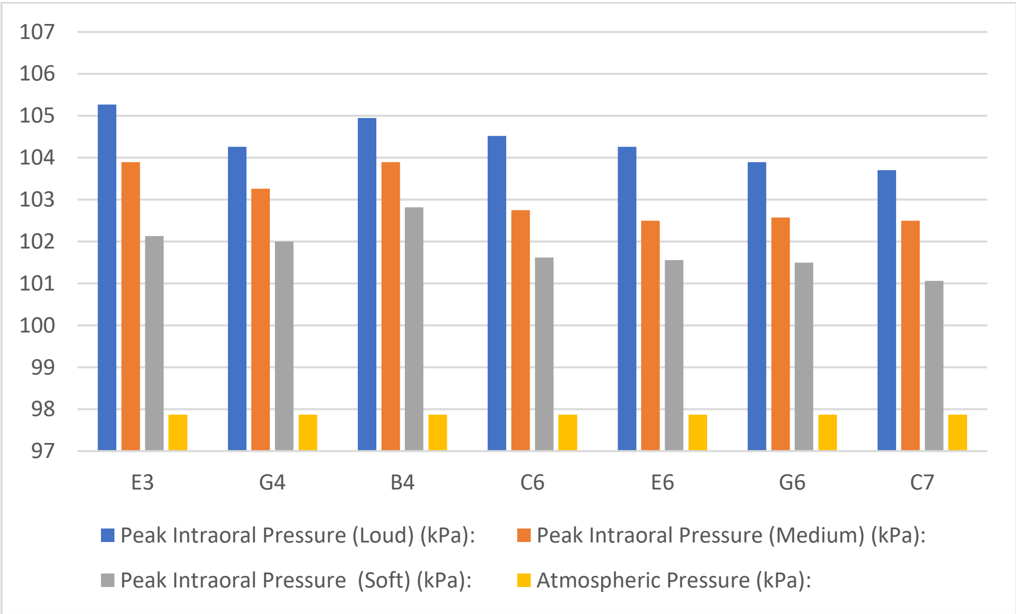


Figure 6.2. Peak intraoral pressure levels for played pitches.

[58] "Phoenix Sky Harbor International Airport, Arizona," Weather Underground, retrieved March 22, 2019, https://www.wunderground.com/history/daily/us/az/phoenix/KPHX/date/2018-12-4.

As Figures 6.1 and 6.2 show, the intraoral pressure of each played pitch decreases as the dynamic gets softer. Previous studies of intraoral pressure in brass playing showed the same relationship between intraoral pressure and dynamic intensity, so this was not a surprising result.[59] Also as expected, certain played pitches such as E_3 and B_4 showed higher levels of intraoral pressure, likely as the result of greater resistance from the clarinet when using the full bore length. Additionally, the peak intraoral pressure for the baseline measurements tend not to spike particularly high, with each peak value exceeding the average by 1.71 kPa or less.

The next four task groups, shown in Figures A.4 through A.31, all use the humming while playing technique. As noted in the previous section, intraoral pressure for humming while playing is expected to show a noticeable change when transitioning from the main air stream to air stored in the cheeks. Figures 6.3 and 6.4 show average and peak intraoral pressure during humming while playing at various dynamic levels for all played pitches.

[59] Kruger, McLean, and Kruger, 12.

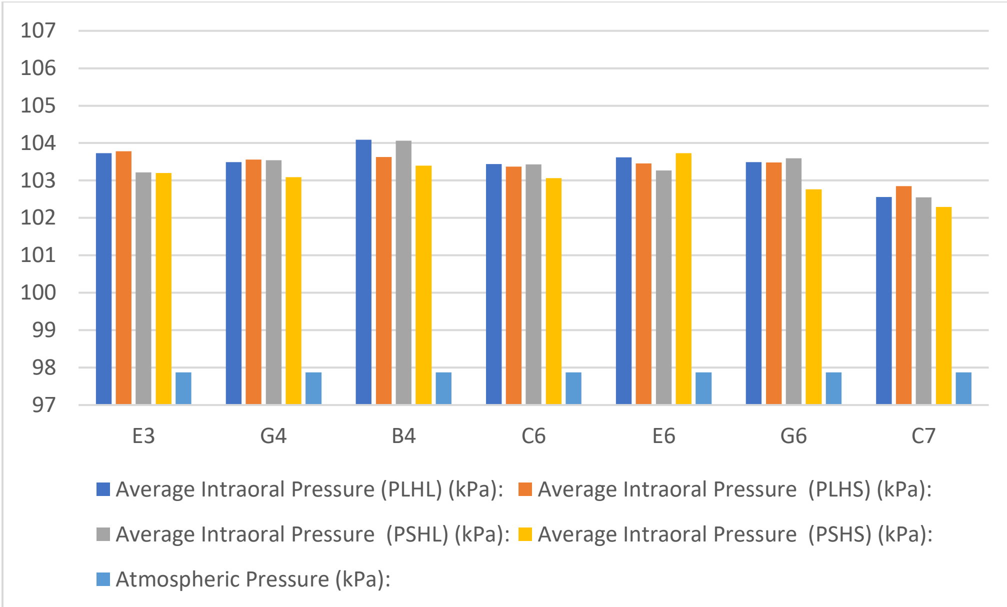


Figure 6.3. Average intraoral pressure during humming while playing. [60]

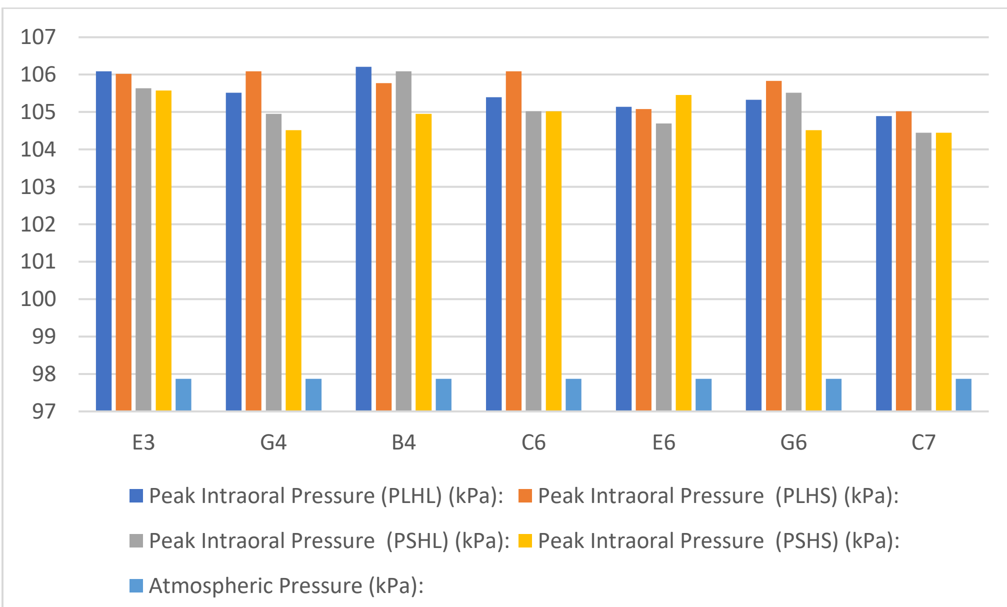


Figure 6.4. Peak intraoral pressure during humming while playing.

[60] Tasks are abbreviated to PLHL for play loud, hum loud, PLHS for play loud, hum soft, PSHL for play soft, hum loud, and PSHS for play soft, hum soft.

Before comparing the average intraoral pressure values for humming while playing to the baseline values without vocalization, one difference is quite apparent. While standard playing consistently showed the expected decrease in intraoral pressure from loudly played tasks to softly played tasks, the average intraoral pressure levels during humming while playing show relatively little change from loud to soft dynamics on the same played pitches, and sometimes even increase slightly at softer dynamics. This could be attributed to the subject inadvertently increasing his embouchure pressure, thereby closing the aperture between the reed and the mouthpiece and increasing intraoral pressure as a result.

The tasks including humming while playing loudly produce very similar intraoral pressure to their corresponding loudly played tasks without vocalization. These tasks with humming while playing deviate from the corresponding baseline tasks by anywhere from 0.09 kPa to 1.07 kPa, although ten of the fourteen tasks deviate by less than 0.58 kPa. The four that deviate by more than 0.58 kPa are all from the pitches E_6 and G_6. Figure 6.5 highlights these differences in average intraoral pressure between the loudly played tasks using humming while playing and the corresponding loudly played baseline task by subtracting atmospheric pressure from each intraoral pressure measurement.

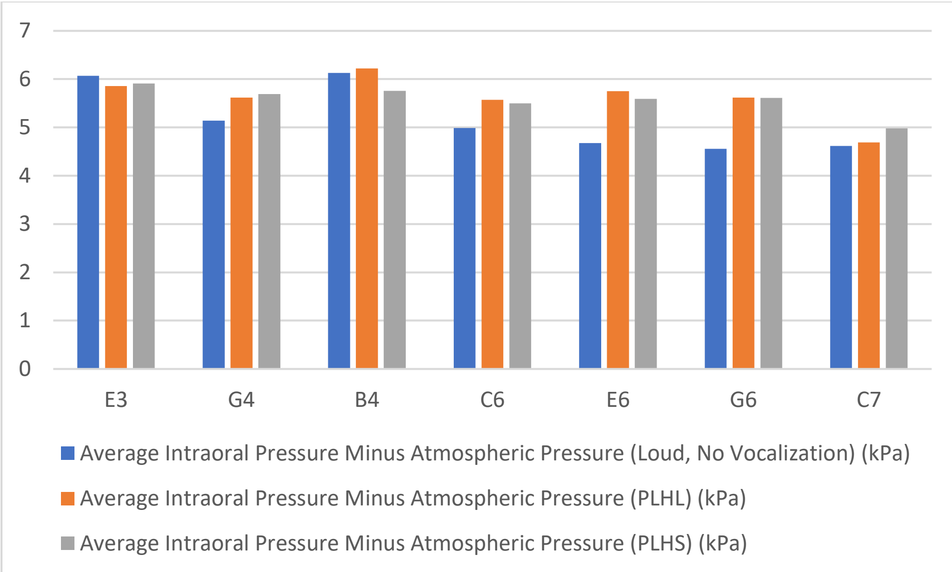


Figure 6.5. Average intraoral pressure minus atmospheric pressure for loudly played tasks utilizing humming while playing.

When comparing the average intraoral pressure results from the softly played tasks using humming while playing to their baseline counterparts, however, the difference is far greater. All of the softly played tasks using humming while playing produced greater intraoral pressure values than the tasks without vocalization, and the difference between the two varied from 1.49 kPa to 2.55 kPa, as shown in Figure 6.6, subtracting atmospheric pressure from each task to highlight the differences.

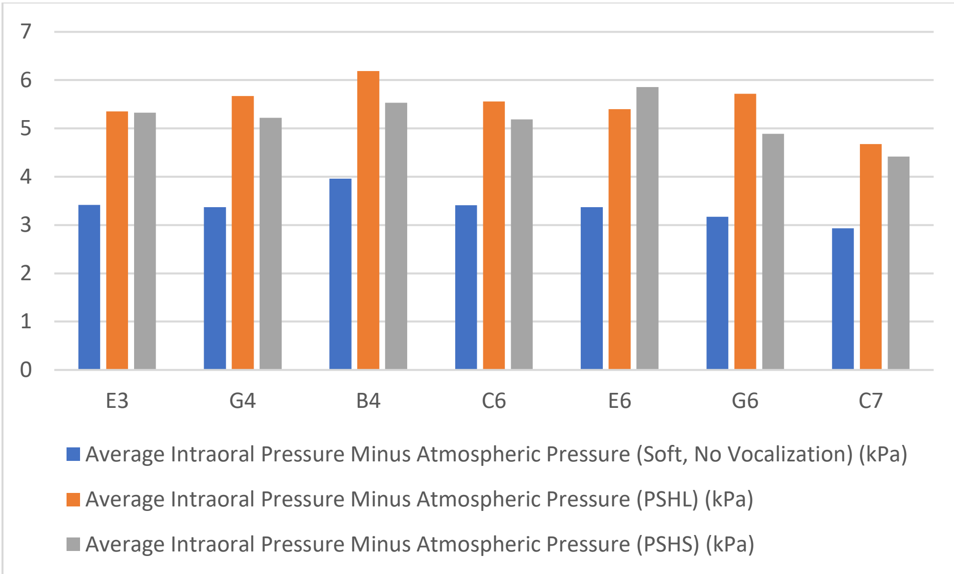


Figure 6.6. Average intraoral pressure minus atmospheric pressure for softly played tasks utilizing humming while playing.

There are two possible explanations for these unexpectedly high intraoral pressure readings. The first possibility is that the subject was able to produce loudly played pitches while humming that were similar in intensity to his loudest possible dynamic without vocalization, but was simply unable to play as softly while humming, compared to his ability to play softly without vocalization. This would essentially mean that the subject had an extremely narrow played dynamic range when executing the humming while playing technique. After aurally comparing the dynamic levels of the tasks including humming while playing loudly to those utilizing humming while playing softly, this hypothesis seems highly unlikely. The majority of the tasks using the same played pitch exhibit a substantial difference in perceived dynamic intensity between the loudly played task and the softly played task. This is confirmed in Chapter 7, when intensity is analyzed more closely, but there is likely another reason behind the higher average intraoral pressure values when humming while playing softly.

The most likely cause of these increased average intraoral pressure values relates to the resistance offered by the clarinet. Until now, the resistance from the clarinet on any given played pitch has been regarded as a constant. However, it is possible that the subject inadvertently increased the resistance from the clarinet by increasing his embouchure pressure when transitioning from the main air stream to the air stored in the oral cavity. While this tightening of the embouchure would certainly be unintentional, it would not be particularly unusual. Since the transition between air sources involves expanding the cheeks to store air in the oral cavity, this nearby motion could easily contribute to potential changes in the embouchure pressure of the subject.

Embouchure pressure was not measured in this study, but one way to investigate whether or not embouchure pressure increased during humming is to look at the pitch contour of the played note during a time of transition in one of the tasks. Because increasing embouchure pressure will raise the pitch of the note played, the pitch contour can provide clues about embouchure pressure when making the transition from the main airstream to the air stored in the oral cavity. Figure 6.7 shows the pitch contour for a played E_3 from a softly played and loudly hummed task.

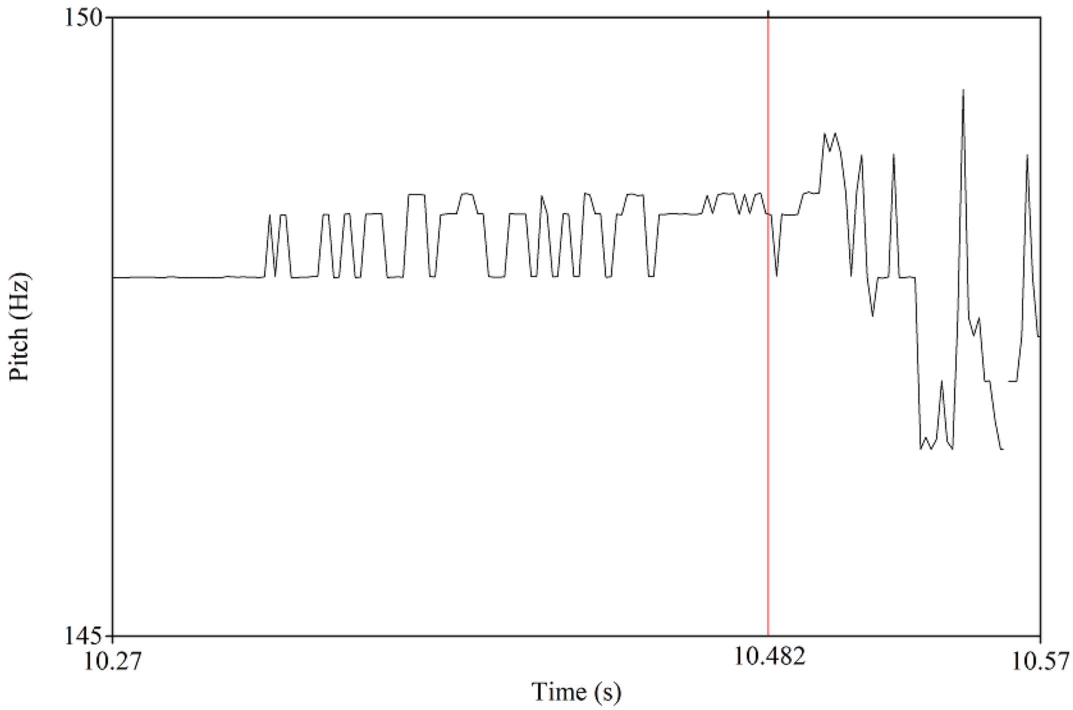


Figure 6.7. Pitch contour of softly played E_3 at point of transition to loudly humming D_3.

The pitch contour shown in Figure 6.7 is from a played E_3 before and after the subject began humming a D_3, as indicated by the red line. The E_3 begins at a steady 147.9 hertz (Hz) from 10.27 seconds to 10.32 seconds before beginning to fluctuate.[61] From 10.32 seconds until the start of the hummed D_3 at 10.482 seconds, the pitch fluctuates, but generally increases, with an average pitch of 148.5 Hz. This increase in pitch would almost certainly correspond to the subject transitioning from the main air stream to the air stored in the oral cavity, since it is necessary to completely transition from one to the other before beginning to hum.

[61] Time markers in Figure 6.7 refer to the Figure's temporal location in Figure A.18.

Figure 6.8 shows the same played note as Figure 6.7, but performed at a loud dynamic level.

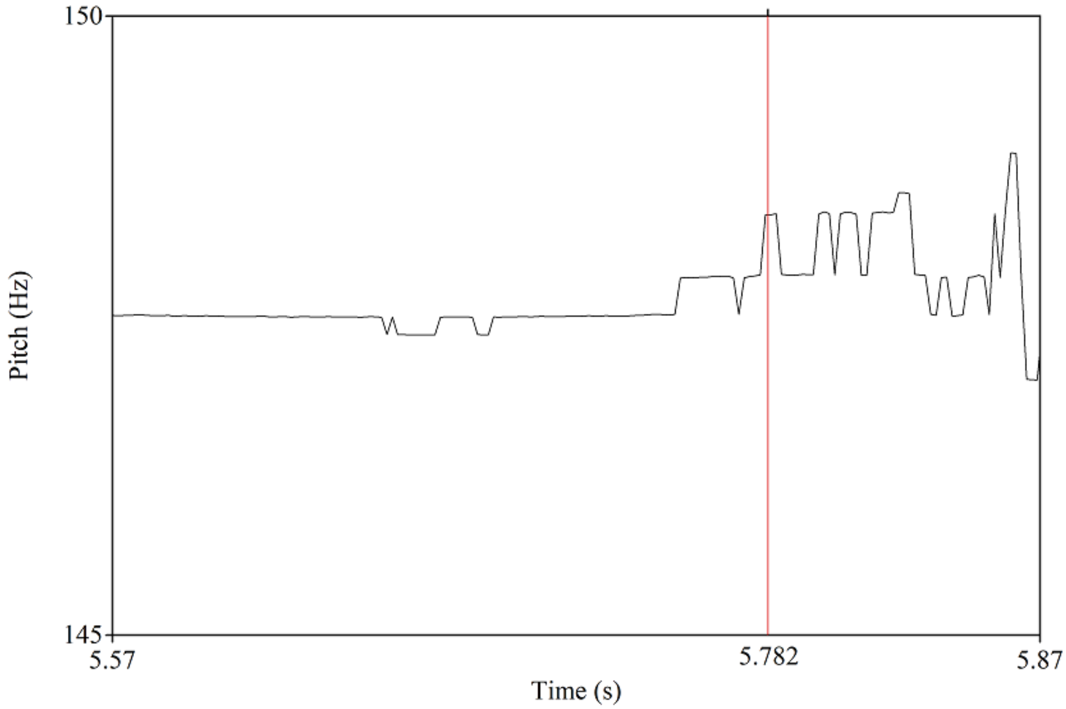


Figure 6.8. Pitch contour of loudly played E_3 at point of transition to loudly humming D_3.

Just as before, the played E_3 begins very evenly, now holding steady at 147.6 Hz for the first 0.05 seconds. Where the softly played E_3 began to increase, however, the loudly played task remains relatively steady for much longer, briefly lowering before increasing just before the start of the hummed pitch. The pitch in the 0.162 seconds leading up to the start of the hummed D_3 produced an average of 147.6 Hz. This average is identical to the initial pitch level of the E_3 in Figure 6.8, whereas the average pitch from the softly played E_3 in Figure 6.7 increased by 0.6 Hz over the same period of time.

While the contours do seem to show that pitch increases during the air transitions in both tasks, the softly played task has a far more dramatic increase. This suggests that the subject likely increased his embouchure pressure when transitioning from the main airstream to the hummed airstream, particularly during softly played tasks, thereby closing the aperture between the reed and the mouthpiece and creating more resistance from the clarinet. This would, in turn, increase the subject's intraoral pressure.

In addition to looking at average intraoral pressure levels, the peak intraoral pressure measurements can be quite useful in identifying one of the difficulties associated with this technique. As Figures 6.3 and 6.4 show, the peak intraoral pressure levels during humming exceed the average levels from the same tasks by anywhere from 1.41 kPa to 2.72 kPa and by an average of 1.99 kPa. This is a greater difference than the 0.87 kPa average found in the baseline tasks, indicating that humming while playing does indeed produce much larger spikes in intraoral pressure than standard playing. This is quite apparent when examining the intraoral pressure graphs showing humming while playing.

For example, in Figure 6.9, which shows intraoral pressure while humming and playing a C_{7}, nearly every hummed pitch shows a pronounced spike in intraoral pressure, although this typically does not last for the entire duration of the hummed note. This would seem to correspond to the transition from the main air stream to the air stored in the oral cavity, and can partially be attributed to the increase in embouchure pressure that has already been investigated. These spikes are not just limited to the softly played notes, however, which means that there is likely another issue to consider.

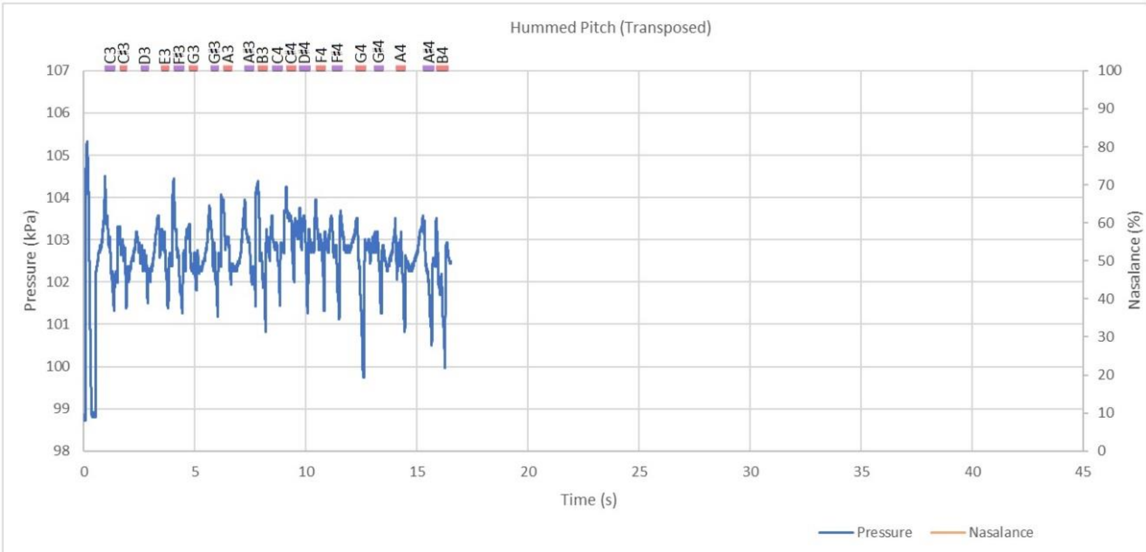


Figure 6.9. Pressure and nasalance graph, play soft, hum loud, C_7.

Perhaps one of the most basic difficulties involved in learning the humming while playing technique relates to discovering how to smoothly maintain one played pitch while shifting between air sources. This is one of the same major difficulties encountered when learning to circular breathe, and while the clarinetist is ultimately aiming to smoothly shift from one air source to the other without altering the intraoral pressure levels at all, in practice, this is often not the case, as can be seen in much of the gathered data.

The spikes in intraoral pressure are likely caused by the subject overestimating the amount of pressure needed when transitioning from the main air stream to the air stored in the oral cavity. This shows that it is possible to maintain a played pitch without a perfectly smooth transition, although the clarinetist should still aim to minimize any changes in intraoral pressure, as it will help create a more seamless shift between air sources. Chapter 8 will further discuss the challenges of smoothing out the transition as they pertain to learning how to produce and perfect the humming while playing technique.

The final four task groups, shown in Figures A.32 through A.59, all utilize the singing while playing technique. The average intraoral pressure measurements for these tasks should closely match the baseline tasks when played at the corresponding pitch and dynamic levels since they do not involve any air source transitions. Figures 6.10 and 6.11 show average and peak intraoral pressure during singing while playing at various dynamic levels for all played pitches, with atmospheric pressure included for reference.

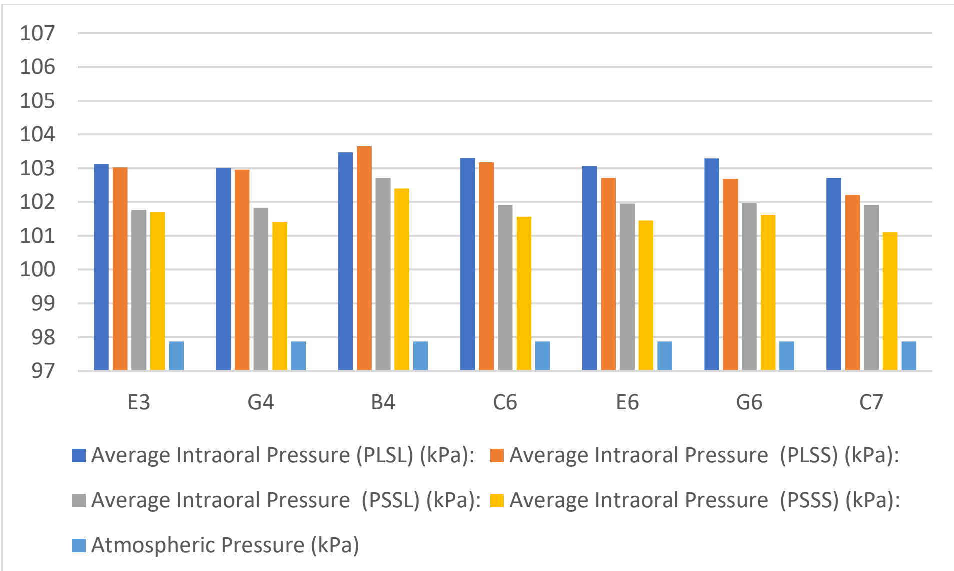


Figure 6.10. Average intraoral pressure during singing while playing. [62]

[62] Tasks are abbreviated to PLSL for play loud, sing loud, PLSS for play loud, sing soft, PSSL for play soft, sing loud, and PSSS for play soft, sing soft.

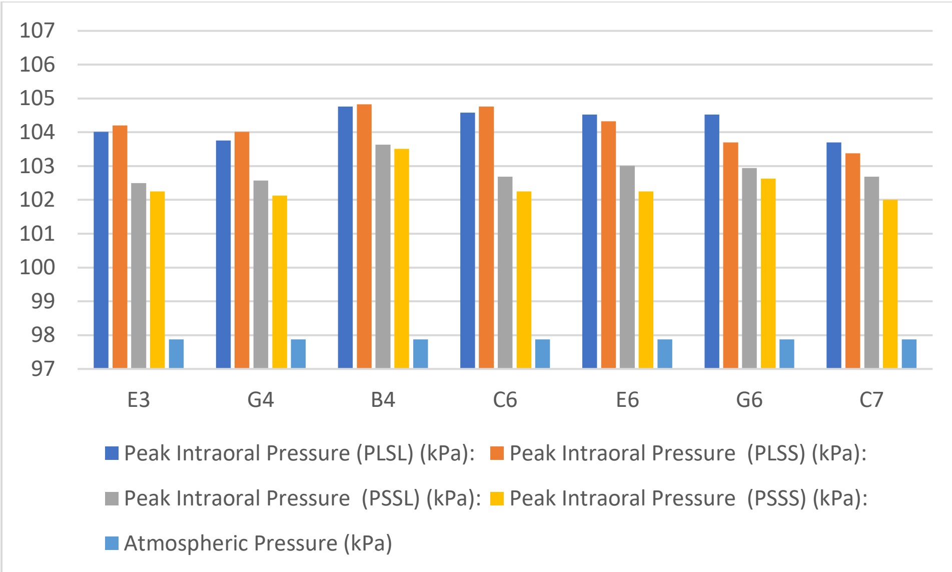


Figure 6.11. Peak intraoral pressure during singing while playing.

Both the average and peak intraoral pressure measurements for singing while playing show the expected relationship between higher pressure levels and louder dynamics across all tasks. When comparing the average intraoral pressure during singing for a given played pitch to its corresponding baseline task played at the same dynamic level, the measurements also match expectations. The tasks utilizing singing while playing deviated from the baseline tasks by anywhere from 0.01 kPa to 1.12 kPa, with an average deviation of 0.49 kPa. These values are quite close to the same deviations measured in humming while playing loudly, which ranged from 0.09 kPa to 1.07 kPa, but less than those measured in humming while playing softly, which ranged from 1.49 kPa to 2.55 kPa. Figures 6.12 and 6.13 highlight the differences between all of the tasks utilizing singing while playing and their corresponding baseline tasks by subtracting atmospheric pressure from each.

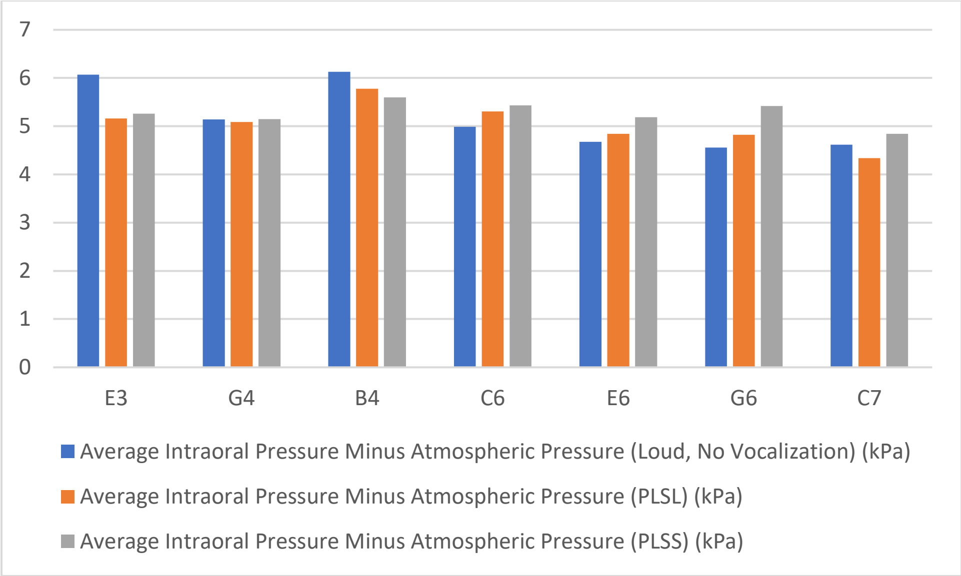


Figure 6.12. Average intraoral pressure minus atmospheric pressure for loudly played tasks utilizing singing while playing.

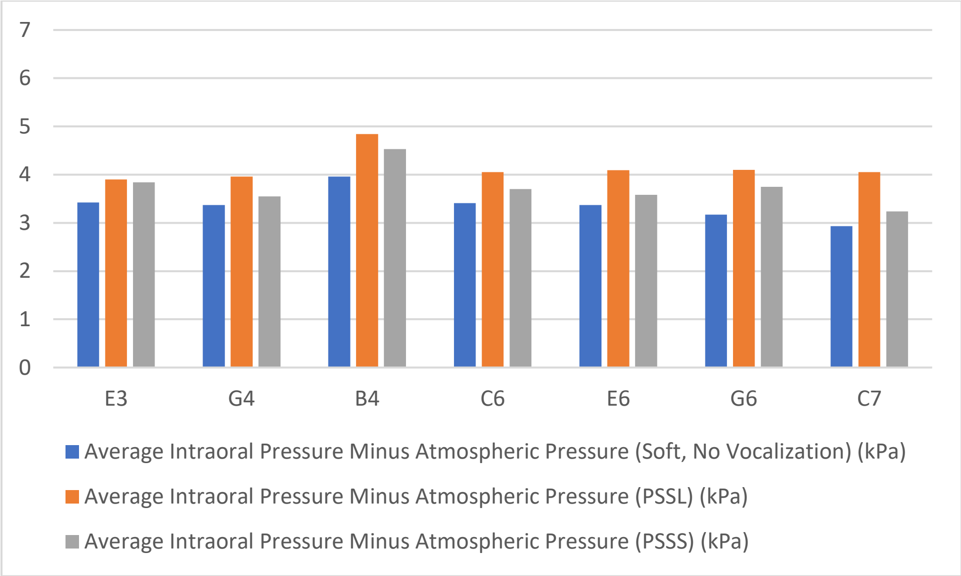


Figure 6.13. Average intraoral pressure minus atmospheric pressure for softly played tasks utilizing singing while playing.

The peak intraoral pressure levels for singing while playing are also much more similar to the levels for standard playing than they are to the levels for humming while playing. The peak intraoral pressure levels for singing while playing exceed their corresponding averages by anywhere from 0.02 kPa to 1.12 kPa, with an average of 0.31 kPa. This is even closer to the average level than the 0.87 kPa deviation found in standard playing, while both values are much lower than the 1.99 kPa average deviation found in humming while playing.

These data help show that intraoral pressure levels found in singing while playing are quite close to those found in standard playing, while humming while playing shows greater variance. Humming while playing also frequently produces large peaks in intraoral pressure. Singing while playing does not typically produce similar peaks, although as explained in Chapter 3, it does require more total pressure than in standard playing, since additional pressure must be allocated to induce vocal fold vibration rather than clarinet sound generation.[63]

[63] Titze, "Voice Research: Lip and Tongue Trills," 51.

CHAPTER 7

SPECTROGRAM AND INTENSITY ANALYSIS

Purpose of Spectrogram Analysis

The analysis in this chapter will focus on the recorded audio for each task, both in terms of the overall acoustic effect produced and the intensity of each task. Spectrogram analysis was one of the primary audio analysis methods chosen for this chapter since musicologists will sometimes use this method as a way to visually represent the overall acoustic effects produced in a recording.[64] A spectrogram will show the frequencies present in a given task and the relative intensity of each frequency over time. If a single pitch is played, the spectrogram should show the fundamental frequency and any of its strong overtones, as shown in Figure 7.1.

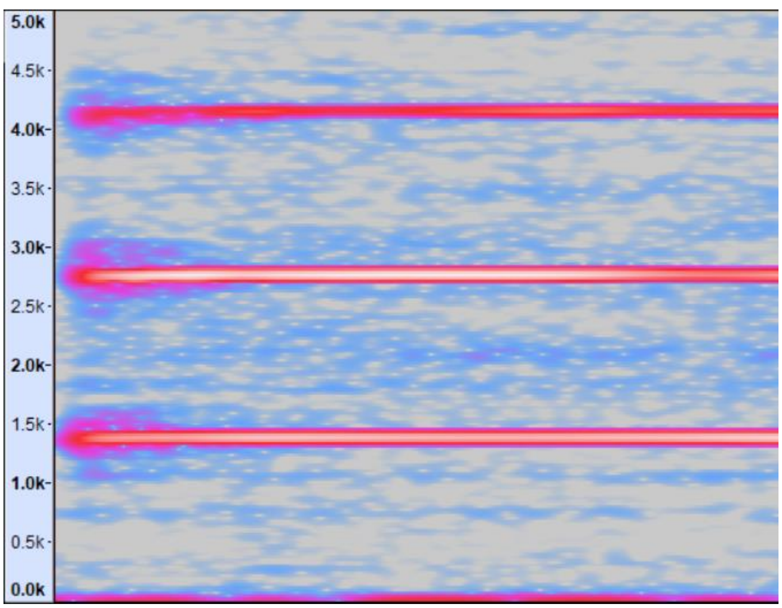


Figure 7.1. Spectrogram of loudly played G_6 with no vocalization.

[64] Stephen McAdams, Philippe Depalle, and Eric Clarke, "Analyzing Musical Sound," in *Empirical Musicology: Aims, Methods, Prospects*, ed. Eric Clarke and Nicholas Cook (Oxford: Oxford University Press, 2004), 157-161.

The frequencies in Figure 7.1 appear as very clearly defined horizontal lines–any other single played pitch will be represented in the same way, but with the horizontal lines placed at the corresponding fundamental and overtone frequencies for that pitch. The main reason for examining spectrograms of the recorded tasks was not to look at played pitches with no vocalization, however, but to investigate how humming while playing and singing while playing produce different acoustic effects relative to both standard playing and each other. If different frequencies appear at different intensity levels for the same combination of played pitches, sung or hummed pitches, and dynamics, then these spectrograms can be used to help describe the similarities or differences in acoustic effects between the techniques. All spectrogram data in this chapter are taken from Appendix B, encompassing Figures B.1 through B.59, with intensity contours from Praat included for reference.

Analysis of Spectrograms

One of the primary differences between the humming while playing spectrograms and those using singing while playing directly relates to how distinctly the two simultaneous pitches appear. The tasks utilizing humming while playing overwhelmingly generated spectrograms that show a clear distinction between the frequencies of the played pitch and the frequencies of the hummed pitch, as shown in Figure 7.2.

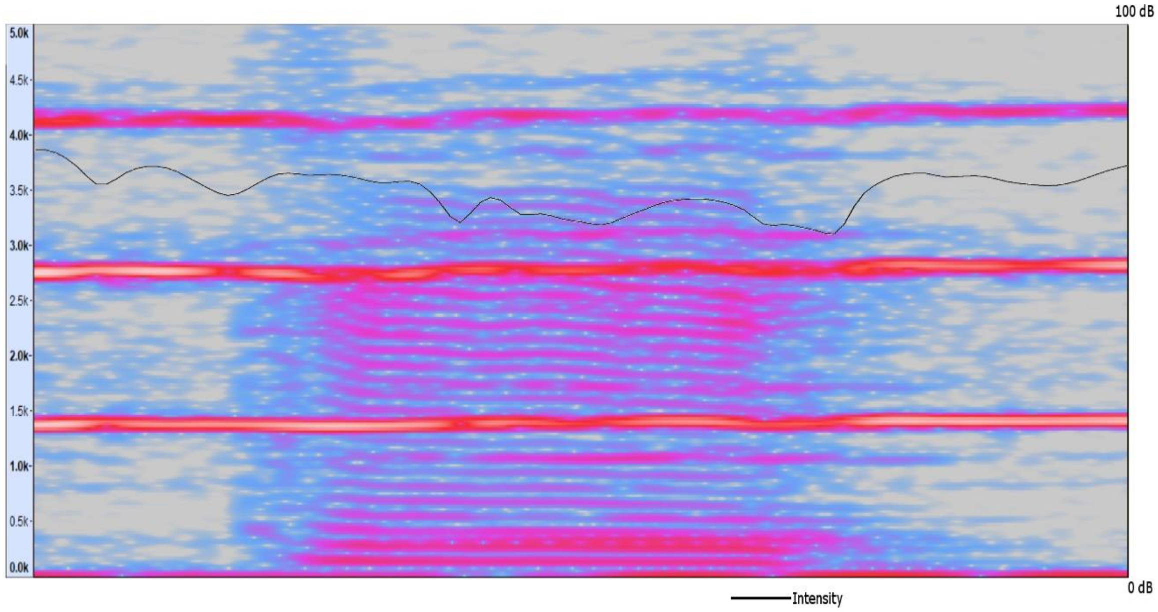


Figure 7.2. Spectrogram of loudly played G_6 with loudly hummed D_3 and intensity contour.

This spectrogram shows a played G_6, as in Figure 7.1, but with the addition of a hummed D_3. The frequencies displaying the greatest intensity are the same ones present in Figure 7.1: the fundamental frequency of 1397 hertz (Hz) for the played G_6 and its overtones. Notably, these frequencies appear to be somewhat less intense in Figure 7.2 than in Figure 7.1, particularly after the third overtone. Assuming that all other factors such as embouchure pressure and voicing remained constant, this indicates that the subject could not play the G_6 as loudly when humming as he could when playing it alone.

The additional frequencies present in Figure 7.2 correspond to the hummed D_3, with the overtones fading at roughly 3000 Hz. It is important to note that the frequencies of the played pitch and the hummed pitch are both present without appearing to interfere with each other. The two are easily differentiated, similar to how two separate instruments simultaneously playing different pitches would appear. This contrasts sharply with the way most of the singing while playing spectrograms appear.

Figure 7.3 again shows a loudly played G_6, but with a D_3 being sung loudly, rather than hummed loudly.

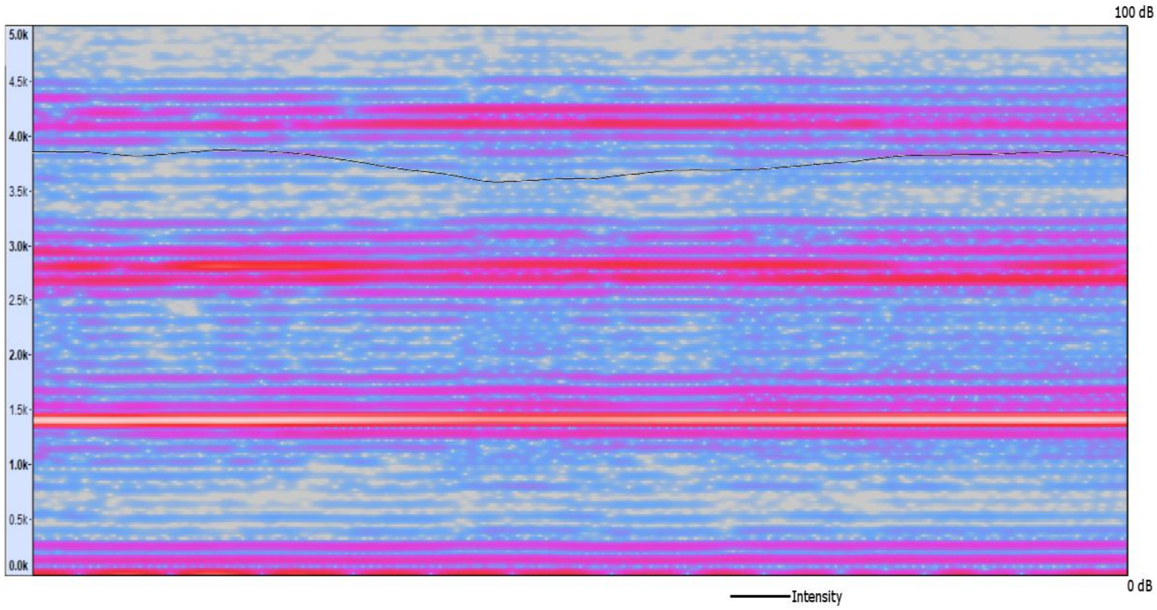


Figure 7.3. Spectrogram of loudly played G_6 with loudly sung D_3 and intensity contour.

The frequencies for the played G_6 are again clearly present, with the overtones fading at roughly the same point as in the hummed task. Additionally, the fundamental of the sung D_3 and its first overtone appear fairly clearly on the spectrogram, just as in the hummed task. However, while the subsequent overtones for the hummed task continued to appear fairly consistently up until they began to fade at 3000 Hz, the sung task shows an entirely different effect.

After the first overtone at roughly 262 Hz, the overtones from the sung D_3 fade significantly. Rather than appearing to be a separate and independent acoustic event from the played pitch like in the hummed task, the sung pitch appears to combine with the played pitch to create a distortion effect that is visible in the additional frequencies surrounding the played pitch. At both the fundamental frequency and all of the overtones present on the spectrogram for the played G_6, several strong nearby frequencies are also present. This is noteworthy because it shows how the singing while playing technique primarily creates a distortion effect modifying the played pitch, rather than generating two distinct pitches being generated simultaneously. While the fundamental and first overtone of the sung pitch are clearly visible, the intensity of many of the frequencies surrounding the played G_6 frequencies appear to be stronger than the lower frequencies from the sung pitch. This means that the overall acoustic effect produced is that of a distorted clarinet pitch blended together with a somewhat less clearly defined sung pitch.

The vast majority of the tasks examined from the study follow these patterns. The tasks using humming while playing always show the same clear differentiation between hummed and played frequencies, while the sung tasks show far more interference between the sung and played pitches. All of the dynamic combinations show these same relationships, as well, although they are easiest to see on the spectrograms at the loudest played and hummed or sung dynamics, simply because the sounding frequencies are easier to see at higher intensity levels.

Although the singing while playing tasks display substantial distortion overall, some combinations of played and sung notes tend to create less distortion than others. Intervals of an octave or unison tend to produce more clarity, although interestingly, there appears to be more distortion as the number of octaves between the two pitches becomes greater. Figures 7.4 and 7.5 both show a loudly played C_6 from the same task, but with a loudly sung C_3 and C_4, respectively.

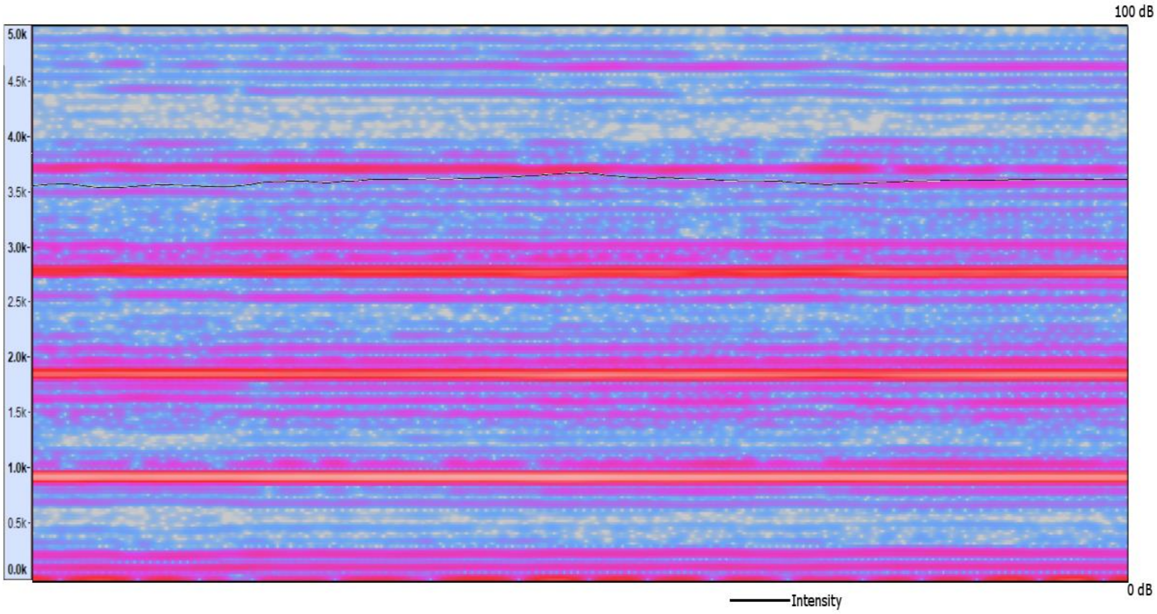


Figure 7.4. Spectrogram of loudly played C_6 with loudly sung C_3 and intensity contour.

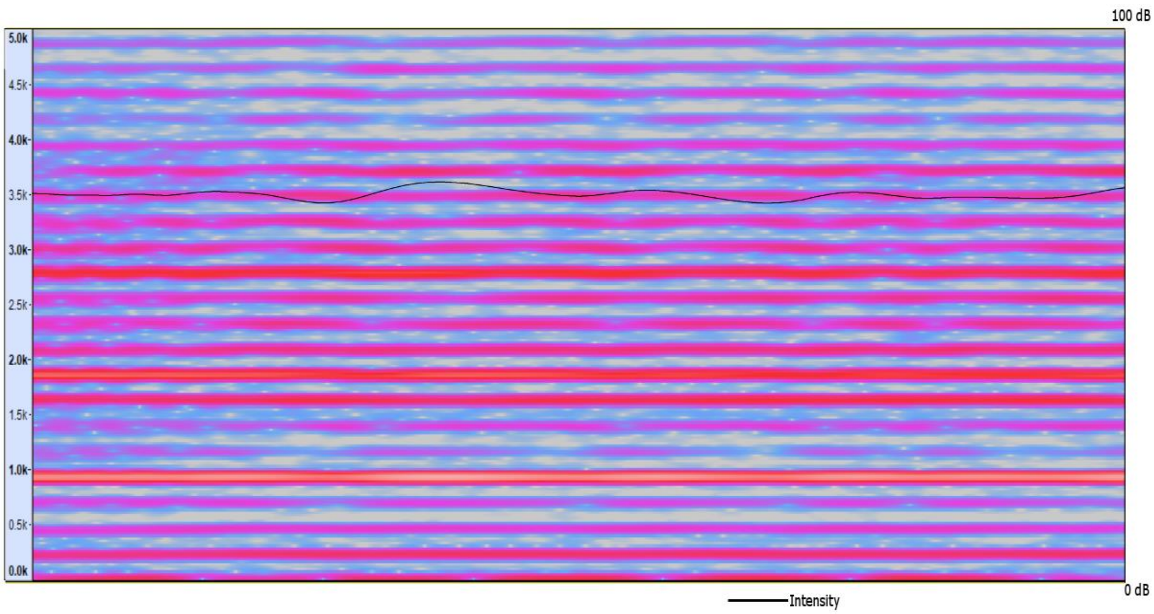


Figure 7.5. Spectrogram of loudly played C_6 with loudly sung C_4 and intensity contour.

In Figure 7.4, there is again visible distortion from the sung C_3, while the sung C_4 in Figure 7.5 produces far more clear and consistent overtones on the spectrogram. This effect is also sometimes seen at the extreme upper end of the subject's vocal range in singing while playing, regardless of the interval between the two pitches. It is possible that this can be attributed to the subject straining and producing a weaker sung pitch toward the top of his vocal range and creating less visible distortion on the spectrogram.

These notes with less distortion during singing tend to be the exception, however. The vast majority of sung pitches produce an acoustic effect that can be described as a distorted clarinet pitch blended together with a sung pitch. In contrast, humming while playing produces distinct played and hummed pitches with minimal interference between the two.

Purpose of I_{RMS} Analysis

In addition to examining the intensity of each frequency present at a given point in time through spectrogram analysis, comparing the overall intensity of the tasks when altering the played, hummed, or sung dynamics can be useful in showing how wide the overall dynamic range of each technique is. To determine this, root mean square measurements of sound pressure (I_{RMS}) will be examined in tasks utilizing the same played, hummed, and sung pitches at different dynamic levels to compare their intensity levels. Since I_{RMS} measurements provide an average intensity value over time, each I_{RMS} value will span the total duration of whatever played pitch is referenced in a given task.

I_{RMS} is one of the most widely used intensity measurements, and is sometimes even generally labelled as "sound intensity."[65] Because of its widespread usage and acceptance as one of the more basic intensity measurements, I_{RMS} levels will be used to

[65] Alexander Lerch, *An Introduction to Audio Content Analysis* (Piscataway, NJ: IEEE Press, 2012), 73.

compare intensity levels in this section. While graphs of I_{RMS} levels were not generated, the waveform dB view of Audacity was used to generate visual representations of the intensity of each task. These do not use the same I_{RMS} measurements referenced in this chapter, but do show very similar general intensity contours and were included as a visual reference in Appendix C, encompassing Figures C.1 through C.59.

Analysis of I_{RMS} Levels

Before analyzing the intensity of the tasks utilizing humming while playing and singing while playing, I_{RMS} levels were extracted in Audacity from the tasks without vocalization to use as baseline measurements for different dynamic levels. Figure 7.6 shows the I_{RMS} levels for every played pitch without vocalization.

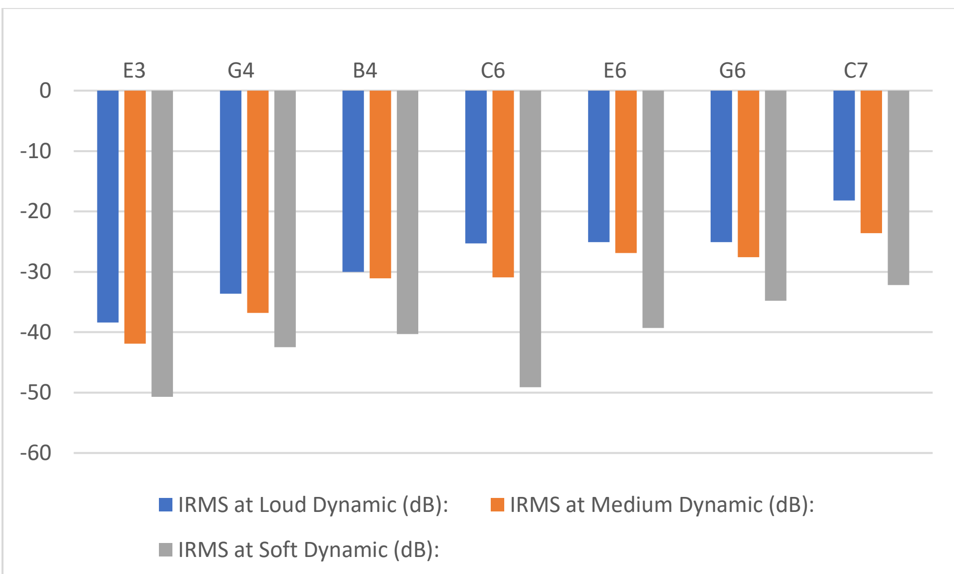


Figure 7.6. I_{RMS} measurements for played pitches without vocalization.

As Figure 7.6 shows, each task at a given dynamic level tended to rise in intensity proportionally with pitch. Because of this, three played pitches were chosen to compare during singing or humming while playing. Played E_3, E_6, and C_7 were chosen because they represent the lowest intensity level, a medium intensity level, and the highest intensity level from the baseline measurements, respectively.

In the tasks utilizing humming or singing, the intensity during five hummed or sung pitches across the vocal range of the subject were examined. The chosen hummed/sung pitches included A_2, E_3, A_3, D_4, and B_4. The hummed/sung E_3, A_3, and D_4 were present in almost every task, while the A_2 and B_4 were present in fewer tasks, but were chosen to investigate whether intensity changed at the outer limits of the subject's vocal range. Figures 7.7, 7.8, and 7.9 show the I_{RMS} levels during humming or singing while playing at various dynamic levels for the played pitches E_3, E_6, and C_7, respectively.

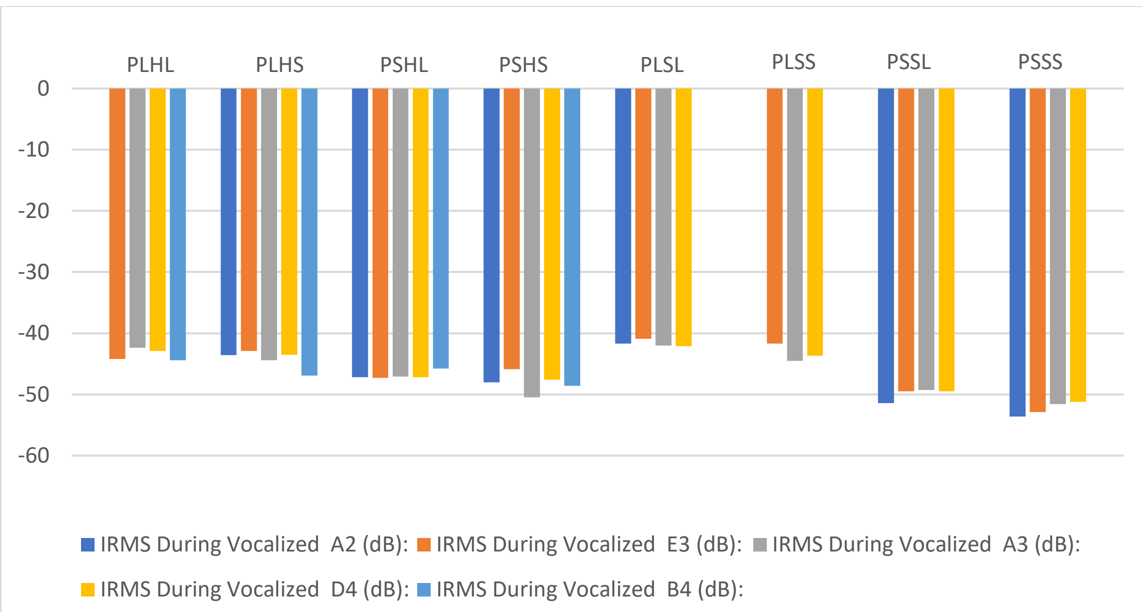


Figure 7.7. I_{RMS} measurements for vocalized pitches during played E_3.[66]

[66] Tasks are abbreviated to PLHL for play loud, hum loud, PLHS for play loud, hum soft, PSHL for play soft, hum loud, PSHS for play soft, hum soft, PLSL for play loud, sing loud, PLSS for play loud, sing soft, PSSL for play soft, sing loud, and PSSS for play soft, sing soft.

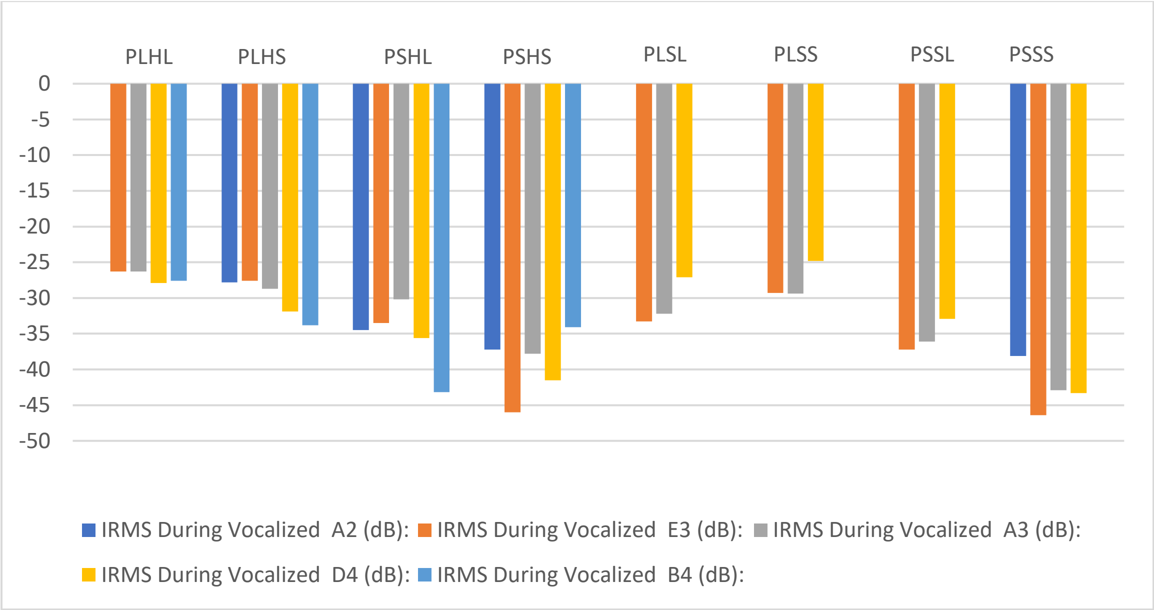


Figure 7.8. I_{RMS} measurements for vocalized pitches during played E_6.

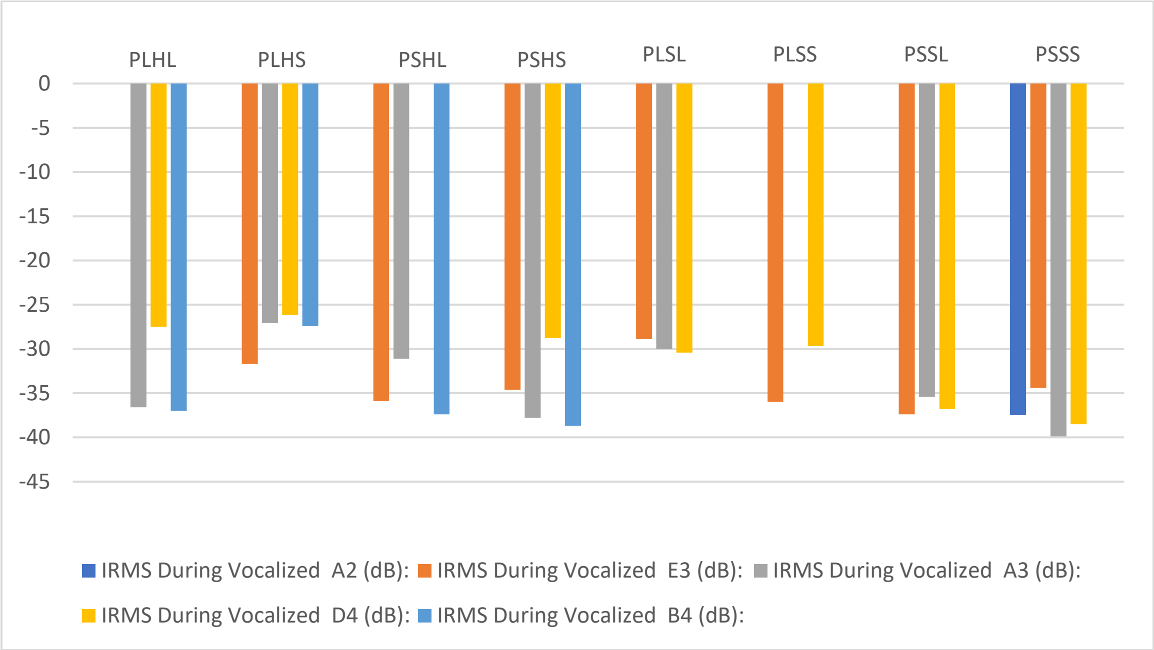


Figure 7.9. I_{RMS} measurements for vocalized pitches during played C_7.

As the figures above show, the I_{RMS} levels during the humming or singing of different pitches within the same task tend to fluctuate. Some, such as the levels from the softly played and loudly hummed task for the played pitch of E_3, stay very consistent across all vocalized pitches. Others, such as the levels from the softly played and softly hummed task for the played pitch of E_6, seem to change without any particular relationship to the raising or lowering of the hummed pitch.

Overall, the tasks with a played E_3 tend to have less fluctuation than the tasks with played E_6 or C_7. When comparing the intensities of every hummed or sung note within a task, the played E_3 tasks are all within 4.6 dB or less of each other, while the E_6 and C_7 tasks diverge by as much as 13.0 dB and 9.9 dB, respectively. Notably, the four greatest changes of intensity within a task come from humming while playing tasks. This is likely due to the increased difficulty of maintaining a steady, consistent tone when switching between air sources in humming while playing, particularly when playing higher pitches.

In addition to examining the changes within a task as the hummed or sung pitch changes, the I_{RMS} measurements from humming and singing while playing tasks were compared to the same measurements from the tasks without vocalization. The results show that none of the singing or humming while playing tasks produced intensity levels as high as those without vocalization that were played loudly with the same pitches. Some of the both singing and humming while playing tasks did produce lower intensity levels than their softly played counterparts without vocalization, however. Of the twenty-seven tokens that were less intense than their corresponding baseline measurements without vocalization, twenty-three were from tasks in which the subject was playing softly, while only four were from tasks in which the subject was playing loudly. The vocalized pitch was also hummed or sung softly in eighteen of these and loudly in nine.

This would seem to indicate that the played pitch is the greater factor in determining the overall intensity when singing or humming while playing, rather than the vocalized pitch.

Additionally, all of the four tokens in which the subject was playing loudly came from tasks with C_7 as the played pitch, likely indicating that the subject found this note to be particularly difficult to play accurately at a wide range of dynamic levels. Seventeen of these tokens came from singing while playing tasks, while the remaining ten came from humming while playing tasks. The highest intensity tokens from the humming and singing while playing tasks were often not substantially less intense than the baseline loud tasks without vocalization. For example, the token of the subject loudly humming an E_3 while loudly playing an E_6 was only 1.2 dB lower than the baseline loud E_6 measurement. The token of the subject loudly singing a D_4 and loudly playing an E_6 was also quite close to the baseline loud measurement, producing I_{RMS} levels only 2.0 dB lower, indicating that singing and humming while playing have similar upper limits in intensity that are not much lower than in standard playing.

Singing and humming while playing tasks again seem to show very similar intensity limits, although these notably extend lower than the corresponding baseline measurements taken for softly played pitches without vocalization. Examples of this can be seen in the E_6 tasks. The token in which the subject played softly and sang an E_3 softly is only 0.4 dB lower than the token in which he played softly and hummed an E_3 softly. However, the baseline E_6 task is 7.1 dB more intense than the token with the softly sung E_3.

Overall, the intensity levels of many of the tasks tend to fluctuate, and the I_{RMS} levels indicate that singing and humming while playing have very similar total intensity output ranges, which are also fairly close to the intensity ranges for standard clarinet playing. The intensity ranges for singing and humming while playing tend not to have upper limits that are as high as in standard playing, although they compensate for this by extending the lower limit below the lower limits of standard clarinet playing. It seems unlikely that a player would actually be able to play with less intensity while adding an additional sound source, however, so it is possible that the tasks that were played softly without vocalization were simply not played as softly as the subject possibly could play, while some of the tasks with vocalization were. Regardless of the cause of this unusual result, the lower intensity limits for singing while playing and humming while playing are often at least as low as the corresponding intensity limits without vocalization.

CHAPTER 8

DISCUSSION OF METHOD FOR PERFORMERS

The primary goal of the method is to provide a set of exercises through which a performer can begin to learn the techniques discussed in this paper. Both the sections on humming and singing while playing initially focus on the fundamentals of how to produce each effect. After the performer feels comfortable simply generating the second vocalized pitch, each section of the method moves to exercises that incorporate more complex and difficult writing for the techniques.

The method is not intended to cover all of the possible ways that composers might utilize the techniques, however. Since different composers invariably find the means to utilize techniques in new and inventive ways, the more difficult exercises in the method simply focus on building comfort and flexibility with each technique. If the performer can learn to produce the techniques with ease and manipulate various elements by working on the method included with this paper, then the author hopes that this will establish a strong fundamental foundation for each technique. Any particularly difficult or unusual writing by composers using these techniques can then be approached with a solid foundation and from a point of flexibility, just as one would hope to approach any type of particularly difficult writing.

One of the unique elements of these techniques addressed in Chapter 9 relates to the differing vocal ranges for individual players. This is largely an issue that composers will have to address individually, with the problem having many solutions. In the case of the current method, the author recommends two possible approaches to practicing the exercises if the written vocal parts are mostly outside the performer's comfortable vocal range.

First, each section allows the performer to transpose all of the exercises into any key. This can be useful for anybody practicing the method, regardless of his or her comfortable vocal range. The reasoning behind this is simply that as many variables as possible are kept constant when initially learning how to produce each technique. For example, the first eight exercises focused on humming while playing utilize only played or hummed C_4 at a medium dynamic level. While this proves to be quite useful in allowing the player to focus on the physiological production methods of humming while playing, once mastered, the player should learn to play and hum the same exercises in every key. These transposed exercises were not notated, however, since all of the early exercises are based on basic scalar patterns familiar to most musicians.

In addition to the pedagogical value of learning these exercises in every key, however, transposition is recommended for players whose comfortable vocal range does not include C_4. In this case, the author recommends either transposing only the hummed part up an octave or transposing both the hummed and the played part up to a comfortable pitch. The author does recommend initially keeping the played pitches in the chalumeau register since these tend to facilitate easier execution. Once the player can comfortably hum and play in this register, then s/he can begin to move up into the clarion register and above.

The remainder of this chapter will examine the method for performers and discuss the reasoning behind each exercise included. All exercises referred to in this chapter are found in Appendix D.

Humming While Playing

The first exercise in the method is intended to properly prepare the player to generate hummed pitches. This exercise isolates the physiological mechanisms used to generate the hummed pitches without requiring the player to think about simultaneously generating played pitches. The player is instructed to seal off the oral cavity and hum out through the nasal cavity. This instruction is based on the nasalance data analysis from Chapter 5, which confirmed the role that the nasal cavity plays in generating the hummed pitches. Additionally, the player is instructed to make an /ŋ/ sound as in the word "cling" in this and all subsequent exercises that require a sealed oral cavity, incorporating the elements of vocal pedagogy related to humming discussed in Chapter 3.

Exercises 2 and 3 focus on preparing the player to shift from using a regular air stream to air stored in the oral cavity without actually making the transition yet. The goal of these exercises is to show the player what it feels like to have his or her oral cavity set for regular playing and then set for humming while playing, with the time between the two getting shorter and shorter. Exercise 3 then begins to shorten the length of the hummed note in order to make the player practice being able to move back and forth from regular to hummed oral cavity positions and air stream usage as quickly as possible.

Exercise 4 isolates the played portion of humming while playing, instructing the player to fill their oral cavity with air and seal it off from the rest of the vocal tract as before, but now focusing on generating a played pitch by squeezing air out through the clarinet. Exercise 5 expands upon this by now adding the transition between the regular air stream and the air stored in the oral cavity, focusing on making a seamless switch between the two. The importance of practicing this exercise and similar ones that focus on listening for any breaks in the sound relate to the pressure data analysis from Chapter 6. As the analysis showed, intraoral pressure almost always spikes as the subject transitioned between air streams. Exercises like number five allow the player to focus on making the transition as smooth as possible, thereby eliminating such a spike and making the played pitch sound as continuous and unbroken as possible.

Exercise 6 is the first one to combine all of the elements from Exercises 1 through 5 and produce hummed pitches while playing. No new concepts are added in this exercise, but the difficulty lies in coordinating all of the previously practiced elements needed to hum while playing. Exercise 7 is identical to the previous one, with the final addition of the transition back to a regular air stream from air stored in the oral cavity to generate the played pitches. Like number five, this exercise is important for the player to practice while attempting to make the played pitch as smooth and unbroken as possible. This is the final exercise to introduce a new physiological concept related to the technique of humming while playing.

The remaining exercises all focus on adding more difficult and complex musical or technical elements to the fundamentals covered in Exercises 1 through 6. Exercise 8 increases the duration of the hummed pitches, requiring the player to store as much air in his/her oral cavity as possible and make it last for the full duration of the written notes. Exercise 9 first introduces changing pitches in the hummed part, while keeping the played pitches constant. Different dynamics are also introduced for the first time, requiring the player to create more independence between the two lines. Exercise 10 continues these trends, expanding the hummed range upward and requiring more dynamic changes in both parts, while also requiring faster hummed note changes. These additions do not greatly increase the physical demands of the exercises, but do require the player to practice coordinating several different elements at once.

Exercise 11 calls for four-measure phrases in each part, while decreasing the complexity of each line. This exercise is primarily focused on increasing the player's endurance with the humming while playing technique. Exercise 12 combines the increased endurance demands of number eleven with the greater rhythmic and dynamic complexity from the earlier exercises.

The first exercise to incorporate changing played notes is Exercise 13, which utilizes a repeating eighth-note pattern in the played part and a simple arpeggiated line in the hummed part. The purpose of introducing changing pitches so late in the method is to allow the player to focus on creating the smoothest transitions possible when shifting between airstreams. When changing notes, it is often easier to hide breaks in the airstream than it is when holding the same pitch. Therefore, the author believes that it is useful to have players focus on holding played pitches when first learning to transition between airstreams–any imperfections in the transitions will be very apparent. They can then work to eliminate any pressure spikes and create the most seamless transitions possible.

The final four exercise in the humming while playing section of the method should provide substantial challenges to players and aid in increasing flexibility with the technique. Exercise 14 incorporates more dynamic changes in both parts, but the biggest challenge will likely be humming pitches while playing throughout the range of the instrument. For example, in measure four, the player must hum a C_5 while playing a C_4, then hum a G_5 while playing a C_6 only two beats later. Not only must the player learn to keep the lines independent, but s/he must also minimize the pressure changes when transitioning between air streams while playing notes that have significantly different resistance levels. If the player can master this exercise, then they should have a great deal of flexibility in both played and hummed ranges when utilizing this technique.

Exercise 15 is relatively short, but requires a great deal of coordination between parts, with parts passing lines and moving in unison. Exercises 16 and 17 are intended to prepare the player to play pieces utilizing completely independent lines that may not be as easy to aurally prepare for as the earlier scalar exercises. Exercise 16 remains tonal, but does not follow the same predictable scalar patterns as the earlier exercises. Additionally, it sets eighth-note triplets against duple eighth notes in the separate parts, requiring the player to gain a sense of rhythmic independence between the two. Exercise 17 utilizes a repeating pattern in the played part, but neither it nor the hummed part are tonal. Therefore, the player must again practice isolating each part and gaining some degree of comfort with playing and humming independent lines.

While countless other possibilities exist for incorporating this technique, the author hopes that by working through the humming while playing method, clarinetists can not only learn to produce the technique for the first time, but also gain enough flexibility with it to be comfortable playing future works that may incorporate it.

Singing While Playing

Just as in the humming while playing section of the method, the singing while playing section begins with an exercise designed to familiarize the player with how to produce the vocal pitch. This exercise emphasizes keeping the oral cavity position constant with a closed velopharyngeal port, thereby making sure that the sung pitch is resonating in the oral cavity, rather than the nasal cavity. The exercise requires the player to match the played pitch with a subsequent sung pitch on every note of a C major scale from C_4 to C_5.

Exercise 19 combines singing and playing for the first time. This occurs much earlier than in the previous section on humming while playing because humming while playing requires a more complex set of physiological changes when compared to regular playing than does singing while playing. Since the previous exercise already practiced the act of generating the sung pitch independently, the two can be combined right away. The exercise focuses on first generating the sung pitch without playing, then adding enough total air pressure to also generate a played pitch. As elaborated upon in Chapter 3, singing while playing requires a greater total amount of air pressure than regular playing, since two different sound sources are using the same air stream to vibrate. This means that in addition to the vocal folds vibrating within a higher-pressure environment, the player will likely feel as if s/he is exerting more effort than usual to produce the played pitch, as mentioned in the description of this exercise.

Exercise 20 adds two new elements. First, it requires the player to start with a played pitch and then add the sung pitch, rather than the other way around. This is important, since many extant pieces utilizing the technique employ it in this way. Second, rather than the player just matching pitches, this exercise adds an ascending and descending played scale over the same sung C_4. This means that the player should hear all of the changes in distortion levels as the intervals change and be able to tune the more consonant intervals to create less dissonant distortion.

Exercise 21 uses a played pedal C_4 and an ascending and descending sung line, rather than the other way around. The distortion changes should again be present, as in Exercise 20, but the player should additionally become familiar with the correlation between higher pitches and increased pressure demands elaborated upon in Chapter 3. As the sung pitch gets higher, the player will have to exert more effort to produce it.

Exercise 22 adds more dynamics and independent lines with changing notes. This is intended as an introduction to independent sung and played lines, however, since each sung pitch matches the played pitch before the two diverge. Exercise 23 introduces parallel motion between the two lines, in addition to starting both lines simultaneously. This simultaneous start was chosen primarily to have the player practice preparing and setting the right air pressure levels from the beginning.

Exercise 24 greatly expands the sung range in an effort to help the player determine his or her comfortable singing range when singing while playing. The player is instructed to switch octaves when necessary, since each player has a practical range limit that is substantially smaller than in humming while playing. Additionally, the sung and played lines are now more independent, moving in contrary motion throughout the exercise.

Exercises 25 and 26 offer significant difficulties in an effort to challenge the player and increase flexibility with the technique. Exercise 25 is tonal, but requires a great deal of independence between the two lines. At certain points in this exercise, the player can anticipate the sung pitch by listening for the same pitch in the played part. However, the majority of this exercise is likely easier to play by becoming comfortable with each line as an independent part. Exercise 26 uses a repeated chromatic pattern in the sung part based around the played pitches. The challenges of this exercise include quickly and accurately singing every minor second in the pattern and making accurate leaps in the sung part when each played pitch changes.

Finally, Exercise 27 emphasizes utilizing singing while playing as an effect to create a heavily distorted clarinet sound. Each sung pitch is written a minor second apart from the played pitch at a very loud dynamic level. Before every sung pitch, however, the same pitch is present two beats prior in the played part. Thus, the player can either anticipate the pitch when it is played or simply sing a minor second above or below the currently played pitch to generate the proper sung pitch.

Just as with humming while playing, many more uses are possible for singing while playing. However, this section of the method is intended to teach players to not only learn how to produce the technique, but gain enough flexibility with it to play a variety of pieces that may utilize it in different ways.

CHAPTER 9

RESOURCE FOR COMPOSERS

The humming while playing and singing while playing techniques both utilize vocalization during clarinet performance to generate a second sounding pitch. However, as the previous chapters in this paper have shown, the two techniques produce very different effects with different possibilities and limitations. To this end, this chapter will provide a set of recommendations to help composers who wish to write works utilizing each technique, in addition to suggesting some areas of future experimentation. While this resource will cover as many relevant areas as possible, it should not be considered as an exhaustive list of all of the limitations and possibilities for each technique. Rather, it serves as a starting point from which further experimentation and exploration can lead to even more possibilities.

Notation and Nomenclature

As stated in Chapter 2, the notation and nomenclature currently used to notate singing or humming while playing is far from clear or uniform. Different composers will sometimes label the different techniques the same way, despite wanting distinctly different effects. Due to the reasons outlined in Chapter 3 relating to vocal pedagogy and the physiological mechanics involved in the production of each technique, the author believes that it is advisable to label the technique of singing while playing as “sung” and the technique of humming while playing as “hummed.” Providing detailed descriptions in the performance notes for any piece using either of the techniques would also likely be useful for performers. Additionally, while multiple notation options exist, for the sake of clarity and ease of reading for performers trying to practice the technique, the author opted to use dual-staff notation with clear labels when indicating humming or singing while playing.

Humming While Playing

The first important consideration to be aware of when utilizing either humming or singing while playing is that the possible vocal range is going to vary depending on the player, since different individuals have different vocal ranges. There are obviously different ways to address this issue, including allowing octave transpositions when needed, allowing entire works to be transposed, writing without exact pitch specification, or requiring that a piece be performed only by clarinetists with certain vocal ranges. All of these approaches come with inherent pros and cons, and each composer will have to decide which approach s/he prefers.

Aside from the challenge of different players having different vocal ranges, however, vocal range is actually one of the great strengths of the humming while playing technique. Because of the physiological mechanisms used to produce the technique, a clarinetist should be able to utilize his or her full vocal range when humming while playing, which is not necessarily the case with singing while playing. In the case of the sole subject for the present study, that range was greater than two octaves on most played pitches. The composer will have to check with the performer s/he is writing for to identify an appropriate vocal range, but in general, humming while playing can be comfortably utilized anywhere in a player’s normal vocal range.

While the vocal range for humming while playing is wide, the playing range for this technique is somewhat more limited. As seen in the study, it is possible to hum while playing pitches ranging from E_3 to C_7, but it should be noted that similar to the circular breathing technique, it is very difficult to hum while playing pitches in the altissimo register of the clarinet.[67] Chapter 6 showed that pressure spikes when transitioning from one air stream to another, and when attempting to maintain a steady pitch in the altissimo register, there is less margin for error regarding changes in the oral cavity. Composers should then be aware that utilizing this technique on altissimo pitches is possible, but quite difficult.

The dynamic range for humming while playing, as examined in Chapter 7, is also fairly substantial. While the total intensity levels for humming while playing were never quite as high as they were for regular playing, they still showed an intensity range close to that of regular playing. It should be noted that the individual played and hummed pitches were not measured separately for intensity. There is also no physiological reason why a player shouldn't be able to hum as loudly or as softly while playing as s/he would when humming alone.

One unique technical element to consider when writing for humming while playing relates to the duration for which the technique can be used. Because it is necessary to use air stored in the oral cavity when humming while playing, the technique can only be used in short bursts, and the composer must give the player enough time to

[67] Daniel Zachary Dierickx, "The Clarinet Works of Jörg Widmann: A Performance Guide to *Fantasie for Clarinet Solo* with a Survey of Unaccompanied Clarinet Repertoire and Guide to Contemporary Techniques" (DMA diss., The Ohio State University, 2018), 88.

re-fill his or her oral cavity with air before using the technique again. This is another performer-dependent element, since the amount of air players can store in their oral cavities and rate of expulsion varies by player. Most of the exercises in the included method call for performers to be able to maintain hummed pitches for at least two seconds and allow at least one second to re-fill their oral cavities with air. This can be used as a starting point, but each player will have different limits, and it is recommended that the composer work with the player s/he is writing for to determine how long they can maintain a hummed pitch.

Beyond outlining the technical possibilities and limitations of this technique, it is important to describe the acoustic possibilities offered by humming while playing. As the spectrogram analysis in Chapter 7 showed, humming while playing produces two clear and distinct pitches, regardless of the interval between the played and hummed notes. There is no distortion, as seen in singing while playing, and the vocalized pitch is only limited by the vocal range and ability of the clarinetist. The overall acoustic effect is that of one person playing a clarinet and another person humming simultaneously. Essentially, this technique provides composers who want to produce multiple sounds in clarinet performance with the ability to create two undistorted, independent pitches, making this technique as unique as either traditional multiphonics or singing while playing.

Additionally, two possible future directions for this technique offer possibilities to break away from the durational limitations mentioned earlier in this section. While the duration of this technique is limited to short bursts when used by one player, multiple players could produce continuous hummed lines when the hummed writing is passed from player to player in an ensemble setting. Finally, an area of future exploration for this technique that offers even greater acoustic possibilities would involve the use of electronic manipulation of the hummed pitches. If a microphone was setup to pick up a player's hummed nasal emissions separately from his or her played clarinet pitches, similar to the Nasometer headset used in the study for this paper, a performer could theoretically manipulate both hummed and played pitches simultaneously using any electronic means at his/her disposal. The range of musical possibilities utilizing the technique of humming while playing is vast and can continue to be expanded by the imaginations of both composers and performers.

Singing While Playing

As in humming while playing, the possible vocal range in singing while playing is first limited by the vocal range of the individual performer. However, while humming while playing is possible throughout the individual's entire vocal range, singing while playing is limited even further. Singing while playing offers a substantially smaller vocal range since the higher sung pitches become more difficult to produce. More pressure is required to generate these higher pitches, but the performer must still have enough left over to generate the played pitches using the same air stream. Additionally, the vocal folds are operating within a higher-pressure environment than in normal phonation, making the singing while playing technique even more difficult to produce.

In the preface to *Variants for Solo Clarinet,* William O. Smith suggests restricting the range of sung pitches in singing while playing to an octave or less.[68] The data

[68] Smith, *Variants*, 4.

gathered in the study for this paper showed that the subject could sing anywhere from one octave to a minor fourteenth in range on a given played pitch, although the majority of the tasks fell somewhere in the middle. Because of this, Smith's range guidelines would seem to be accurate, although when working with individual players, a composer will likely be able to stretch this range somewhat if needed. Regardless, the sung range when singing while playing is substantially smaller than in humming while playing.

Singing while playing offers fewer difficulties than humming while playing when extending the played range into the altissimo register. Because no significant manipulation of the oral cavity is typically needed when producing sung pitches while playing, a performer should be able to comfortably sing and play when producing played pitches throughout the full range of the instrument. A possible exception to this would be when attempting to sing pitches at the outer limits of the performer's vocal range, however, since any straining to produce sung pitches could result in unintentional changes in the oral cavity and jeopardize the stability of the played pitch.

The dynamic range available in singing while playing is very similar to that of humming while playing. While the maximum intensity measured in singing while playing was not as high as in regular playing, the overall intensity range was quite wide. This would indicate that composers should be able to utilize roughly the full dynamic range available in standard clarinet playing when using the singing while playing technique.

Unlike humming while playing, singing while playing does not have any limitations tied to the duration of the sung pitches. A performer can sing while playing for the duration of any played pitches. The one exception to this would be if a performer is circular breathing. For the duration of the player's inhalation, the oral cavity would be isolated from the rest of the vocal tract, just as in humming while playing, meaning that singing while playing would not be possible.

The most important distinction between singing and humming while playing likely does not relate to the technical possibilities or limitations of each, however, but in the different acoustic effects produced by each technique. Singing while playing does produce two simultaneous pitches that can be distinguished from one another, but the aural effect is quite different from the clear, distinct pitches produced in humming while playing. Singing while playing produces a distortion effect as the two pitches generated by the same airstream clash with audible “beats.”

As the spectrogram analysis in Chapter 7 showed, the amount of distortion varies depending on how consonant or dissonant the interval is between the played and sung pitches, but some amount of distortion is almost always present. Because of this, singing while playing should be considered a completely separate effect from humming while playing, even though they are both produced through vocalization. Humming while playing can be utilized when the composer wishes to have two clear, distinct pitches, and offers many new compositional possibilities for the future, including electronic experimentation. Alternatively, singing while playing can be utilized when the composer wants to distort the played pitch while simultaneously producing a less distinct sung pitch.

CHAPTER 10

CONCLUSION

Both singing and humming while playing are challenging and advanced techniques that use vocalization to create unique acoustic effects involving the production of multiple pitches simultaneously. Beyond their obvious connection through vocalization, however, these two techniques differ greatly. Not only are the physiological mechanisms used to produce each technique quite different, but each technique comes with its own unique set of possibilities, challenges, and limitations. As with any technique, and particularly with techniques such as these that offer so many different combinations of acoustic possibilities, the exploration and discovery of ways to incorporate them into future compositions can only add to the musical palette available to composers. The author hopes that this paper not only provides useful information for composers who wish to use these new colors on their canvasses, but also helps the performers who want to learn how to play their works.

BIBLIOGRAPHY

Audacity Team (2018), Audacity: Free Audio Editor and Recorder (Computer program), Version 2.2.2. Retrieved February 10, 2019. https://audacityteam.org.

Bernotas, Bob. "Masterclass with Dick Griffin: Multiphonics on the Trombone." *Online Trombone Journal* (1999). http://trombone.org/articles/library/viewarticles.asp?ArtID=85.

Boersma, Paul and David Weenink. Praat: Doing Phonetics by Computer (Computer program), Version 6.0.47. Retrieved February 10, 2019. http://www.praat.org/.

Bowling, Micah. "Intraoral Pressure and Sound Pressure During Woodwind Performance." DMA diss., University of North Texas, 2016.

Caravan, Ronald. *Five Duets for One Clarinetist.* Verona, NJ: Seesaw Music, 1976.

Caravan, Ronald. *Polychromatic Diversions for Clarinet.* Oswego, NY: Ethos Publications, 1979.

Caravan, Ronald. *Preliminary Exercises and Etudes in Contemporary Techniques for Clarinet.* Oswego, NY: Ethos Publications, 1979.

De Boer, Gillian and Tim Bressmann. "Comparison of Nasalance Scores Obtained With the Nasometers 6200 and 6450." *The Cleft Palate-Craniofacial Journal* 51, no. 1 (January 2014): 90-97.

Dierickx, Daniel Zachary. "The Clarinet Works of Jörg Widmann: A Performance Guide to *Fantasie for Clarinet Solo* with a Survey of Unaccompanied Clarinet Repertoire and Guide to Contemporary Techniques." DMA diss., The Ohio State University, 2018.

Errante, F. Gerard. *Another Look at October for Solo Clarinet.* Verona, NJ: Seesaw Music, 1986.

Fröst, Martin. Interview by Stephen Hetherington. *The OHMI Trust: An Interview with Martin Frost*, November 26, 2011. Video, 19:19. https://vimeo.com/34971609.

Gardner, Joshua T. and Eric C. Hansen. *Extreme Clarinet.* Cedartown, GA: Potenza Music, 2012.

Gibson, Christopher Allan. "The Soft Palate Air Leak in Clarinetists: A Multiple Case Study of Stress Velopharyngeal Insufficincy." DMA diss., University of Missouri, Kansas City, 1995.

Gray, Henry. *Anatomy of the Human Body.* 20th ed., edited by Warren H. Lewis. Philadelphia: Lea & Febiger, 1918.

Haislet, Matthew William. "The Art of Multiphonics: A Progressive Method for Trombone." DA diss., University of Northern Colorado, 2015.

Hilbert, Robert. *Pee Wee Russell: The Life of a Jazzman*. New York: Oxford University Press, 1993.

Hunt, Jonathan Robert. "On the Shoulders of Giants: Bechet, Noone, Goodman and the Efflorescence of Jazz Clarinet and the Improvised Solo." PhD diss., The University of Adelaide, 2013.

Kruger, Jonathan, James McLean, and Mark Kruger. "More Air, Less Air, What Is Air?" *ITG Journal* 36, no. 3 (March 2012): 12-19.

Lerch, Alexander. *An Introduction to Audio Content Analysis.* Piscataway, NJ: IEEE Press, 2012.

Martinsson, Rolf. *Concert Fantastique: Clarinet Concerto No. 1, Op. 86.* Stockholm: Gehrmans Musikförlag, 2010.

Martinsson, Rolf. *Suite Fantastique for Clarinet and Piano.* Stockholm: Gehrmans Musikförlag, 2011.

McAdams, Stephen, Philippe Depalle, and Eric Clarke. "Analyzing Musical Sound." In *Empirical Musicology: Aims, Methods, Prospects,* edited by Eric Clarke and Nicholas Cook, 157-196. Oxford: Oxford University Press, 2004.

Miller, Richard. "Sotto Voce: What Does Humming Accomplish." *Journal of Singing* 52, no. 3 (January/February 1996): 49-50.

Nasometer II, Informational brochure. Montvale, NJ: PENTAX Medical, 2016.

Nasometer II: Model 6450. Informational brochure. Lincoln Park, NJ: KayPENTAX.

Perry, Jamie L. "Anatomy and Physiology of the Velopharyngeal Mechanism." *Seminars in Speech and Language* 32, no. 2 (2011): 83-92.

Seikel, J. Anthony, Douglas W. King, and David G. Drumright. *Anatomy and Physiology for Speech, Language, and Hearing.* 3rd ed. Clifton Park, NY: Thomson Delmar Learning, 2005.

Smith, William O. *Fancies for Clarinet Alone.* New York: MJQ, 1972.

Smith, William O. *Jazz Set for Solo Clarinet.* Rochester, NY: SHALL-u-mo Publications, 1981.

Smith, William O. *Musing for Three Clarinets.* Rome: EDI-PAN, 1990.

Smith, William O. *Variants for Solo Clarinet.* London: Universal Edition, 1967.

Stevens, Kenneth N. *Acoustic Phonetics.* Cambridge, MA: The MIT Press, 1998.

Titze, Ingo. "Voice Research: Lip and Tongue Trills—What Do They Do for Us?" *Journal of Singing* 52, no. 3 (January/February 1996): 51-52.

Vernier Software and Technology (2019), Logger Pro (Computer program), Version 3.9. Retrieved February 9, 2019. https://www.vernier.com/products/software/lp/.

Weather Underground. "Phoenix Sky Harbor International Airport, Arizona." Retrieved March 22, 2019. https://www.wunderground.com/history/daily/us/az/phoenix/KPHX/date/2018-12-4.

APPENDIX A

NASALANCE AND INTRAORAL PRESSURE DATA

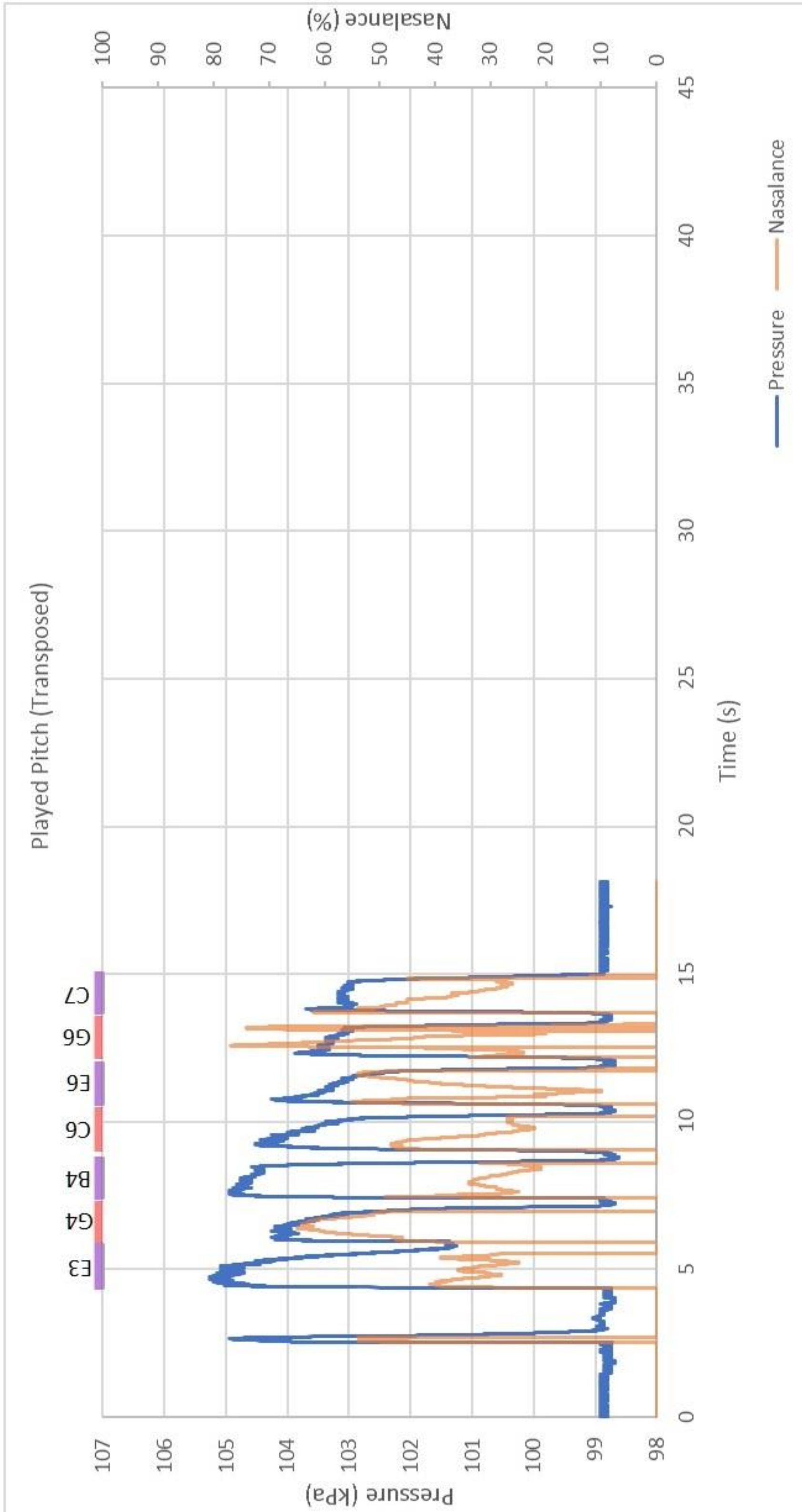


Figure A.1. Pressure and nasalance graph, play loud, no vocalization, all pitches.

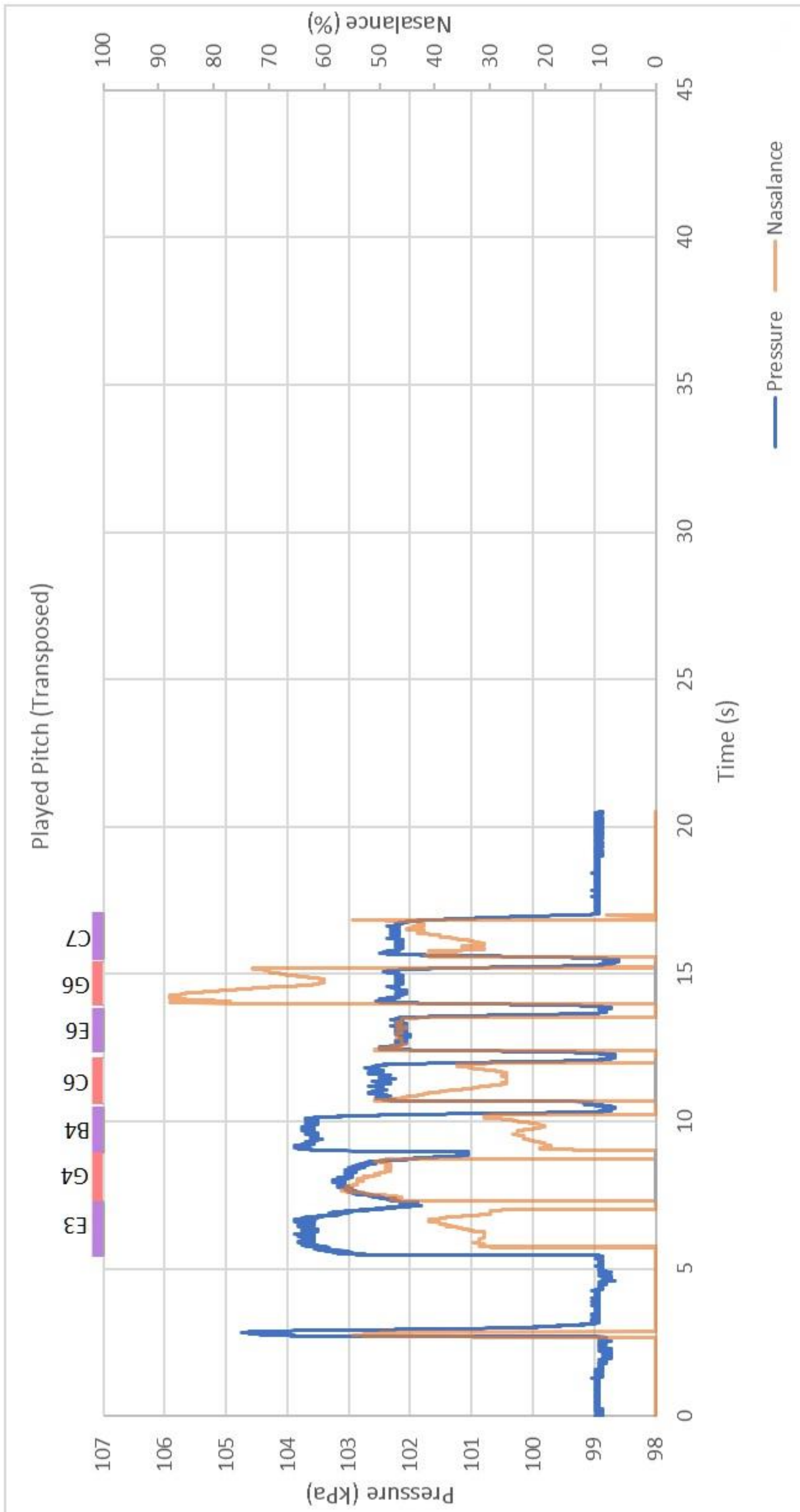


Figure A.2. Pressure and nasalance graph, play medium, no vocalization, all pitches.

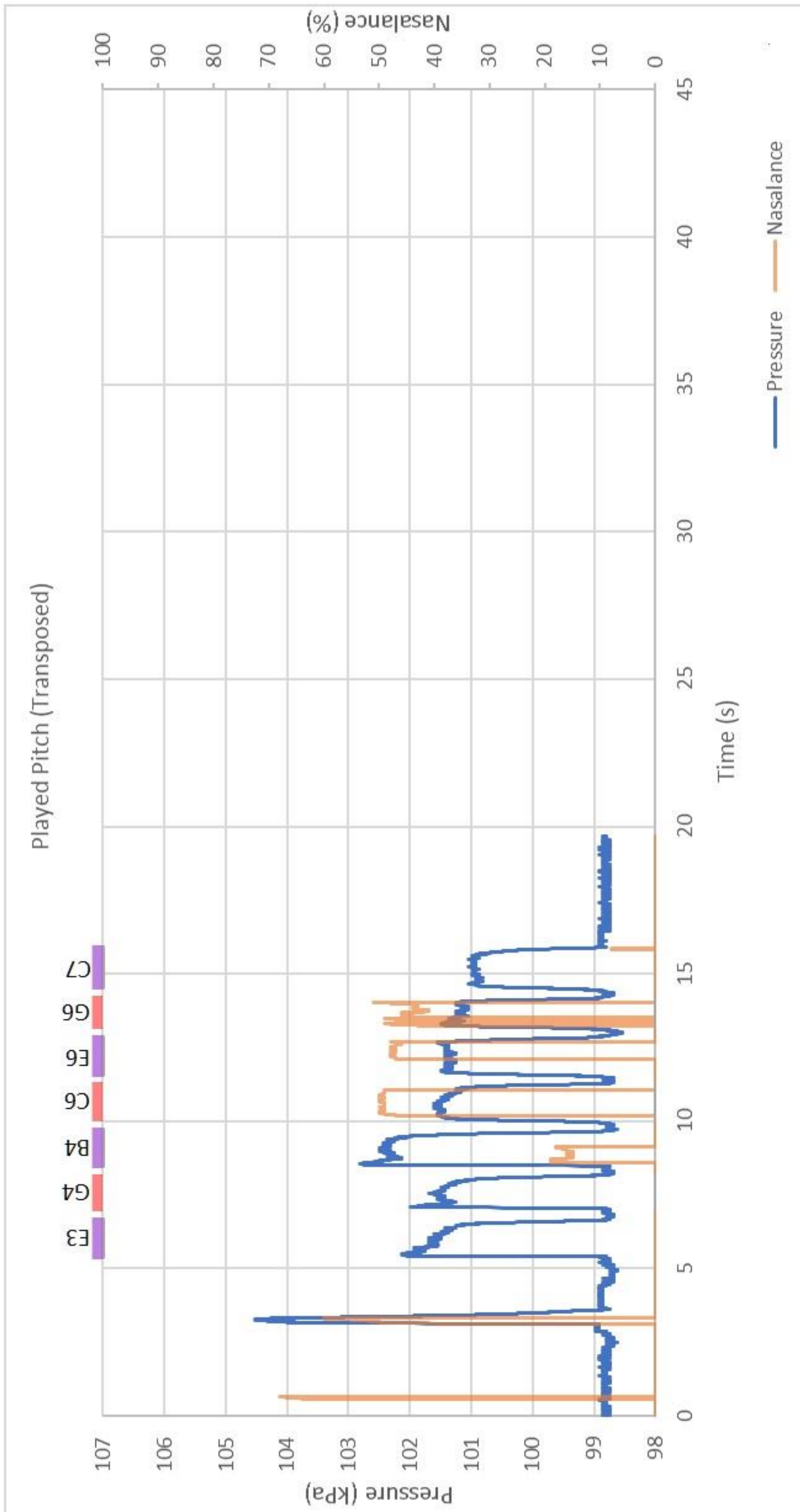


Figure A.3. Pressure and nasalance graph, play soft, no vocalization, all pitches.

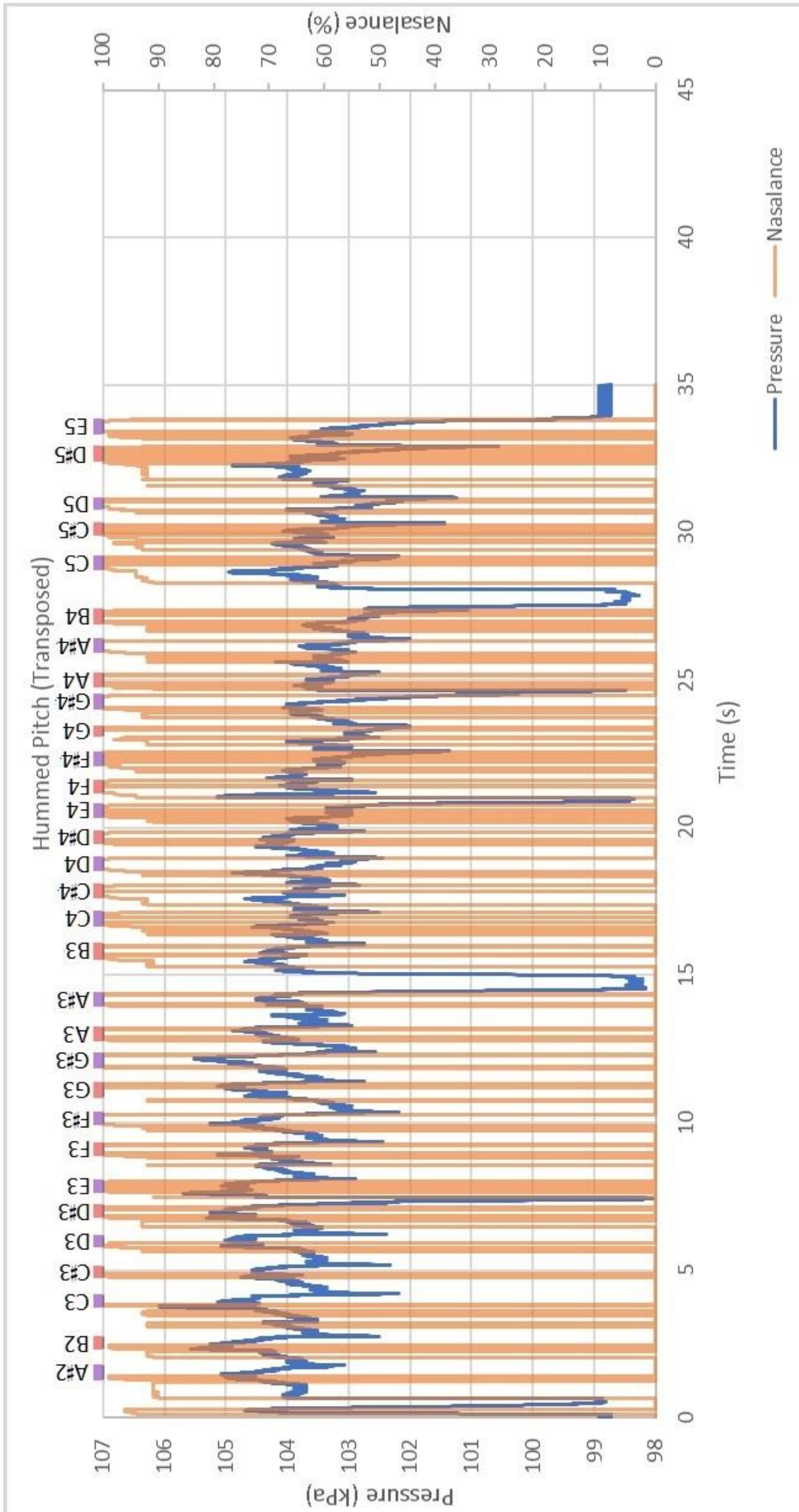


Figure A.4. Pressure and nasalance graph, play loud, hum loud, E_3.

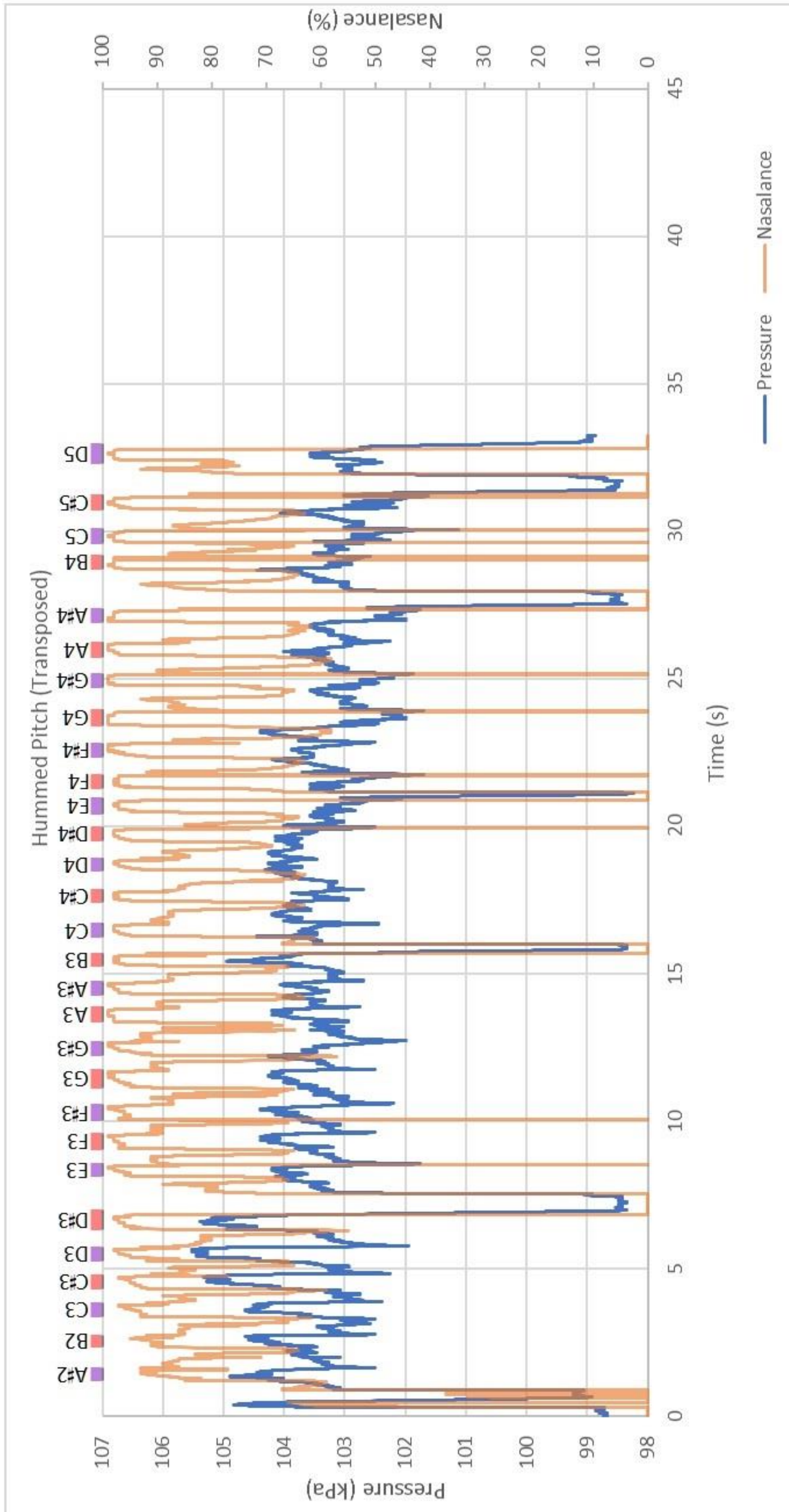


Figure A.5. Pressure and nasalance graph, play loud, hum loud, G4.

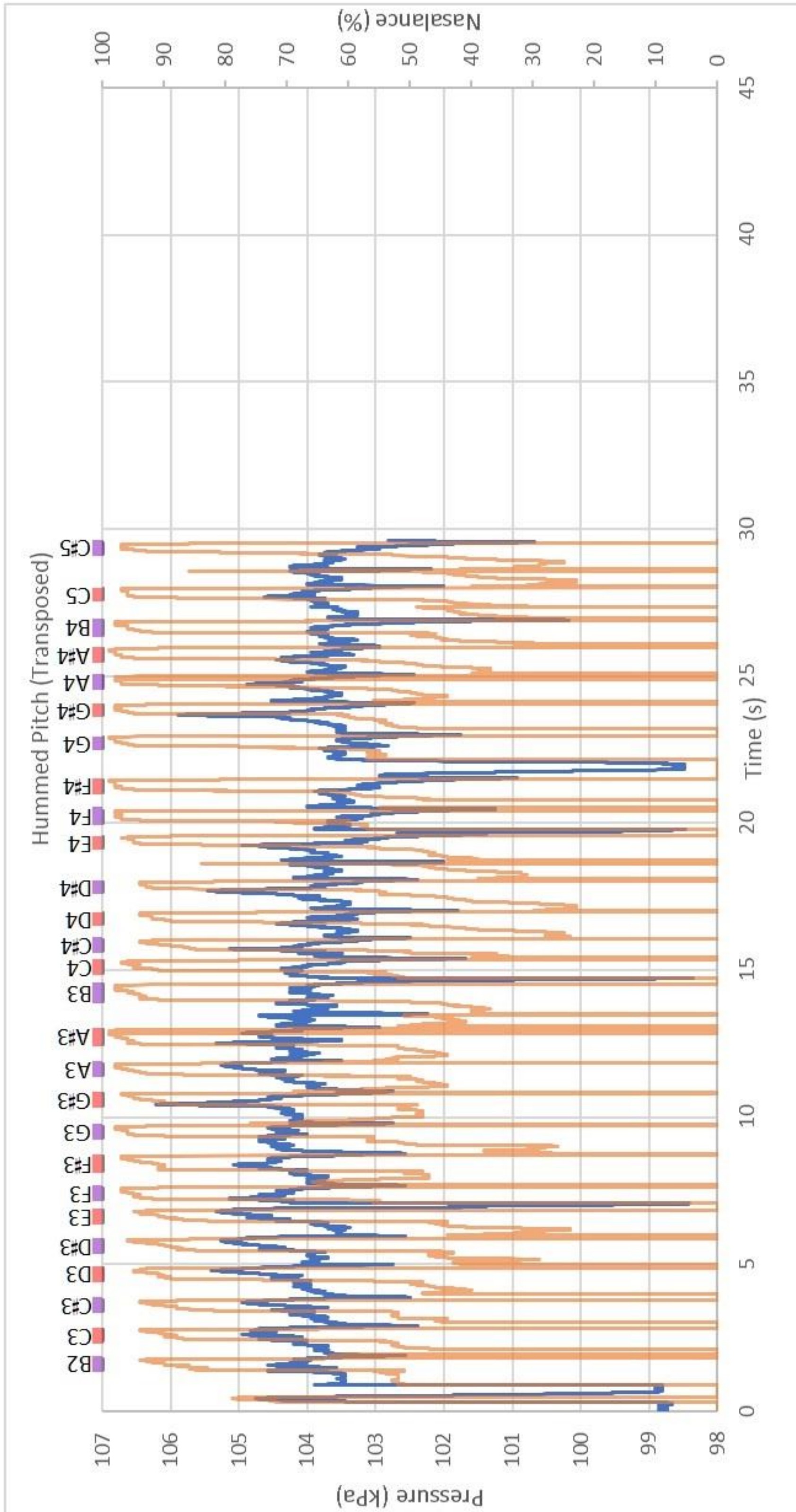


Figure A.6. Pressure and nasalance graph, play loud, hum loud, B_4.

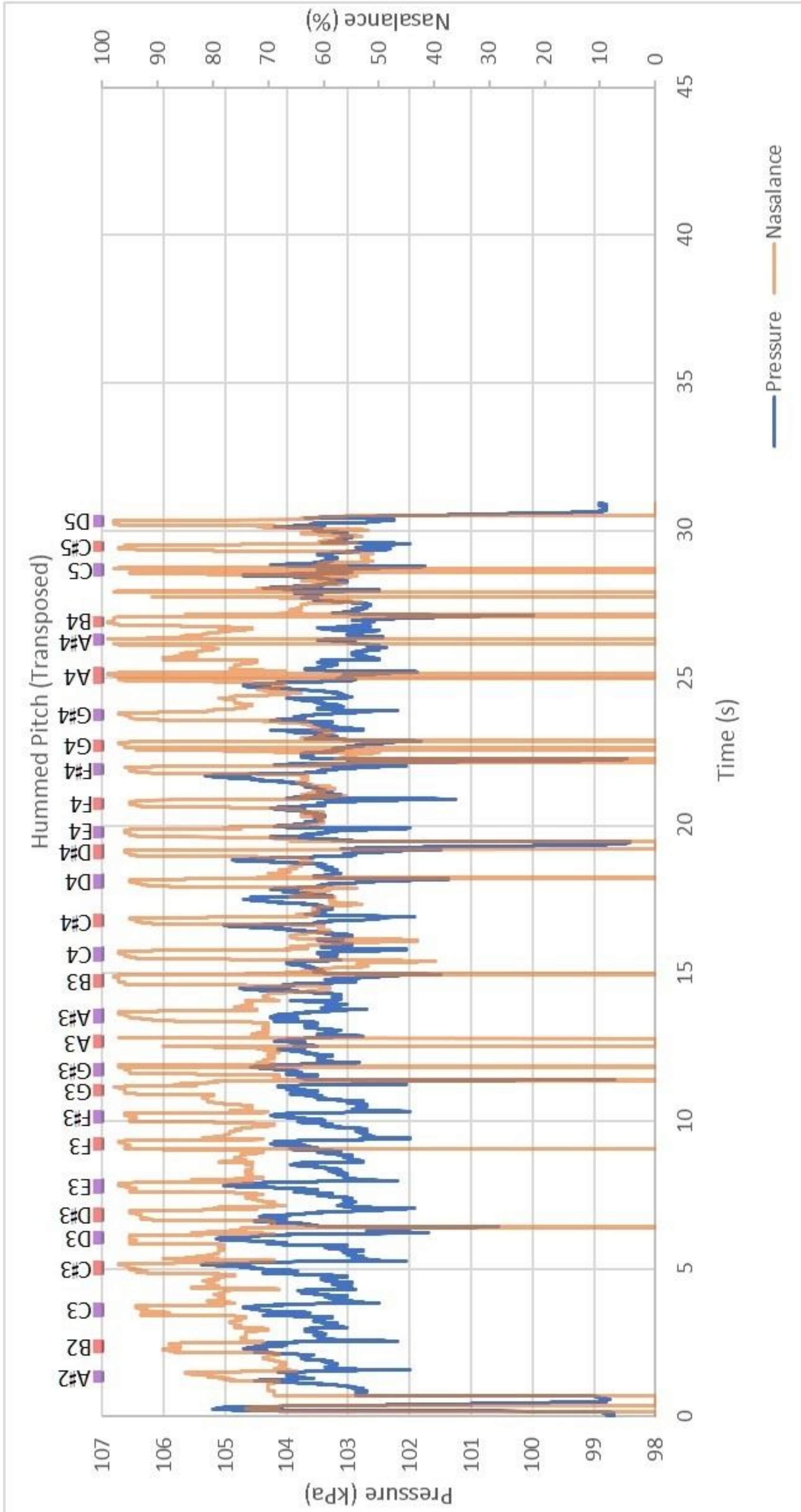


Figure A.7. Pressure and nasalance graph, play loud, hum loud, C_6.

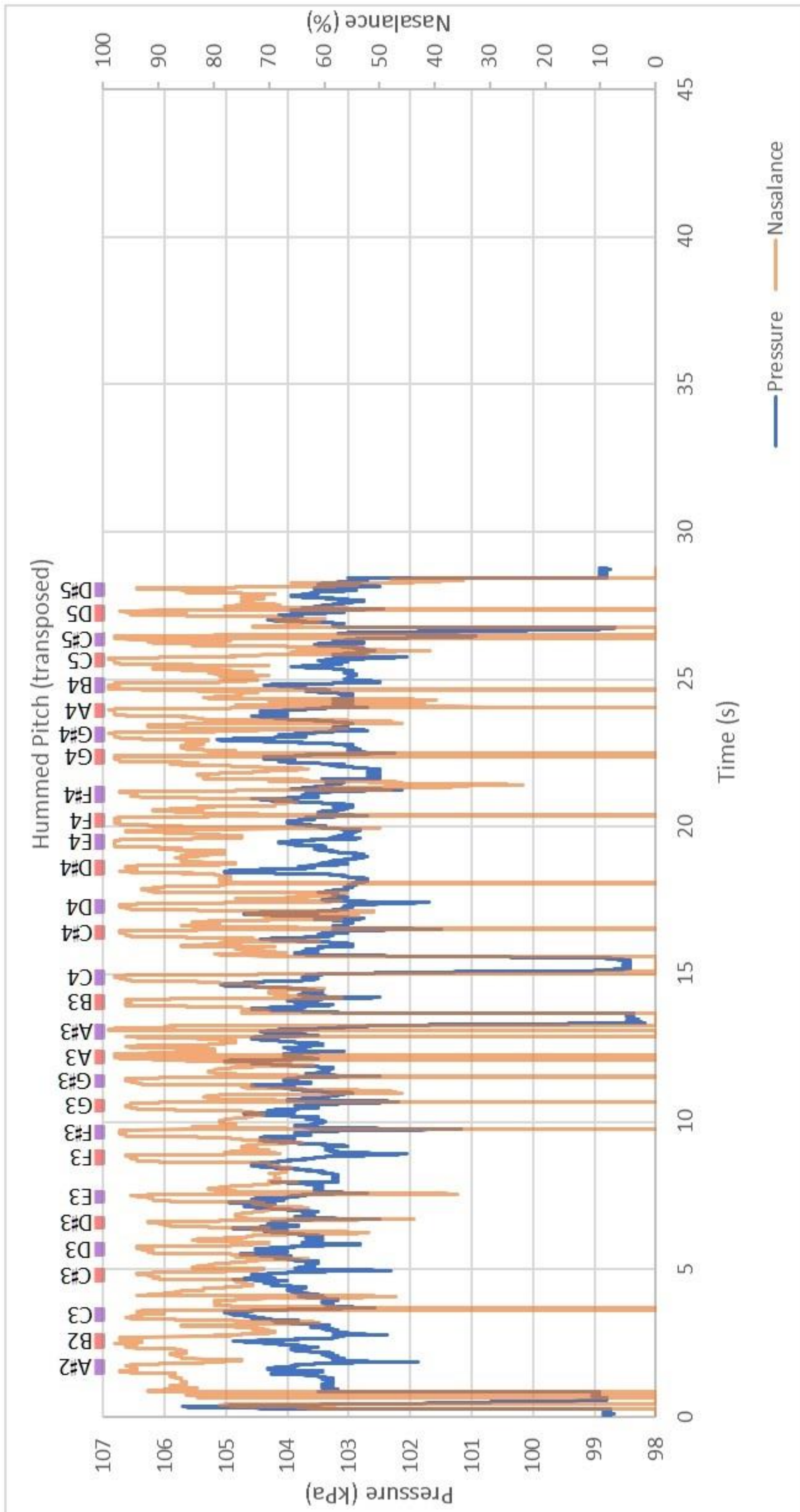


Figure A.8. Pressure and nasalance graph, play loud, hum loud, E_6.

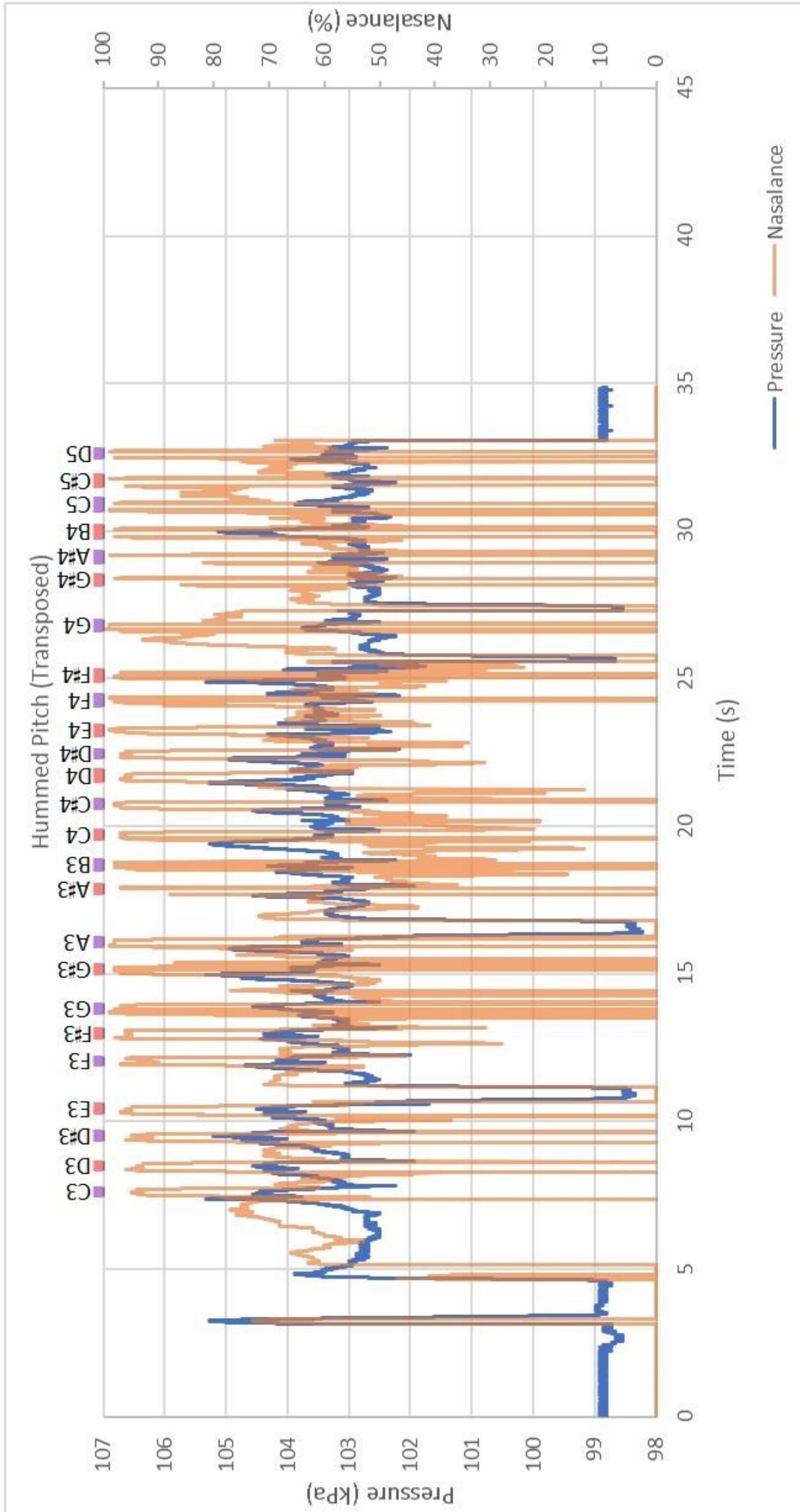


Figure A.9. Pressure and nasalance graph, play loud, hum loud, G_6.

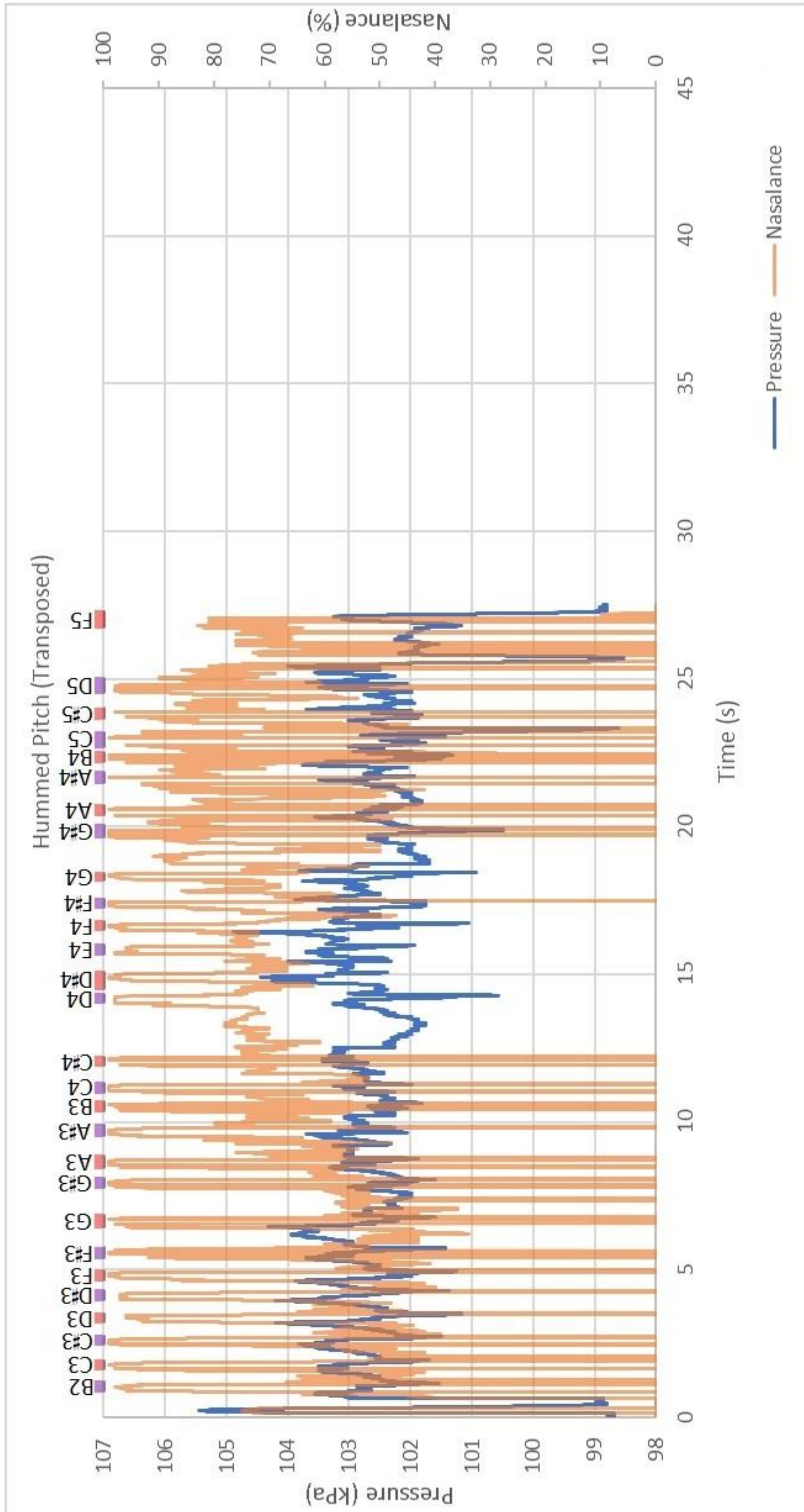


Figure A.10. Pressure and nasalance graph, play loud, hum loud, C_7.

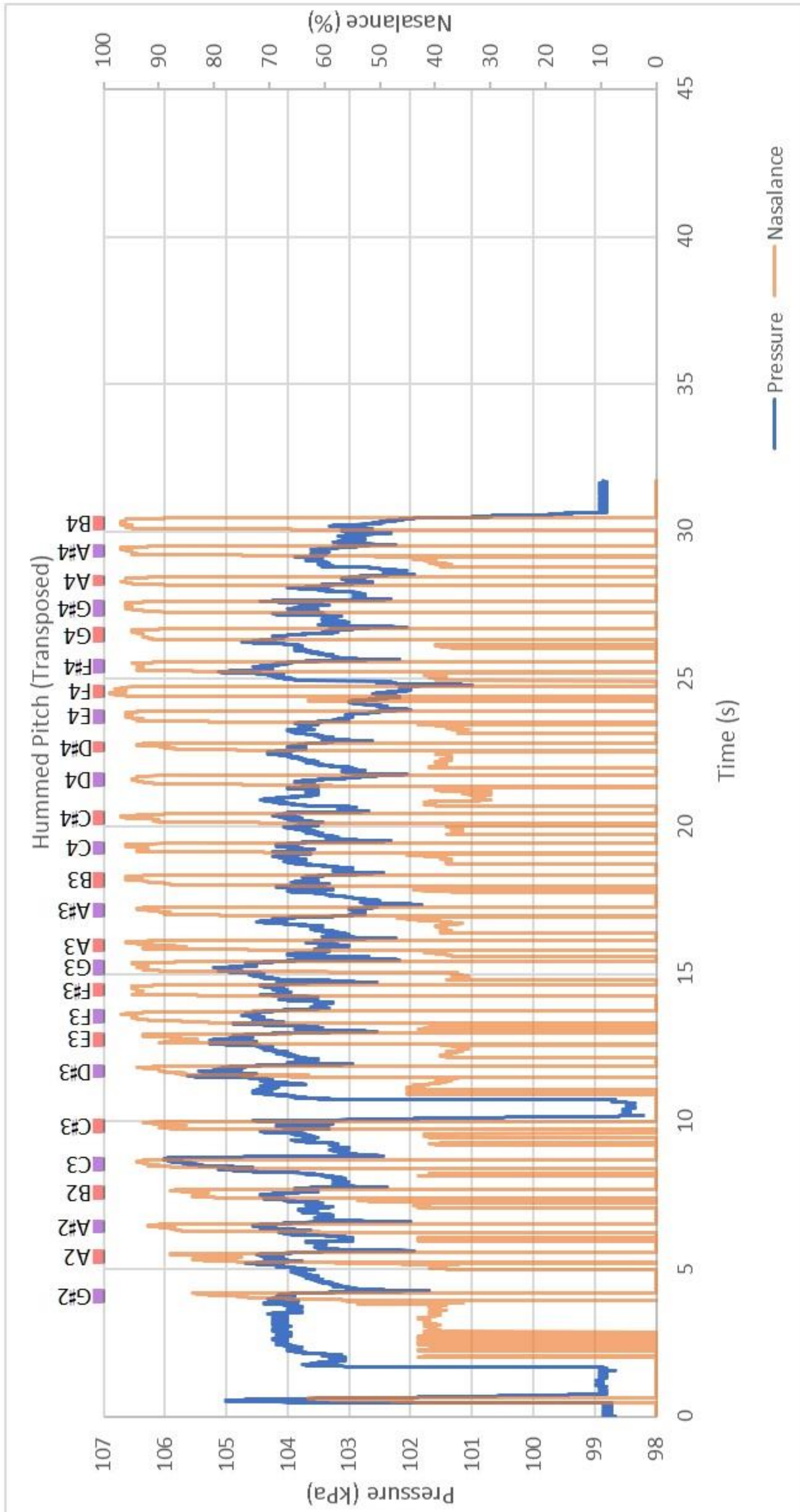


Figure A.11. Pressure and nasalance graph, play loud, hum soft, E_3.

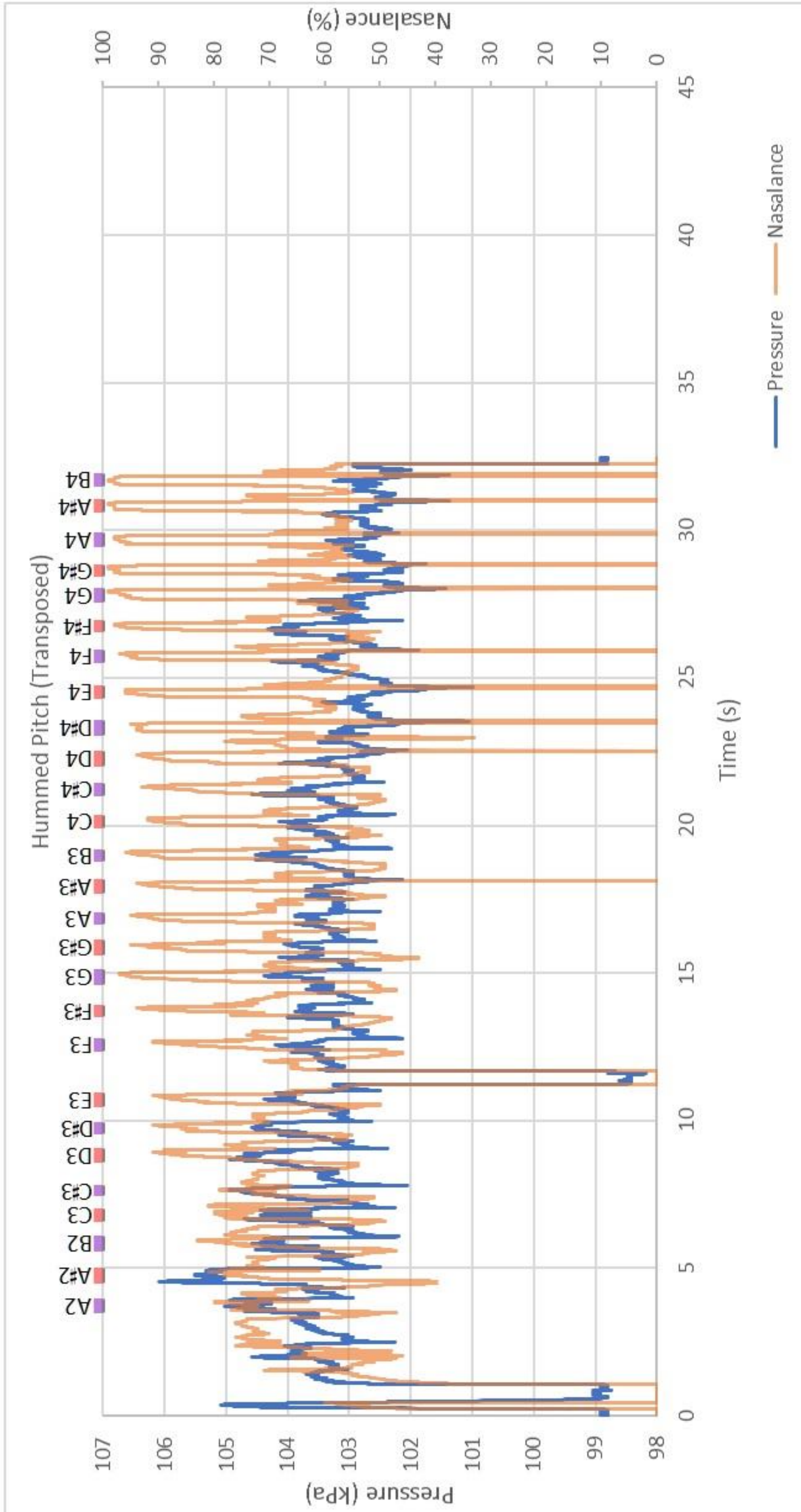


Figure A.12. Pressure and nasalance graph, play loud, hum soft, G4.

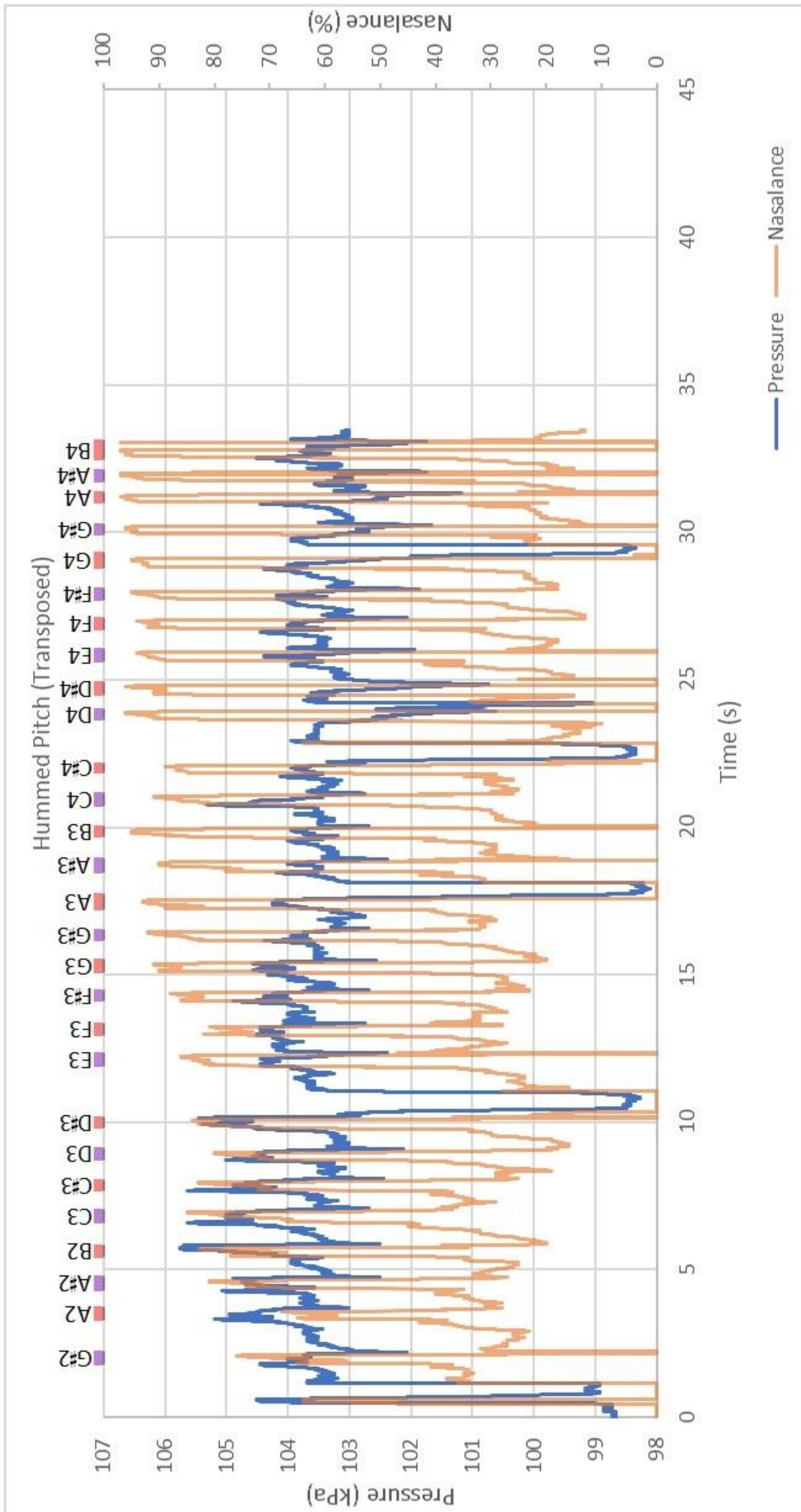


Figure A.13. Pressure and nasalance graph, play loud, hum soft, B4.

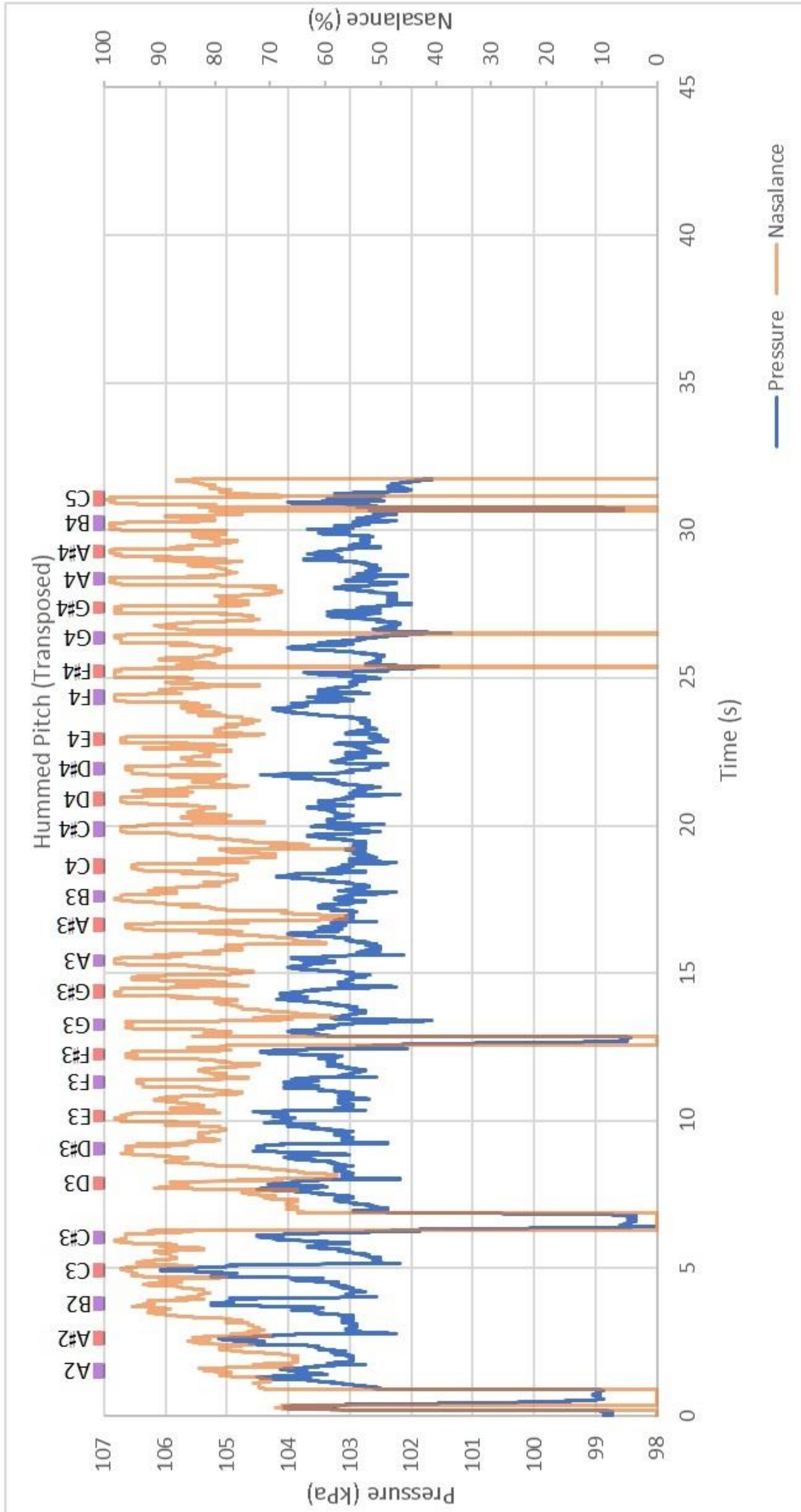


Figure A.14. Pressure and nasalance graph, play loud, hum soft, C_6.

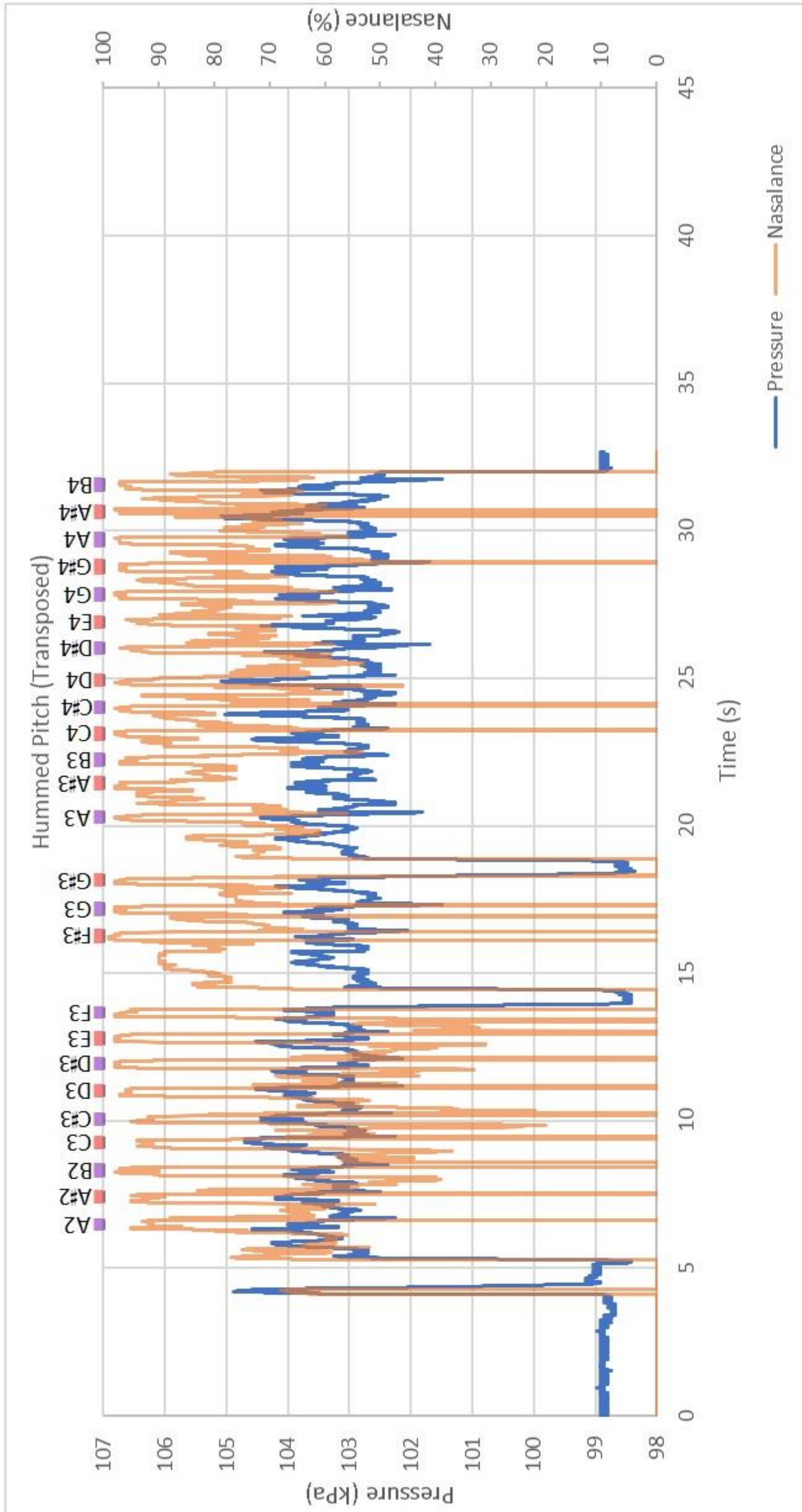


Figure A.15. Pressure and nasalance graph, play loud, hum soft, E6.

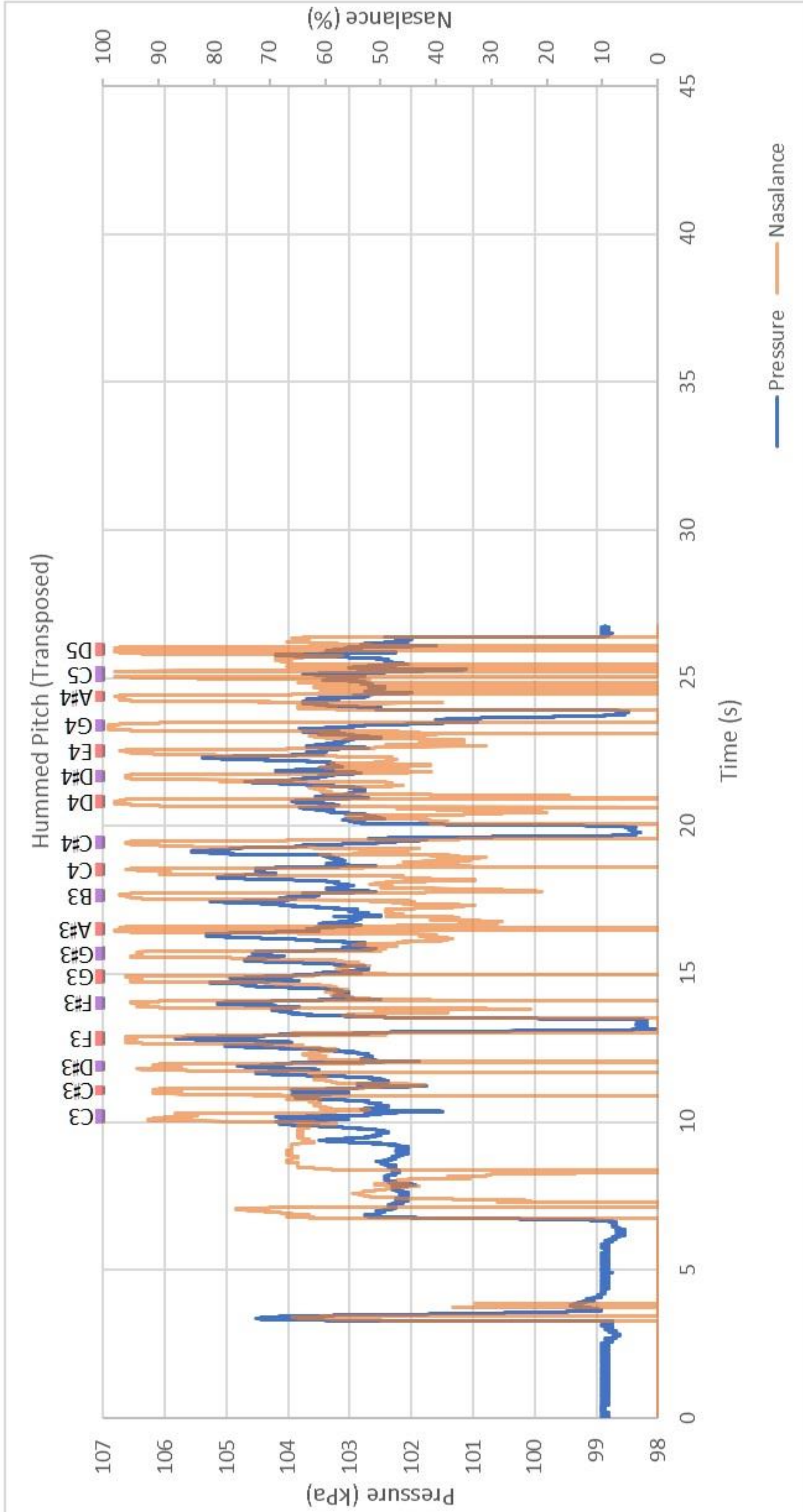


Figure A.16. Pressure and nasalance graph, play loud, hum soft, G_6.

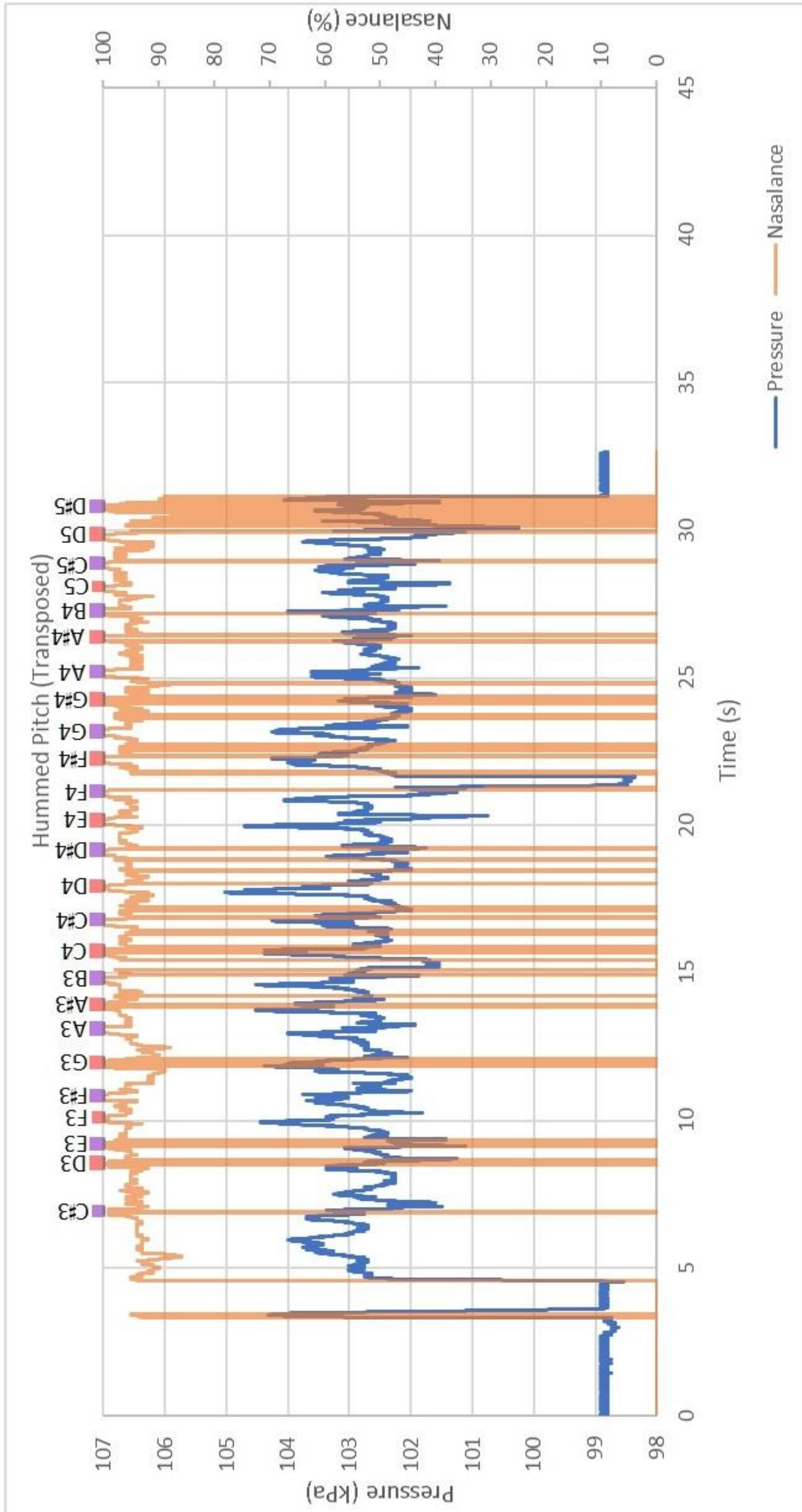


Figure A.17. Pressure and nasalance graph, play loud, hum soft, C_7.

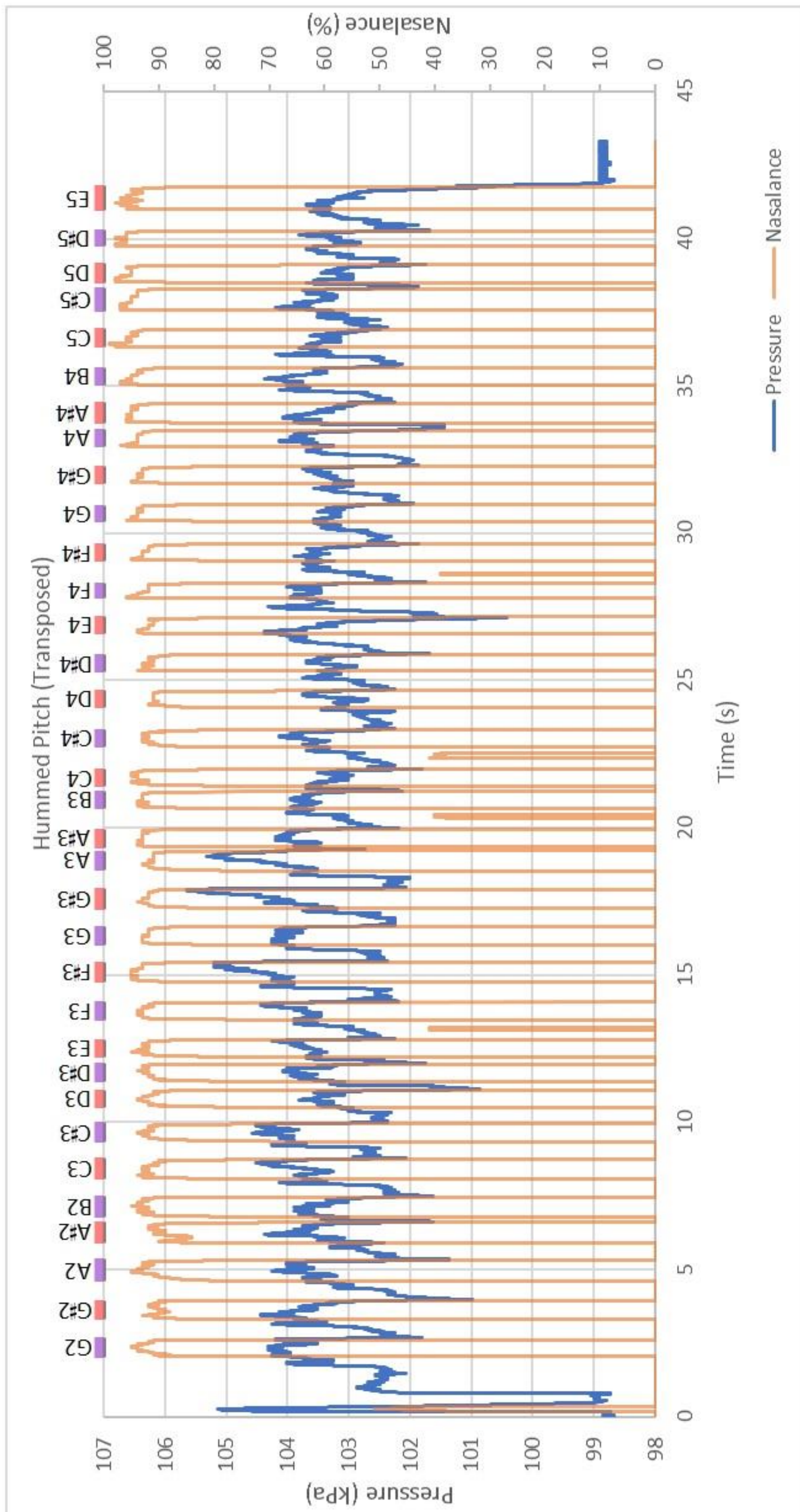


Figure A.18. Pressure and nasalance graph, play soft, hum loud, E3.

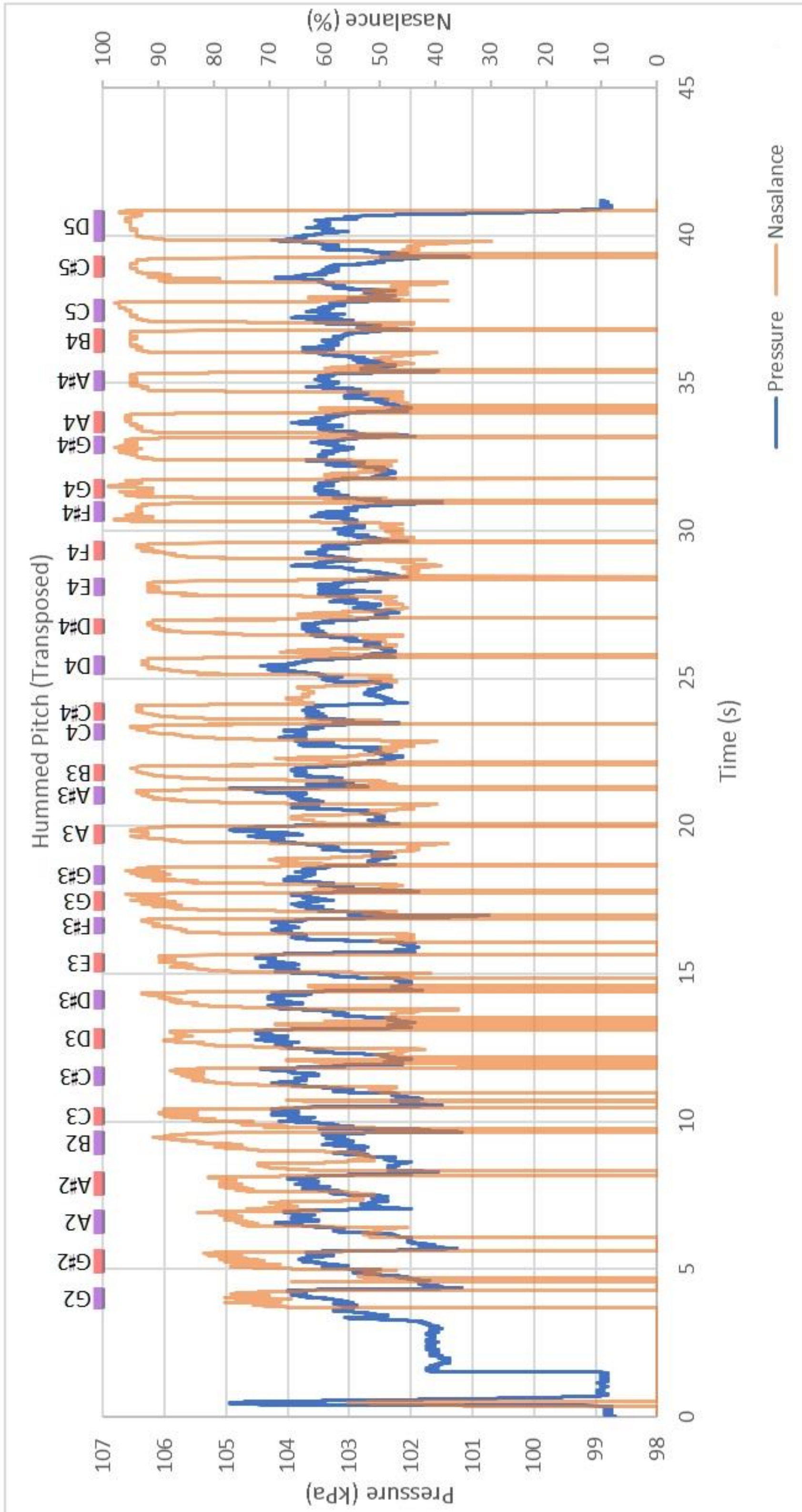


Figure A.19. Pressure and nasalance graph, play soft, hum loud, G4.

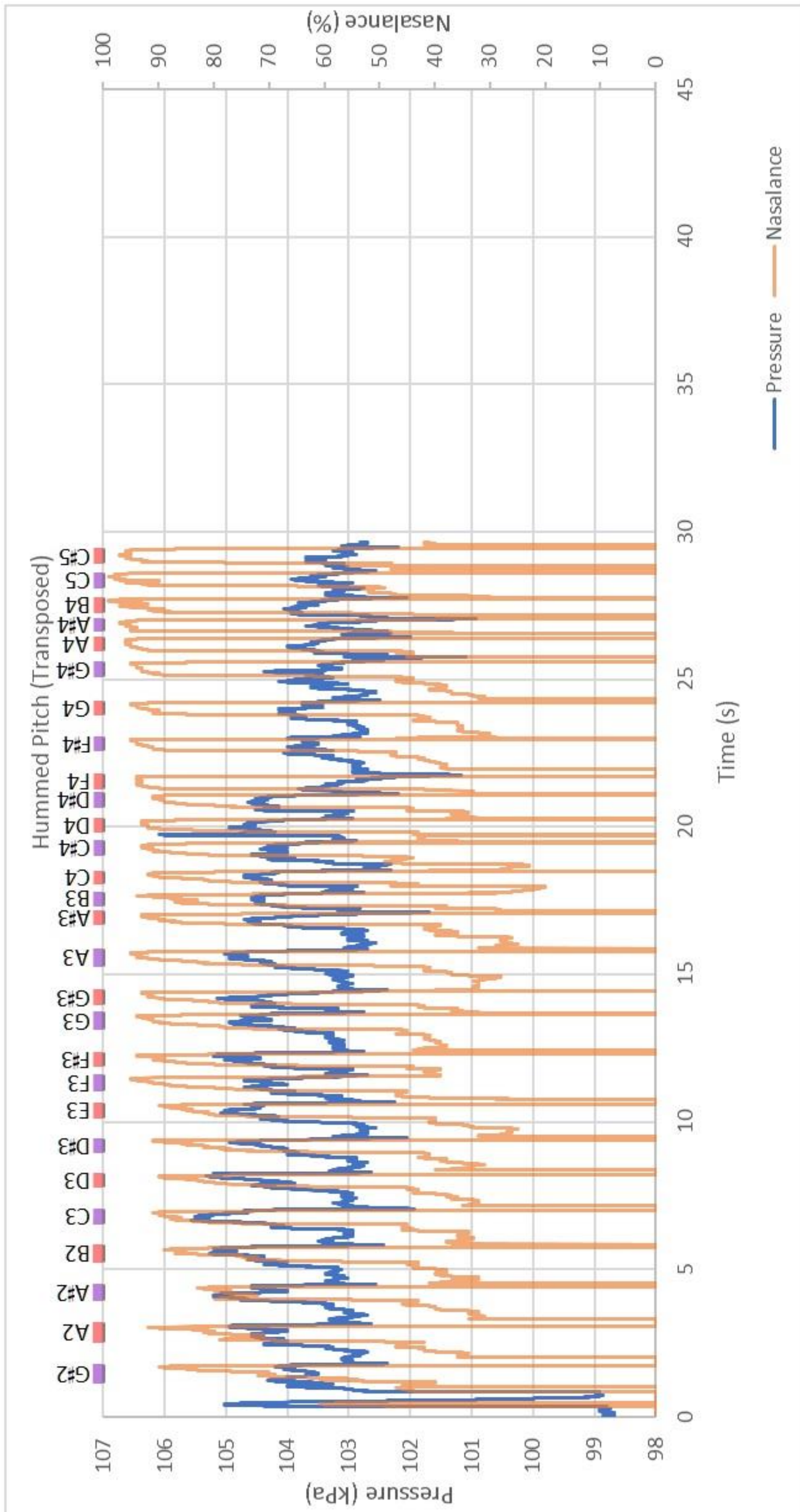


Figure A.20. Pressure and nasalance graph, play soft, hum loud, B4.

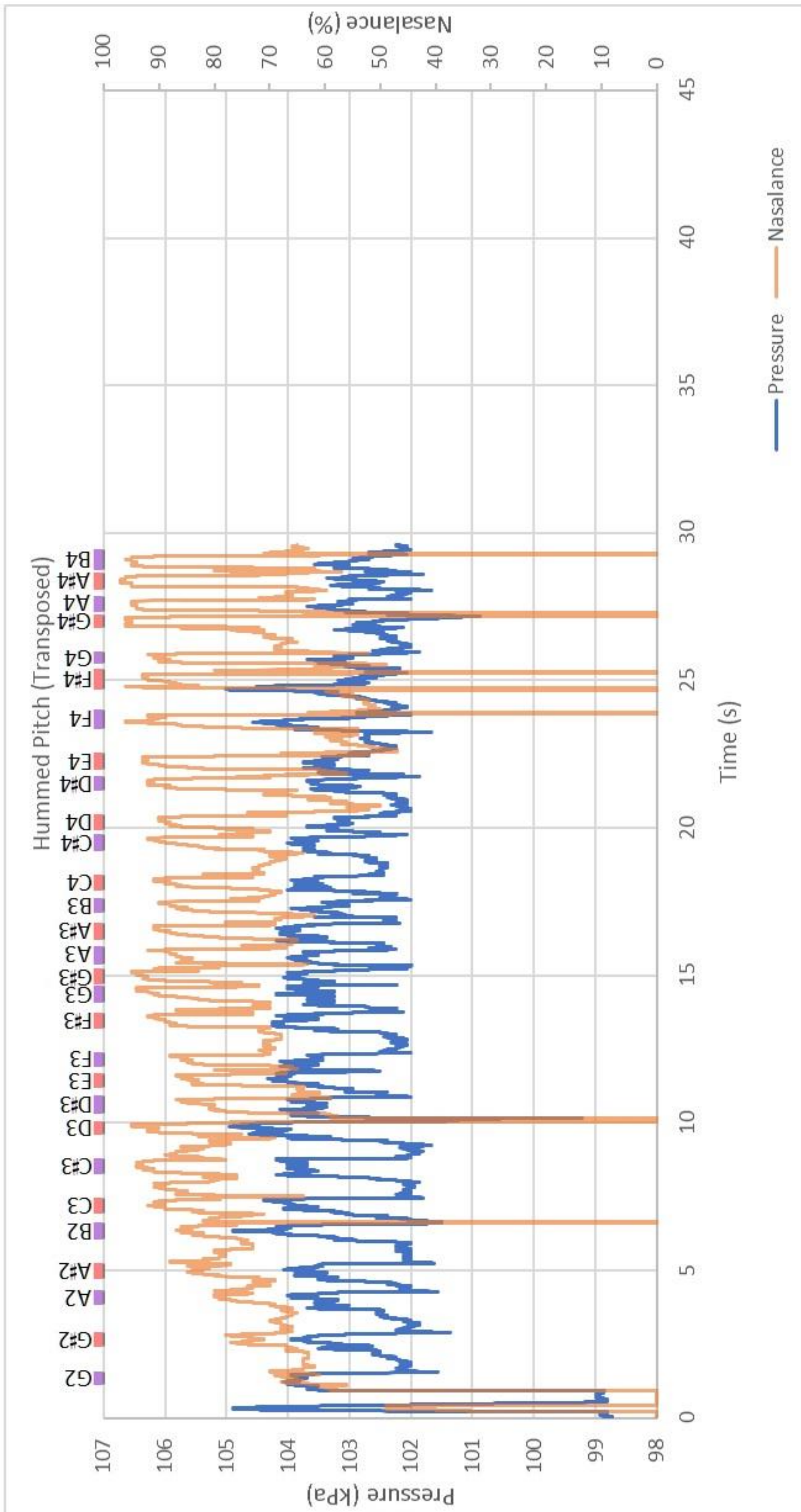


Figure A.21. Pressure and nasalance graph, play soft, hum loud, C_6.

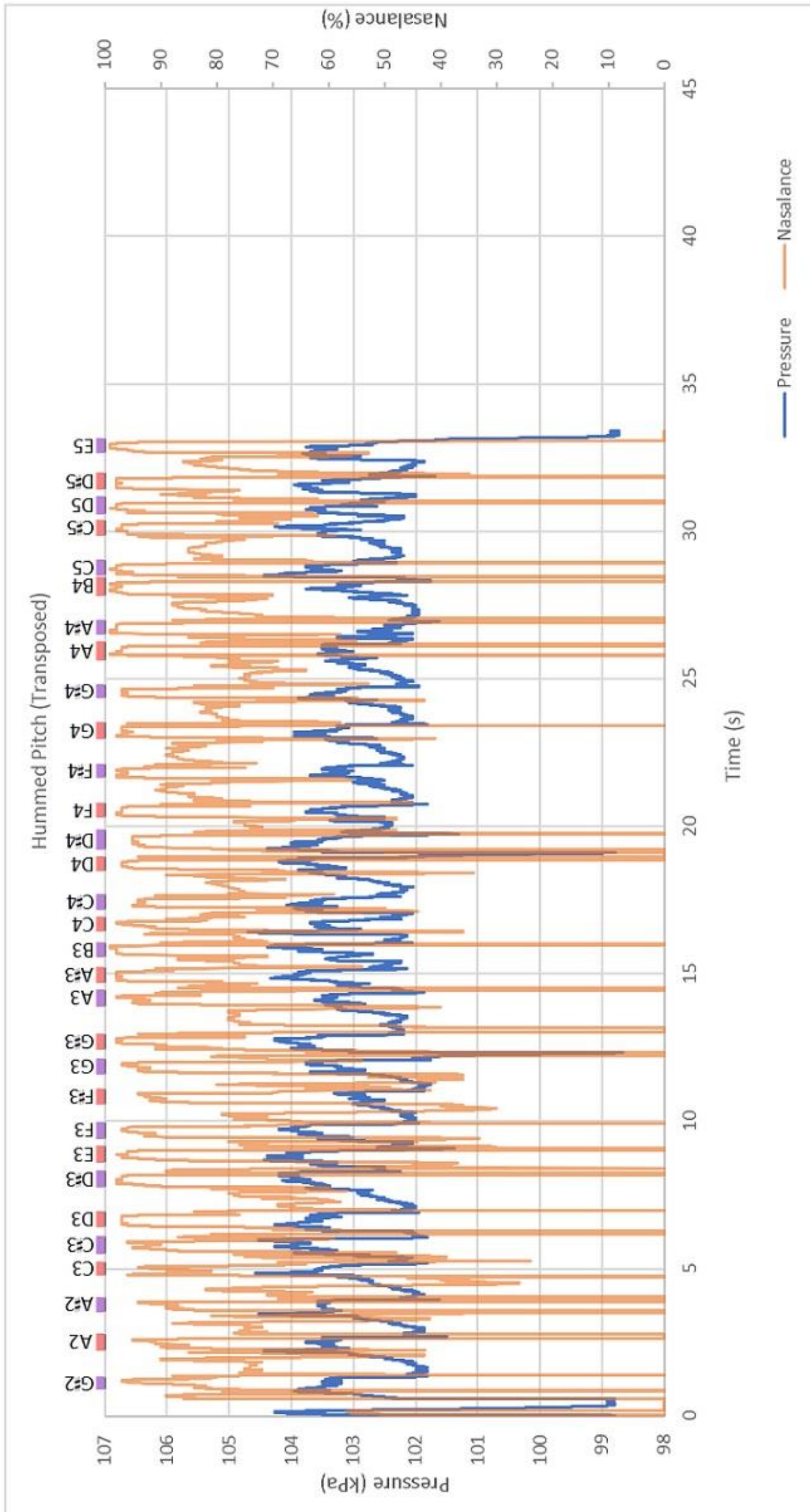


Figure A.22. Pressure and nasalance graph, play soft, hum loud, E_6.

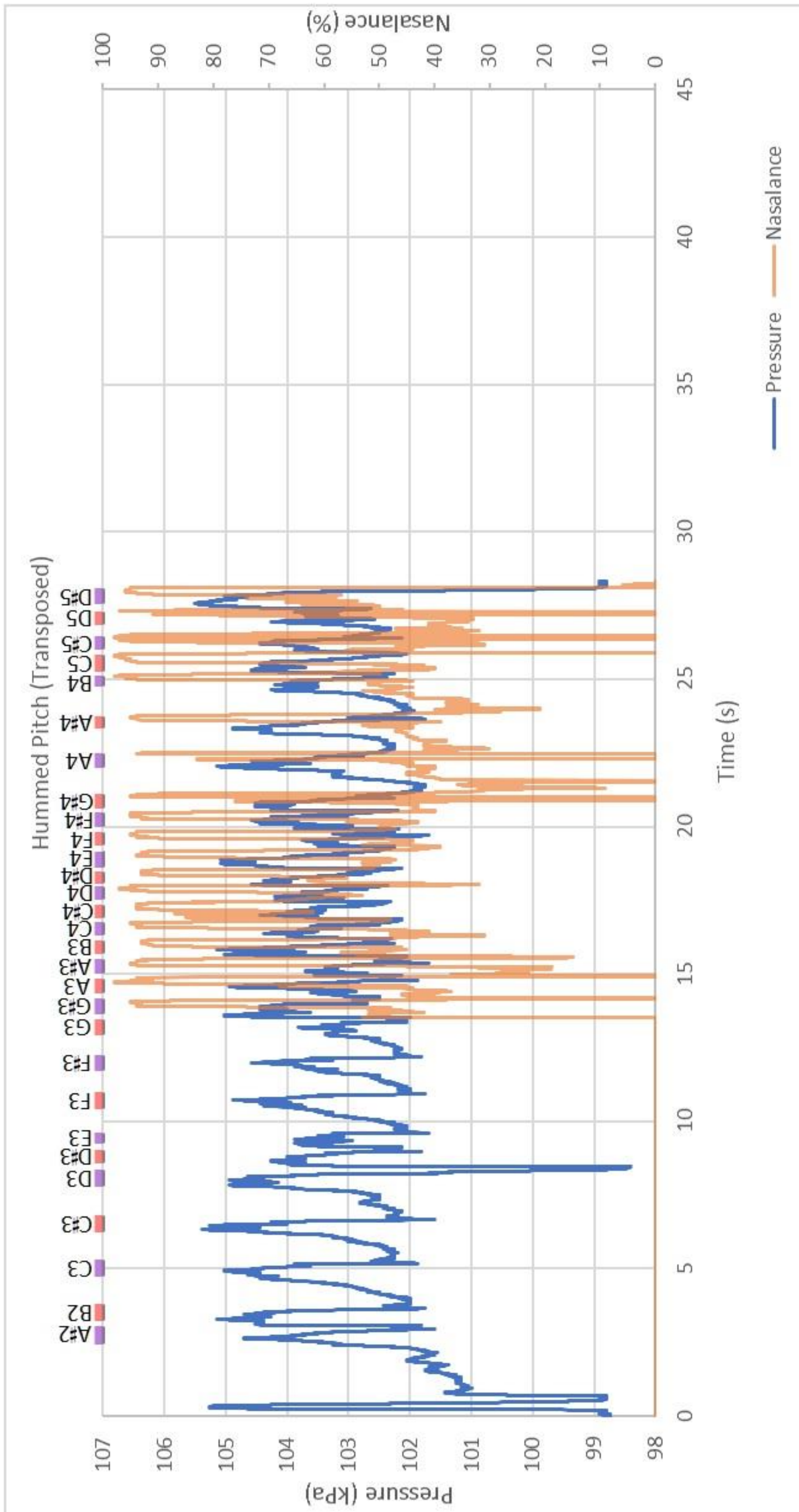


Figure A.23. Pressure and nasalance graph, play soft, hum loud, G_6.

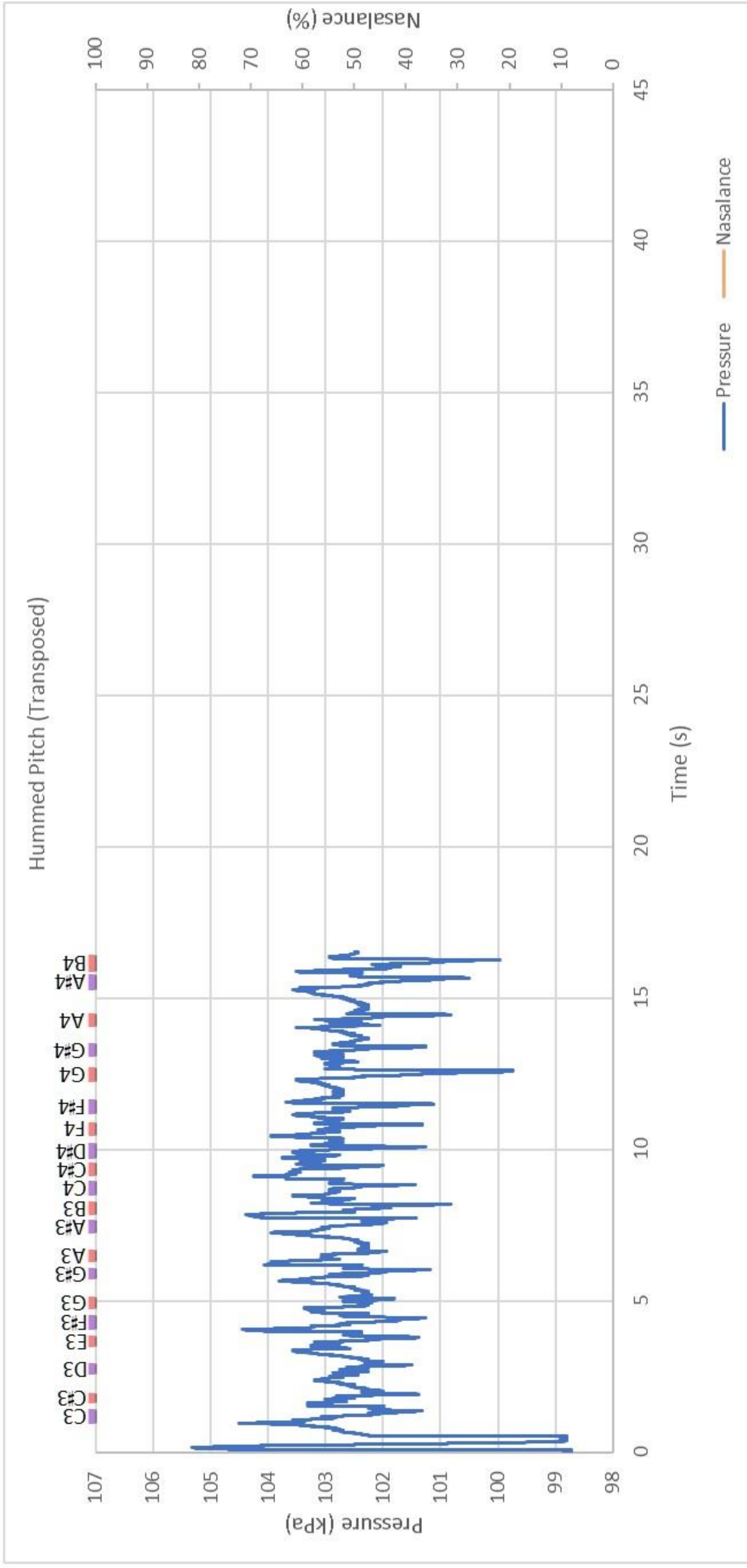


Figure A.24. Pressure and nasalance graph, play soft, hum loud, C_7.

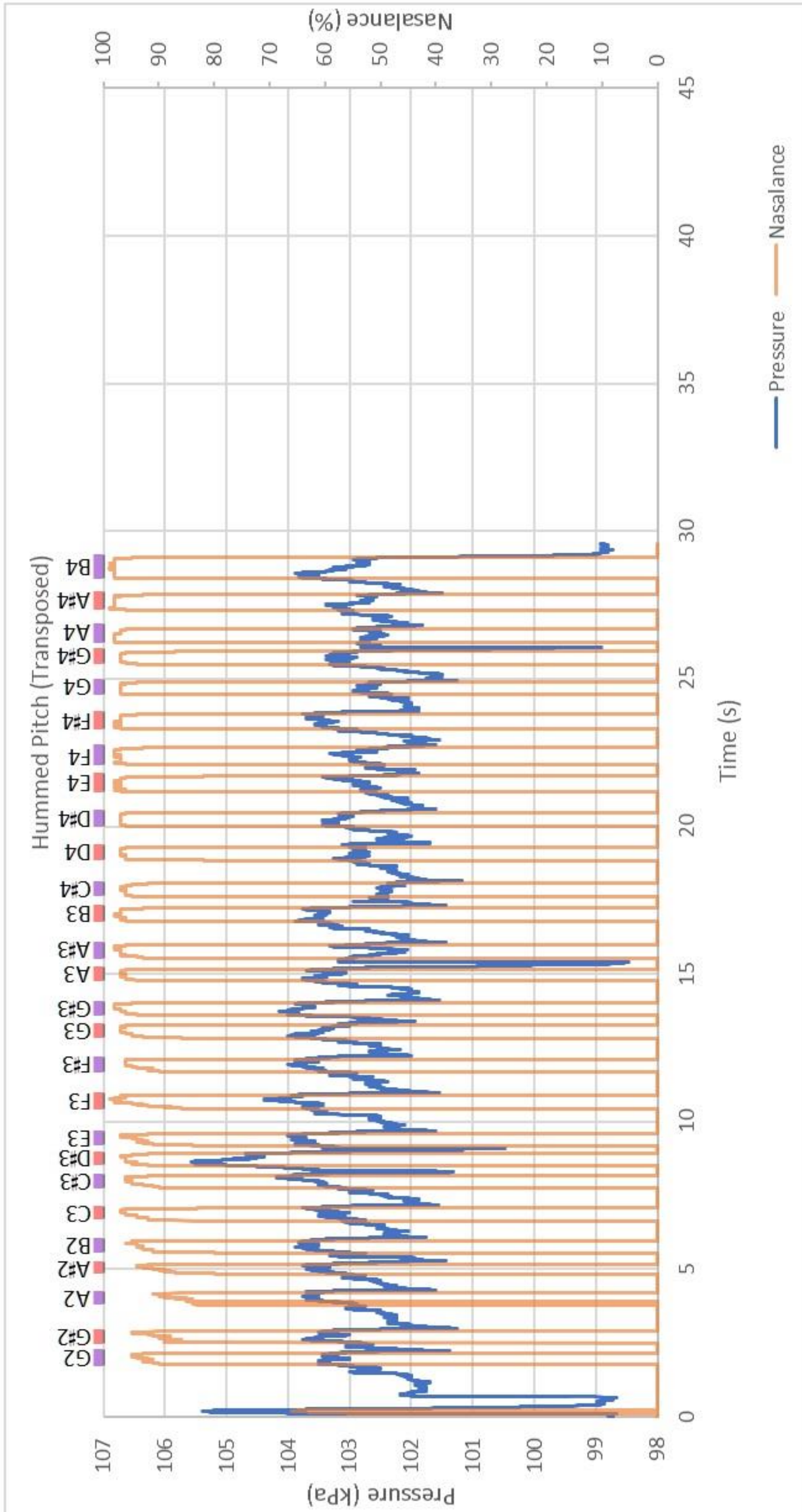


Figure A.25. Pressure and nasalance graph, play soft, hum soft, E_3.

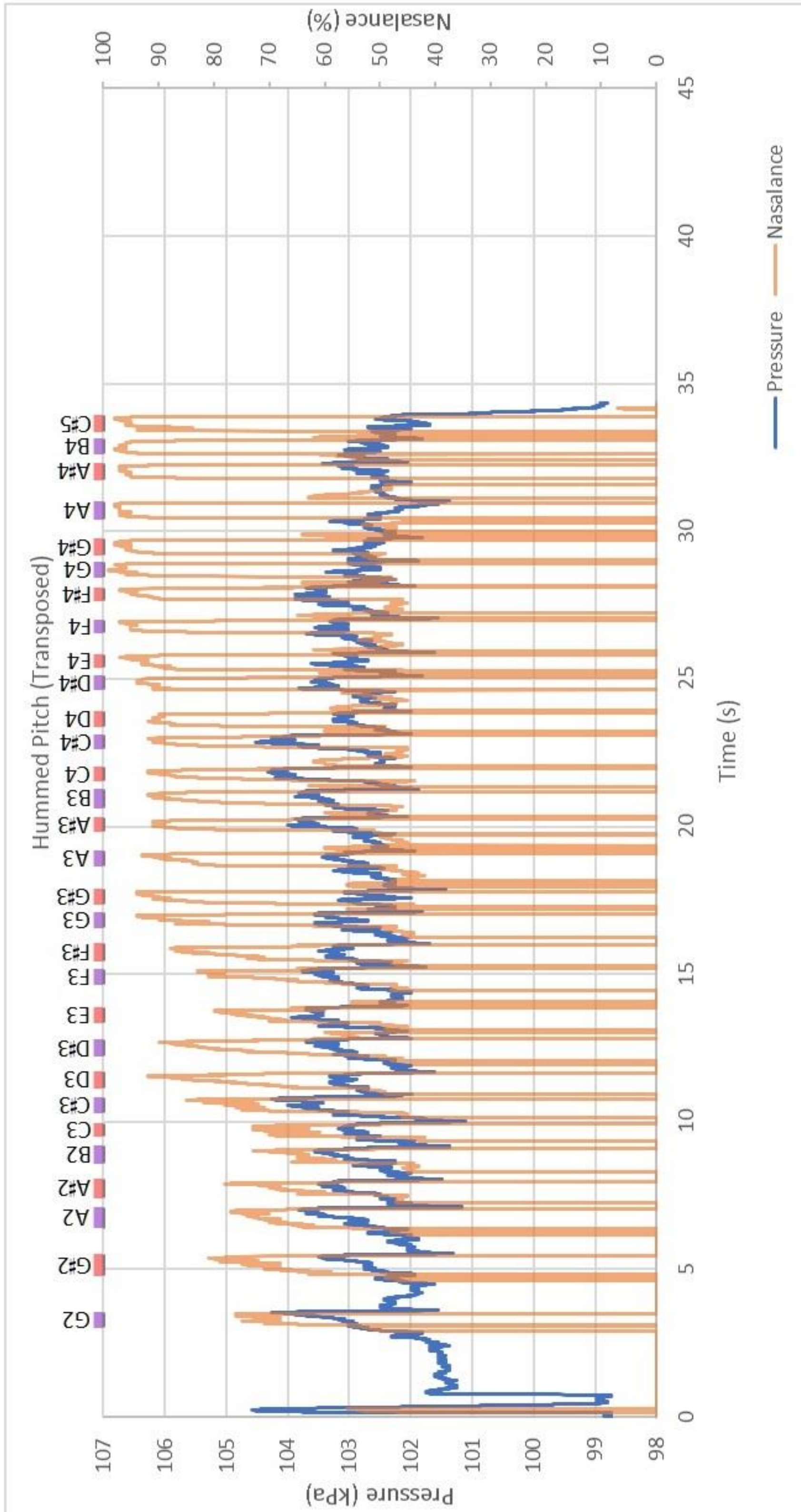


Figure A.26. Pressure and nasalance graph, play soft, hum soft, G_4.

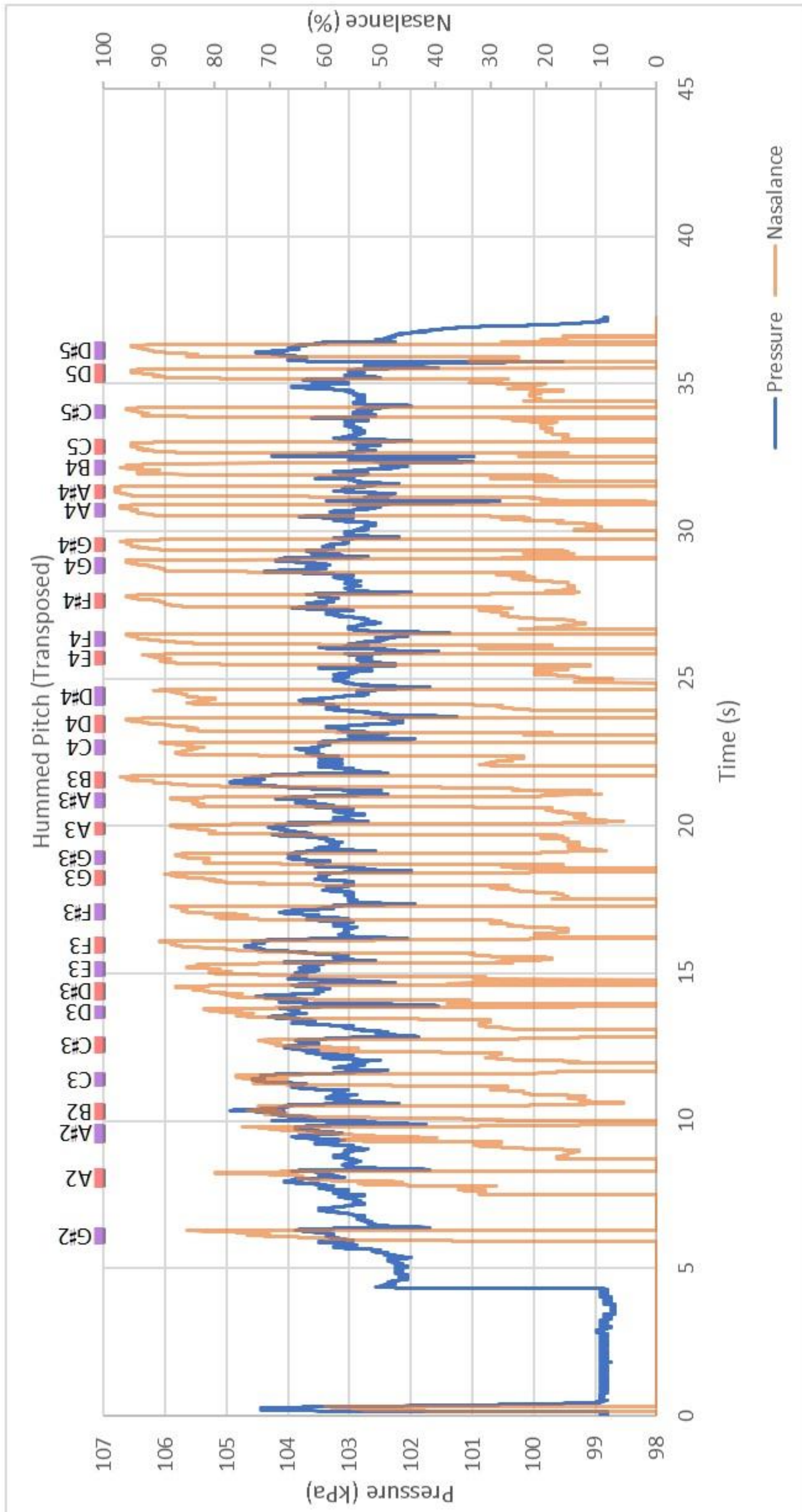


Figure A.27. Pressure and nasalance graph, play soft, hum soft, B4.

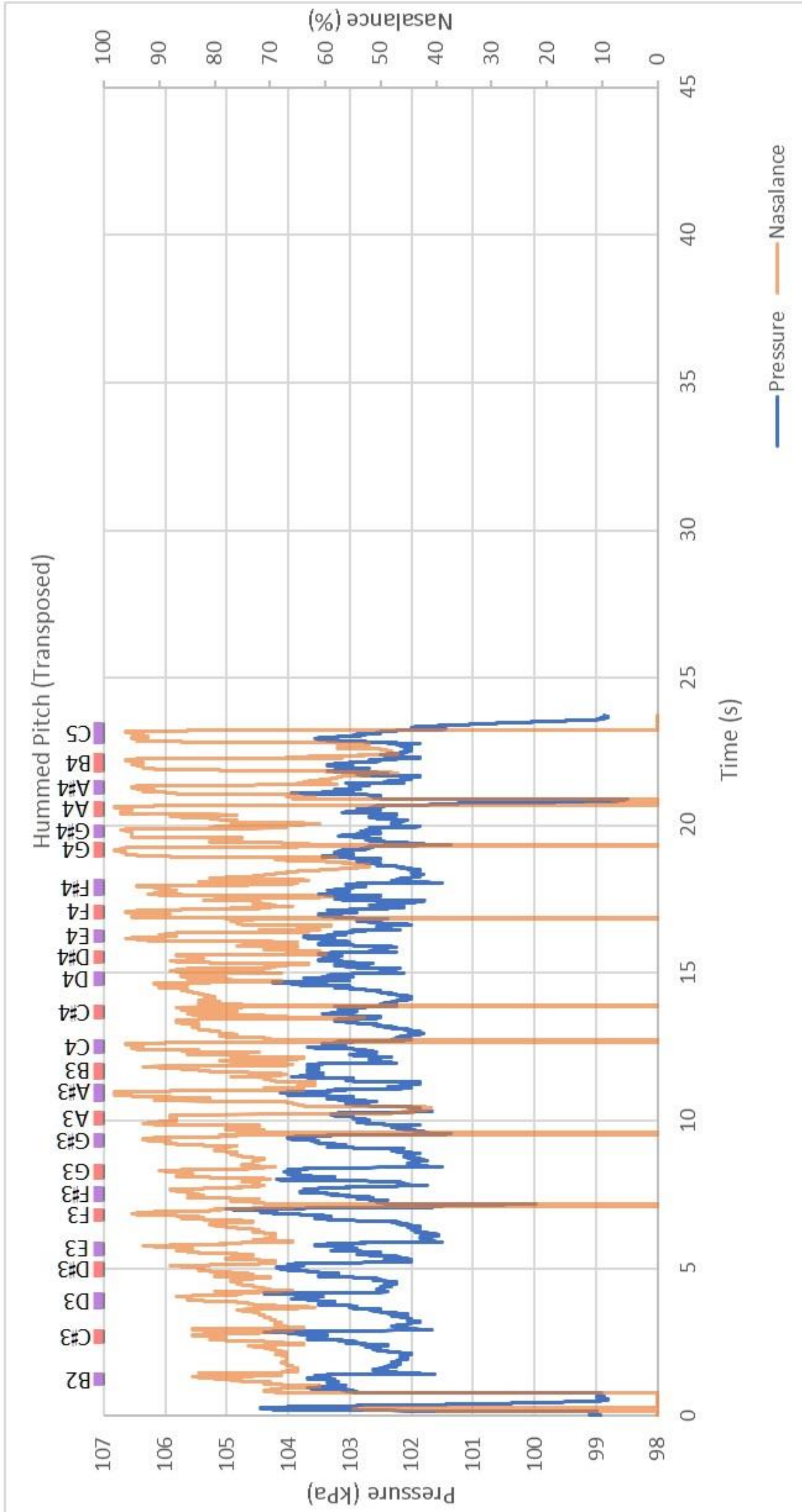


Figure A.28. Pressure and nasalance graph, play soft, hum soft, C_6.

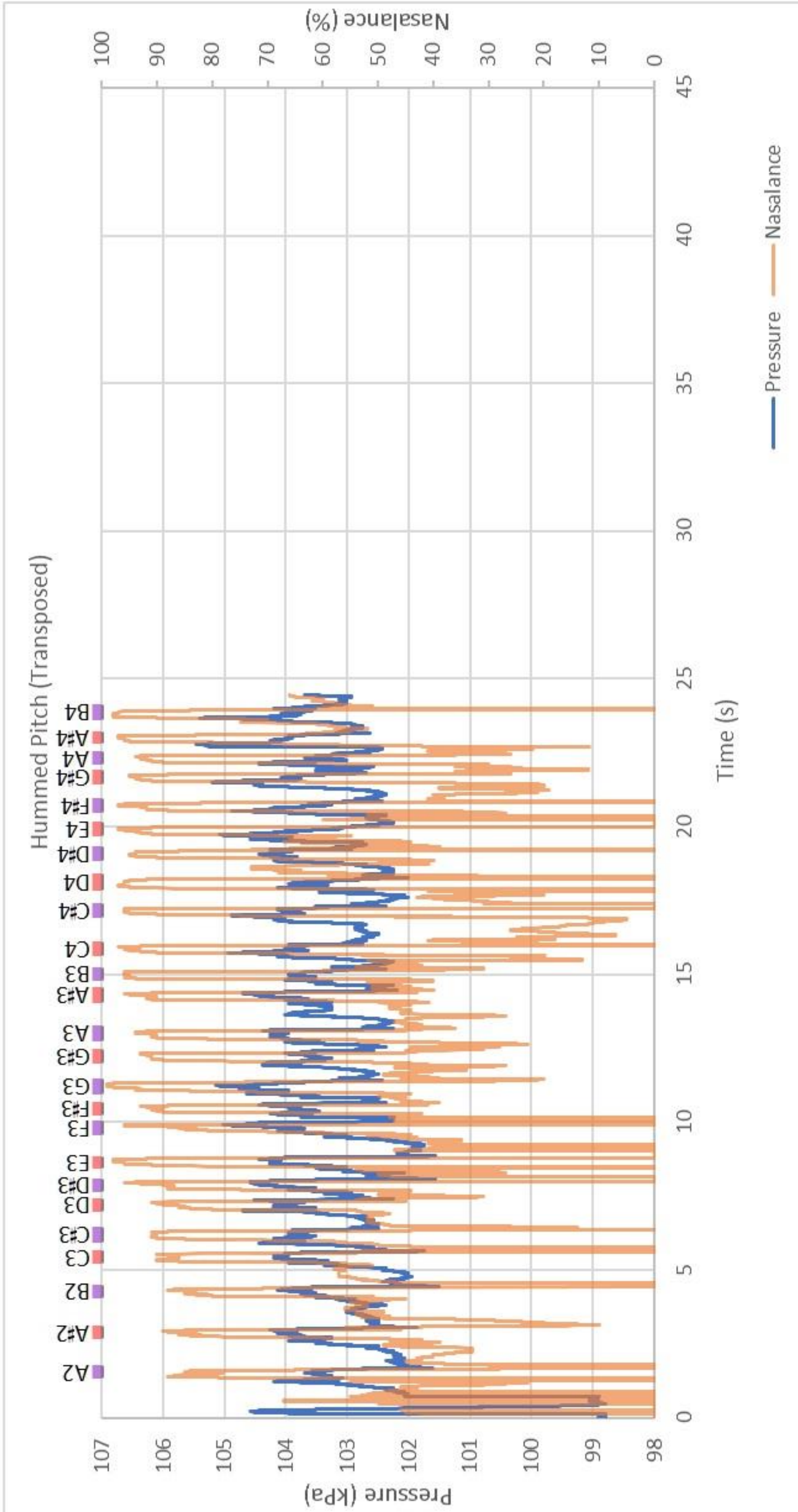


Figure A.29. Pressure and nasalance graph, play soft, hum soft, E_6.

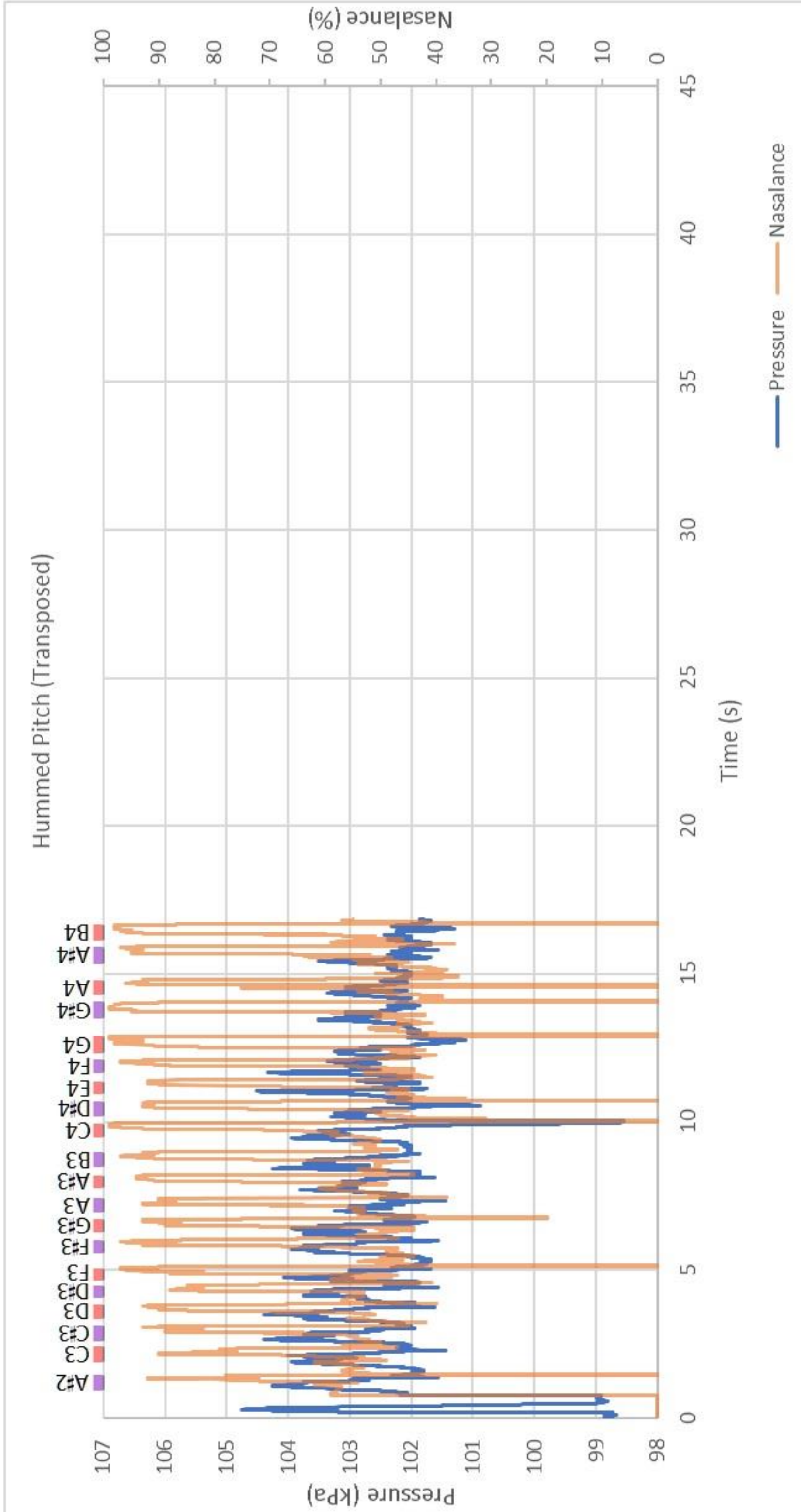


Figure A.30. Pressure and nasalance graph, play soft, hum soft, G_6.

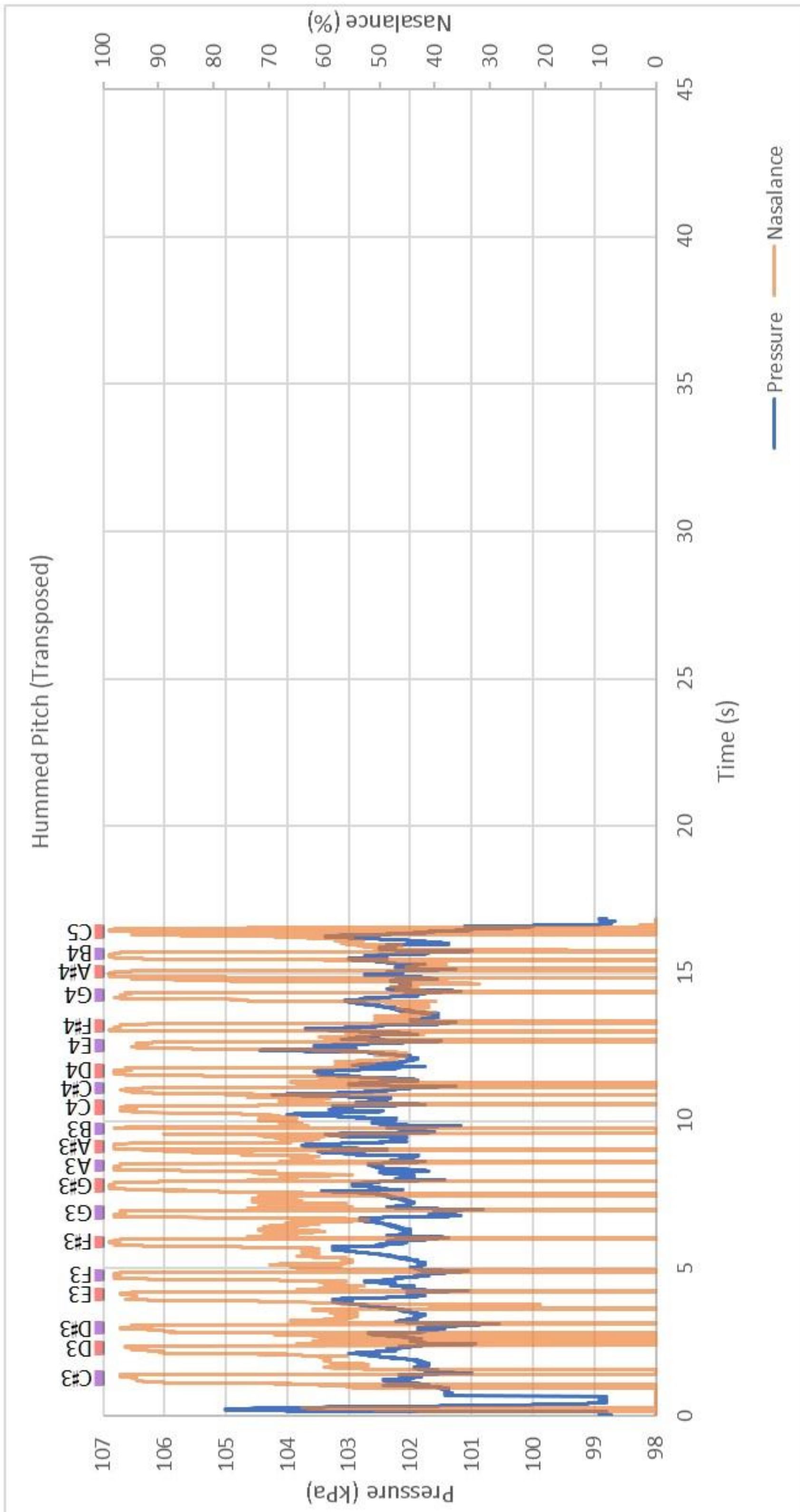


Figure A.31. Pressure and nasalance graph, play soft, hum soft, C_7.

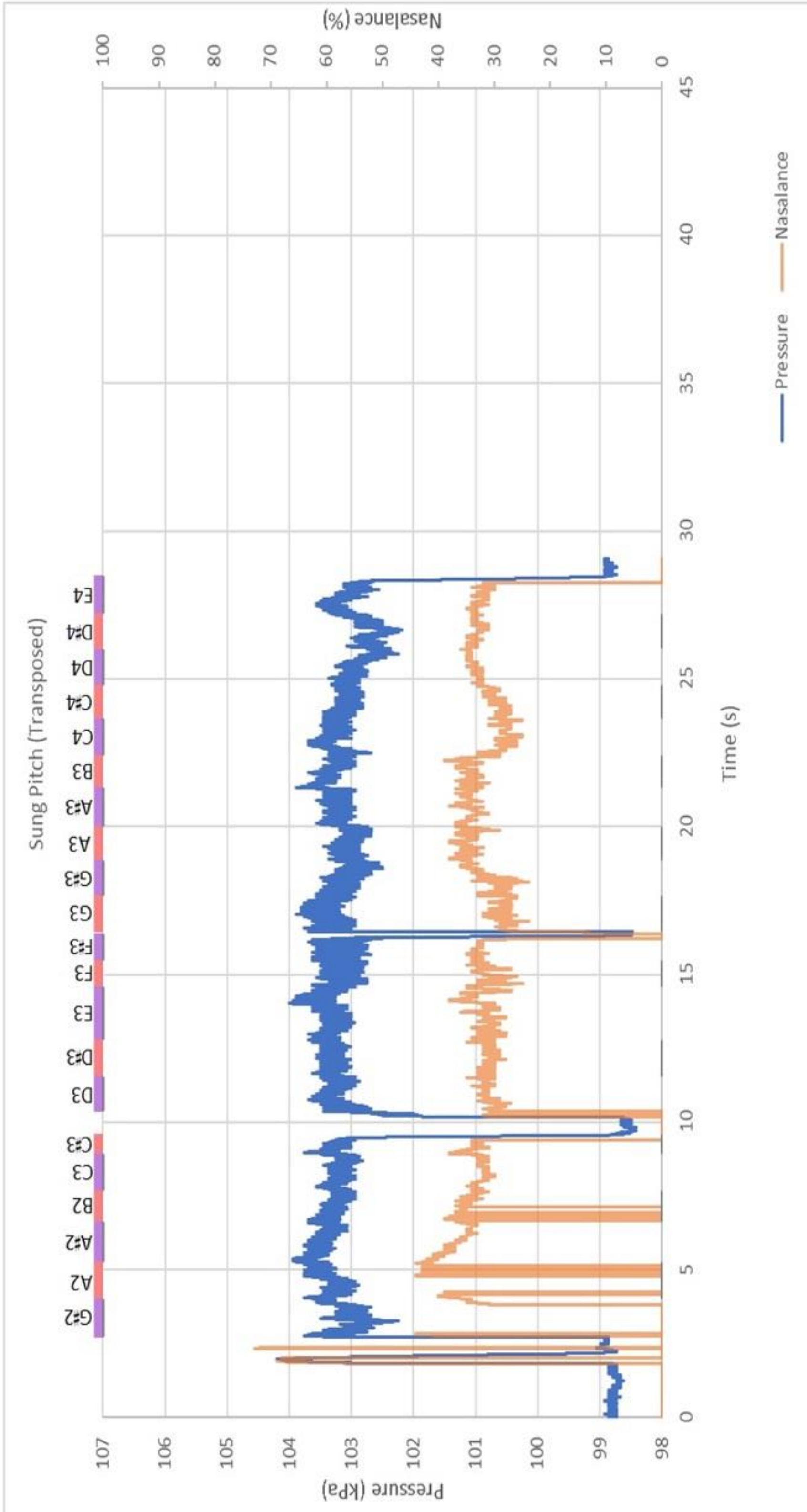


Figure A.32. Pressure and nasalance graph, play loud, sing loud, E3.

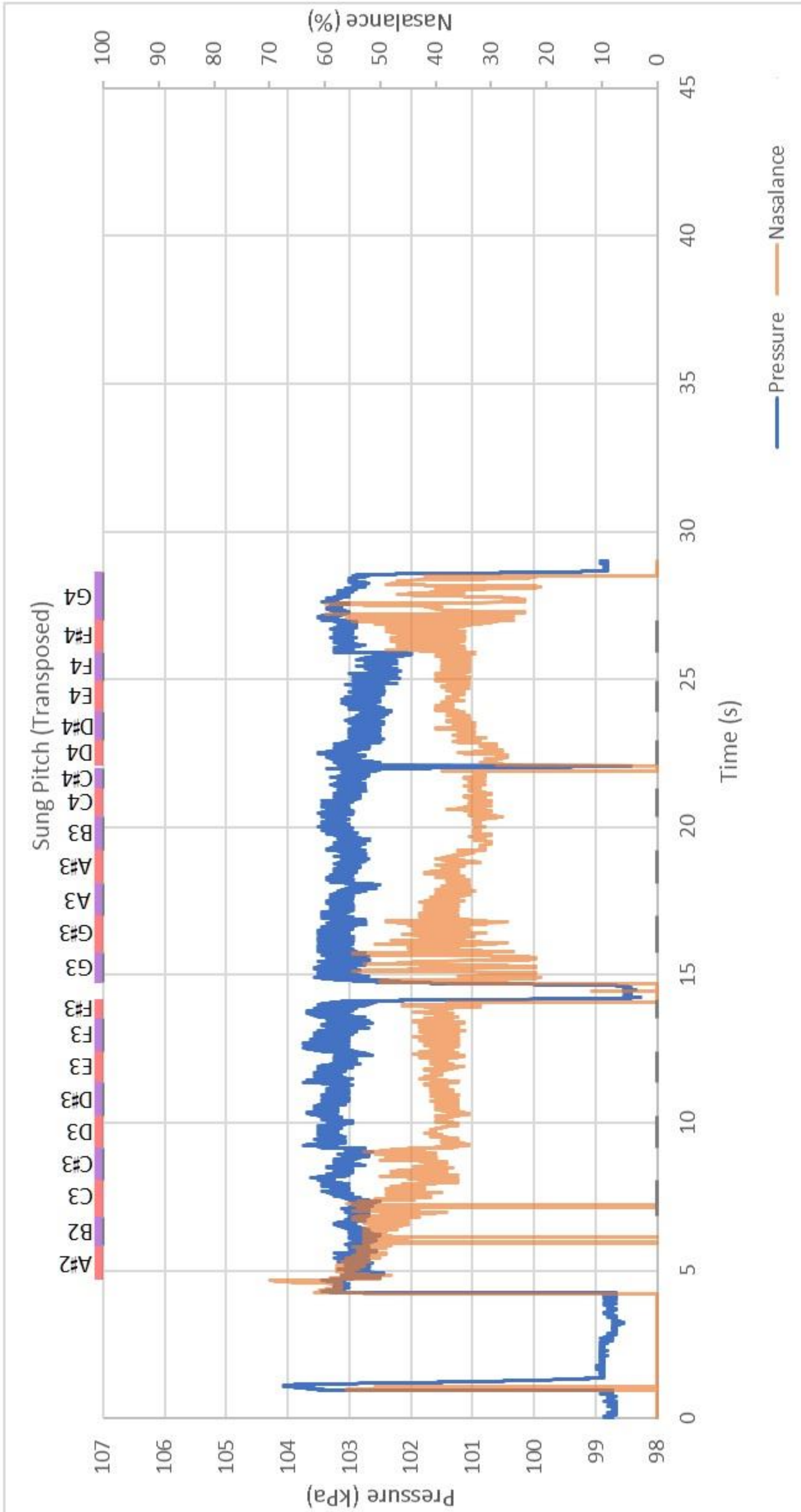


Figure A.33. Pressure and nasalance graph, play loud, sing loud, G_4.

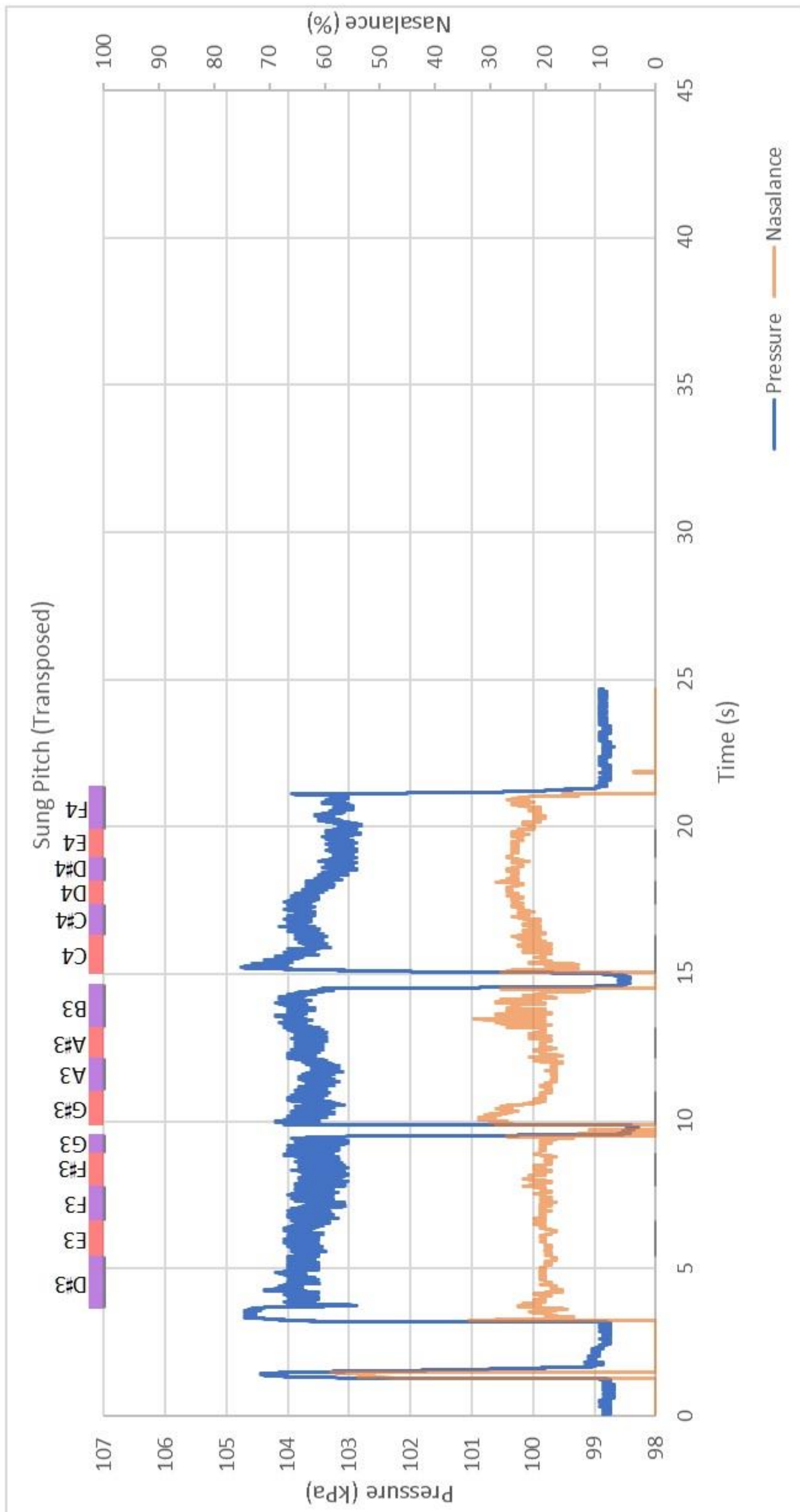


Figure A.34. Pressure and nasalance graph, play loud, sing loud, B4.

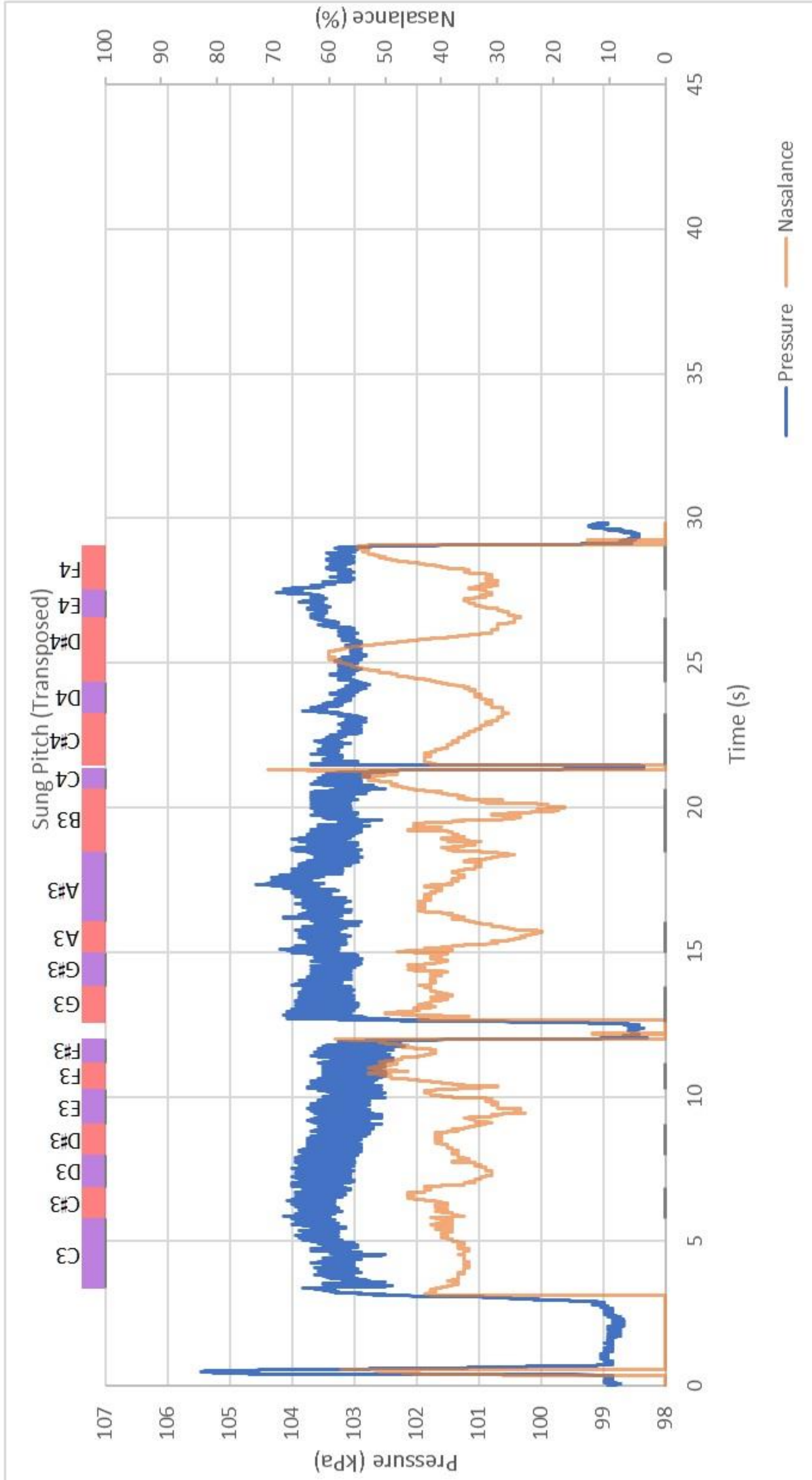


Figure A.35. Pressure and nasalance graph, play loud, sing loud, C_6.

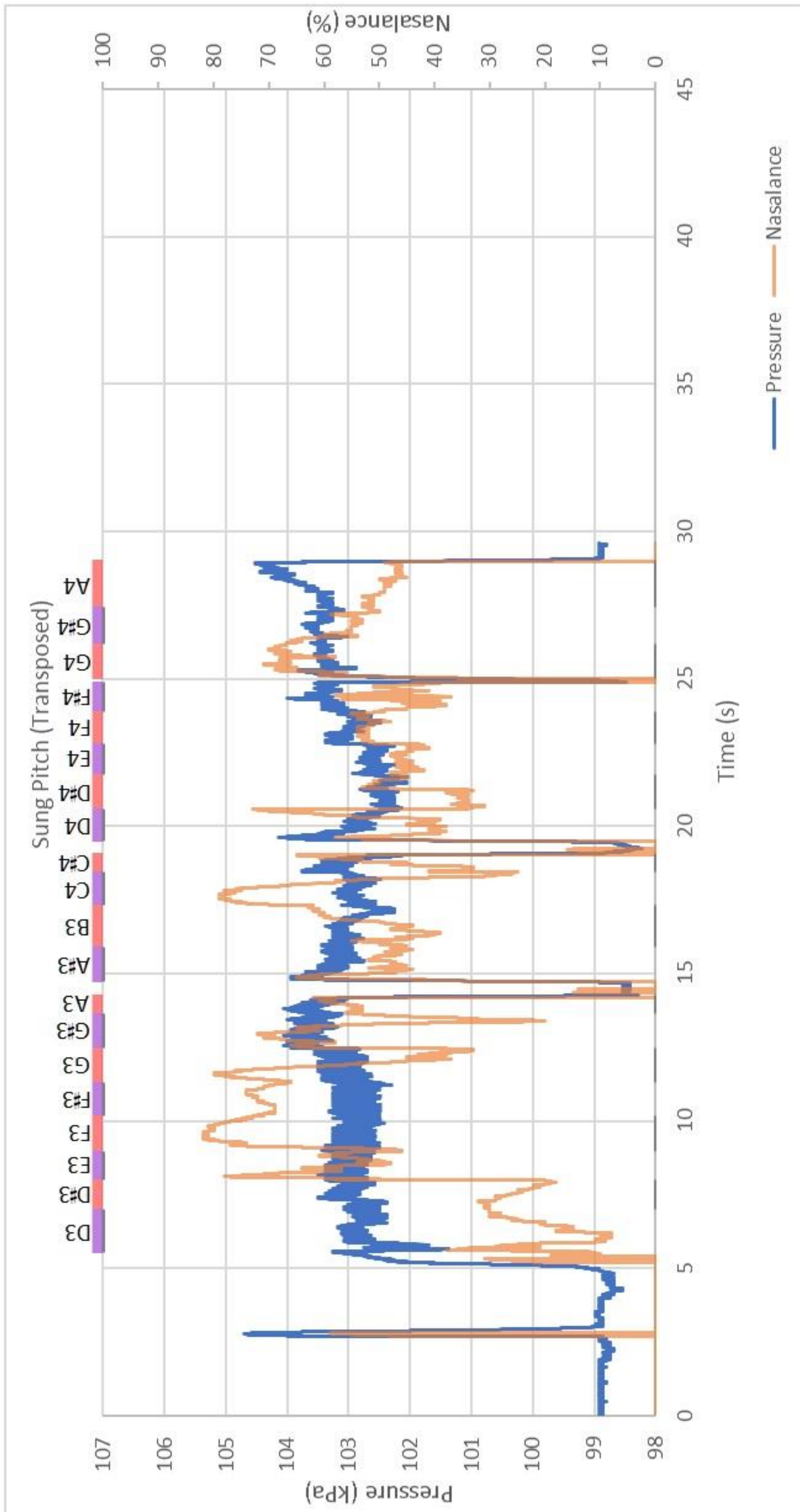


Figure A.36. Pressure and nasalance graph, play loud, sing loud, E_6.

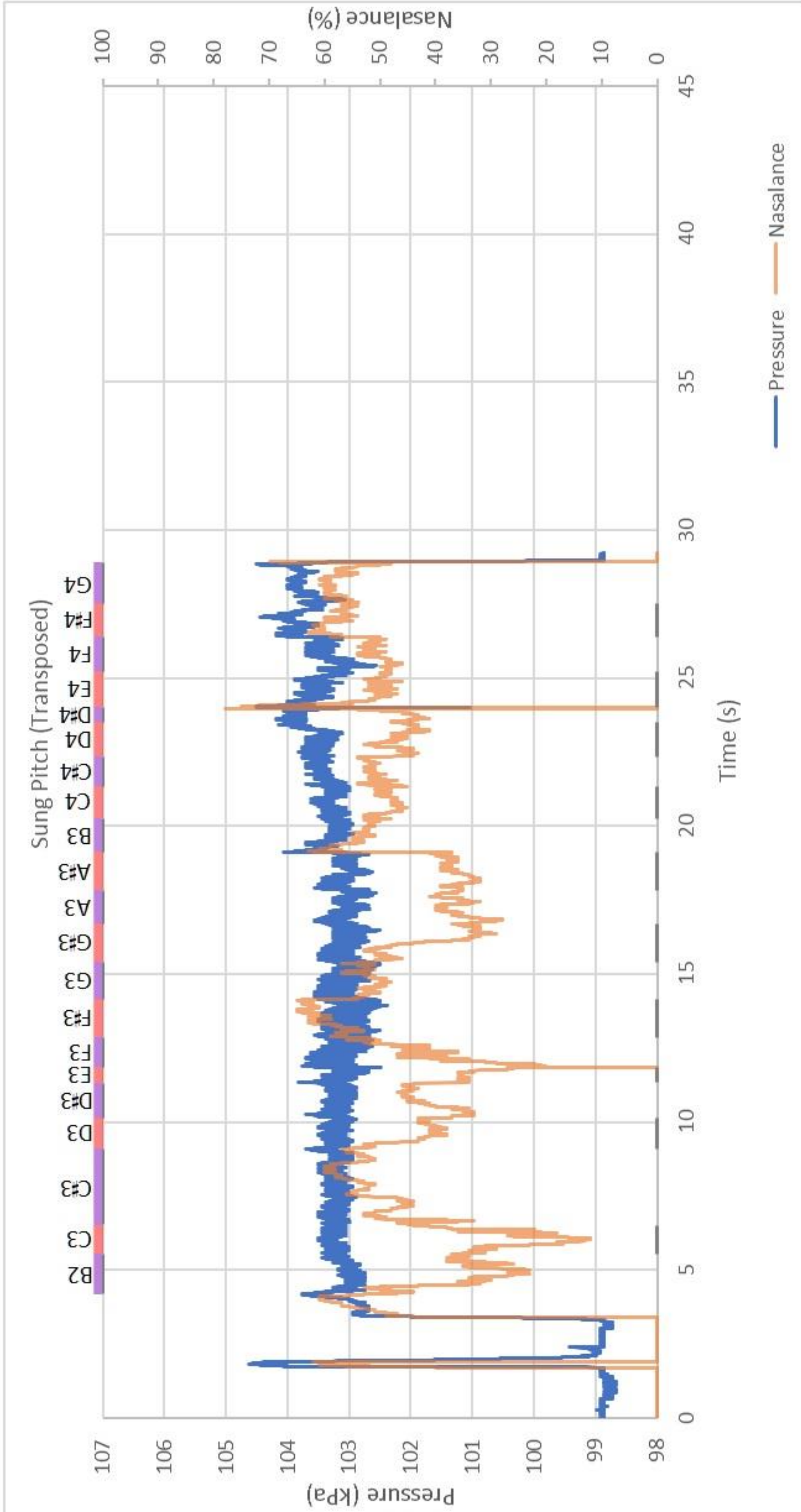


Figure A.37. Pressure and nasalance graph, play loud, sing loud, G_6.

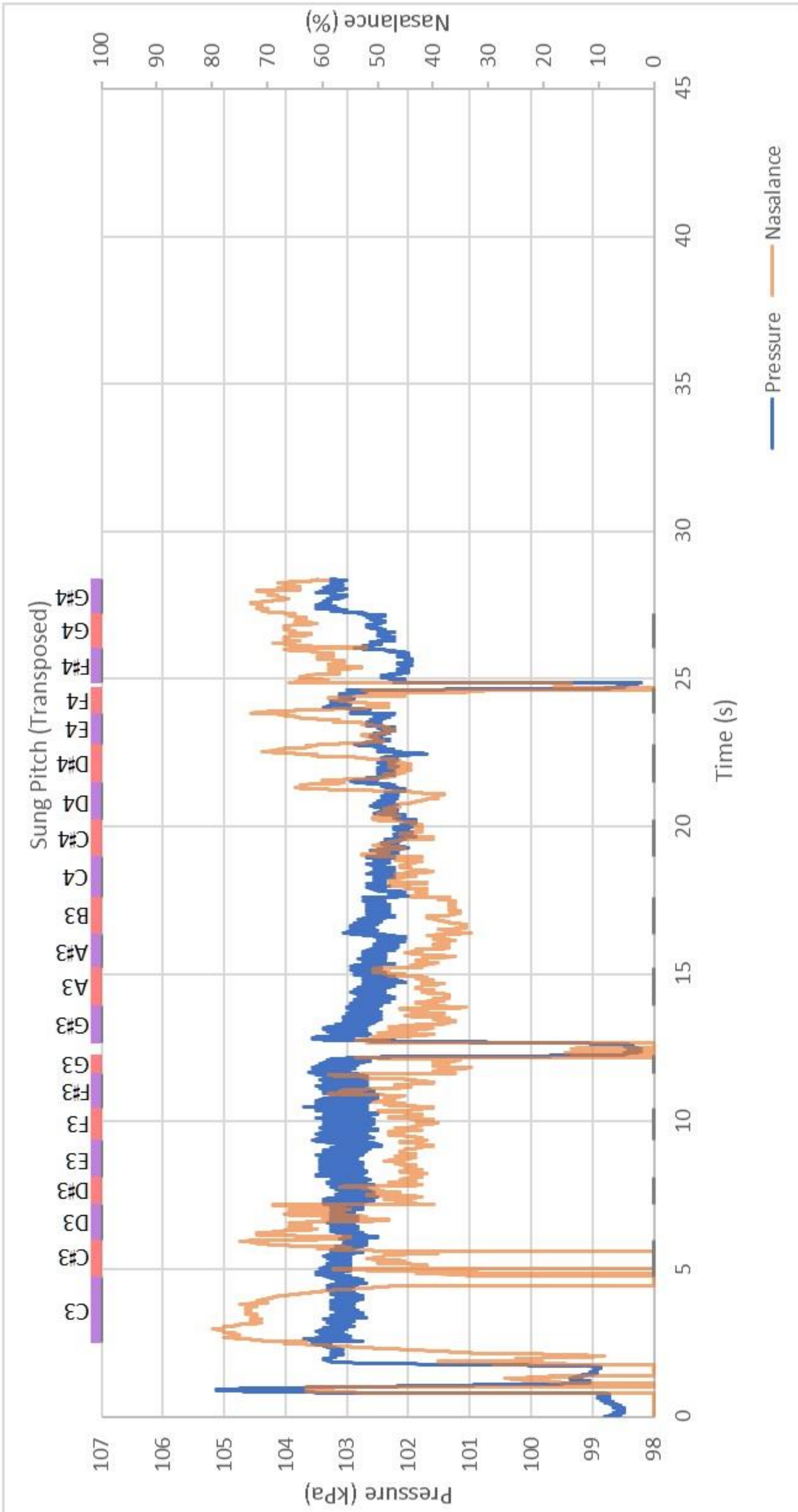


Figure A.38. Pressure and nasalance graph, play loud, sing loud, C_7.

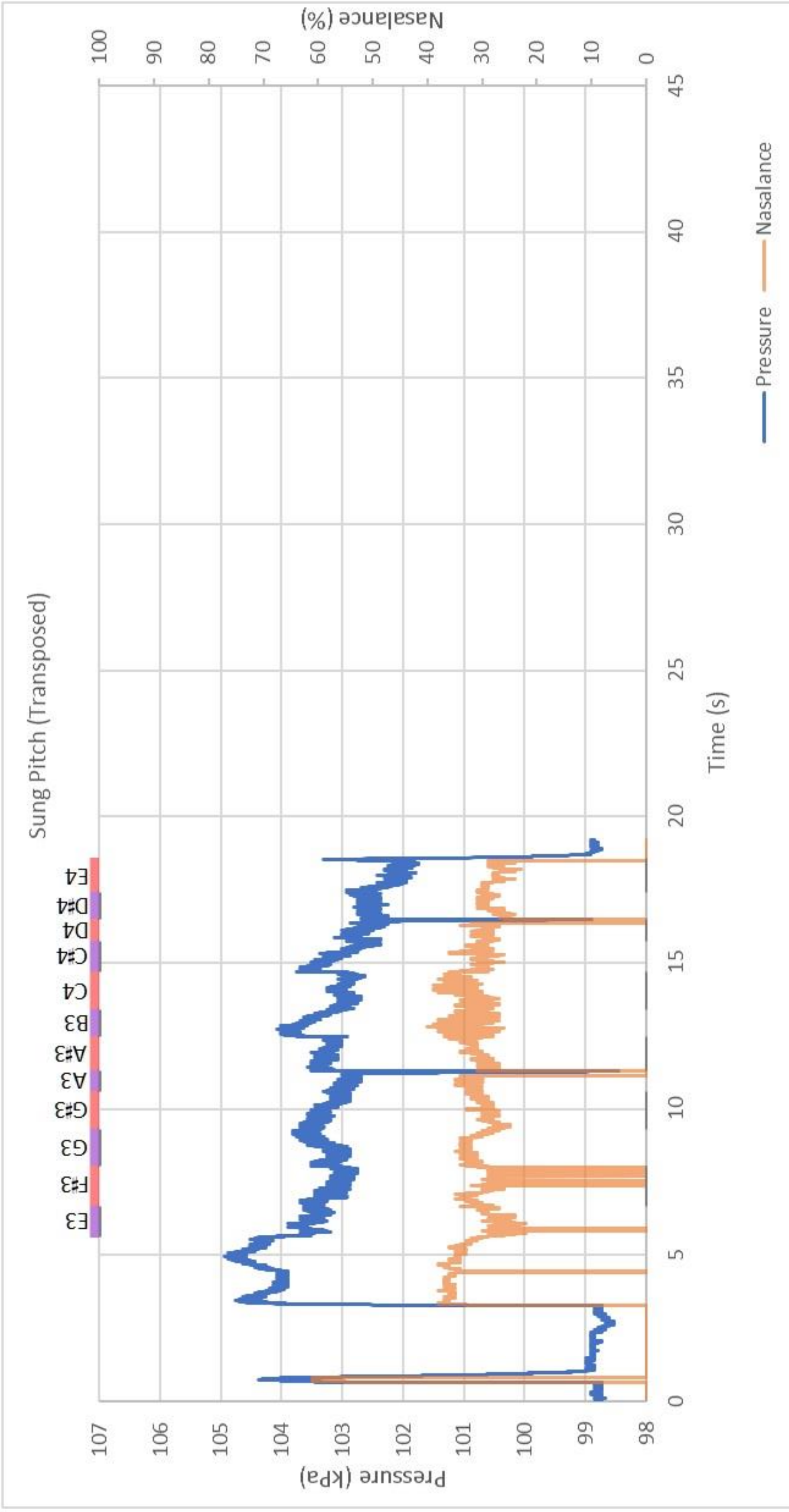


Figure A.39. Pressure and nasalance graph, play loud, sing soft, E_3.

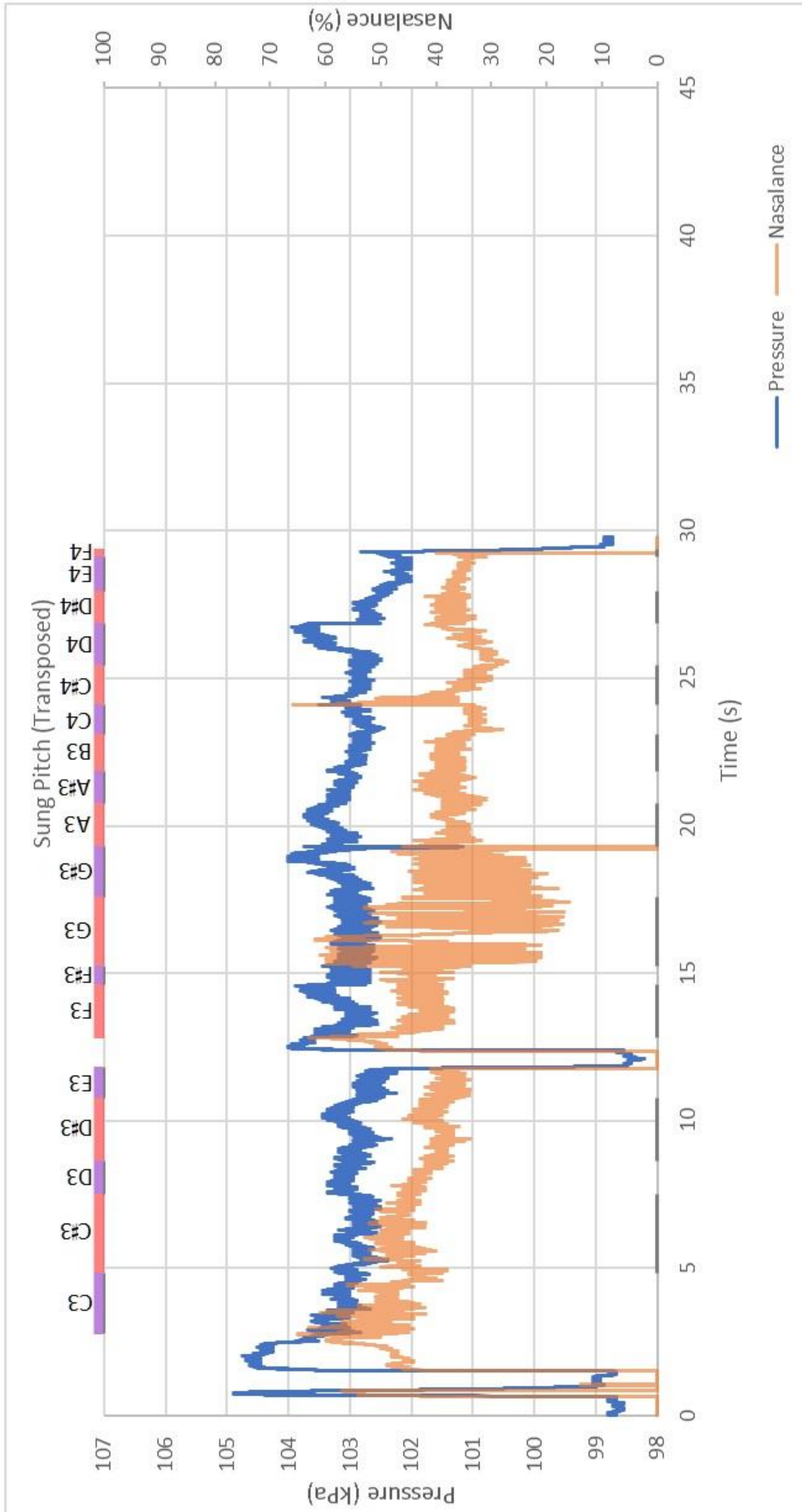


Figure A.40. Pressure and nasalance graph, play loud, sing soft, G4.

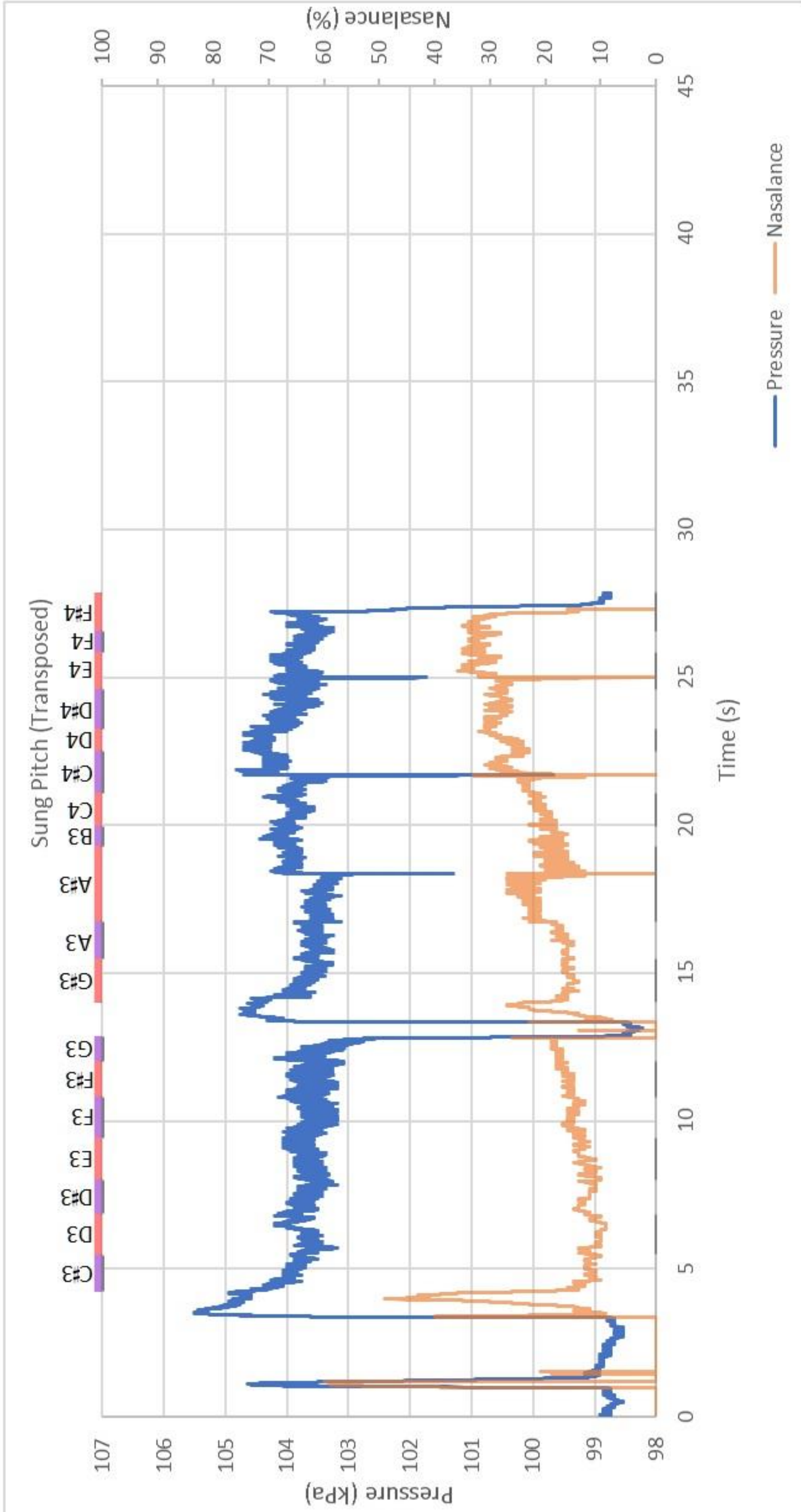


Figure A.41. Pressure and nasalance graph, play loud, sing soft, B4.

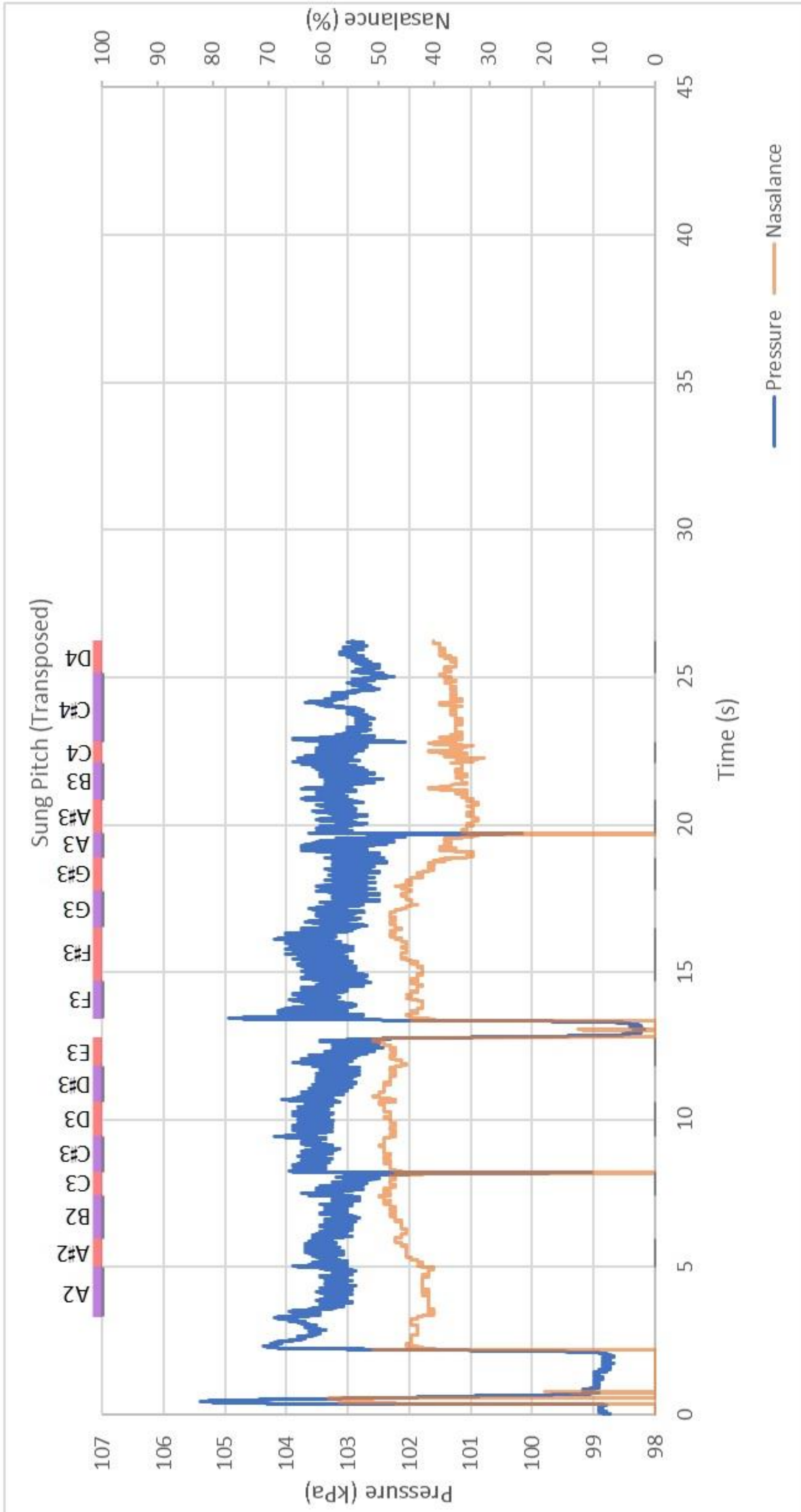


Figure A.42. Pressure and nasalance graph, play loud, sing soft, C_6.

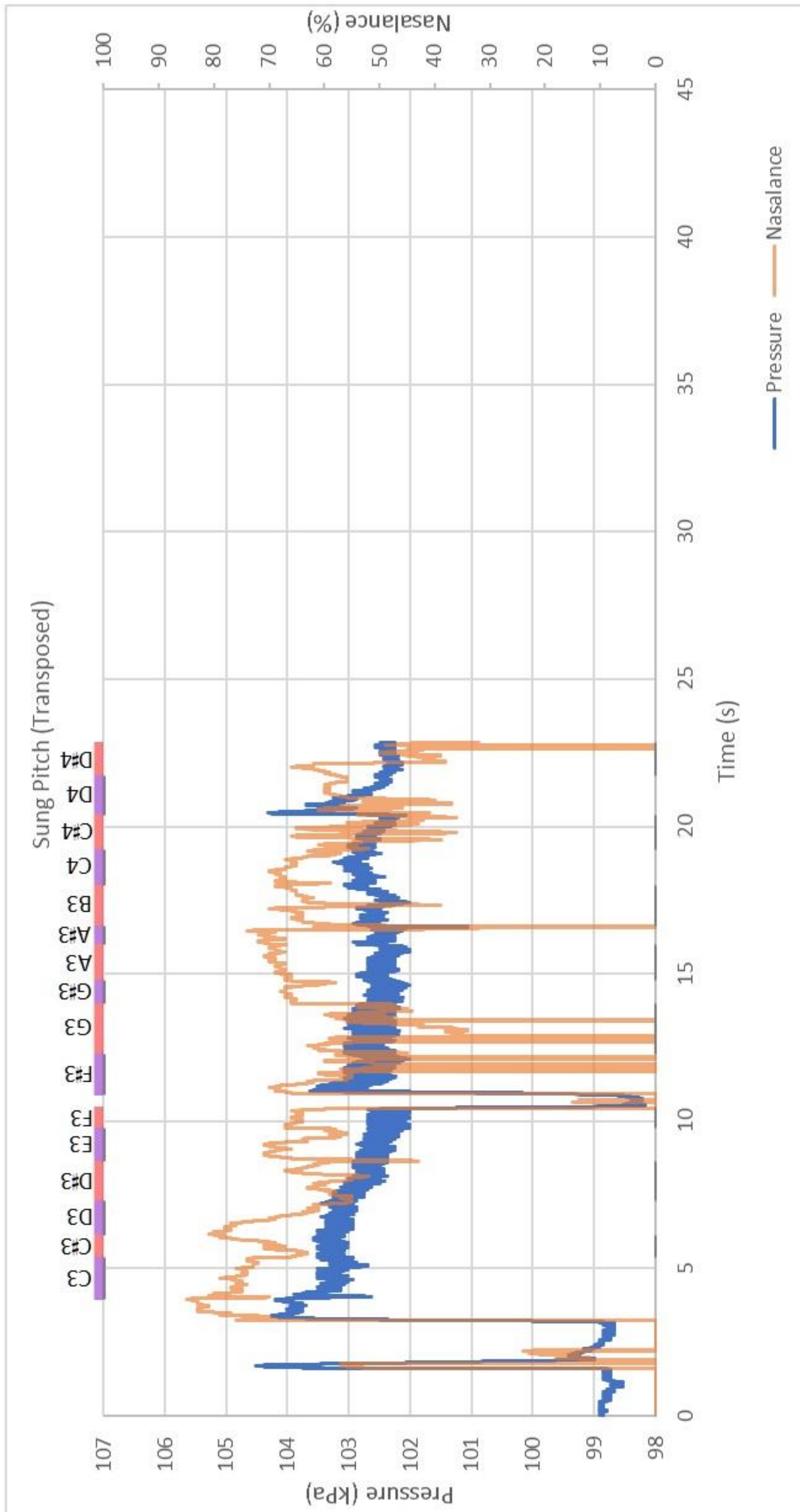


Figure A.43. Pressure and nasalance graph, play loud, sing soft, E_6.

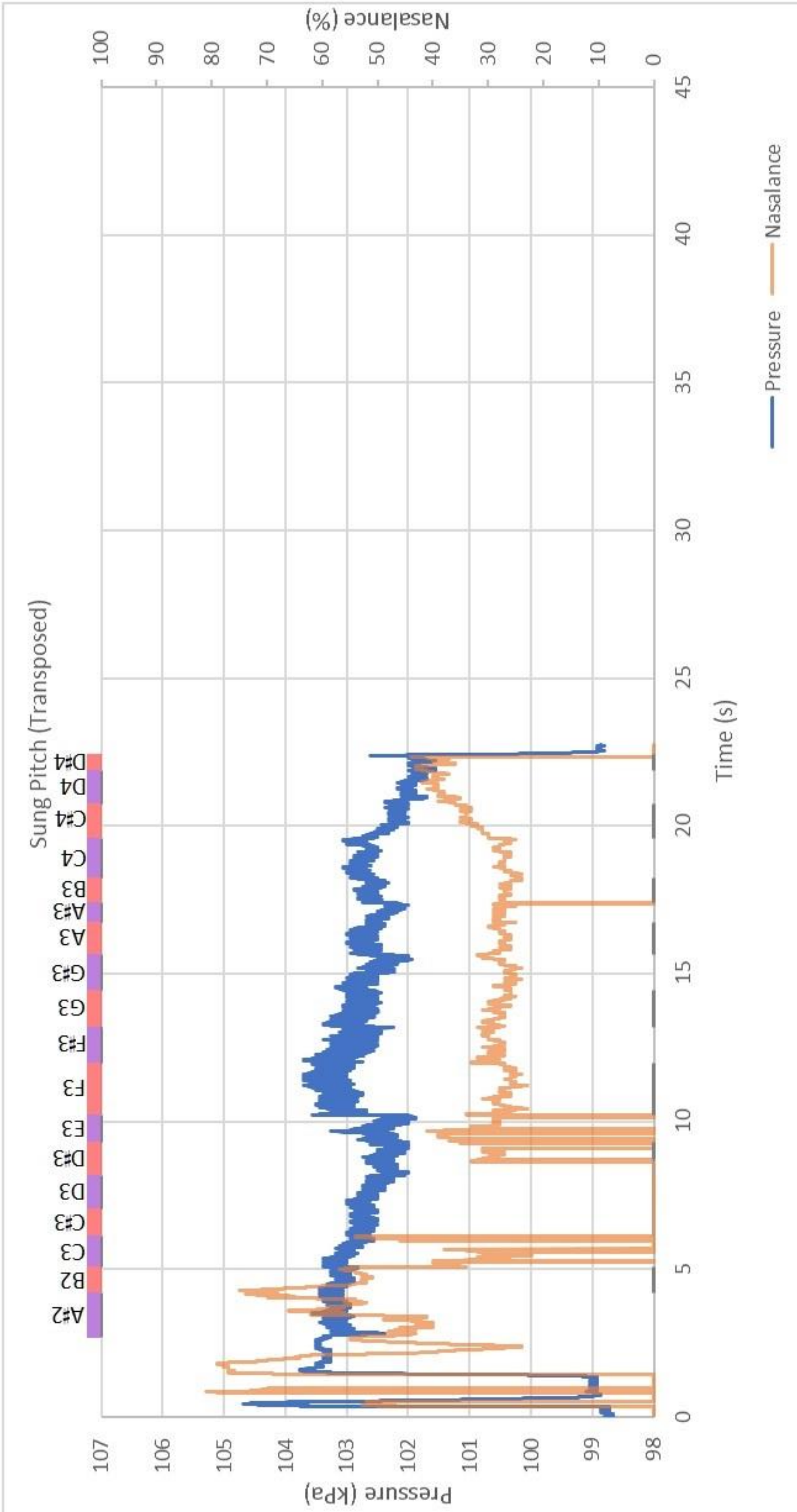


Figure A.44. Pressure and nasalance graph, play loud, sing soft, G_6.

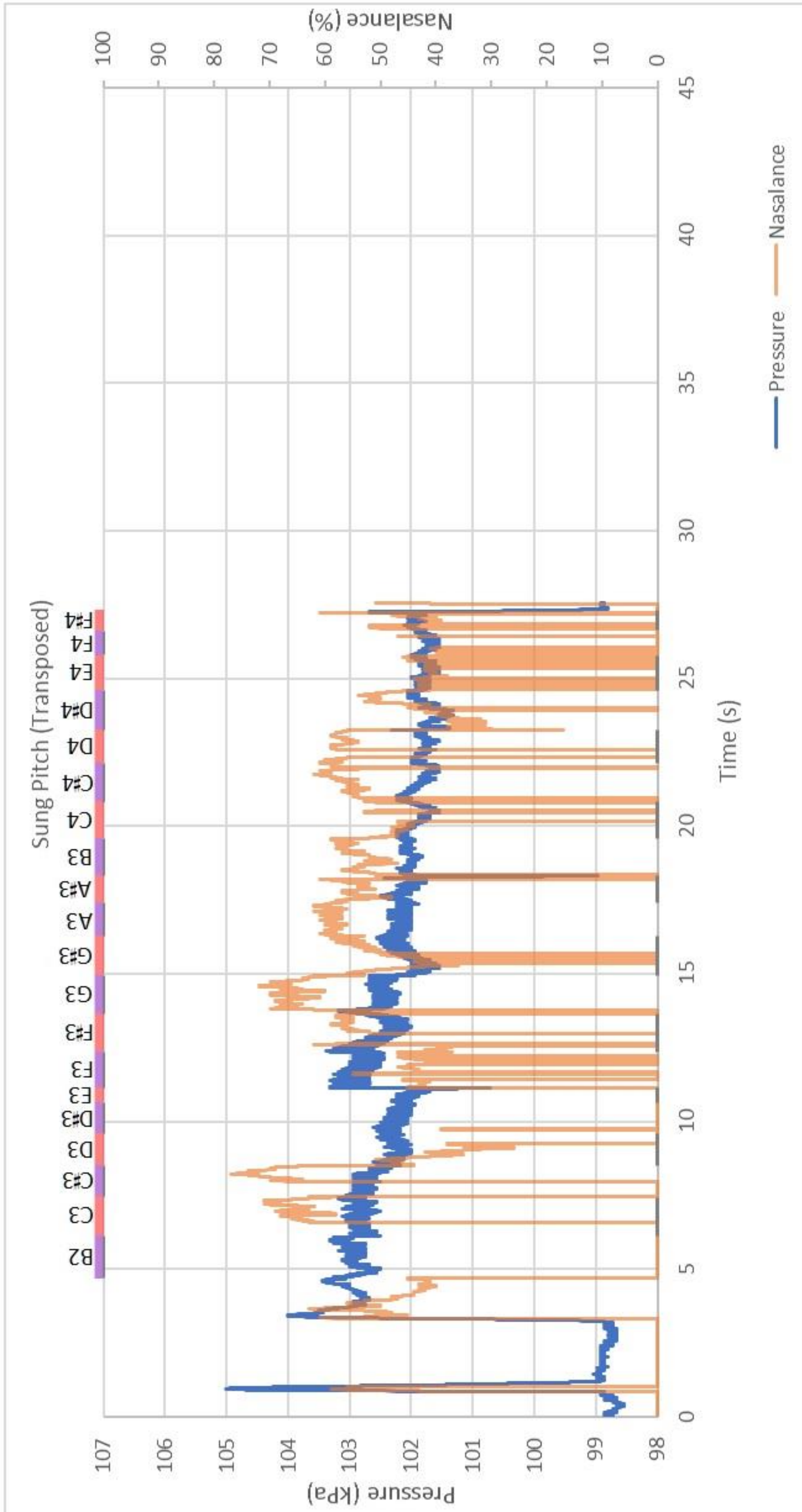


Figure A.45. Pressure and nasalance graph, play loud, sing soft, C_7.

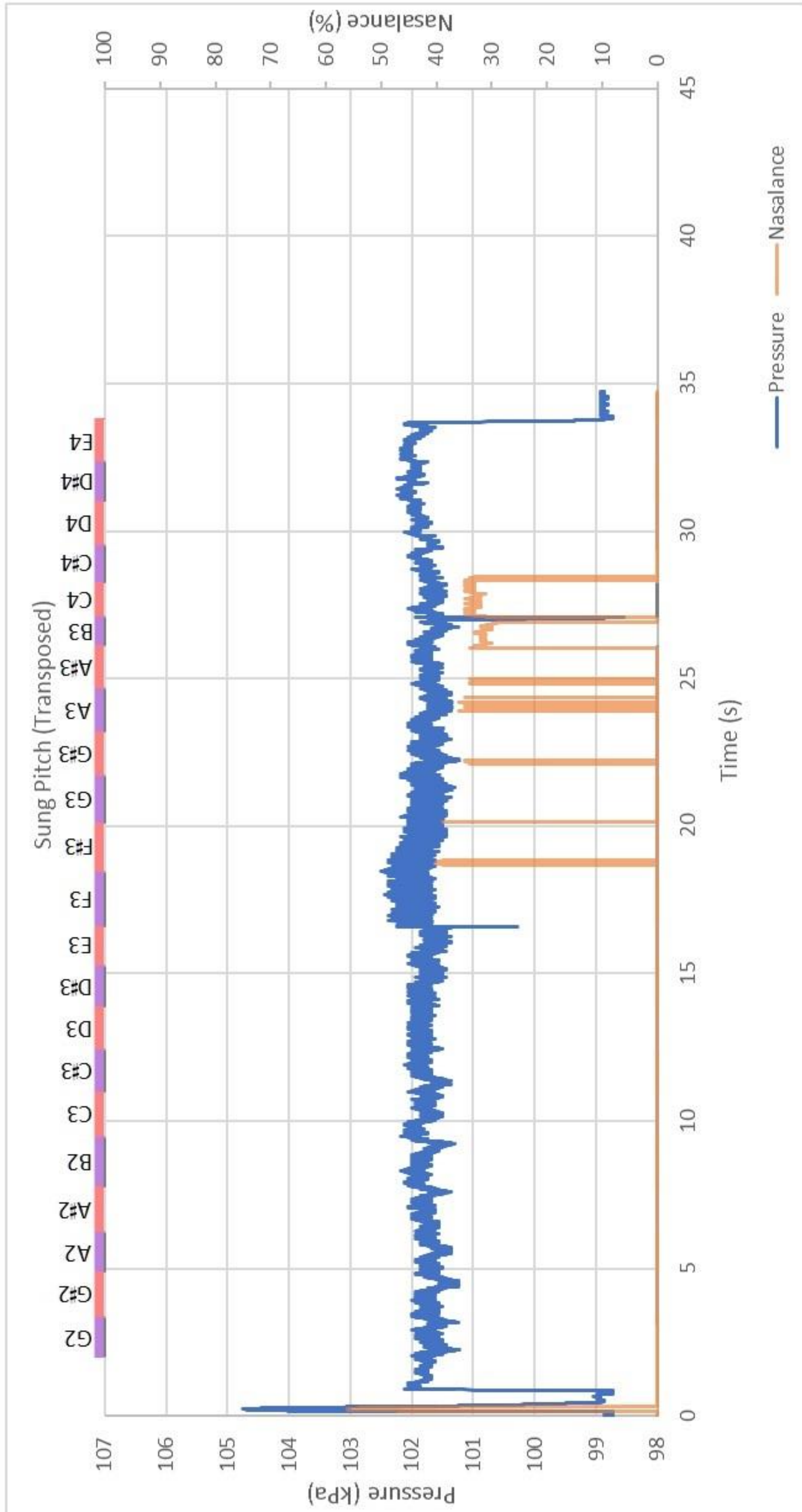


Figure A.46. Pressure and nasalance graph, play soft, sing loud, E_3.

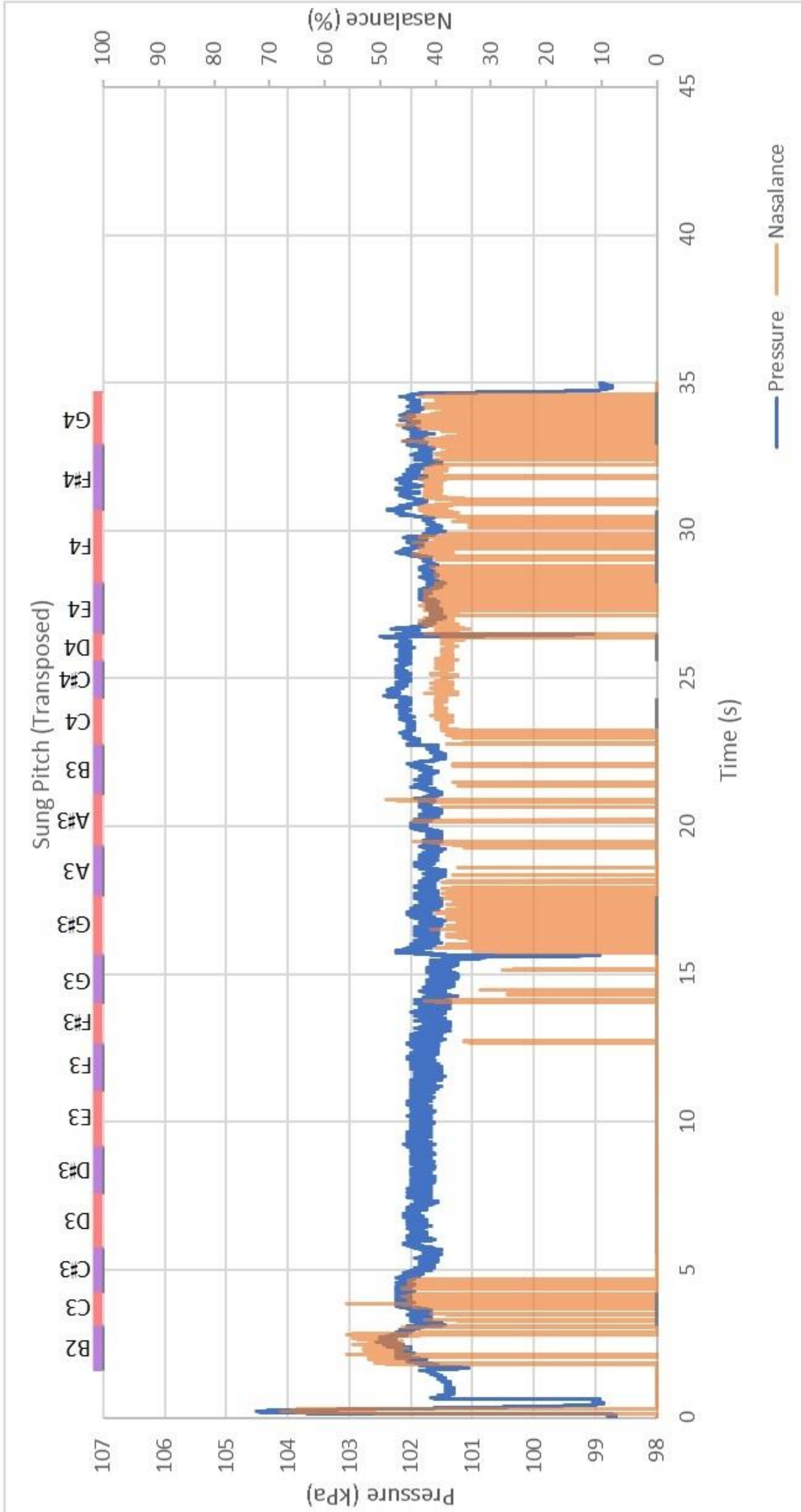


Figure A.47. Pressure and nasalance graph, play soft, sing loud, G_4.

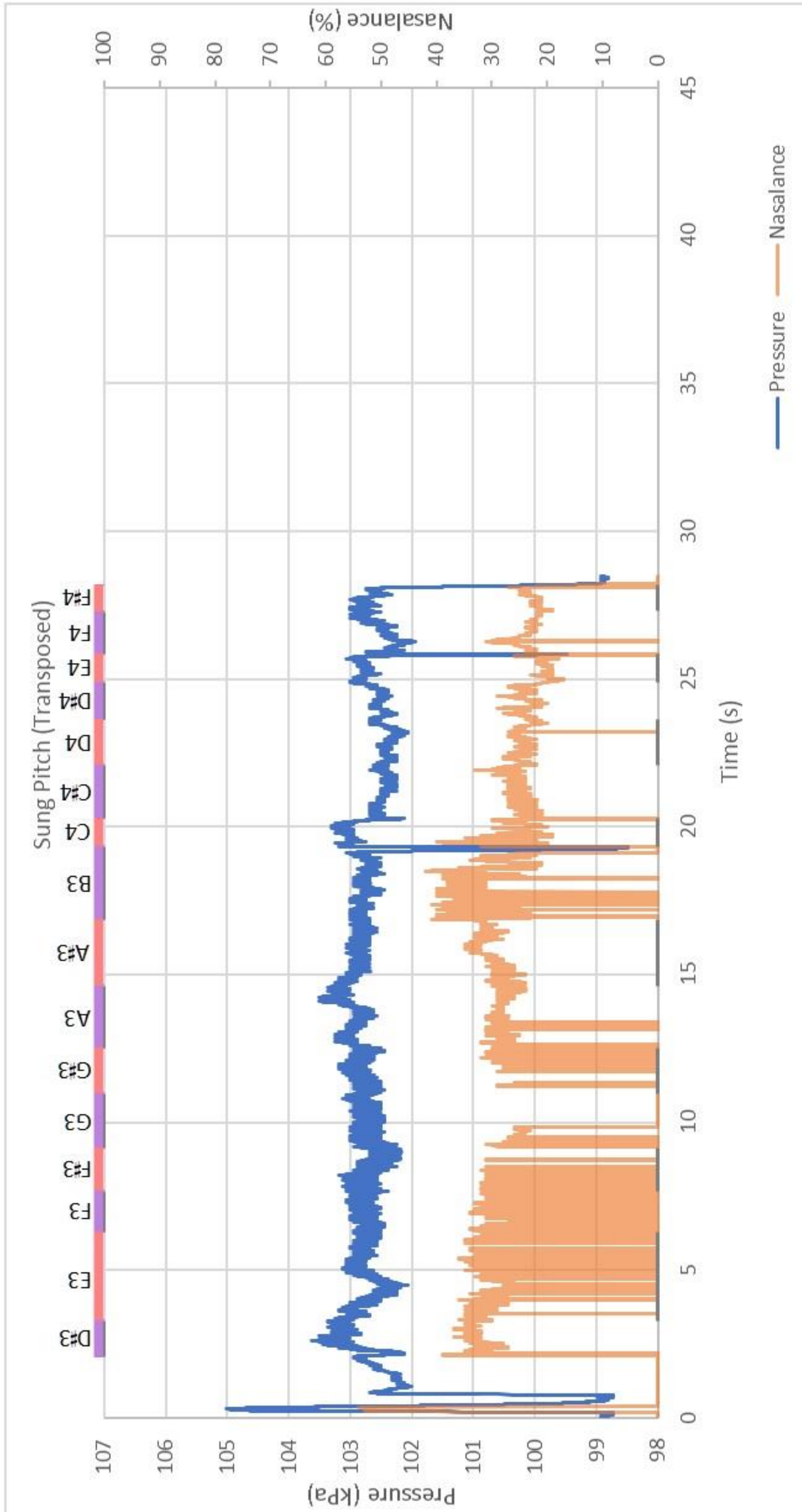


Figure A.48. Pressure and nasalance graph, play soft, sing loud, B_4.

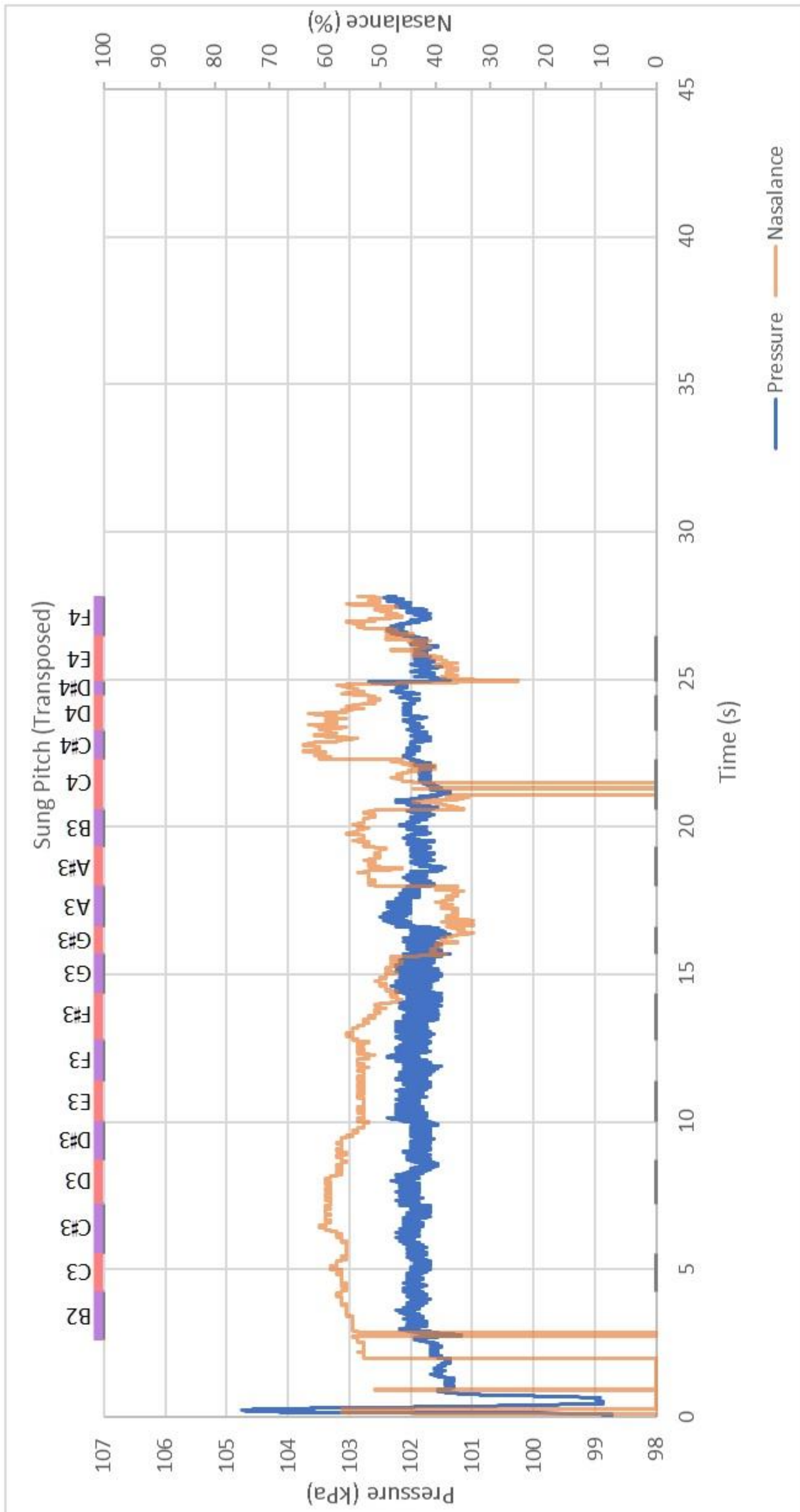


Figure A.49. Pressure and nasalance graph, play soft, sing loud, C_6.

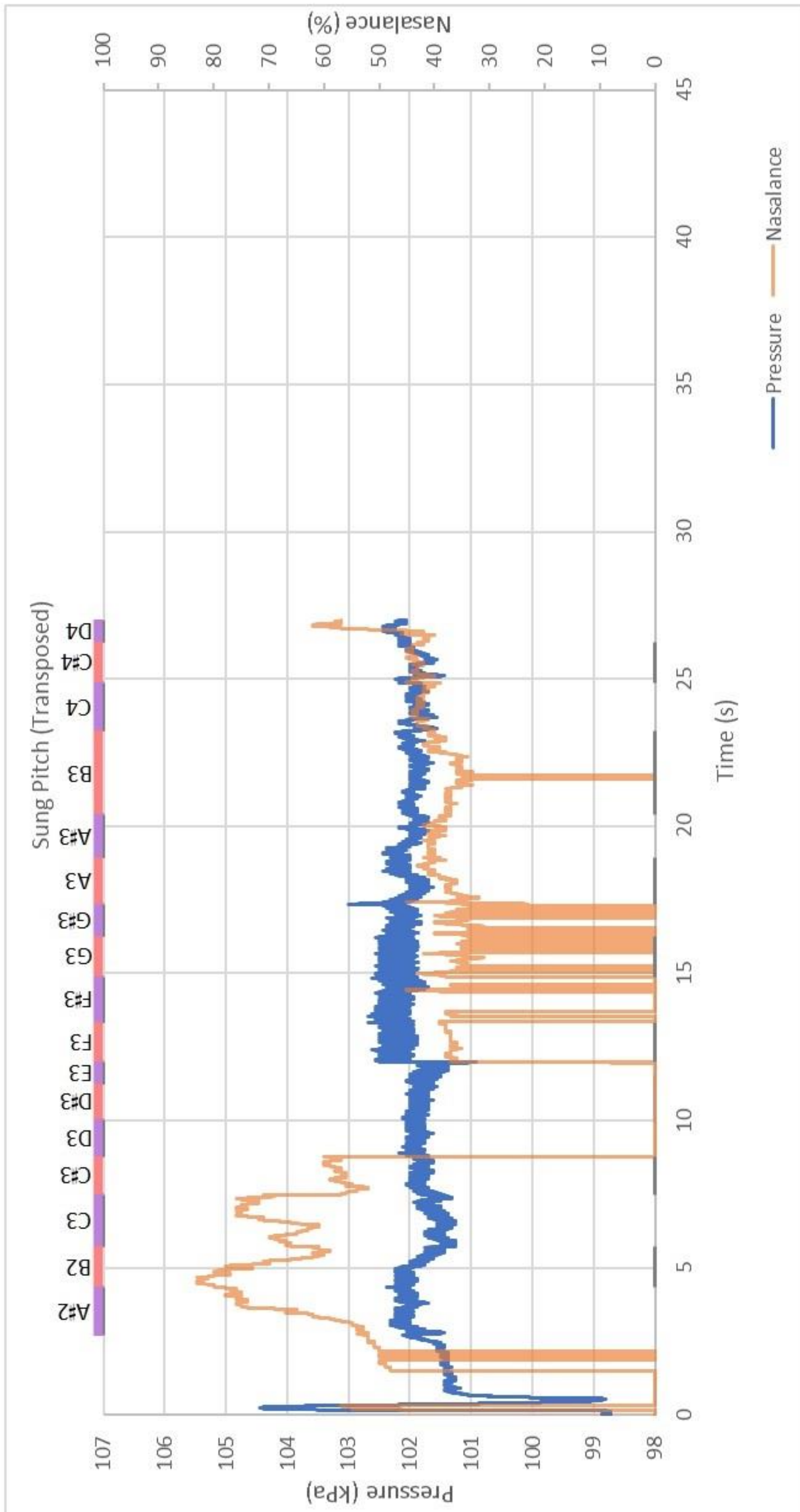


Figure A.50. Pressure and nasalance graph, play soft, sing loud, E_6.

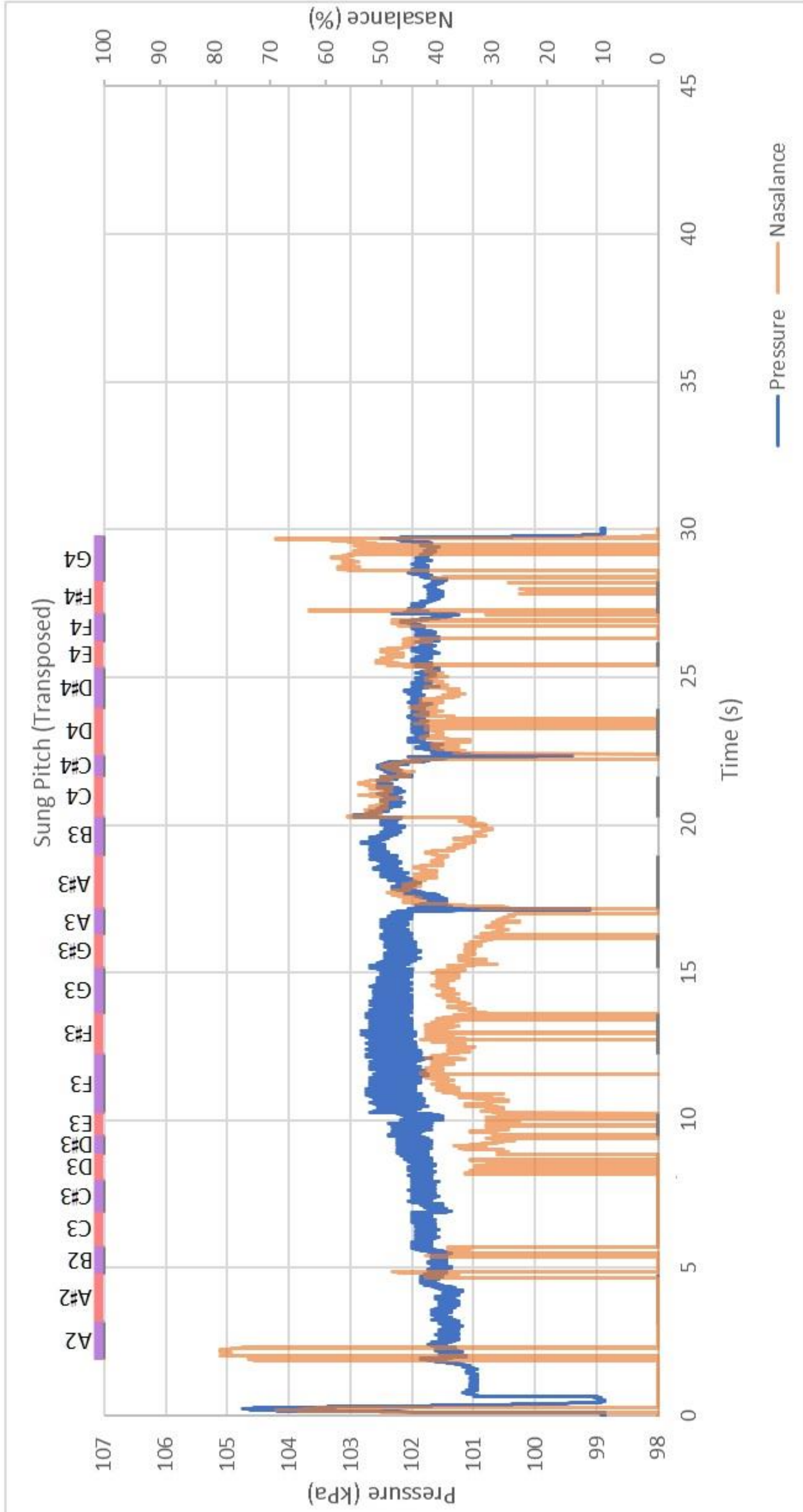


Figure A.51. Pressure and nasalance graph, play soft, sing loud, G_6.

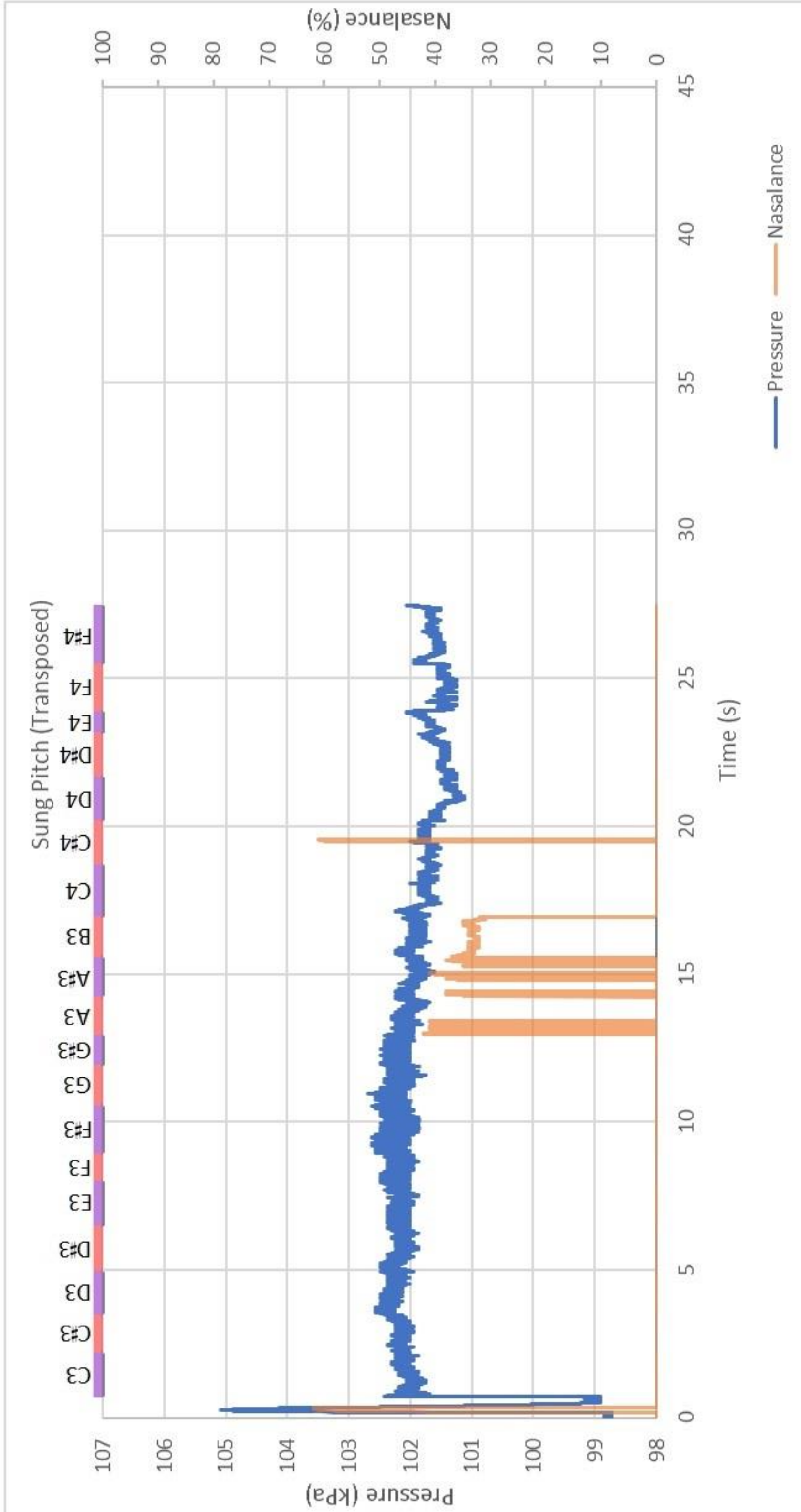


Figure A.52. Pressure and nasalance graph, play soft, sing loud, C_7.

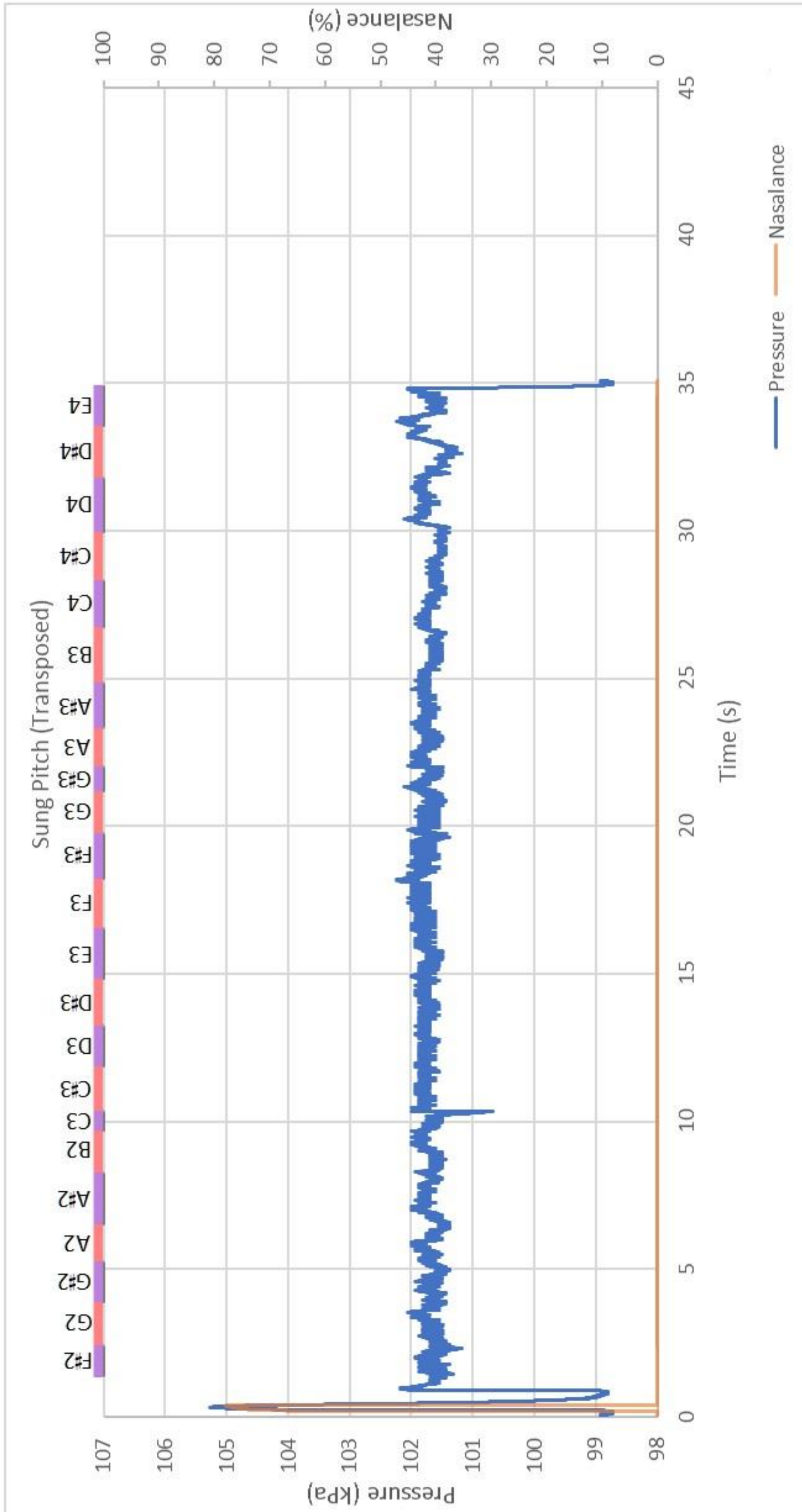


Figure A.53. Pressure and nasalance graph, play soft, sing soft, E3.

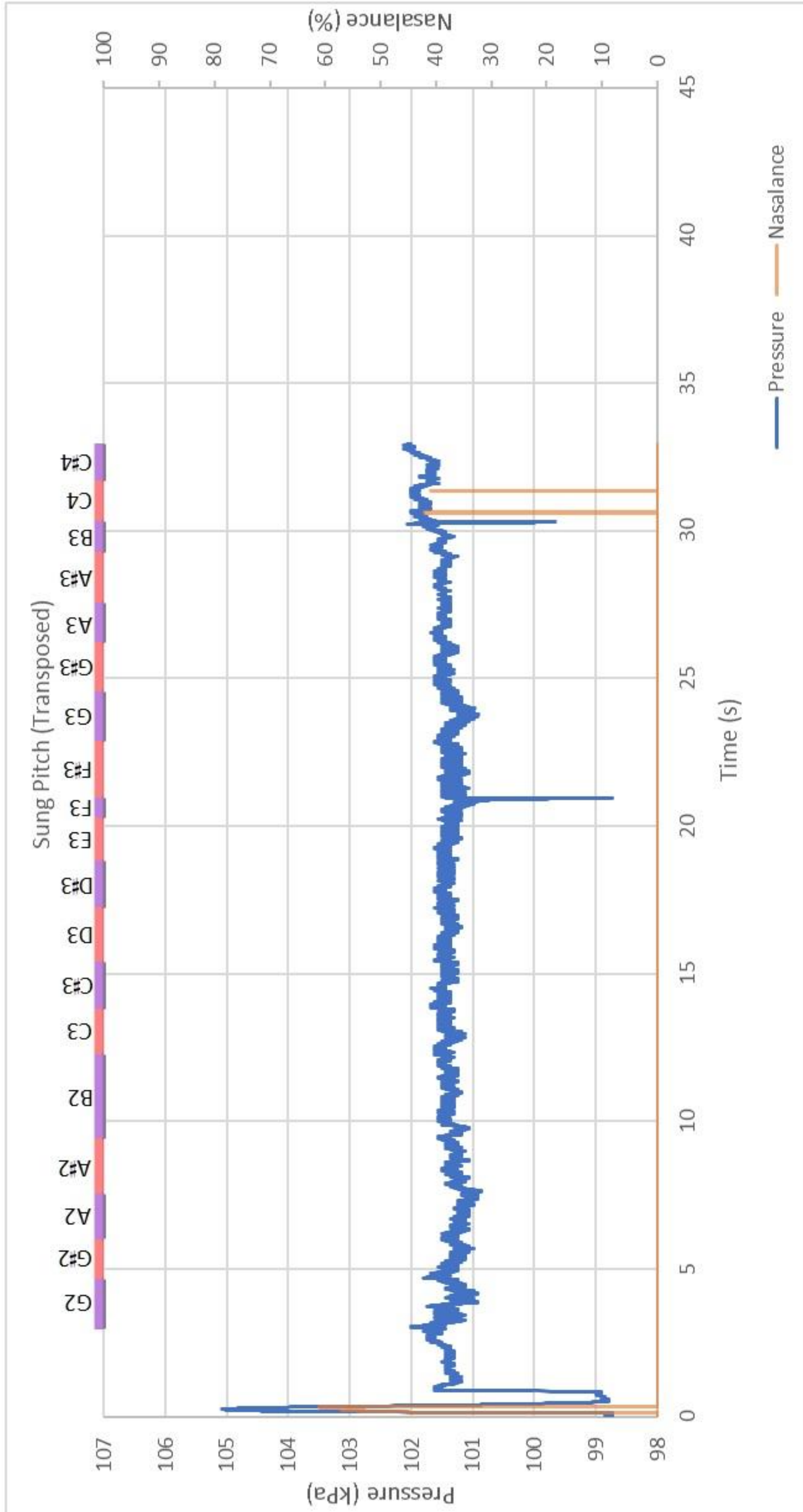


Figure A.54. Pressure and nasalance graph, play soft, sing soft, G4.

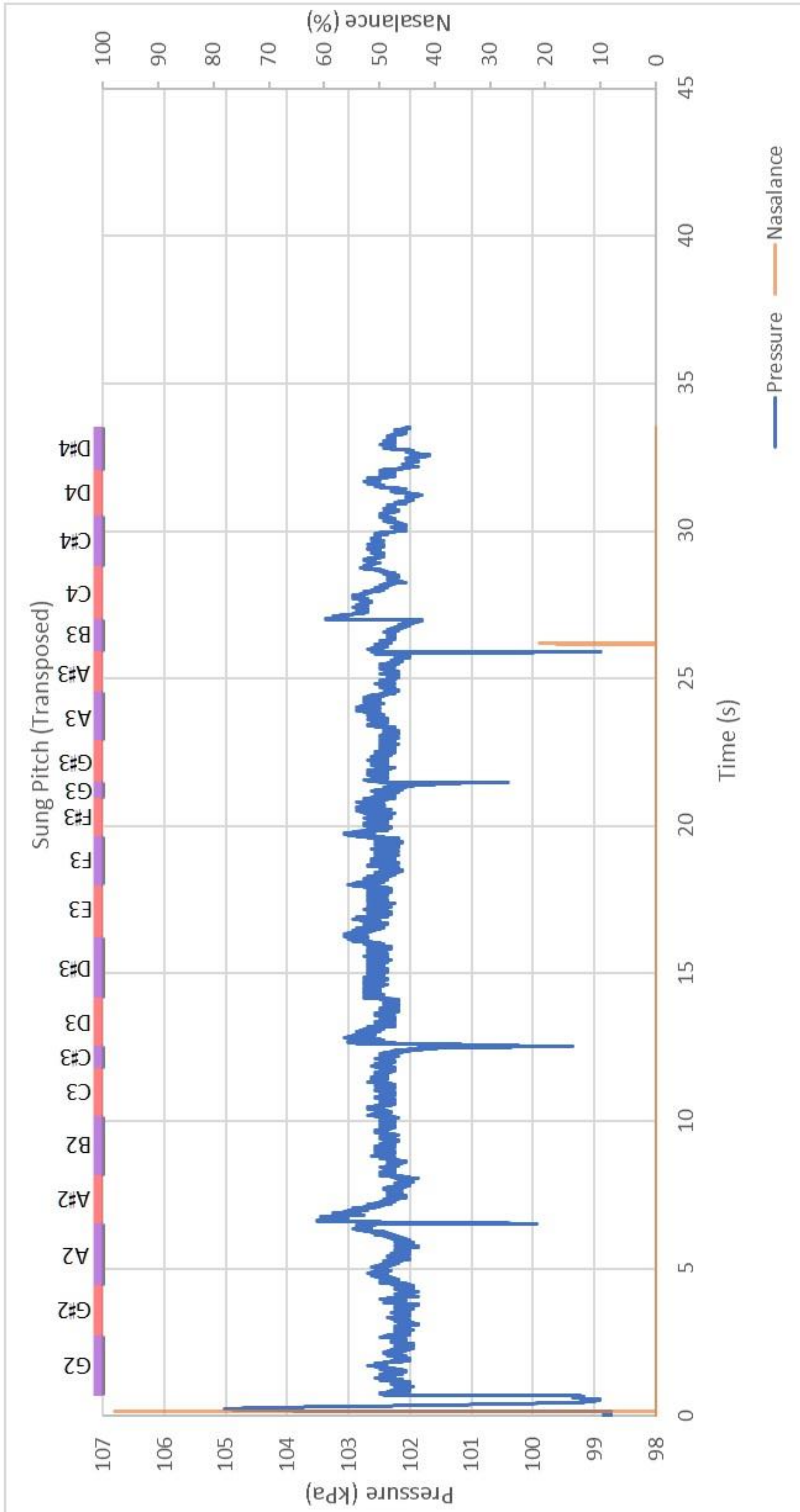


Figure A.55. Pressure and nasalance graph, play soft, sing soft, B4.

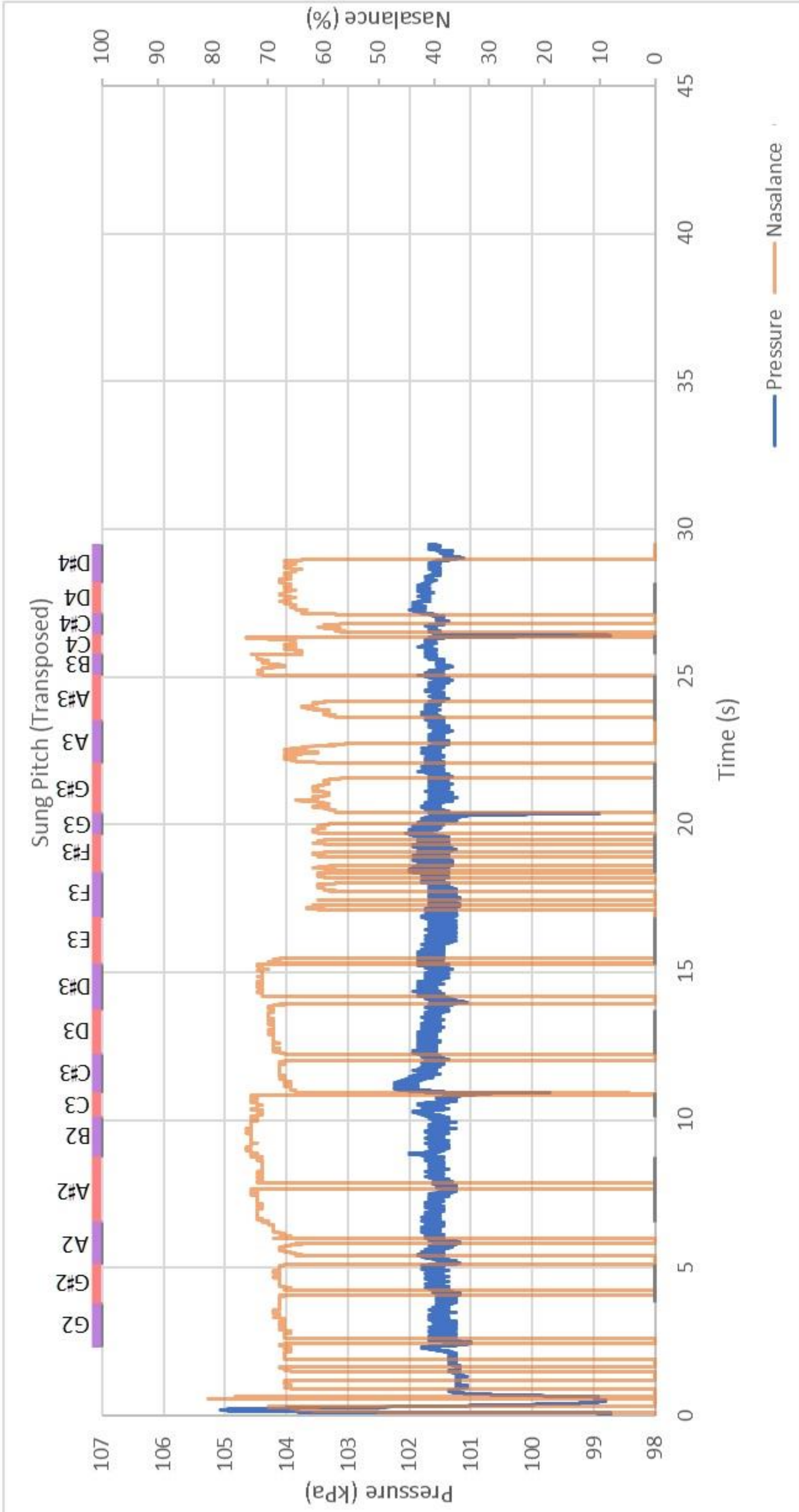


Figure A.56. Pressure and nasalance graph, play soft, sing soft, C_6.

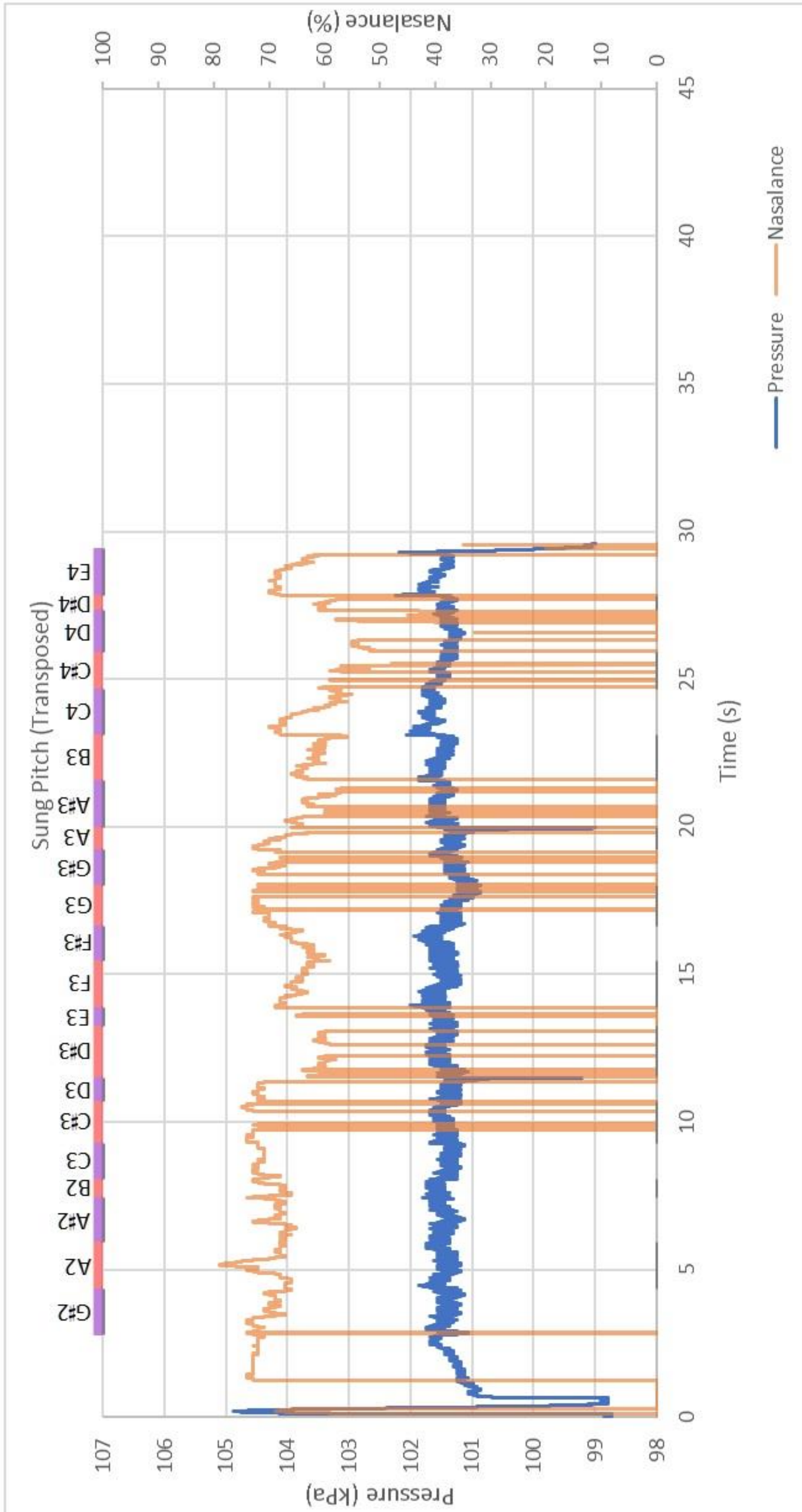


Figure A.57. Pressure and nasalance graph, play soft, sing soft, E_6.

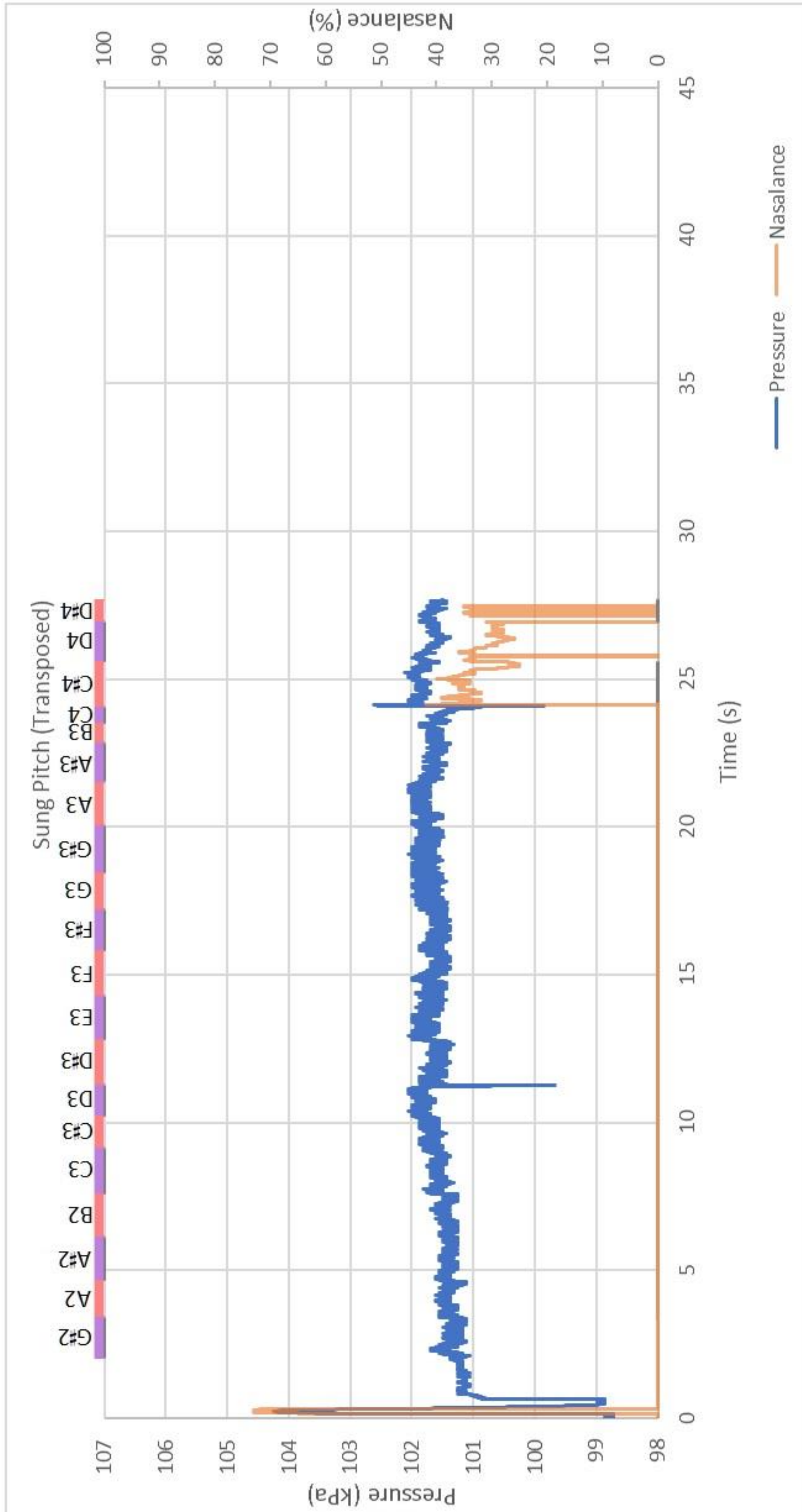


Figure A.58. Pressure and nasalance graph, play soft, sing soft, G_6.

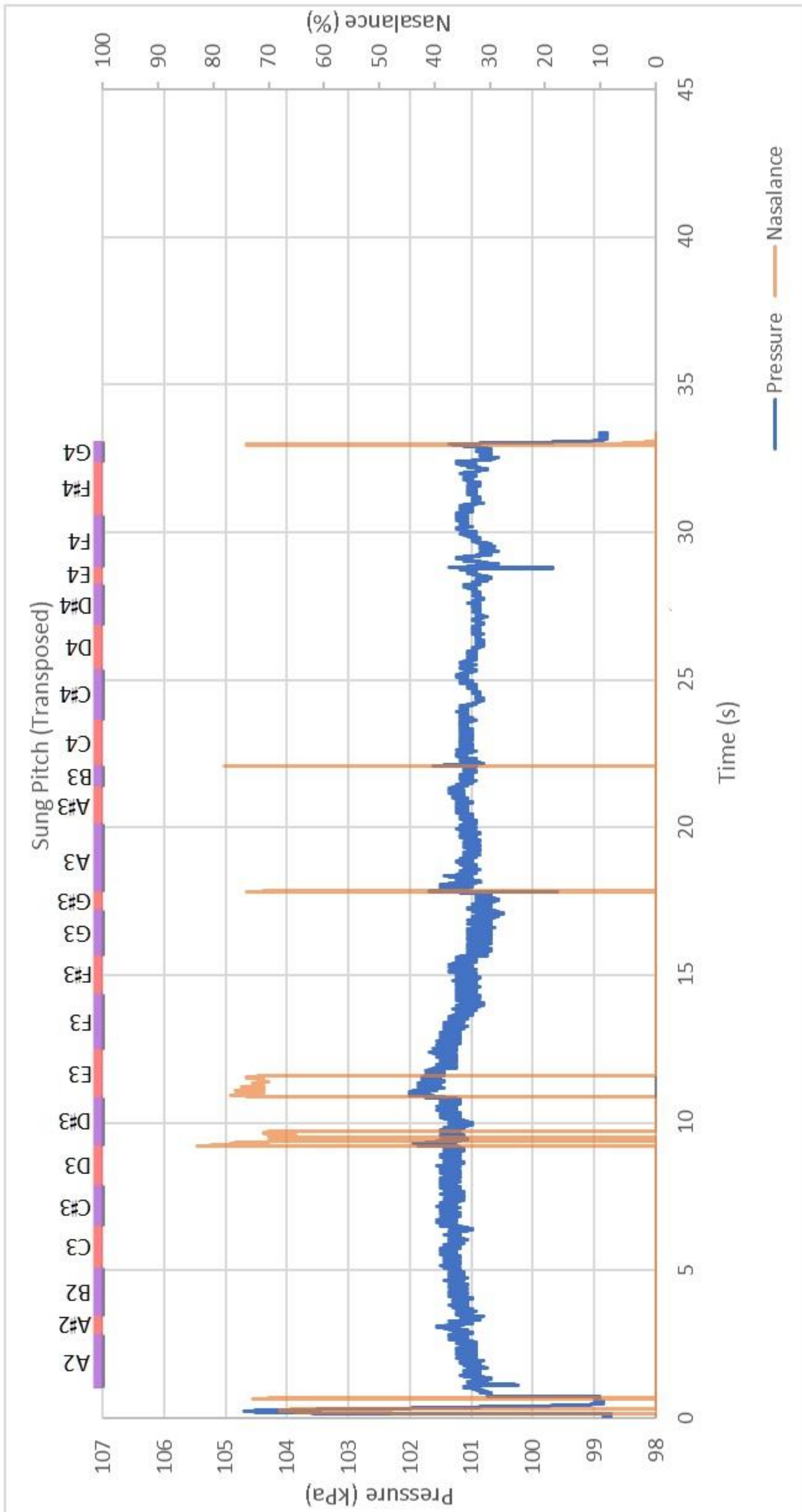


Figure A.59. Pressure and nasalance graph, play soft, sing soft, C_7.

APPENDIX B

SPECTROGRAMS OF RECORDED TASKS

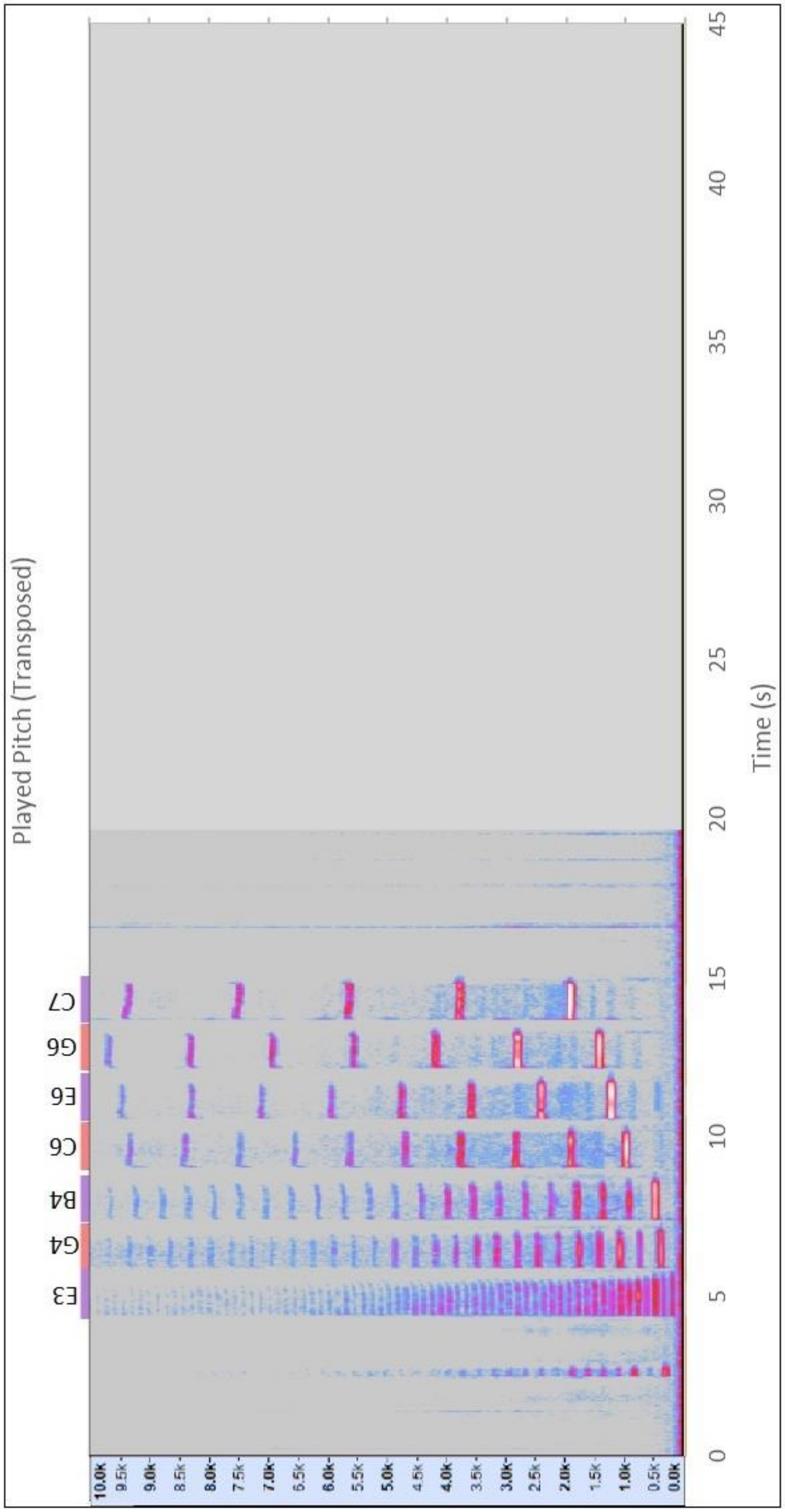


Figure B.1. Spectrogram for play loud, no vocalization, all pitches.

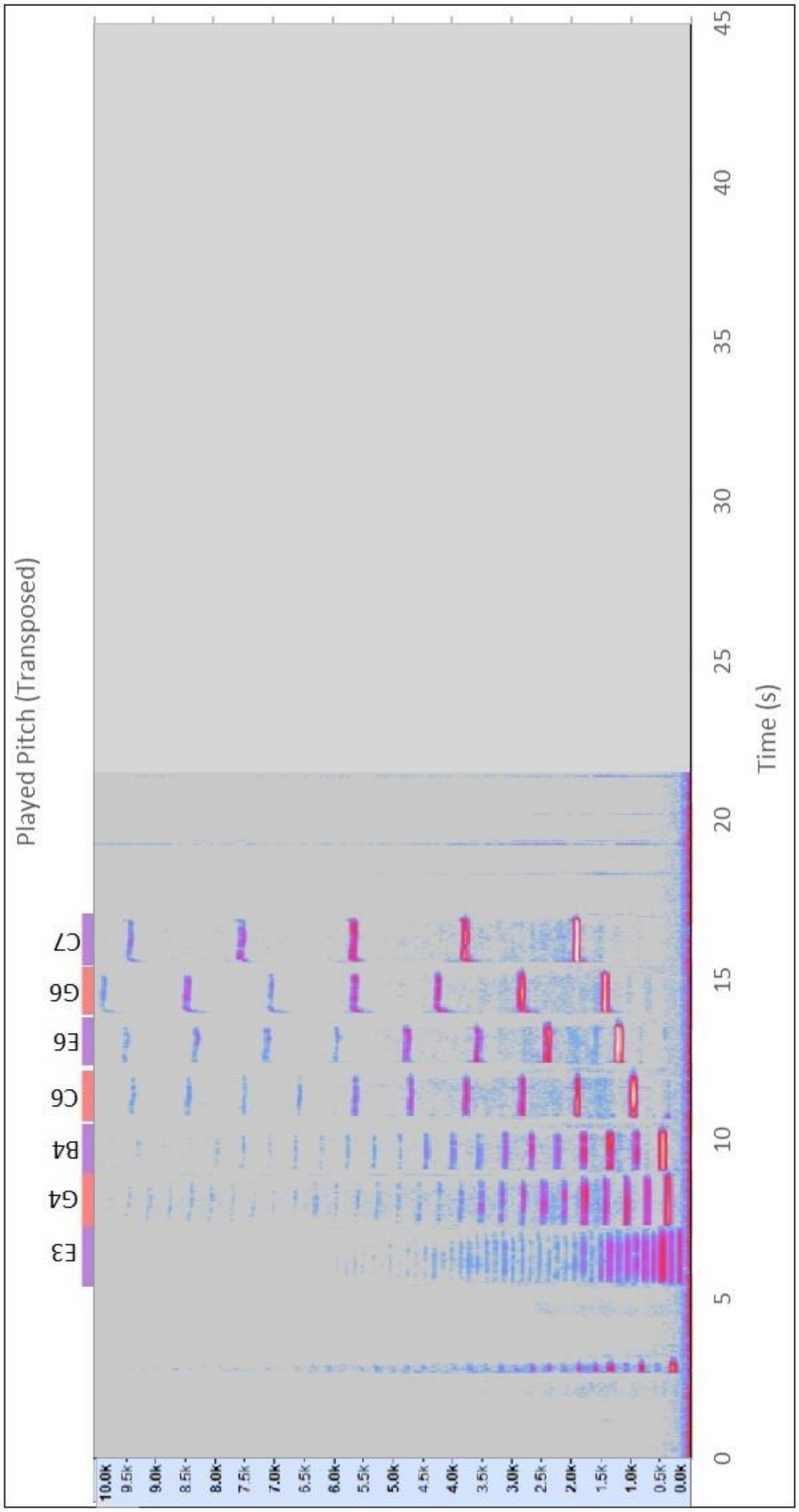


Figure B.2. Spectrogram for play medium, no vocalization, all pitches.

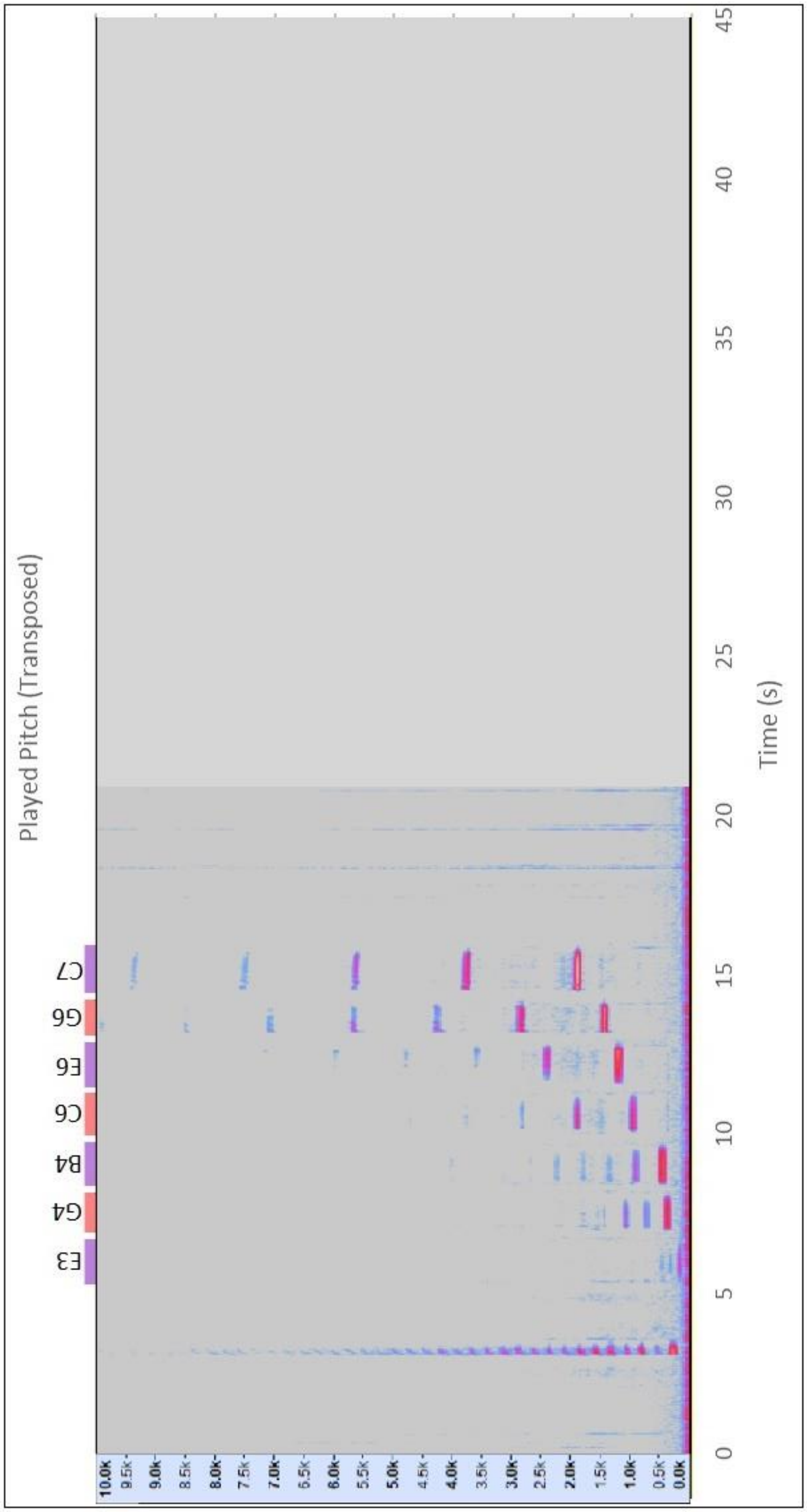


Figure B.3. Spectrogram for play soft, no vocalization, all pitches.

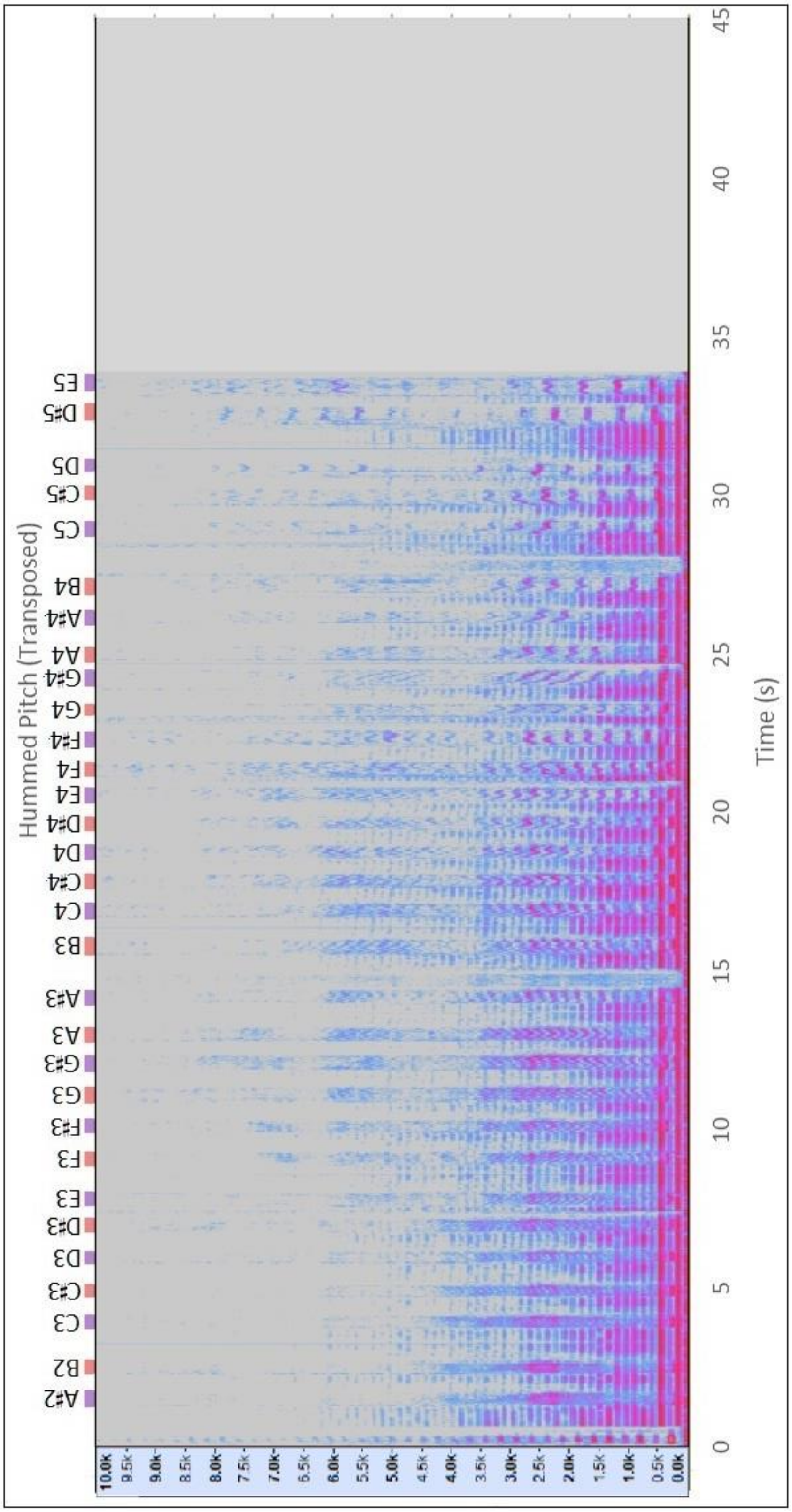


Figure B.4. Spectrogram for play loud, hum loud, E_3.

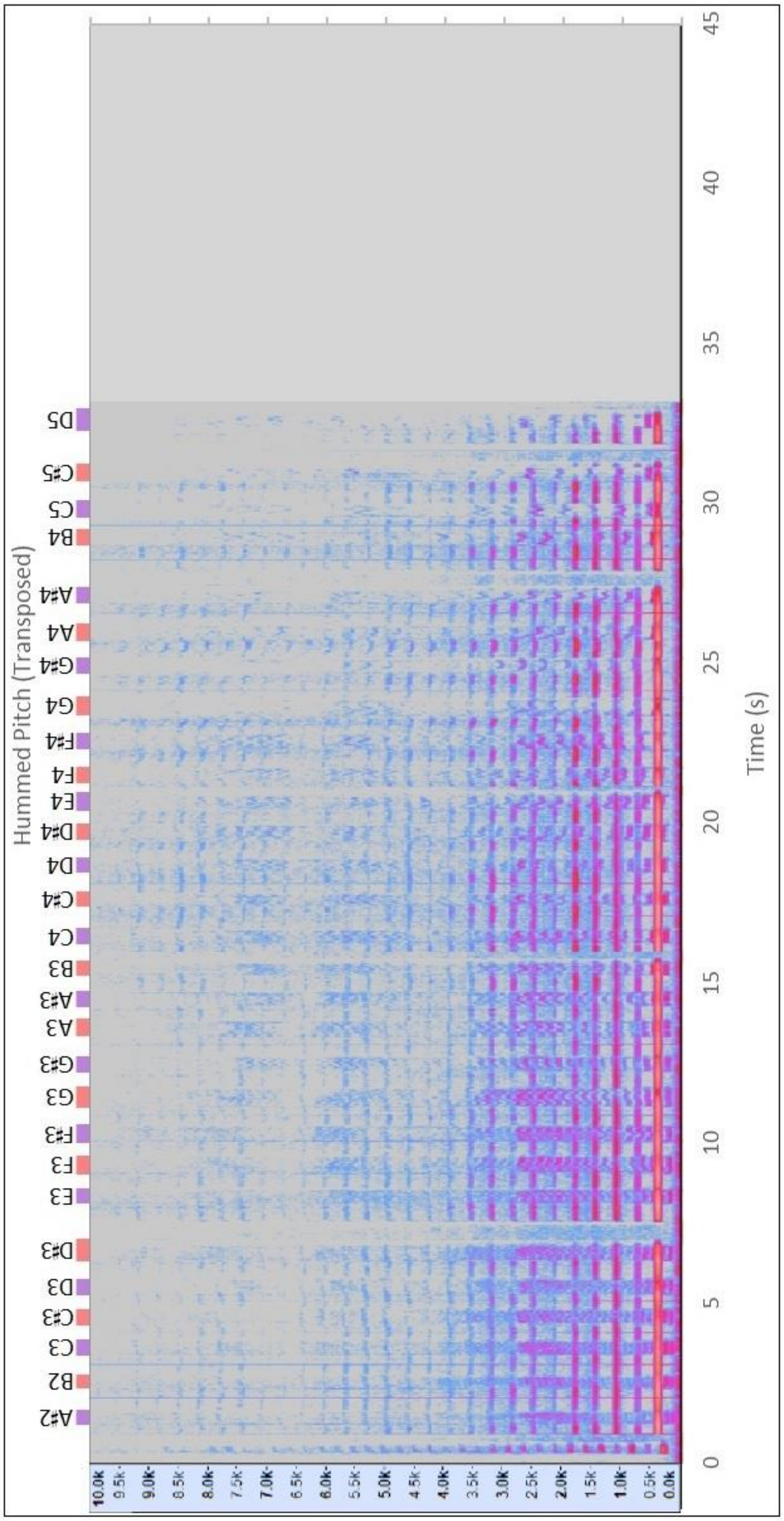


Figure B.5. Spectrogram for play loud, hum loud, G_4.

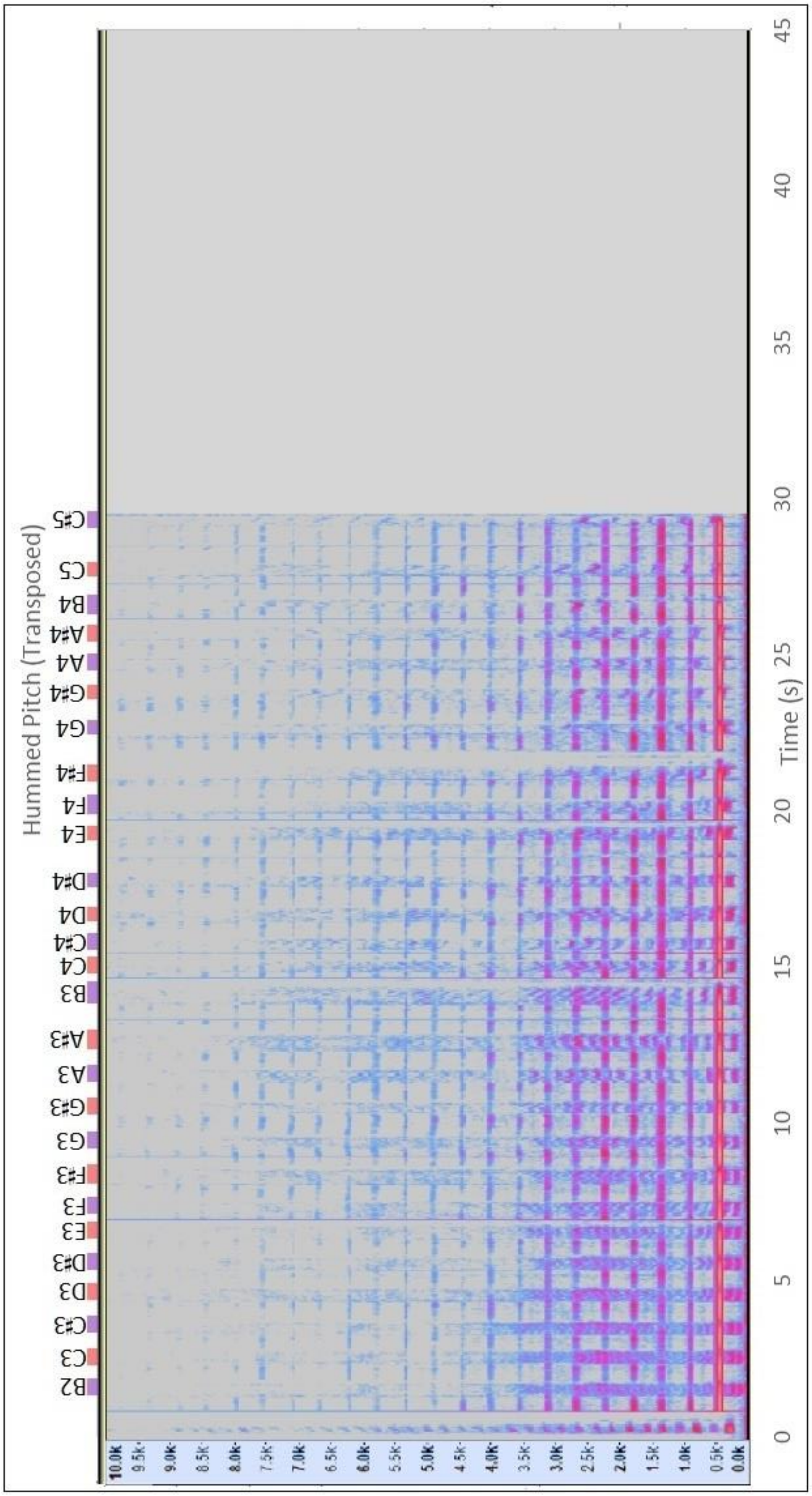


Figure B.6. Spectrogram for play loud, hum loud, B_4.

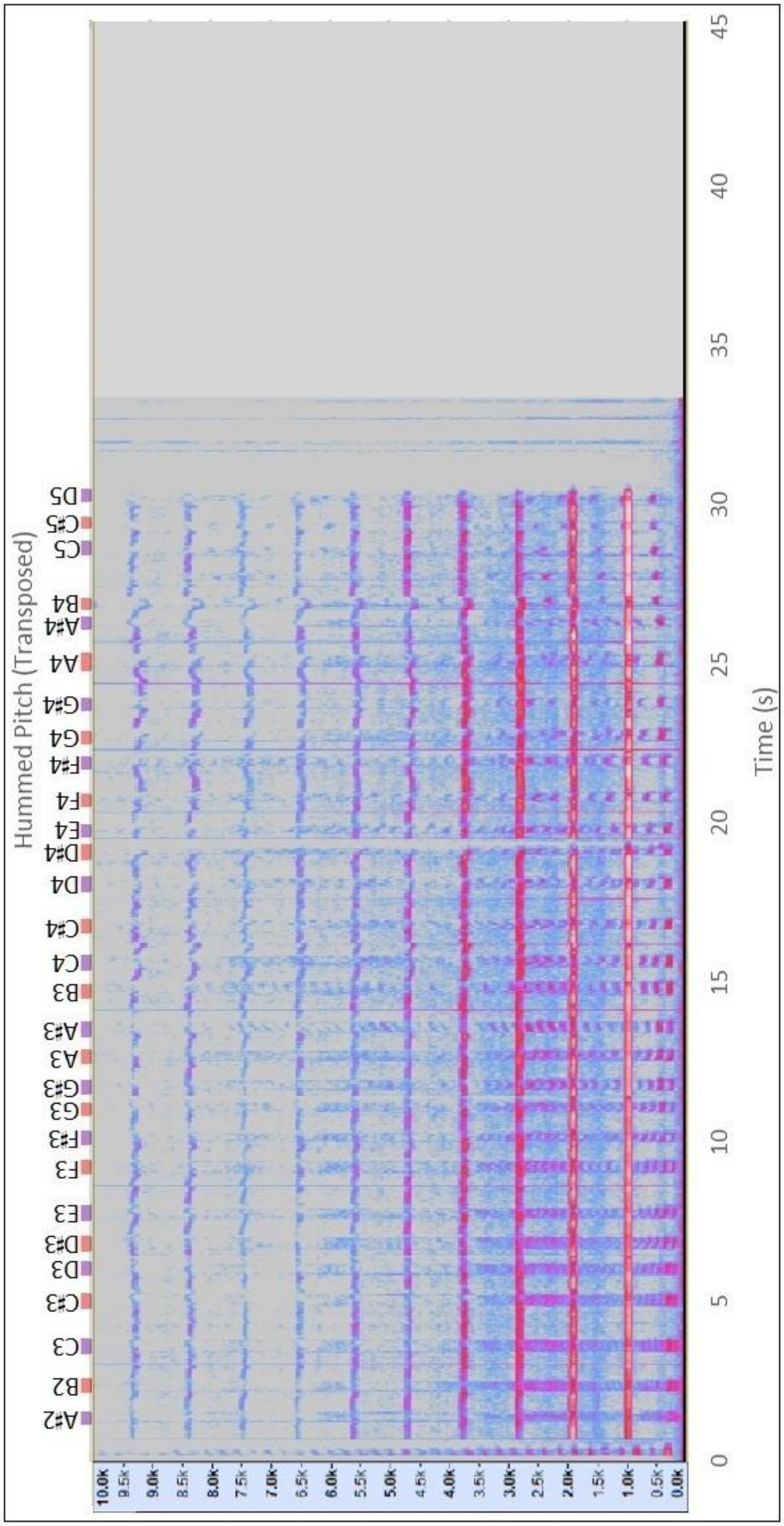


Figure B.7. Spectrogram for play loud, hum loud, C_6.

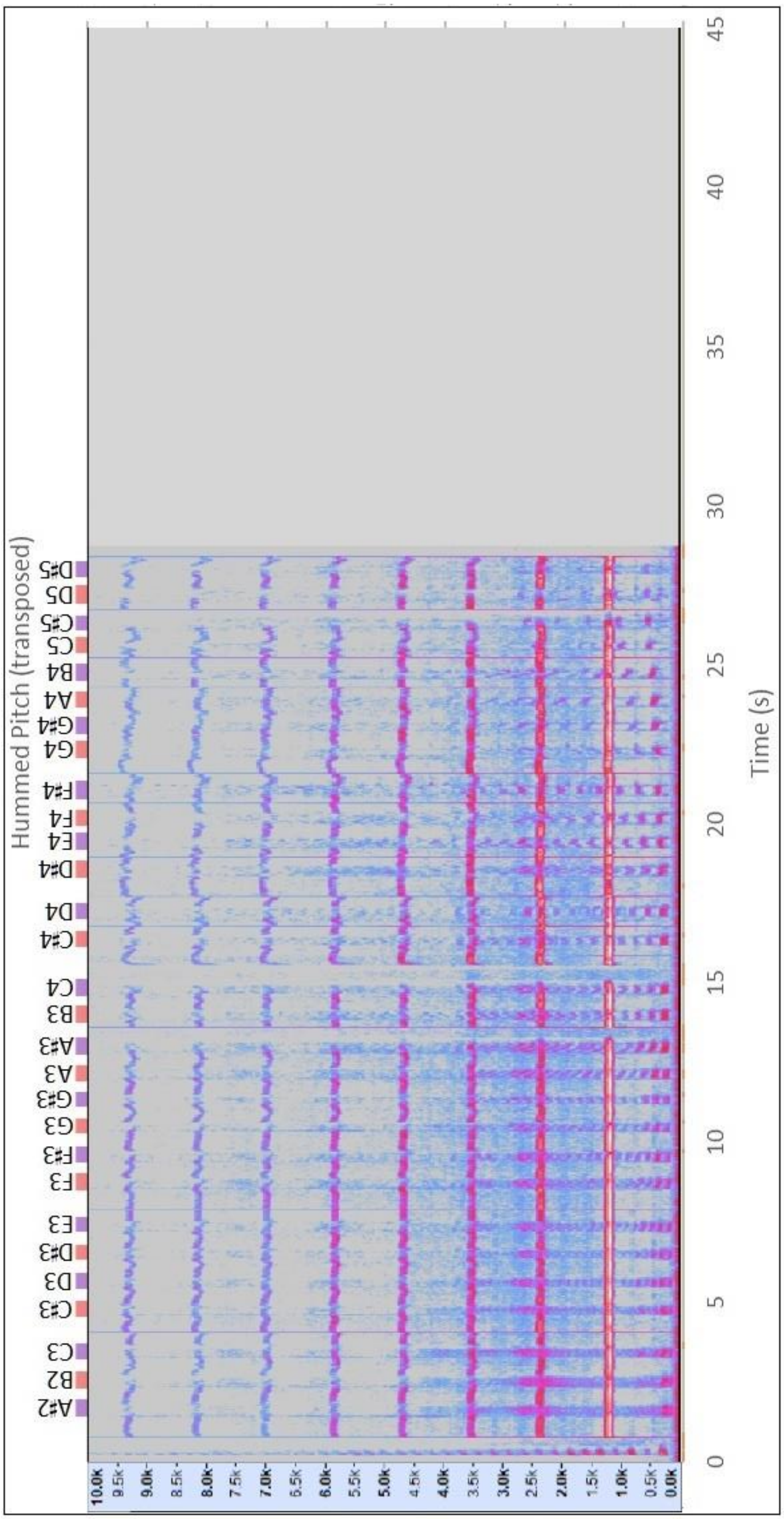


Figure B.8. Spectrogram for play loud, hum loud, E_6.

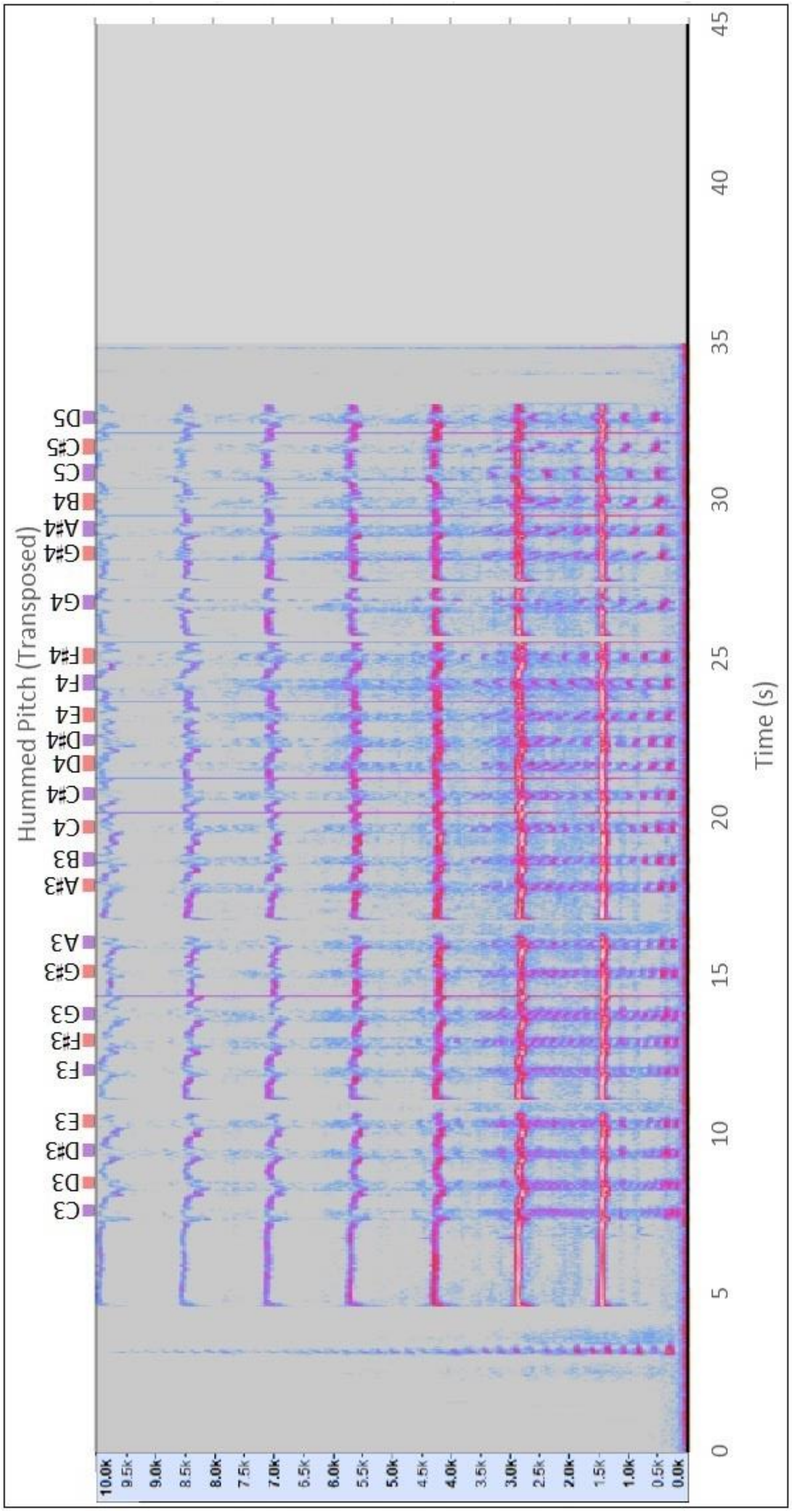


Figure B.9. Spectrogram for play loud, hum loud, G_6.

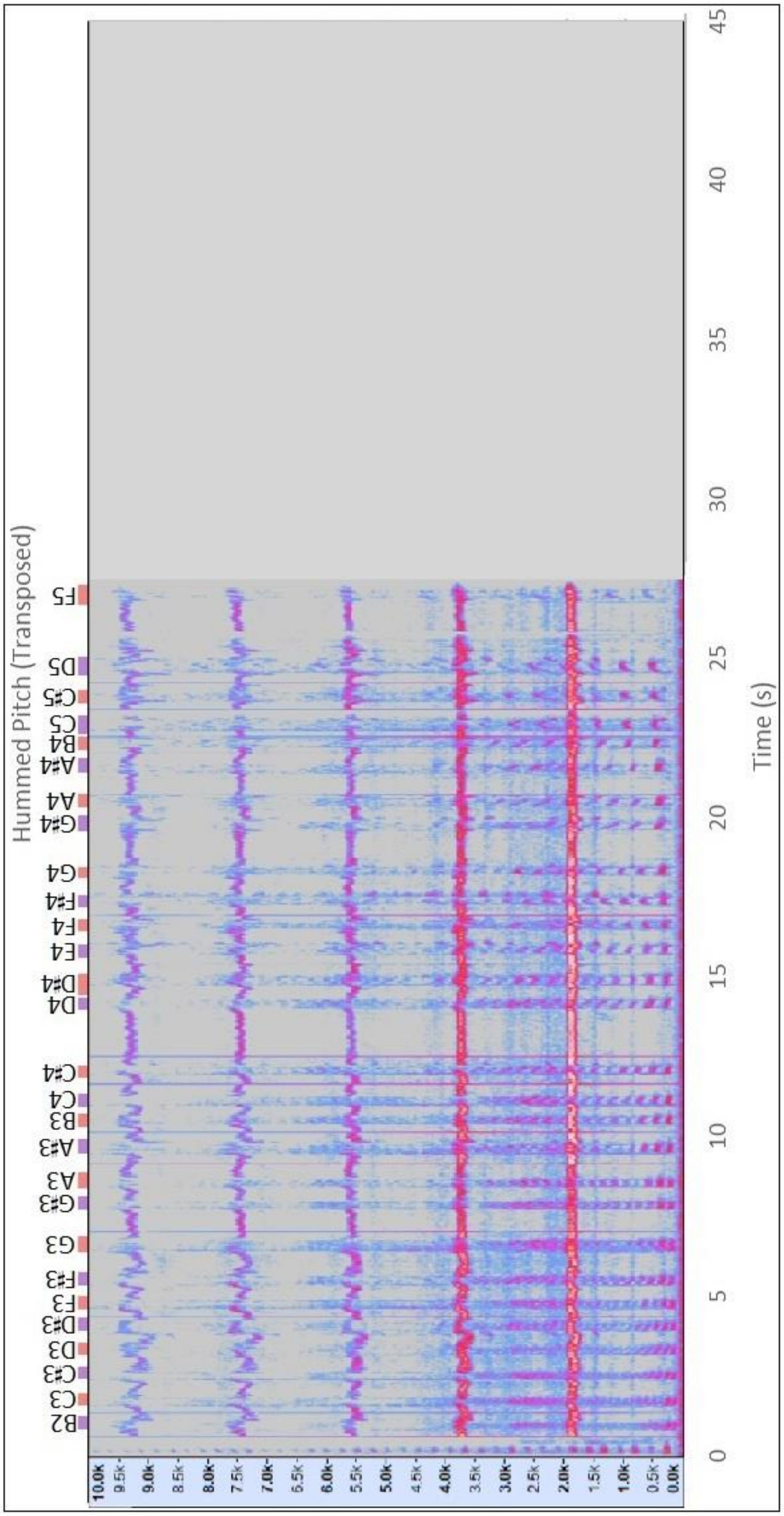


Figure B.10. Spectrogram for play loud, hum loud, C_7.

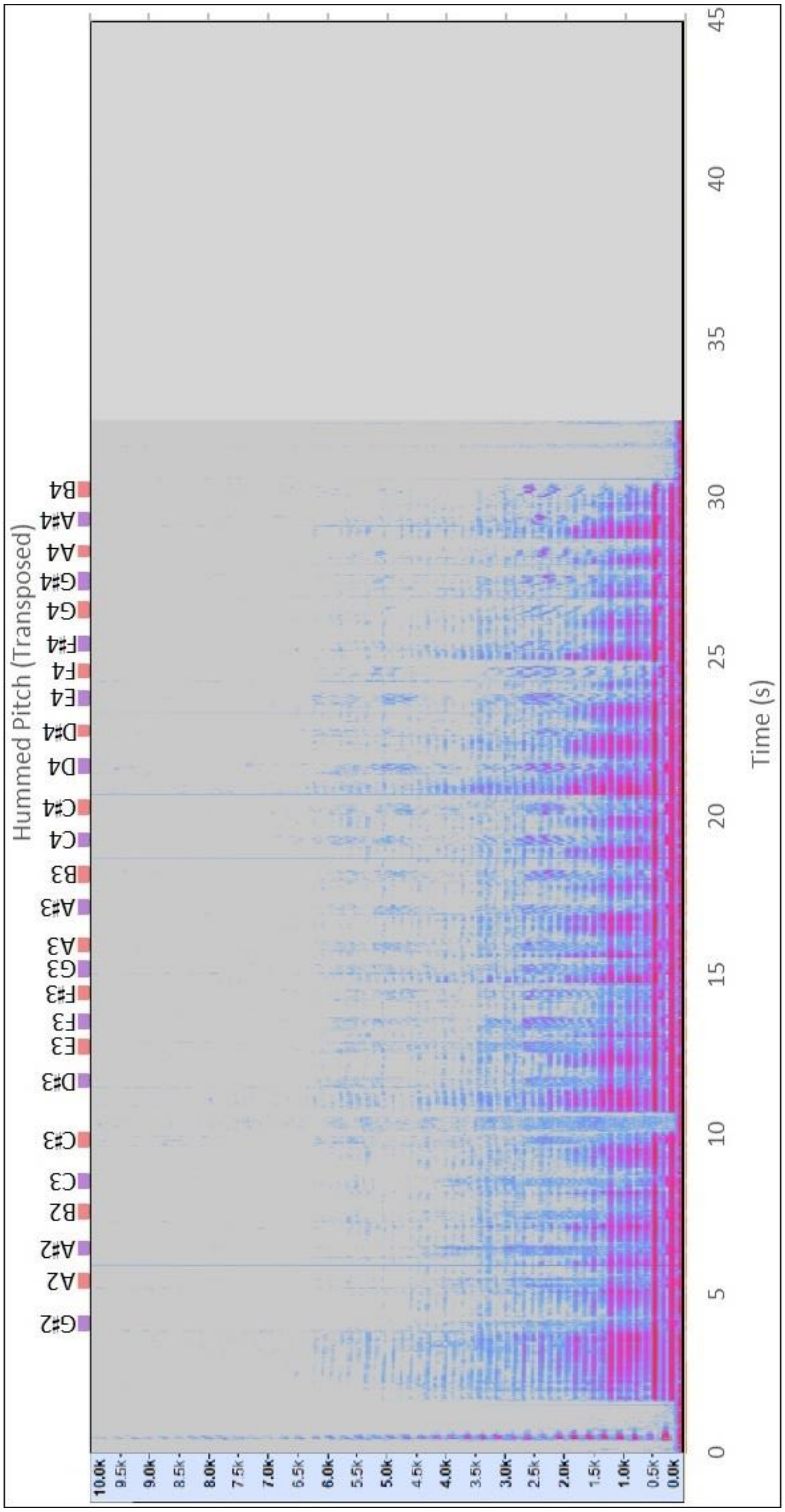


Figure B.11. Spectrogram for play loud, hum soft, E_3.

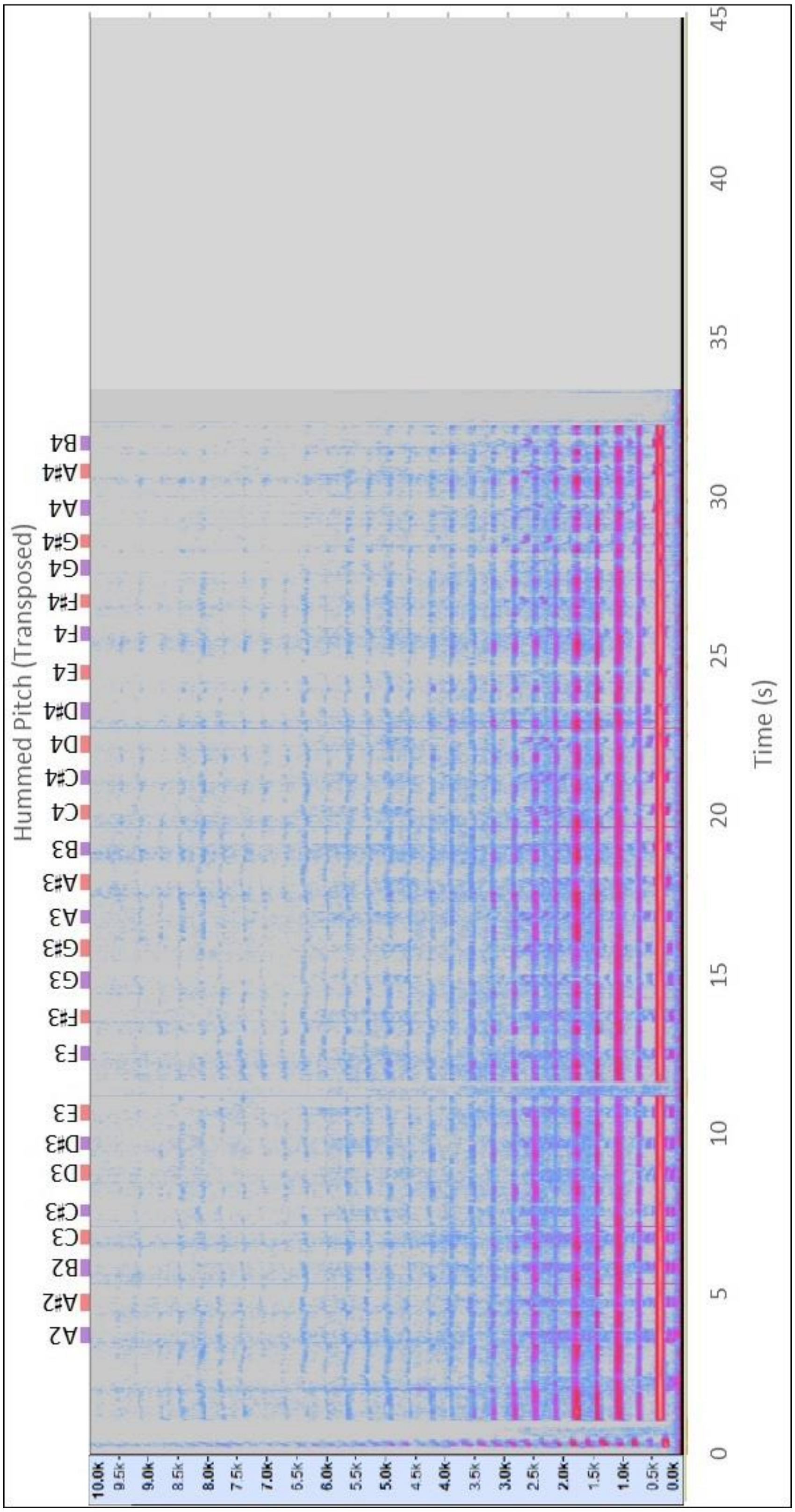


Figure B.12. Spectrogram for play loud, hum soft, G_4.

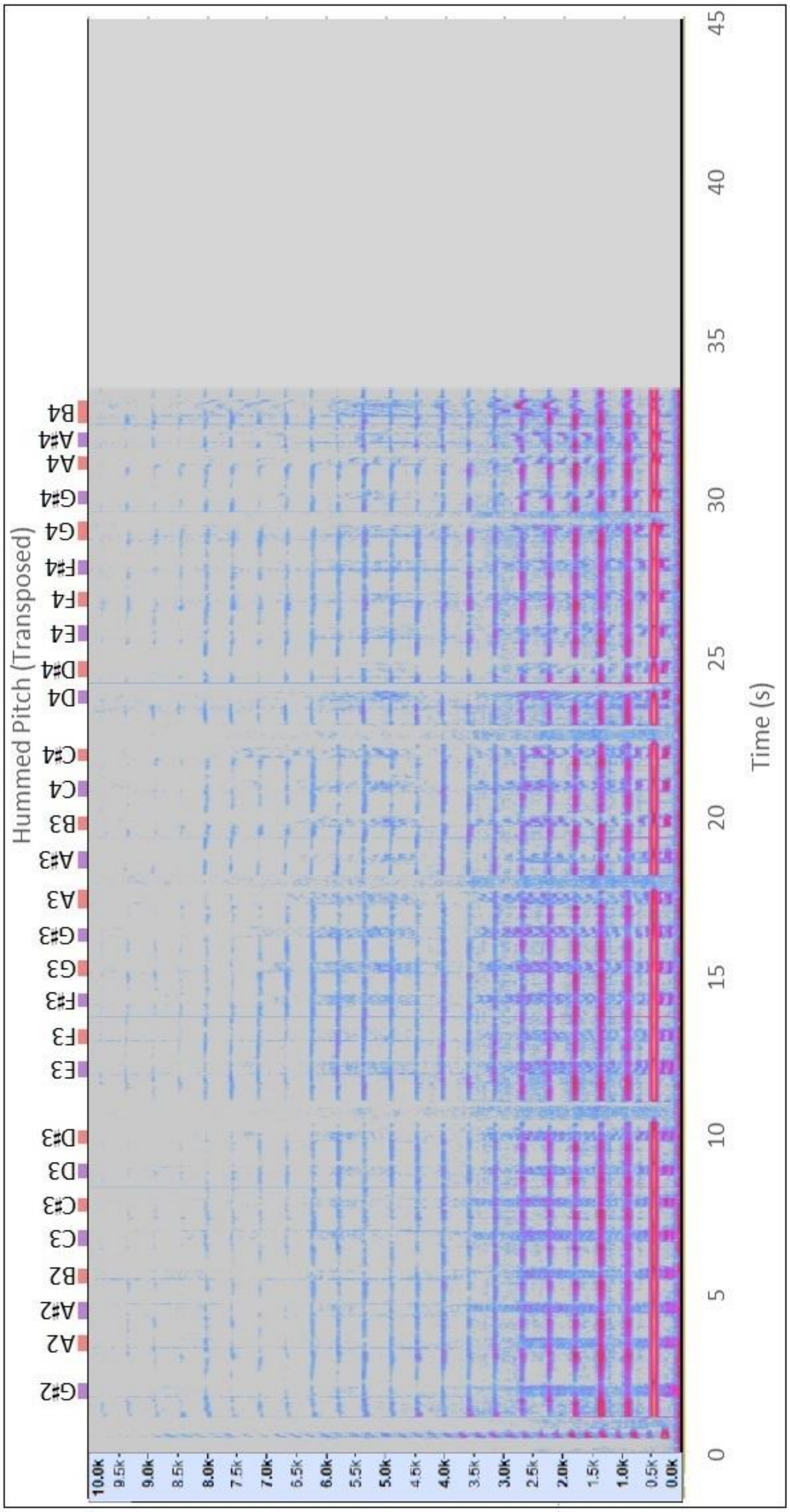


Figure B.13. Spectrogram for play loud, hum soft, B4.

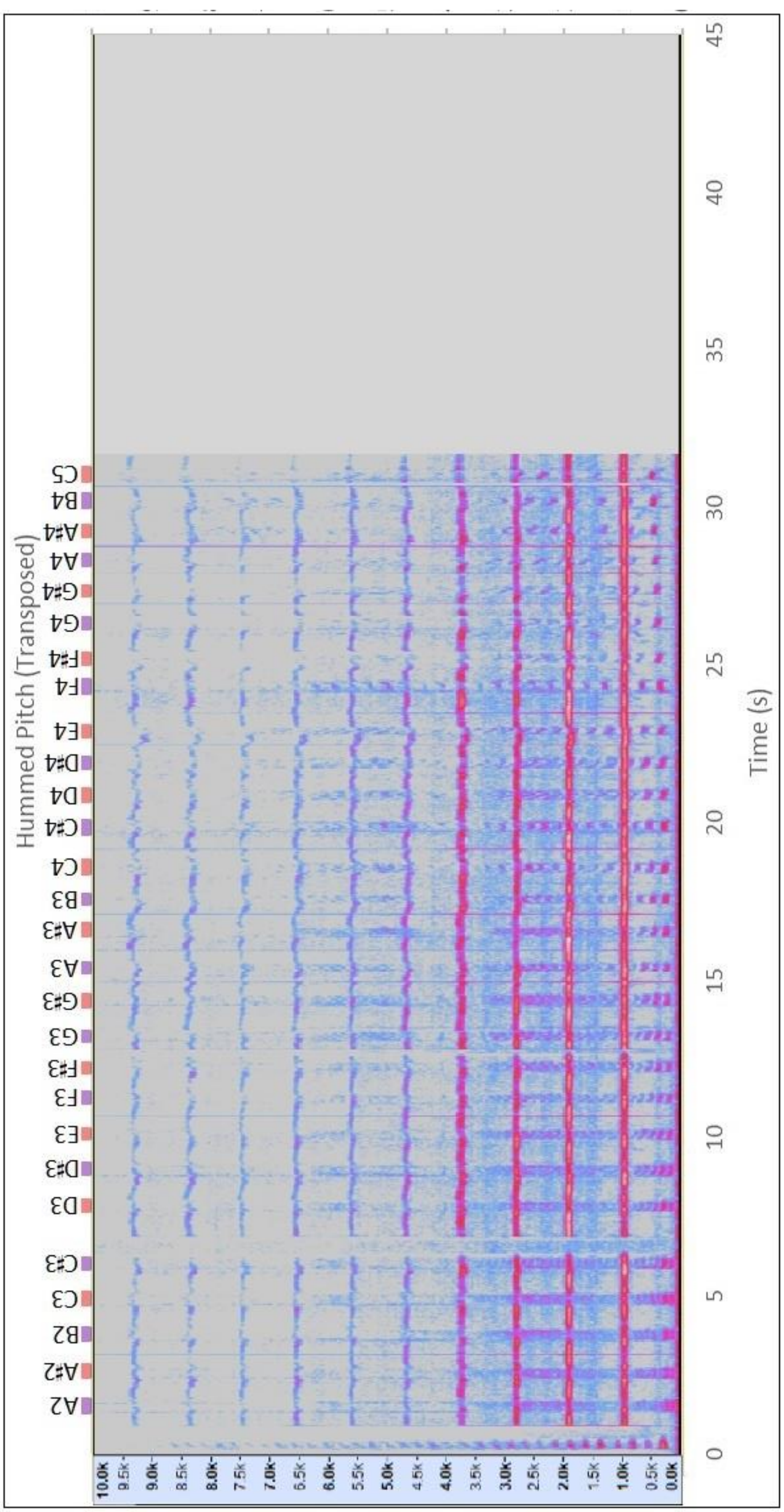


Figure B.14. Spectrogram for play loud, hum soft, C_6.

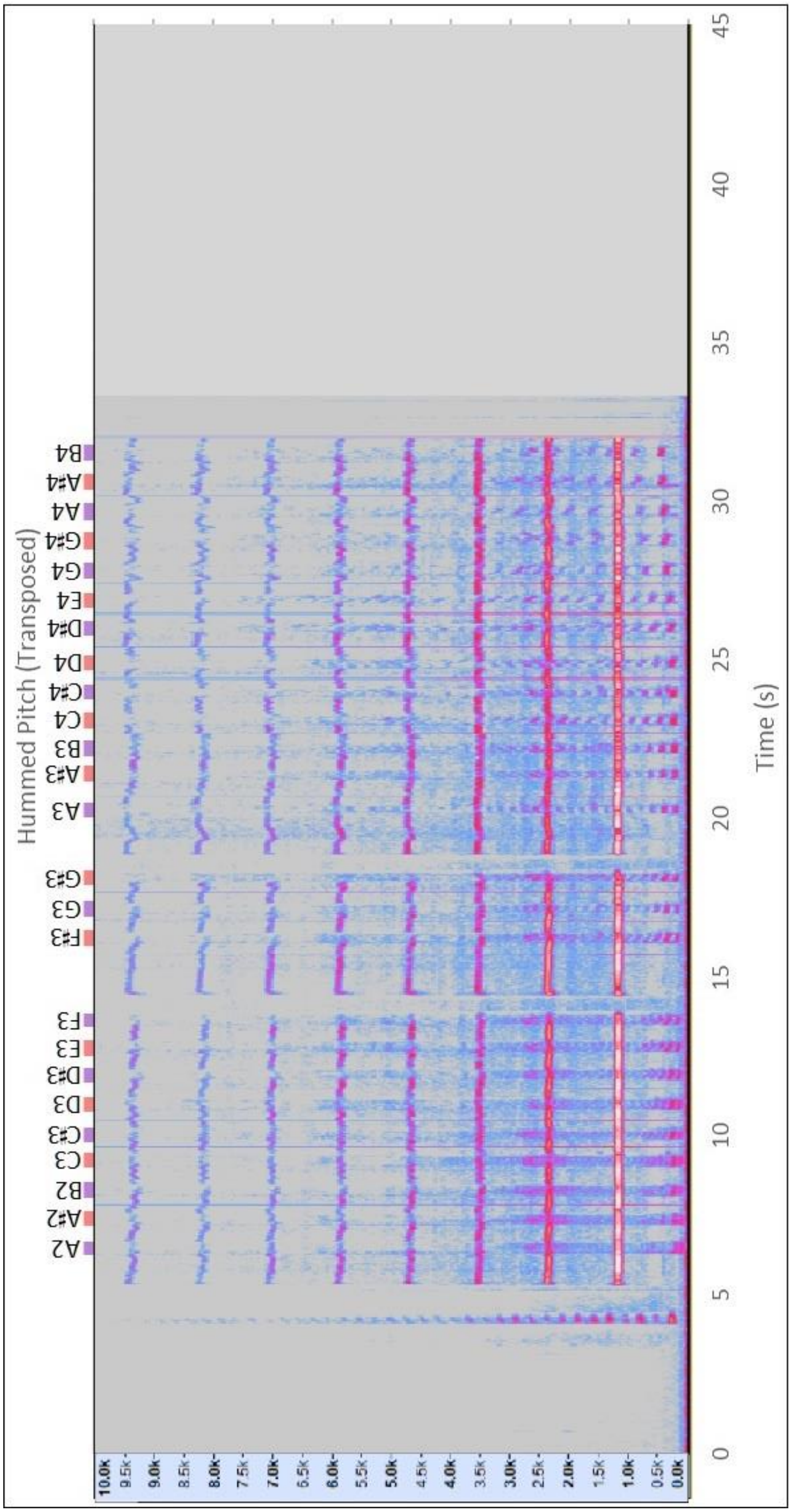


Figure B.15. Spectrogram for play loud, hum soft, E_6.

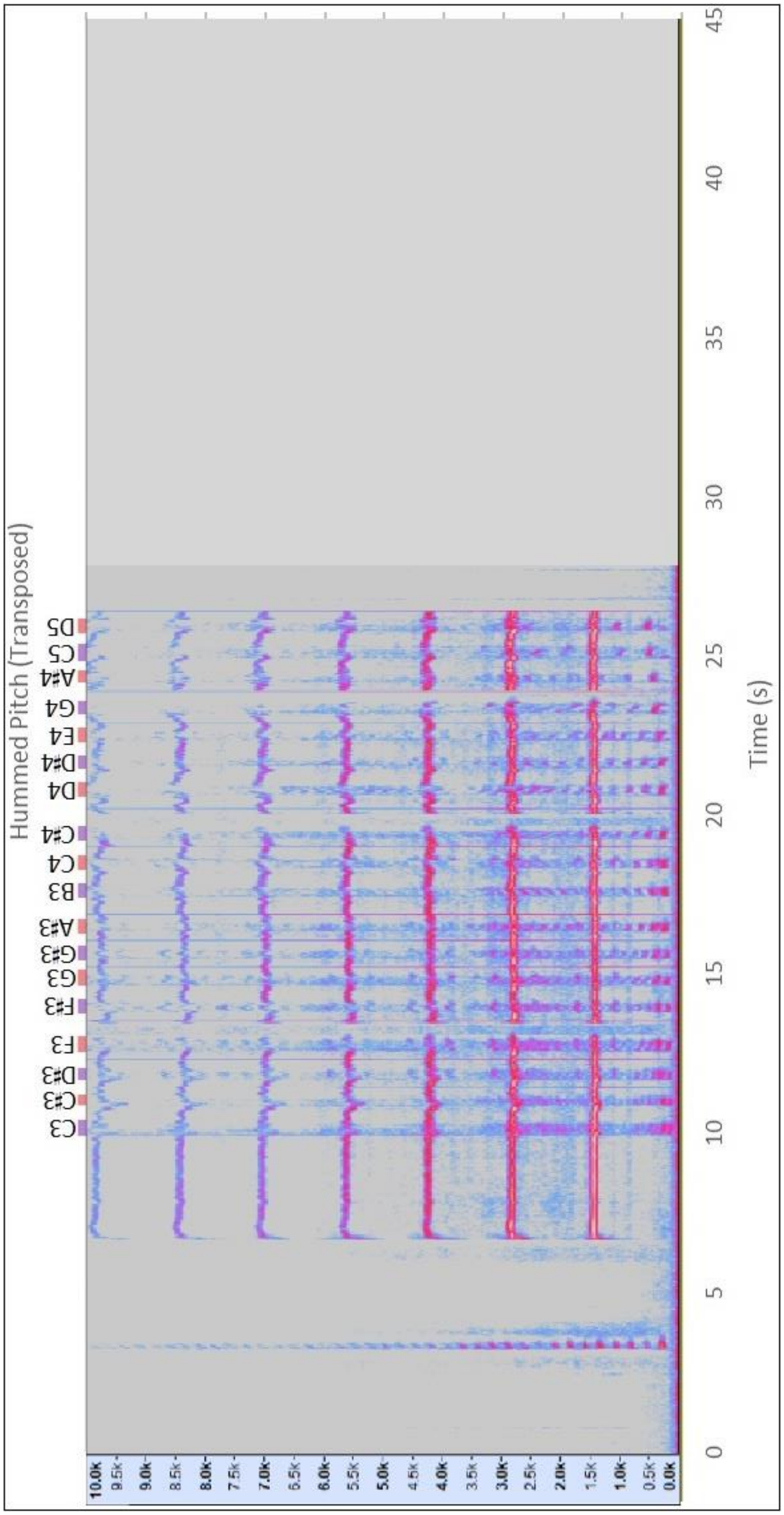


Figure B.16. Spectrogram for play loud, hum soft, G_6.

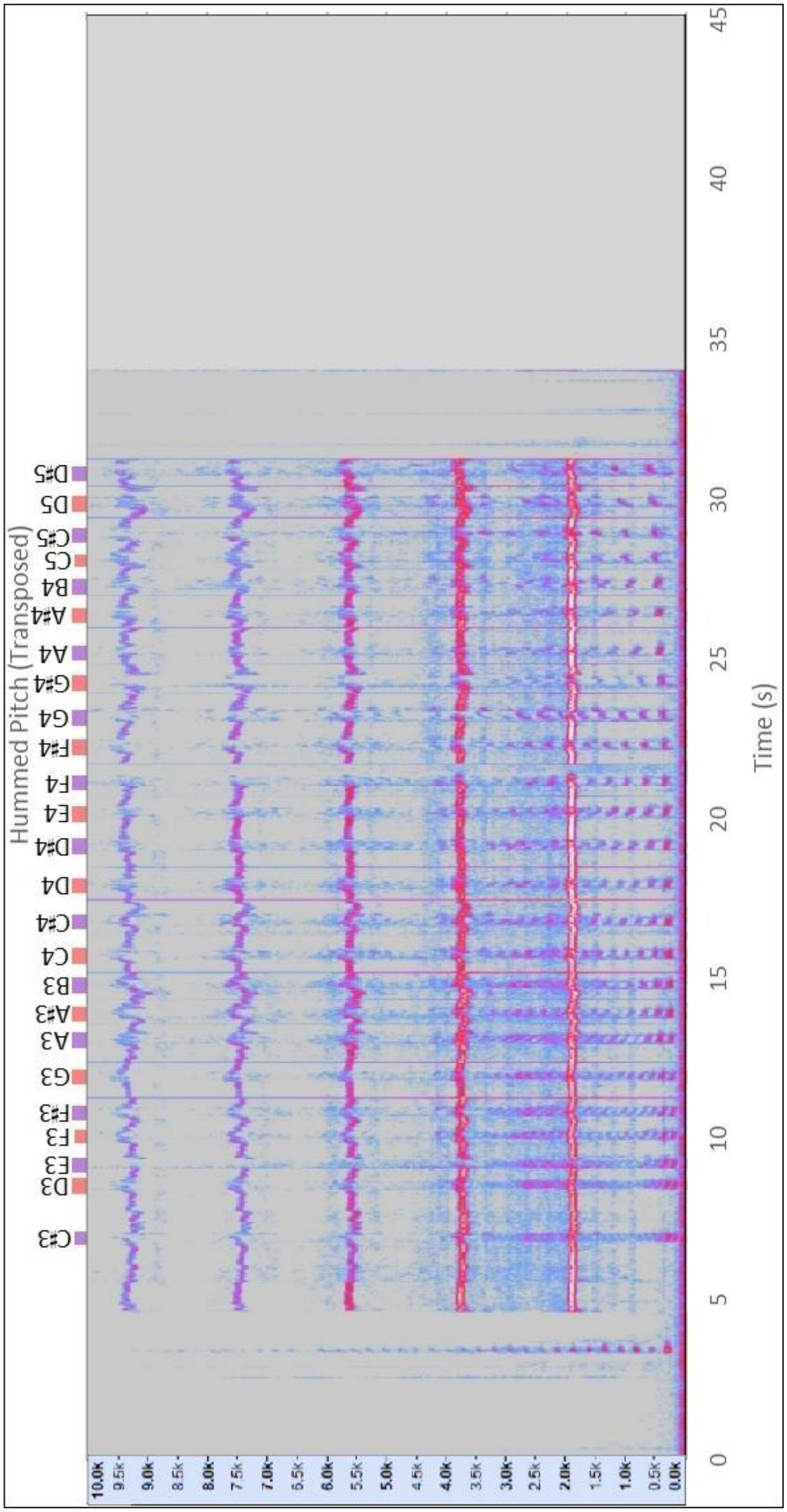


Figure B.17. Spectrogram for play loud, hum soft, C_7.

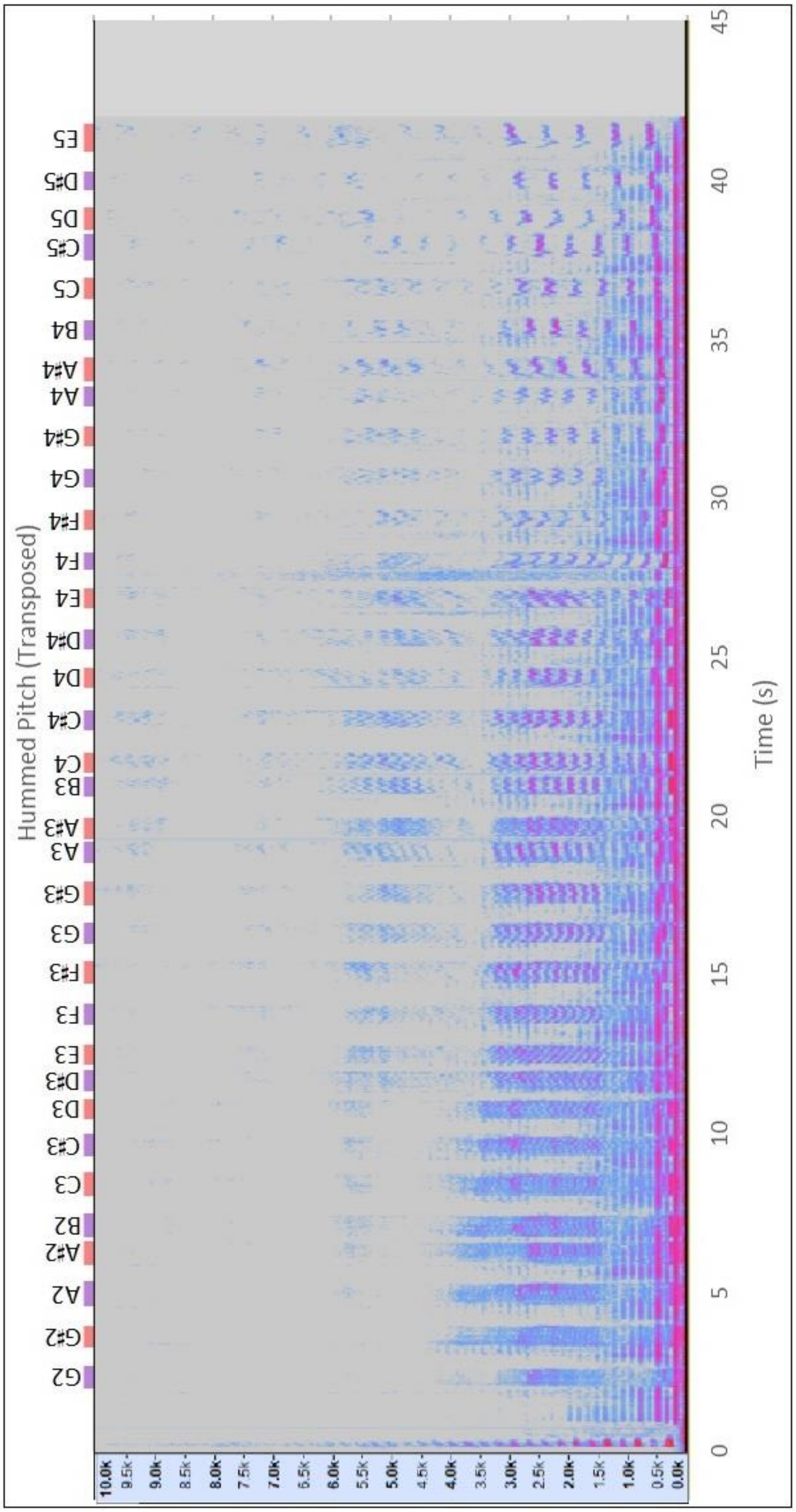


Figure B.18. Spectrogram for play soft, hum loud, E_3.

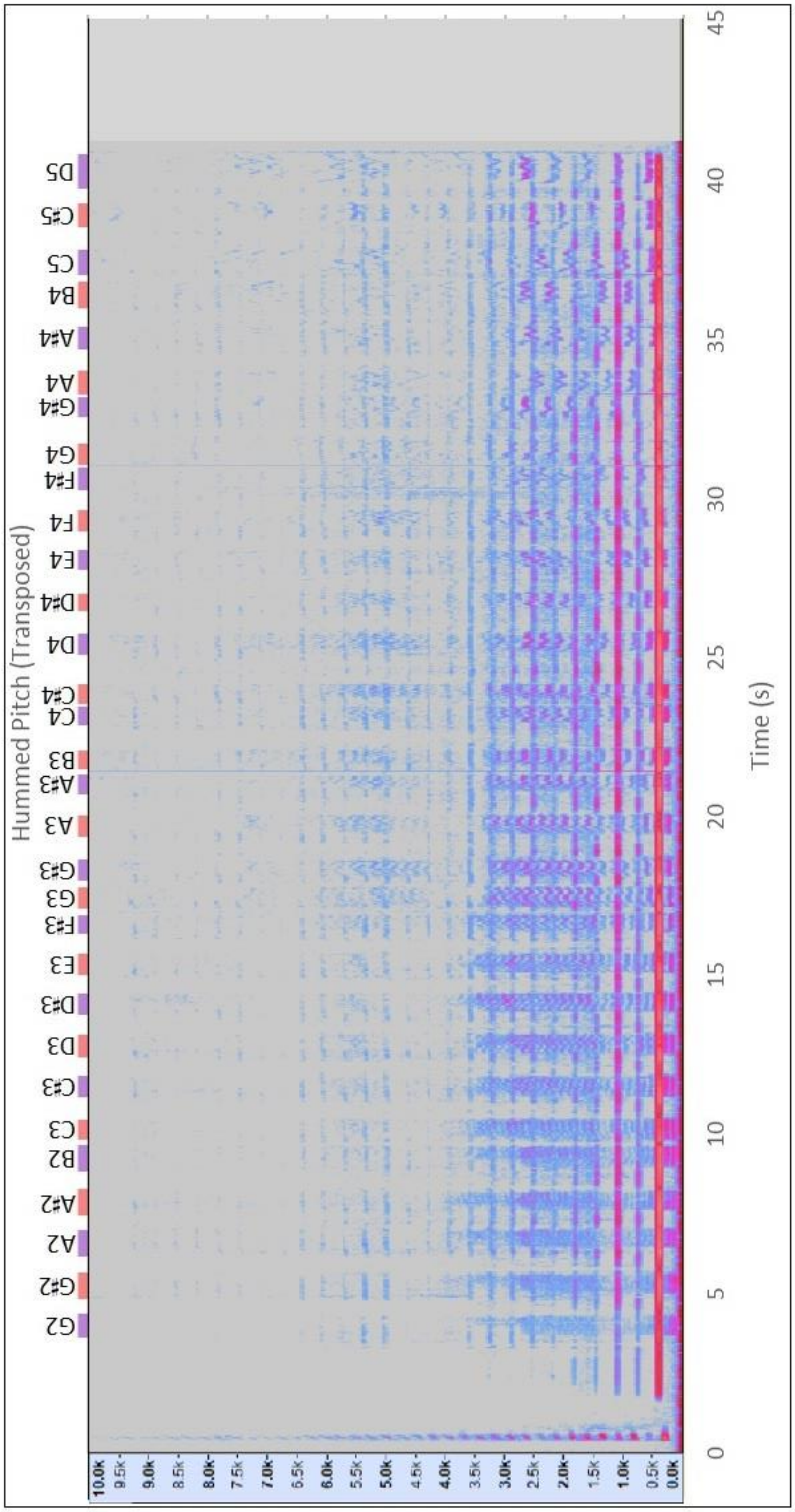


Figure B.19. Spectrogram for play soft, hum loud, G_4.

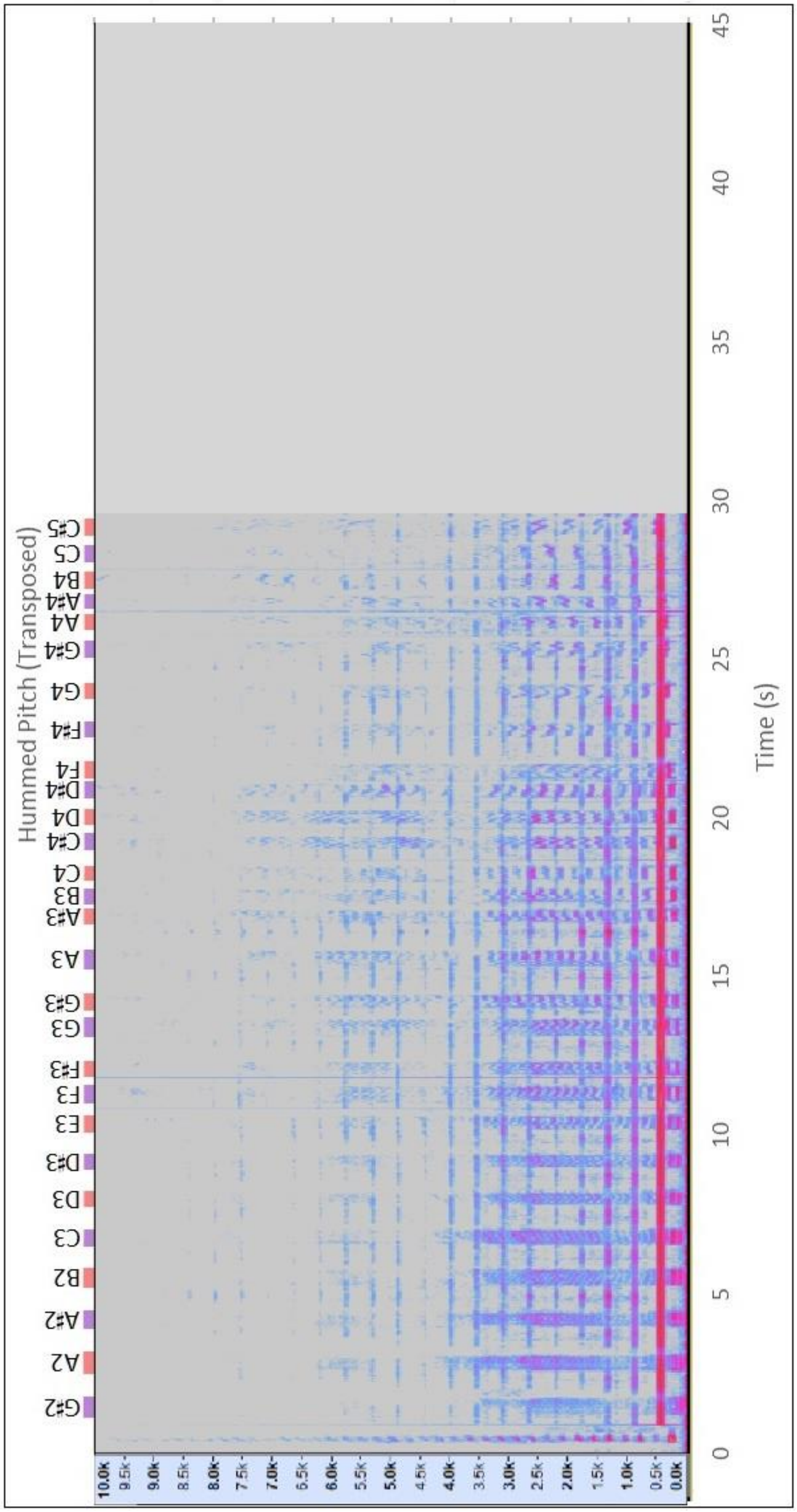


Figure B.20. Spectrogram for play soft, hum loud, B4.

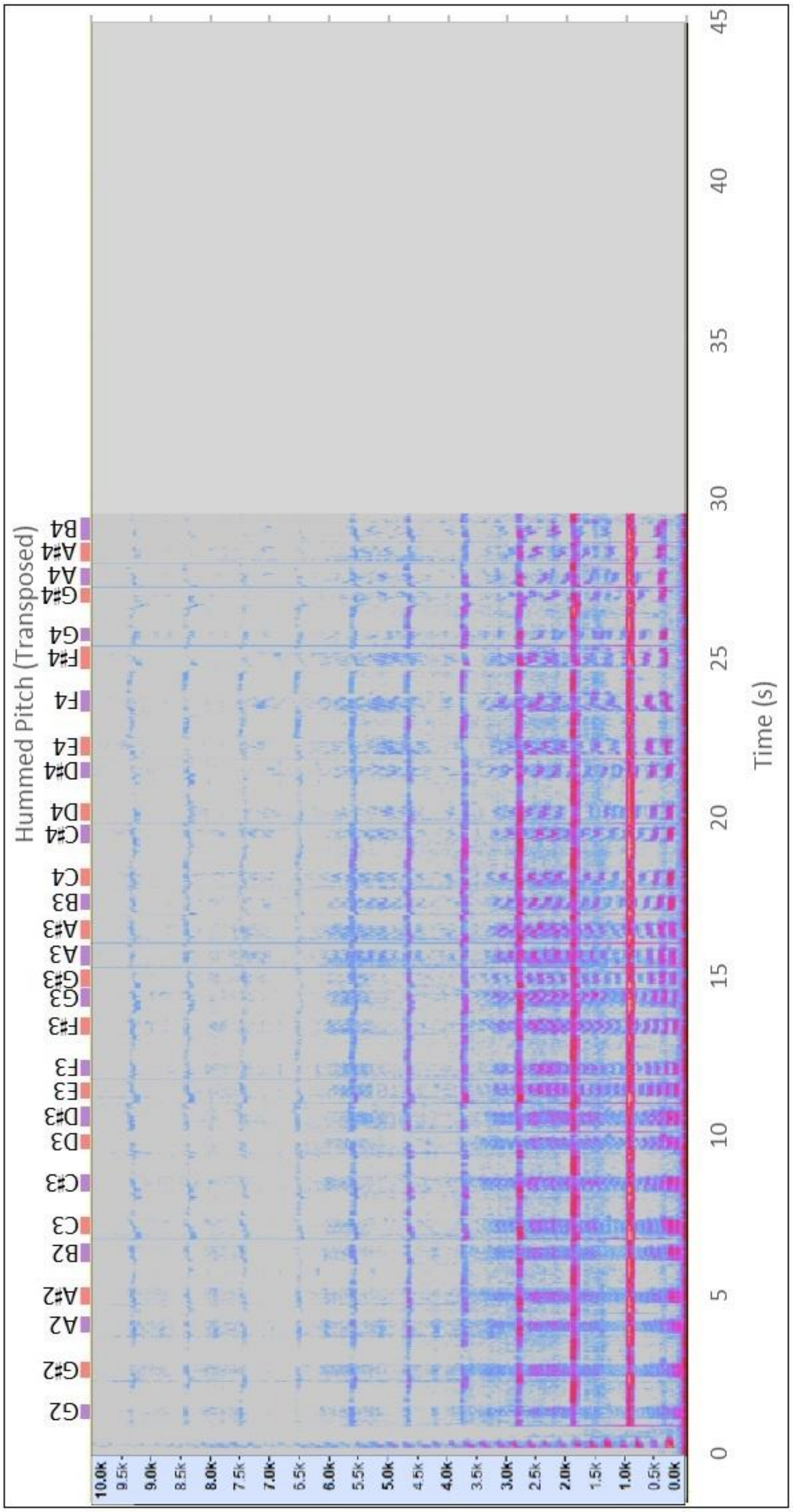


Figure B.21. Spectrogram for play soft, hum loud, C_6.

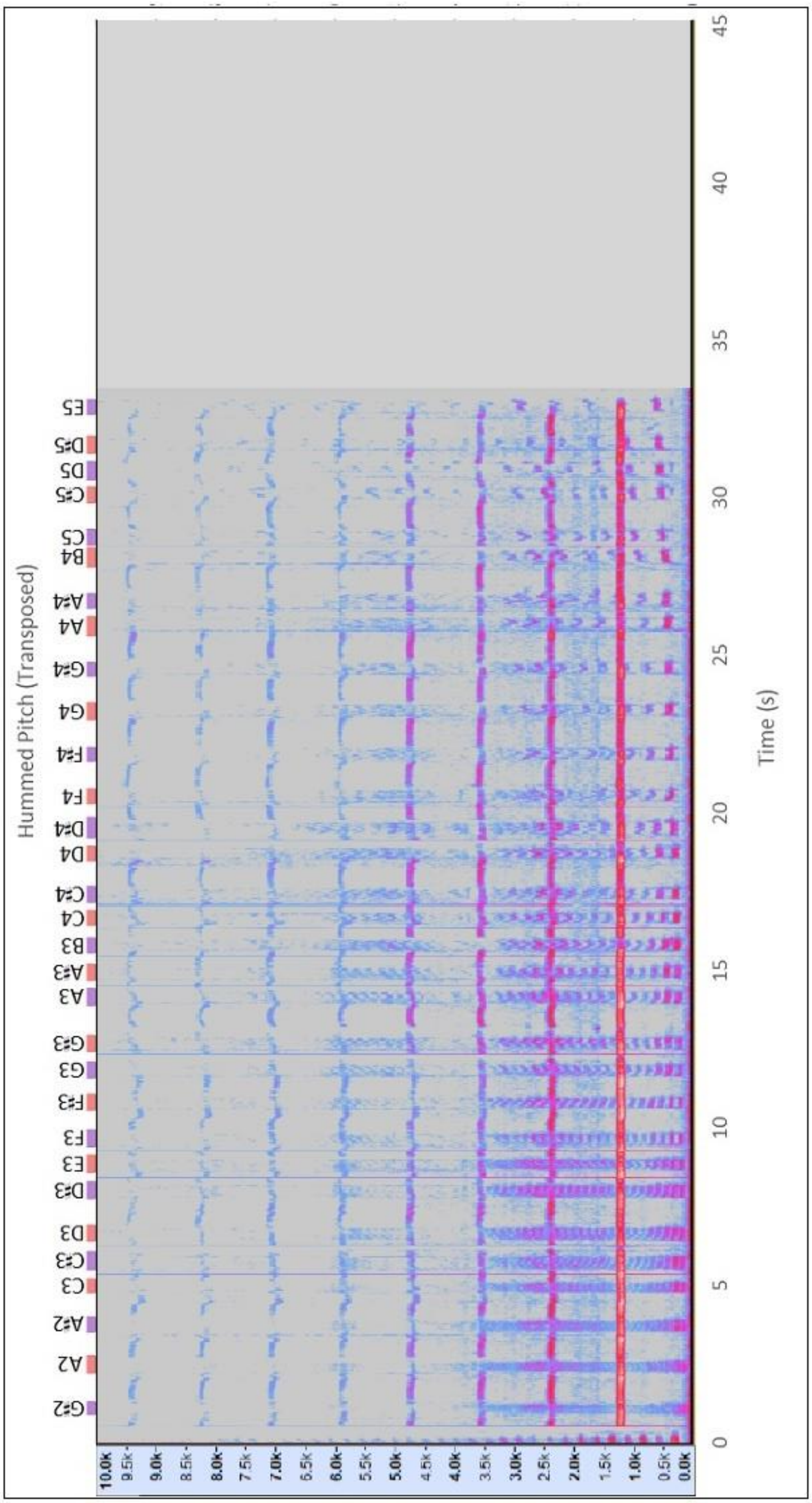


Figure B.22. Spectrogram for play soft, hum loud, E_6.

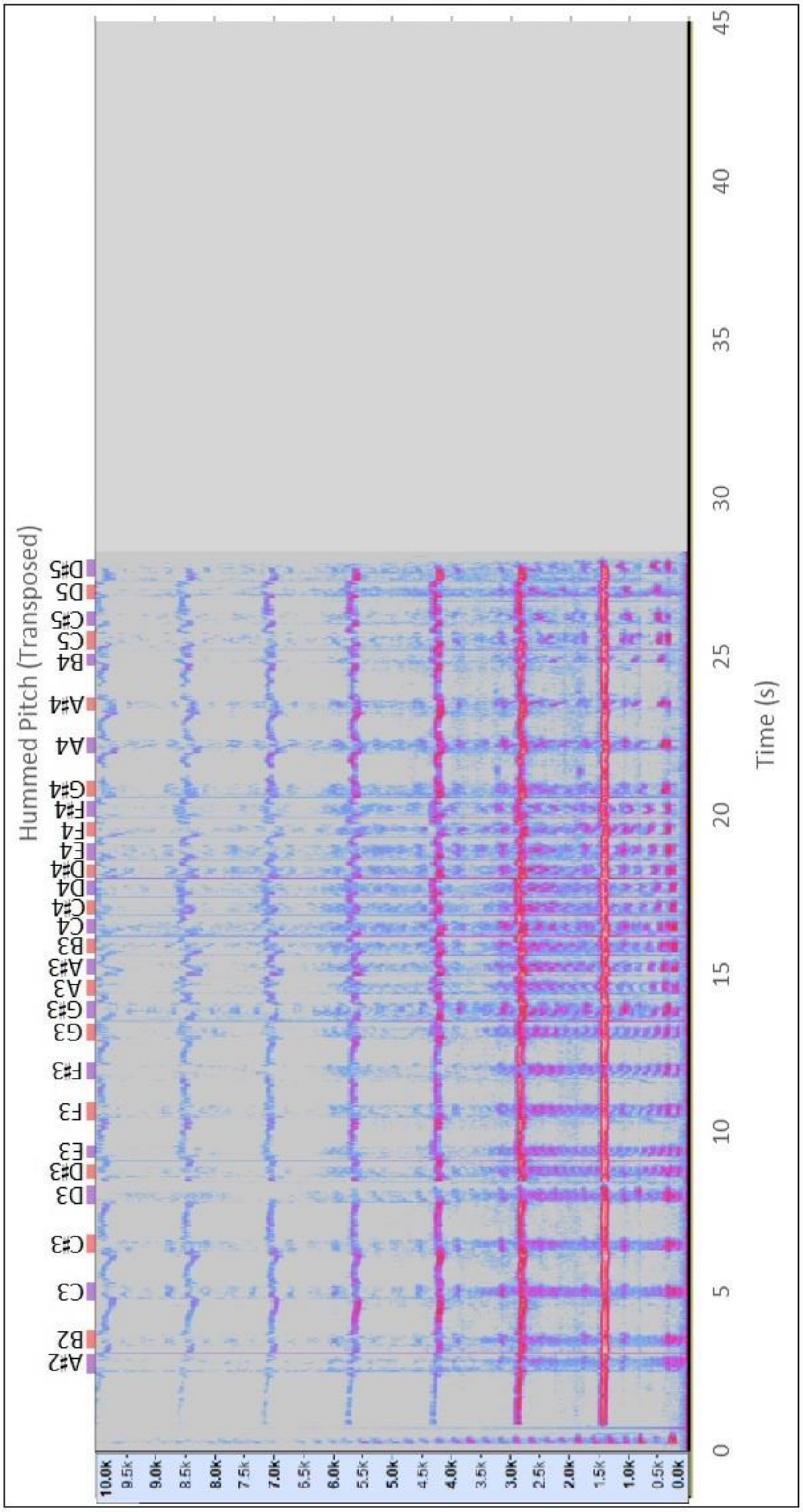


Figure B.23. Spectrogram for play soft, hum loud, G_6.

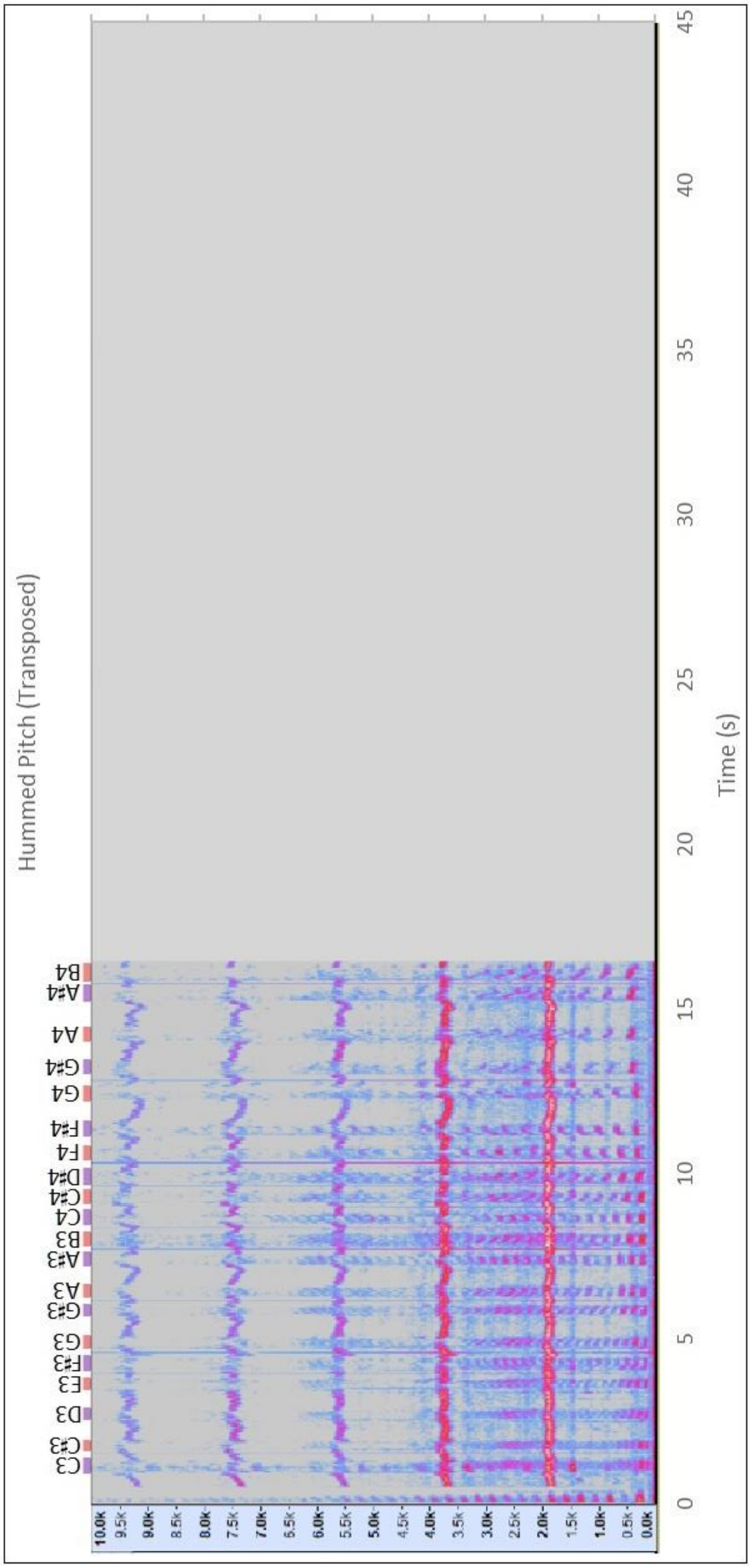


Figure B.24. Spectrogram for play soft, hum loud, C_7.

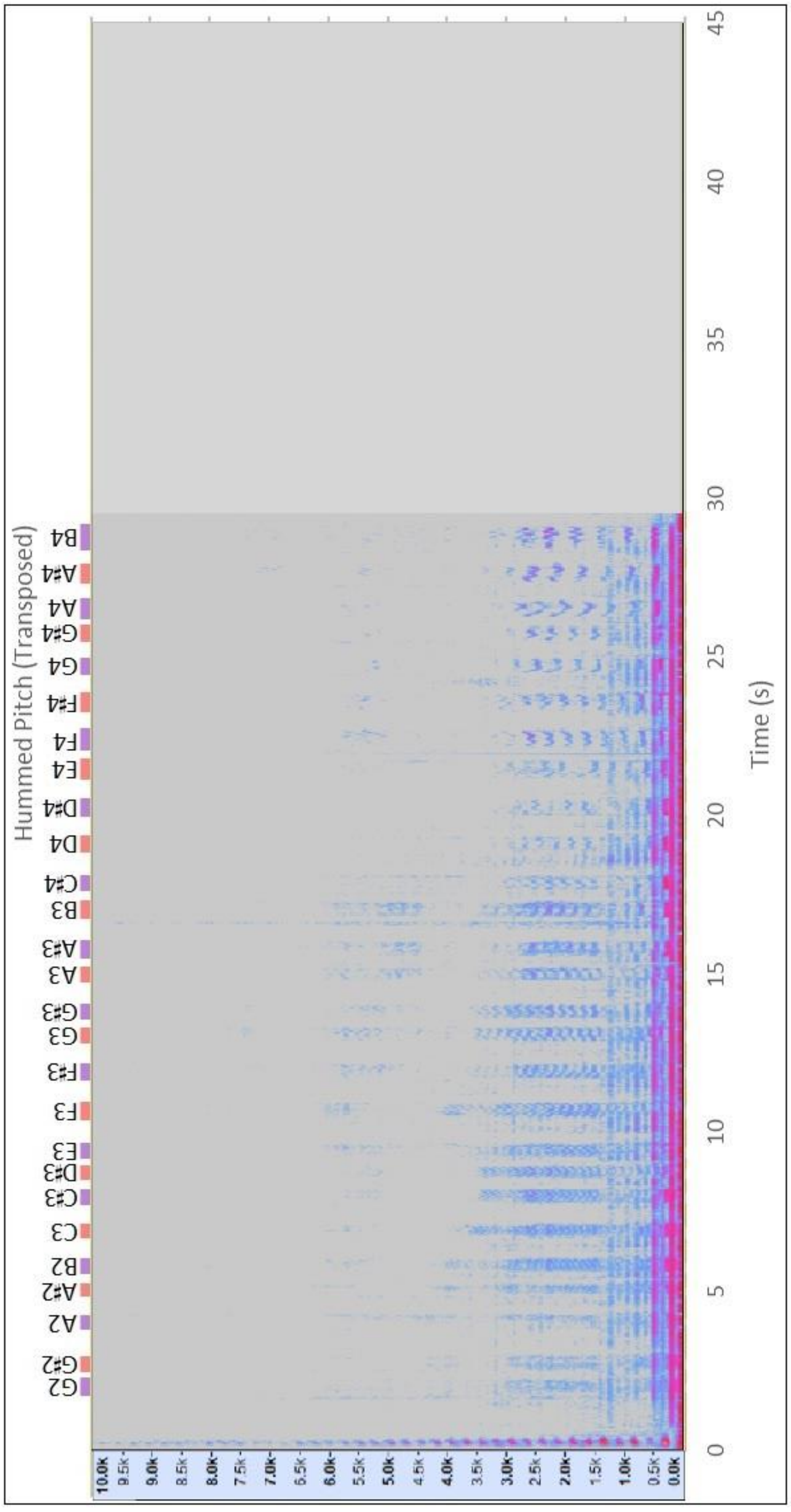


Figure B.25. Spectrogram for play soft, hum soft, E_3.

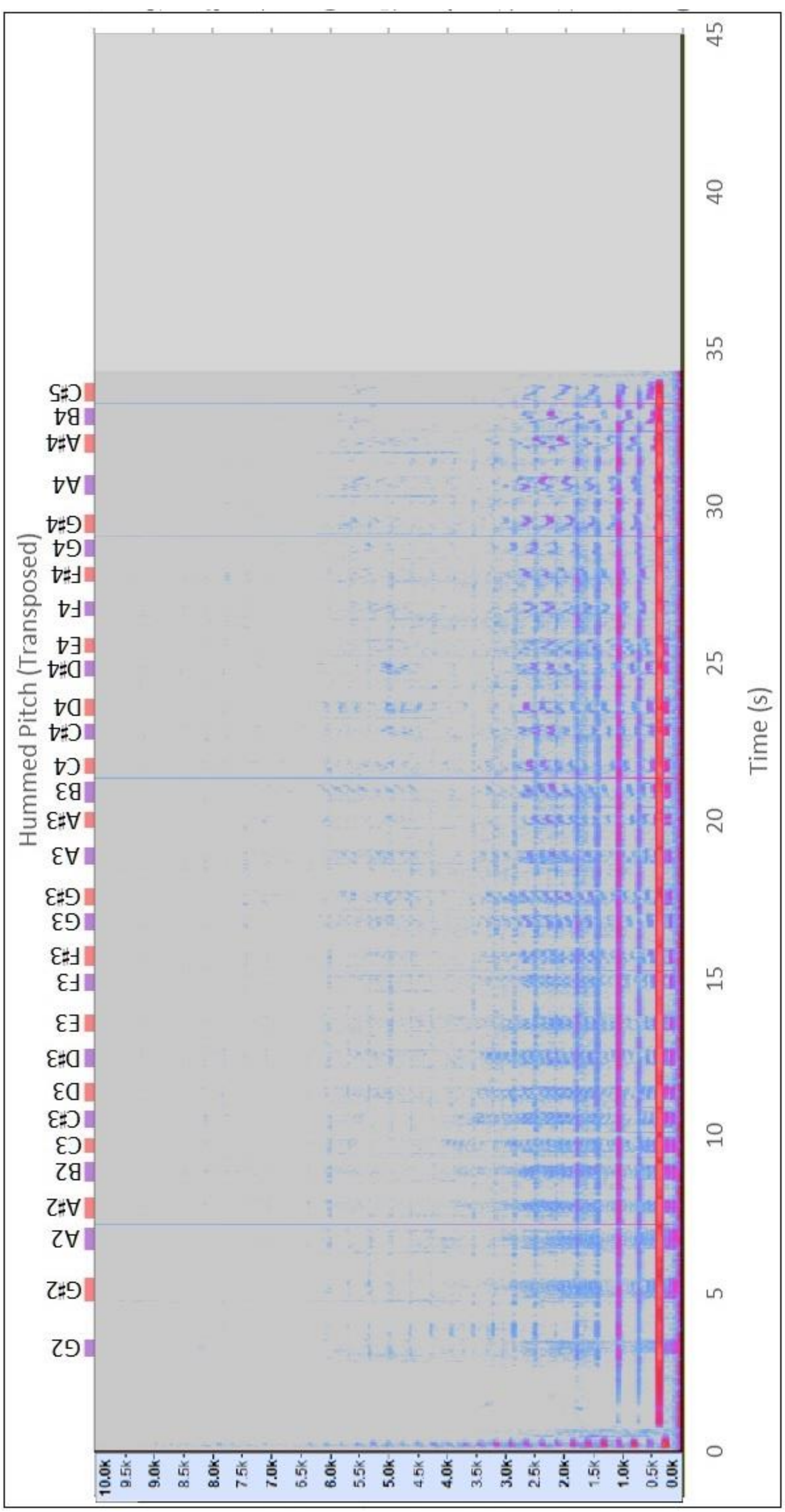


Figure B.26. Spectrogram for play soft, hum soft, G_4.

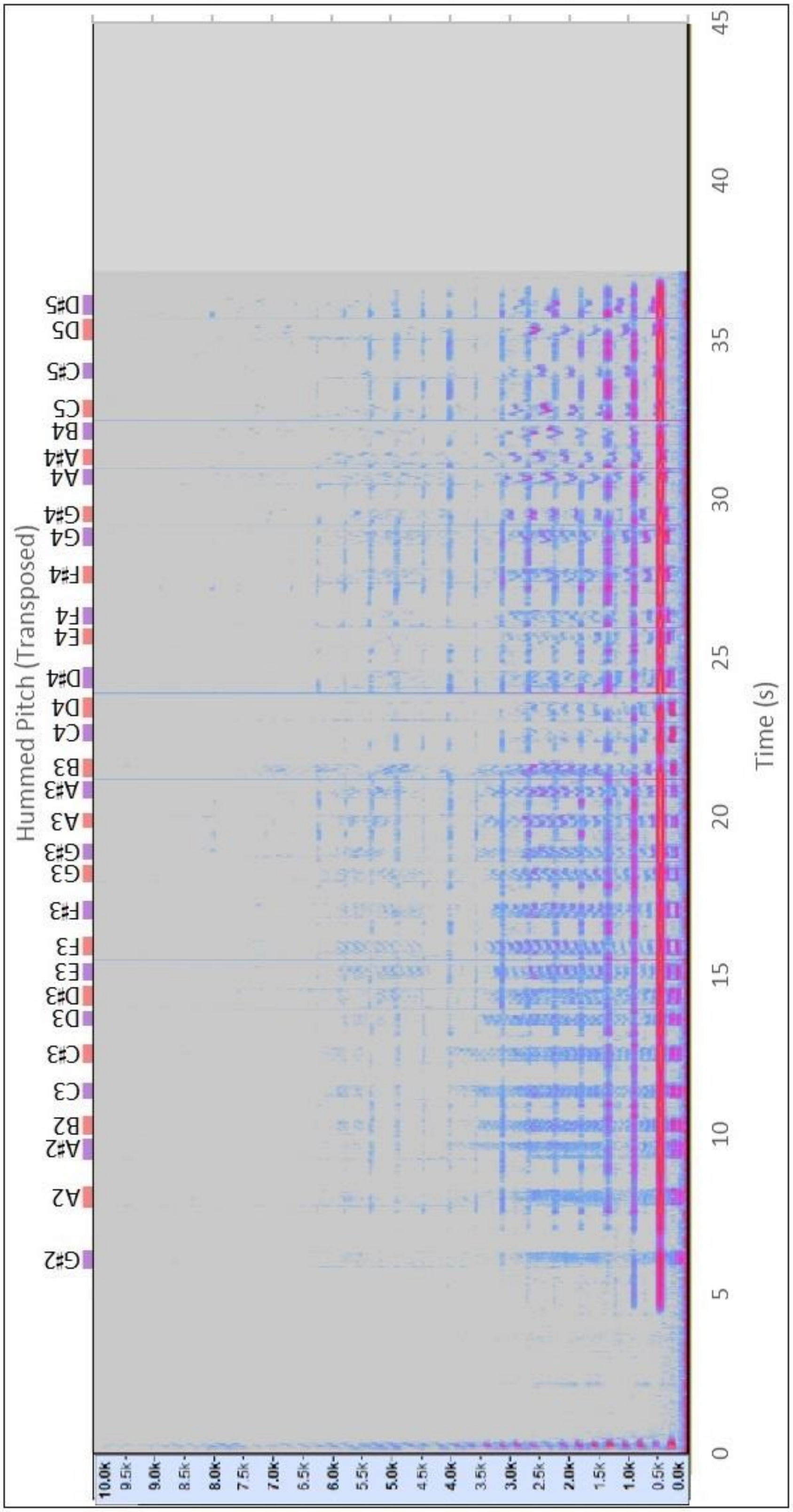


Figure B.27. Spectrogram for play soft, hum soft, B4.

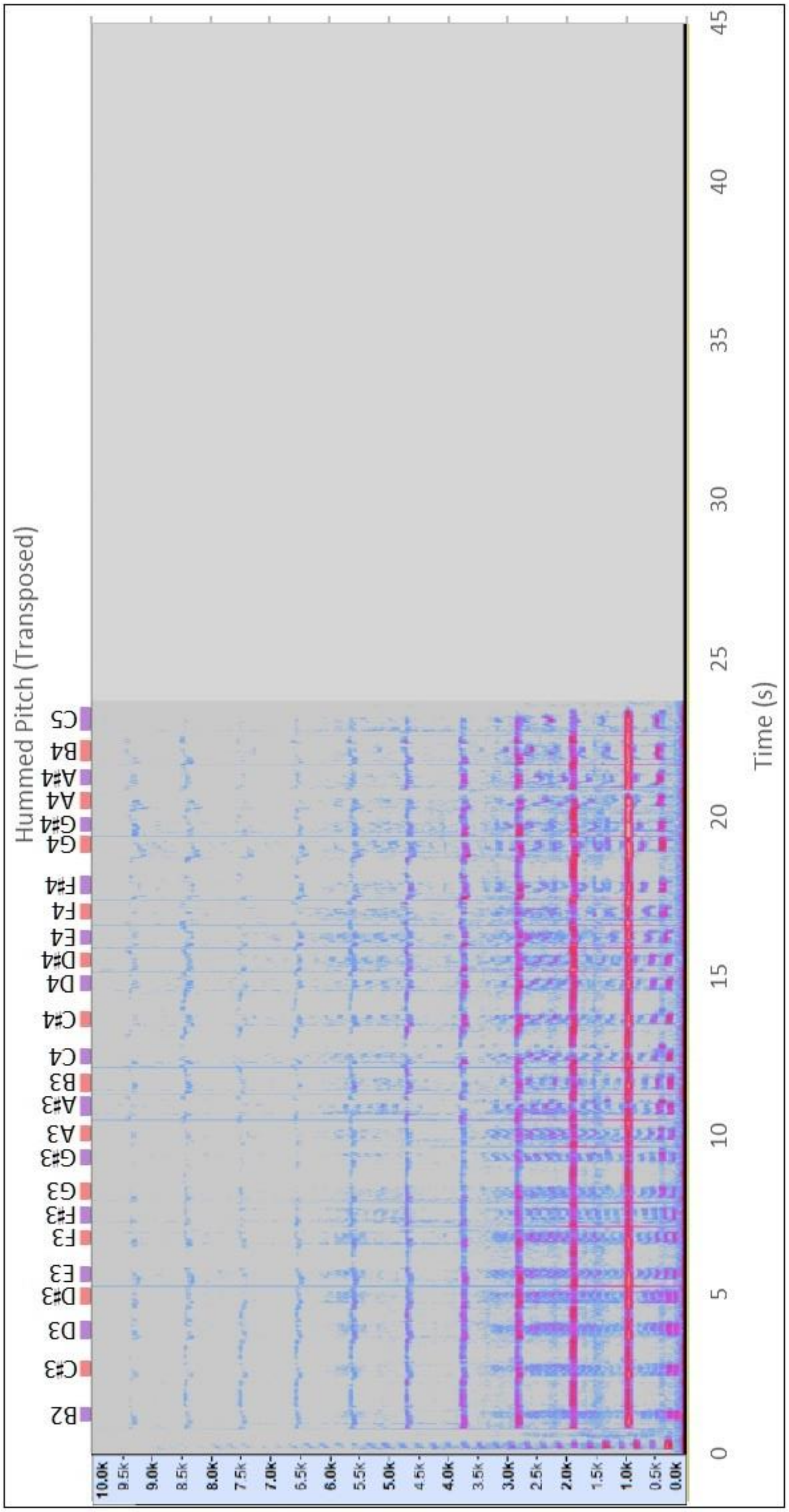


Figure B.28. Spectrogram for play soft, hum soft, C_6.

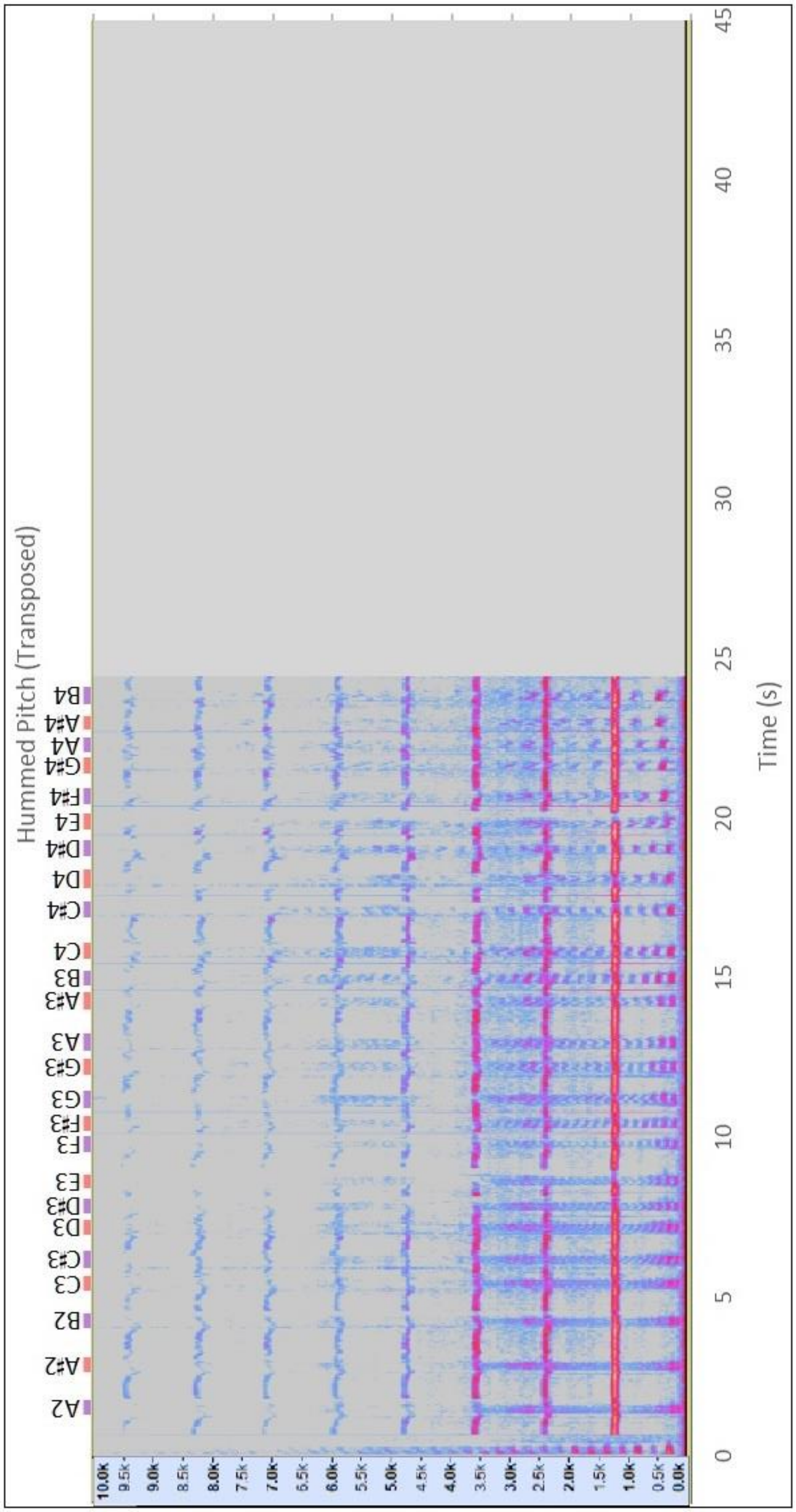


Figure B.29. Spectrogram for play soft, hum soft, E_6.

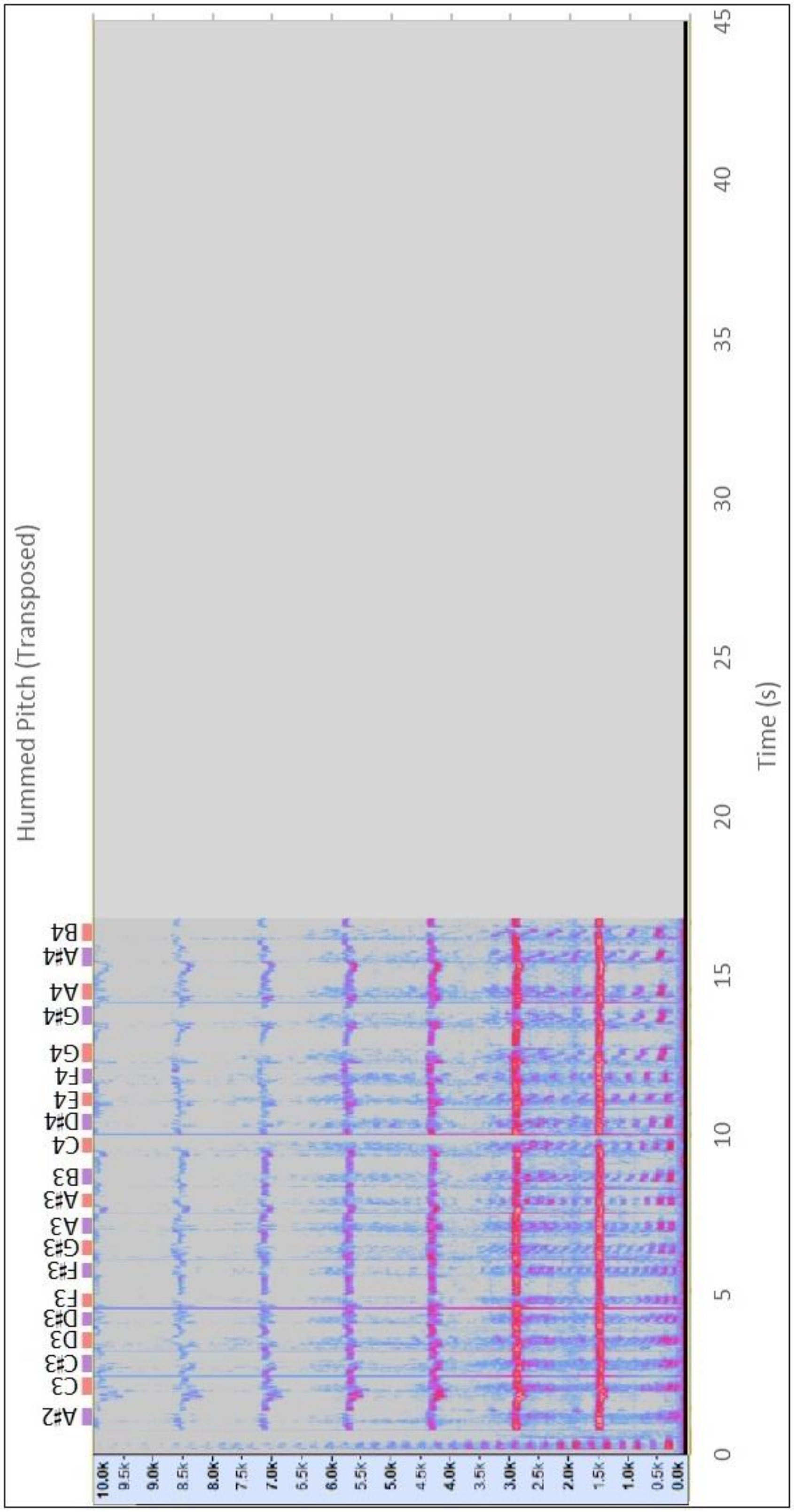


Figure B.30. Spectrogram for play soft, hum soft, G_6.

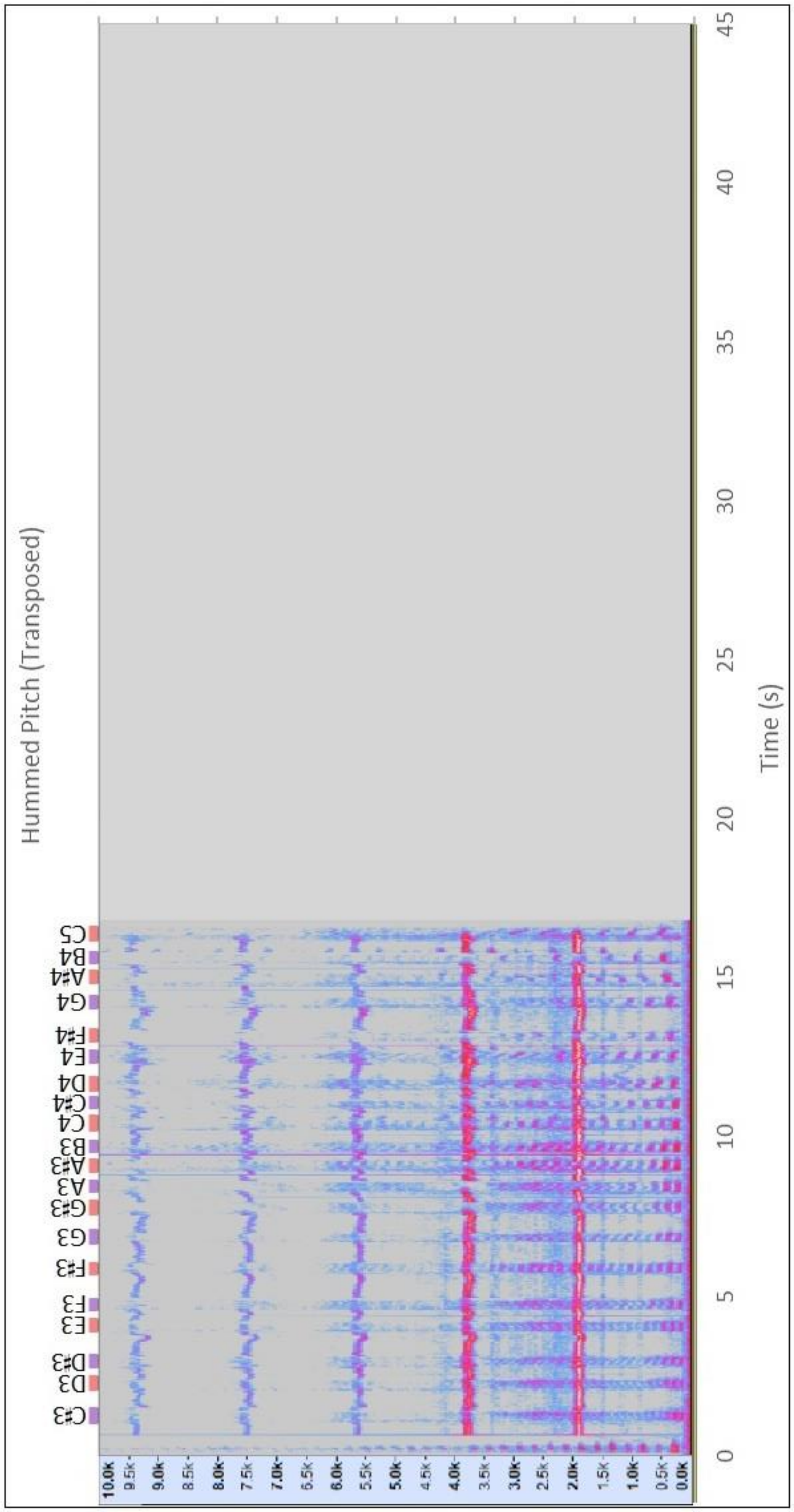


Figure B.31. Spectrogram for play soft, hum soft, C_7.

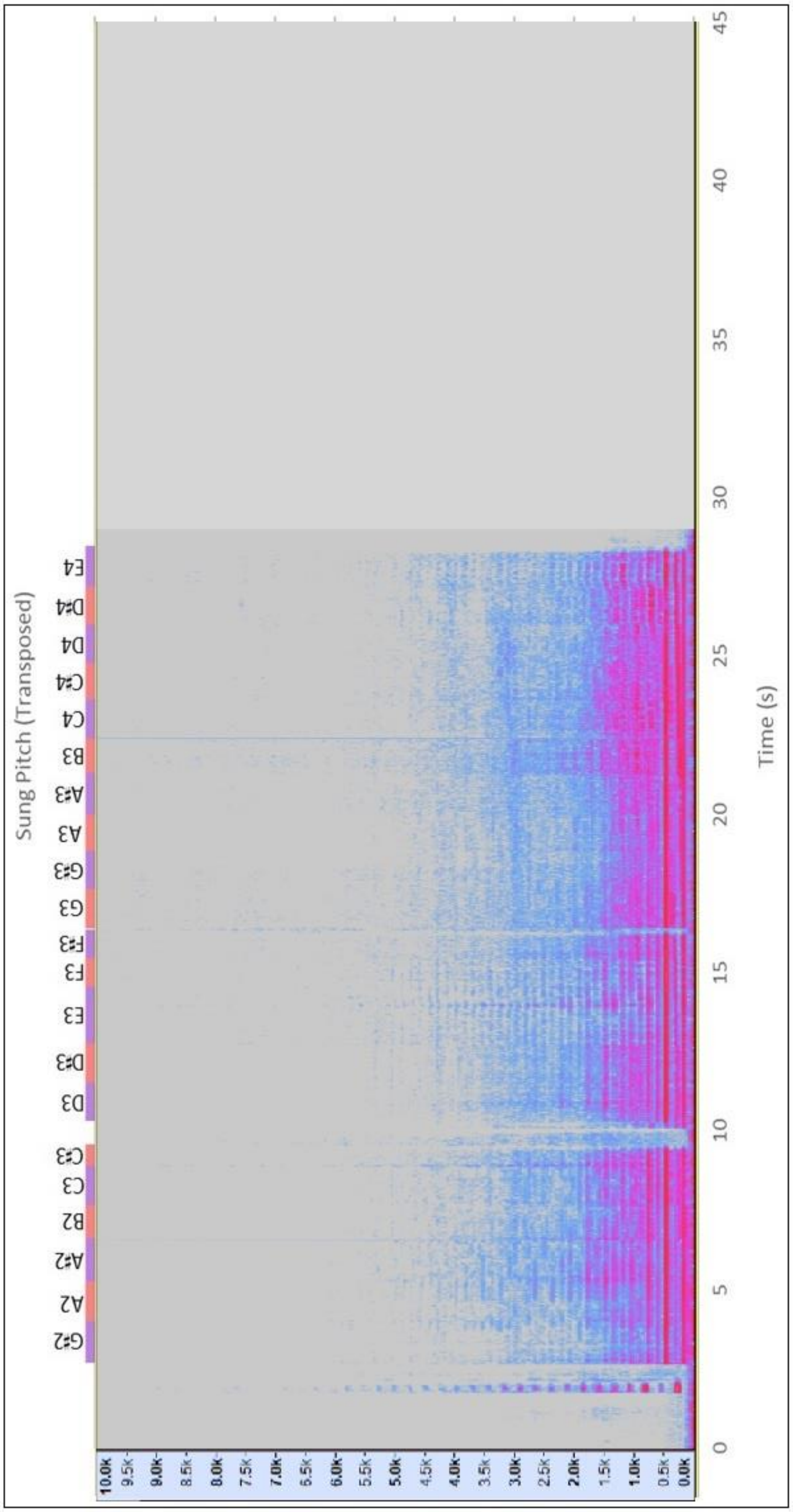


Figure B.32. Spectrogram for play loud, sing loud, E_3.

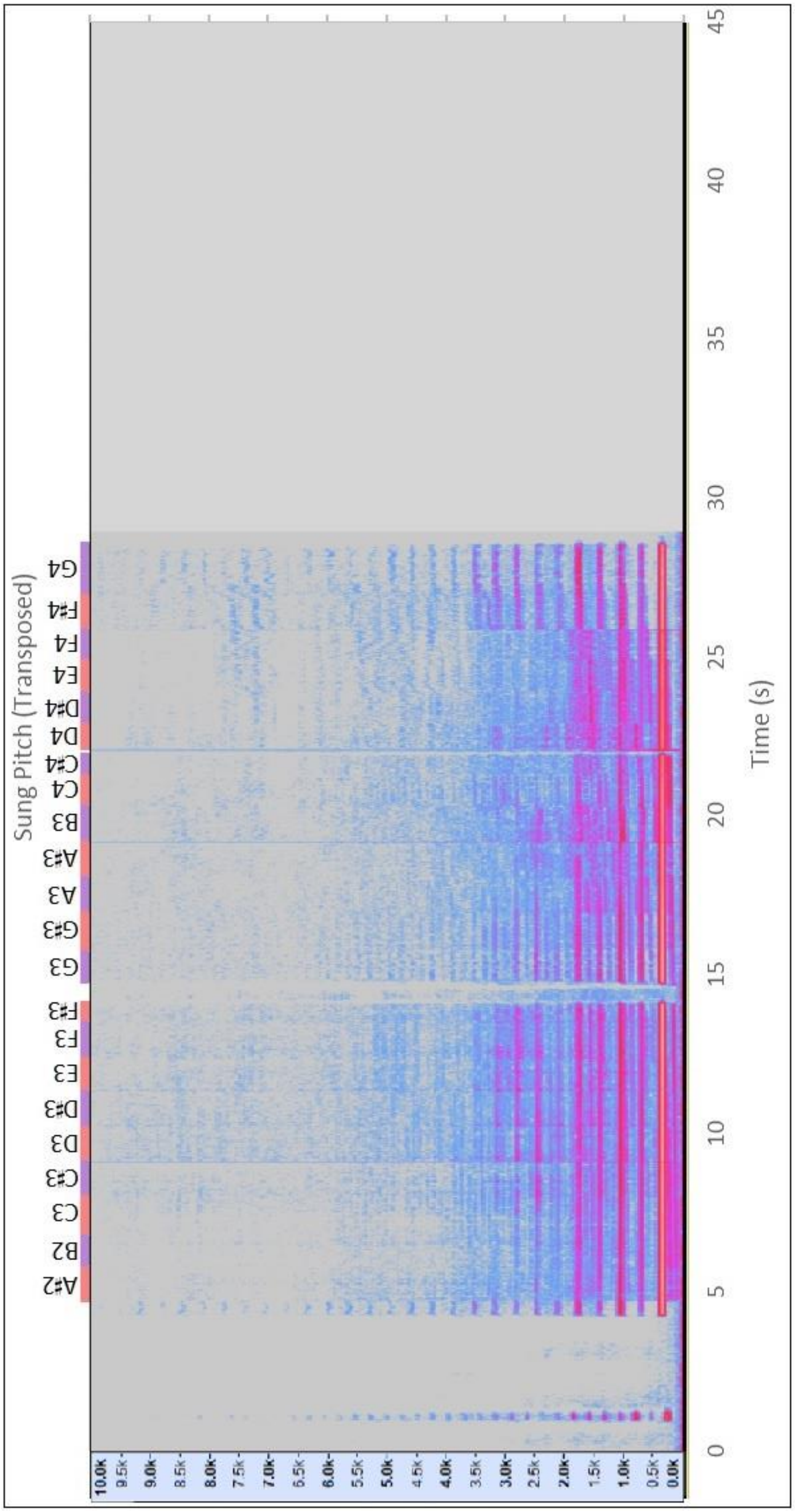


Figure B.33. Spectrogram for play loud, sing loud, G_4.

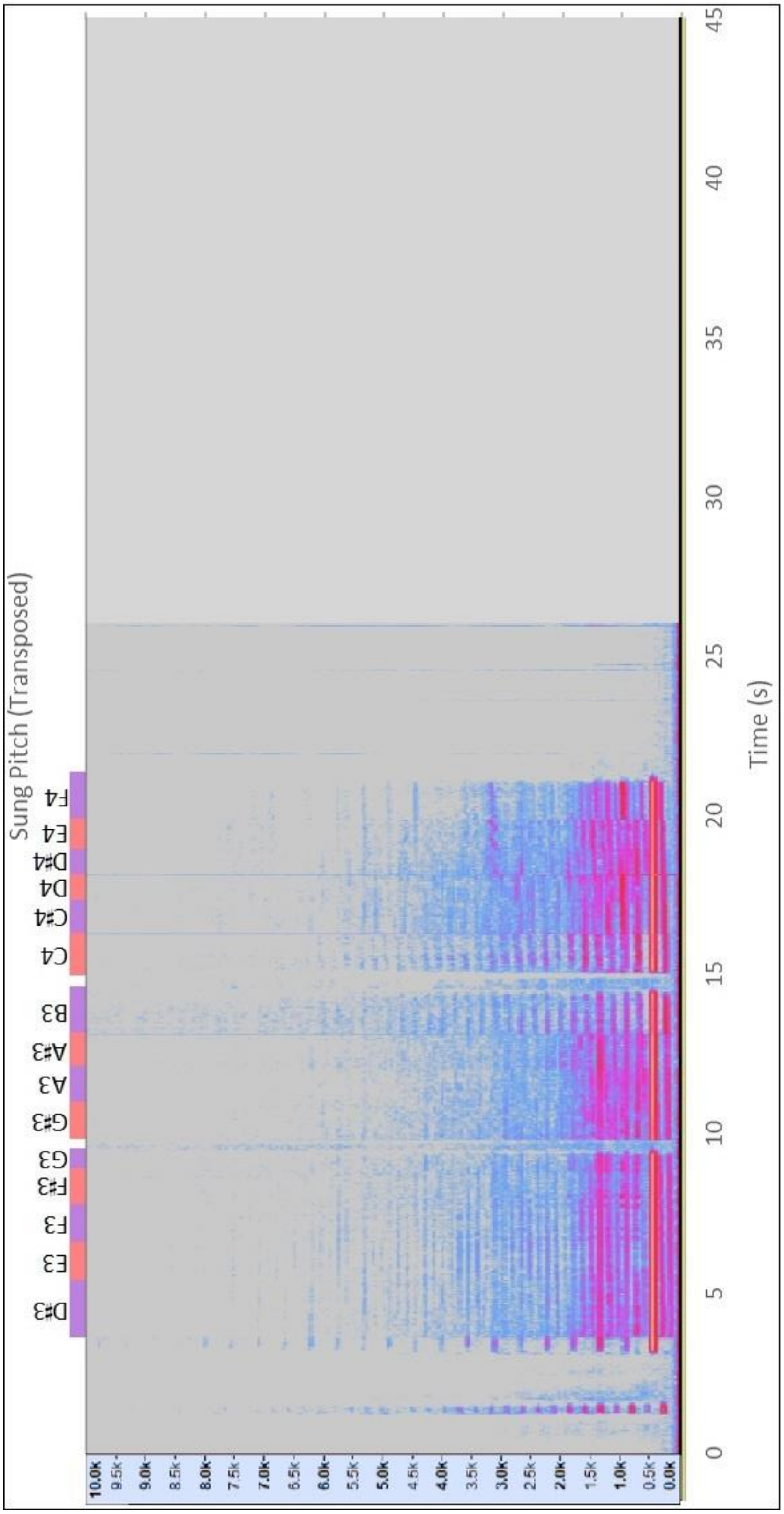


Figure B.34. Spectrogram for play loud, sing loud, B4.

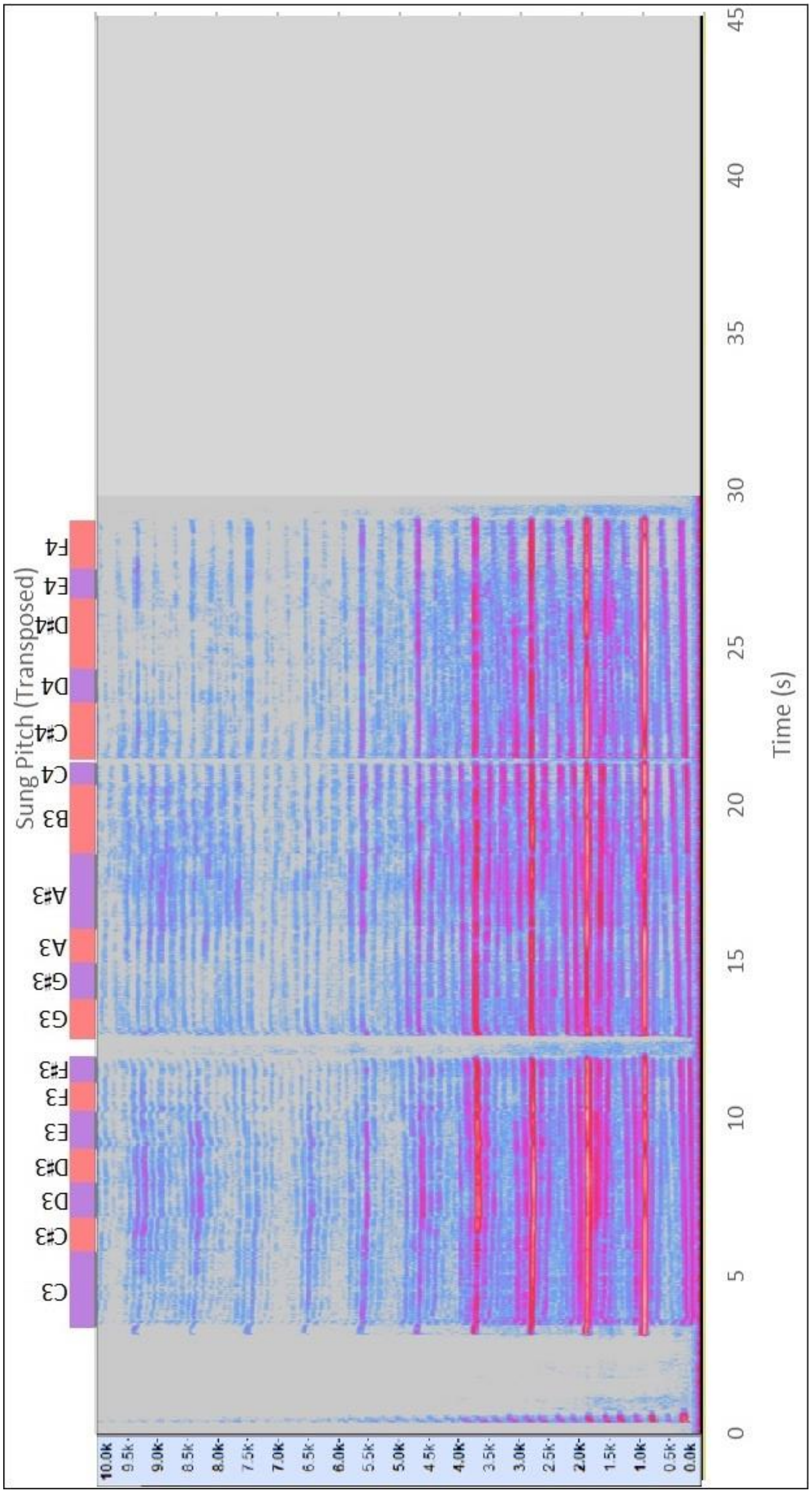


Figure B.35. Spectrogram for play loud, sing loud, C_6.

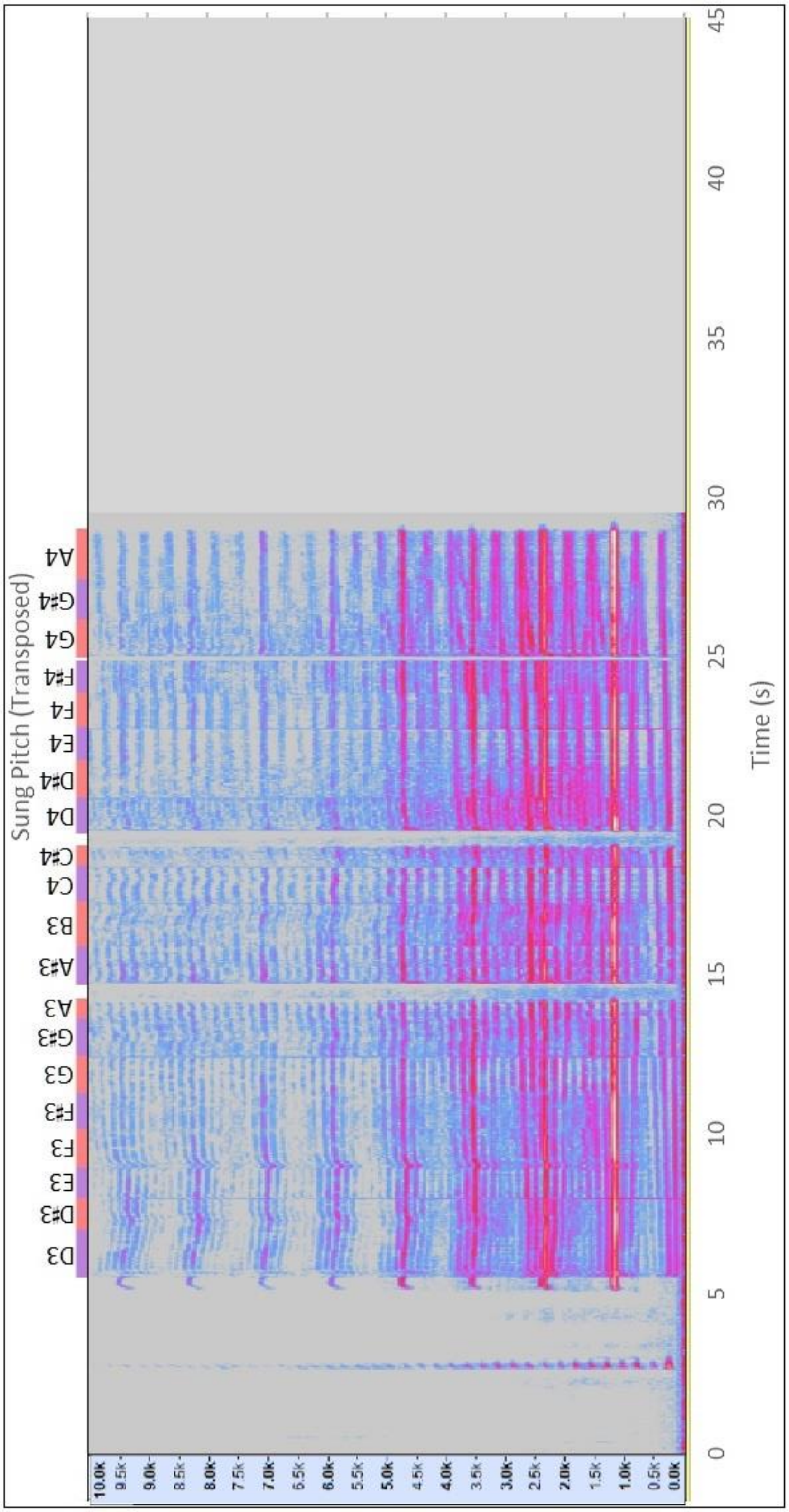


Figure B.36. Spectrogram for play loud, sing loud, E_6.

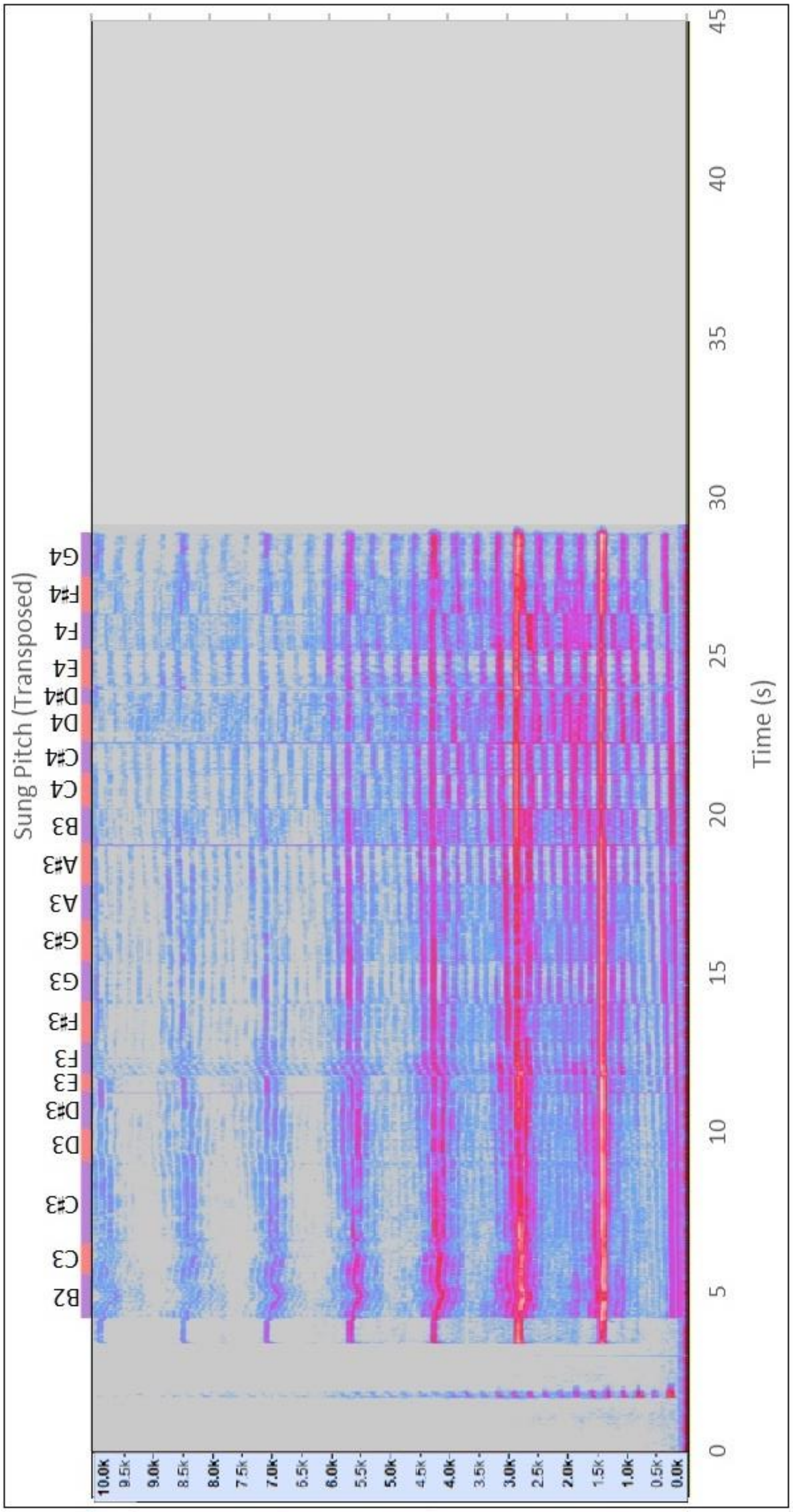


Figure B.37. Spectrogram for play loud, sing loud, G_6.

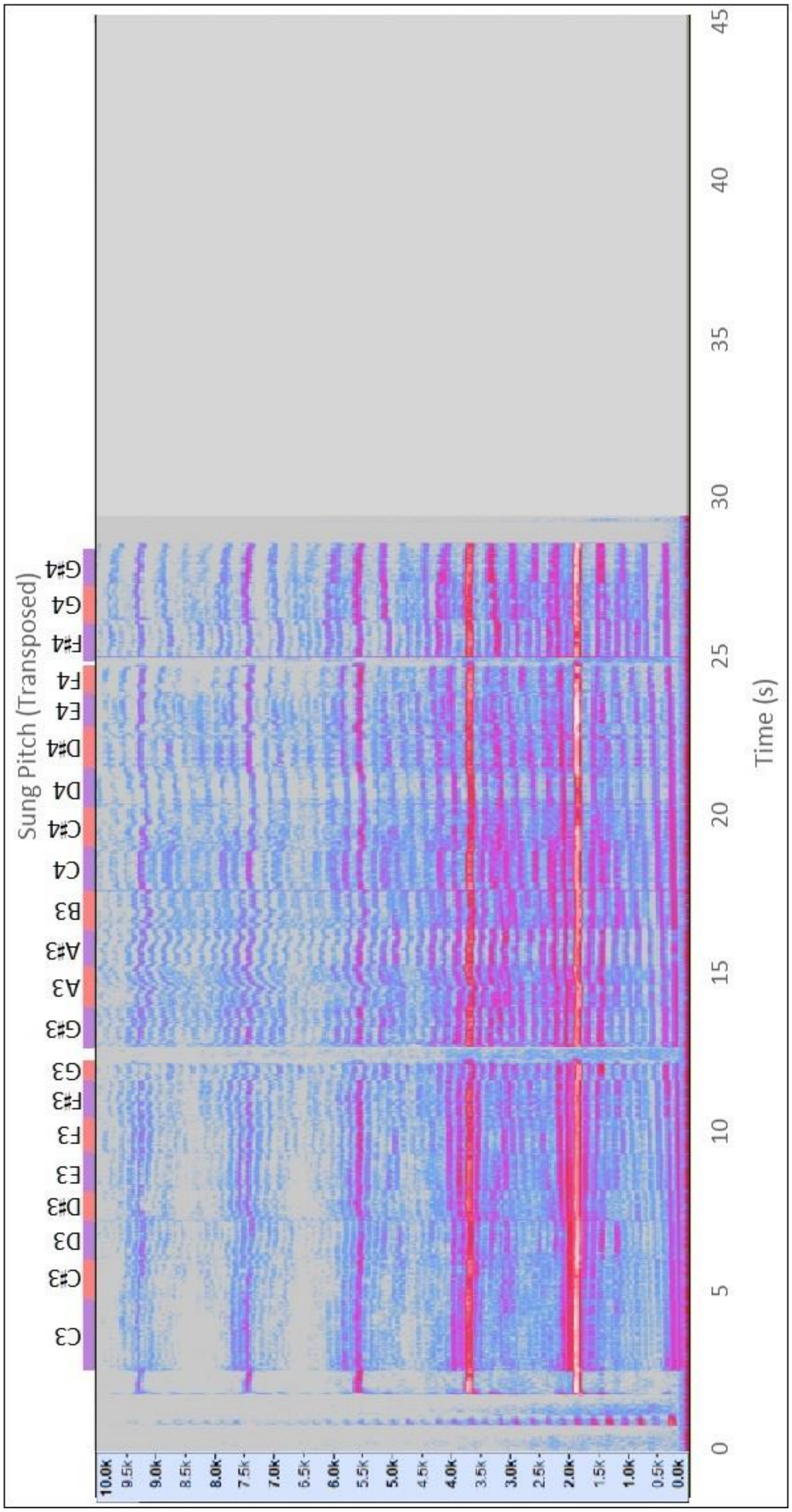


Figure B.38. Spectrogram for play loud, sing loud, C_7.

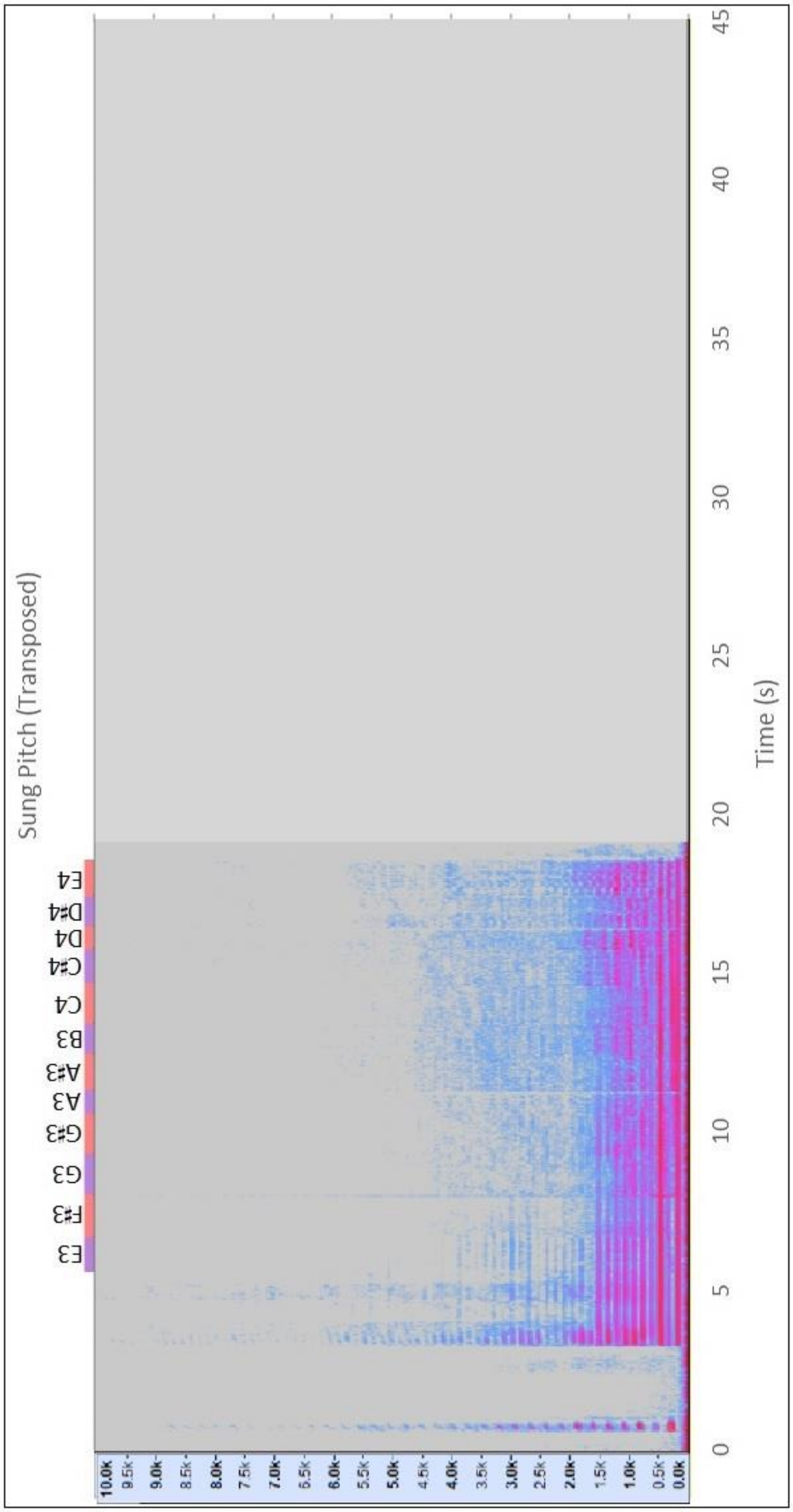


Figure B.39. Spectrogram for play loud, sing soft, E_3.

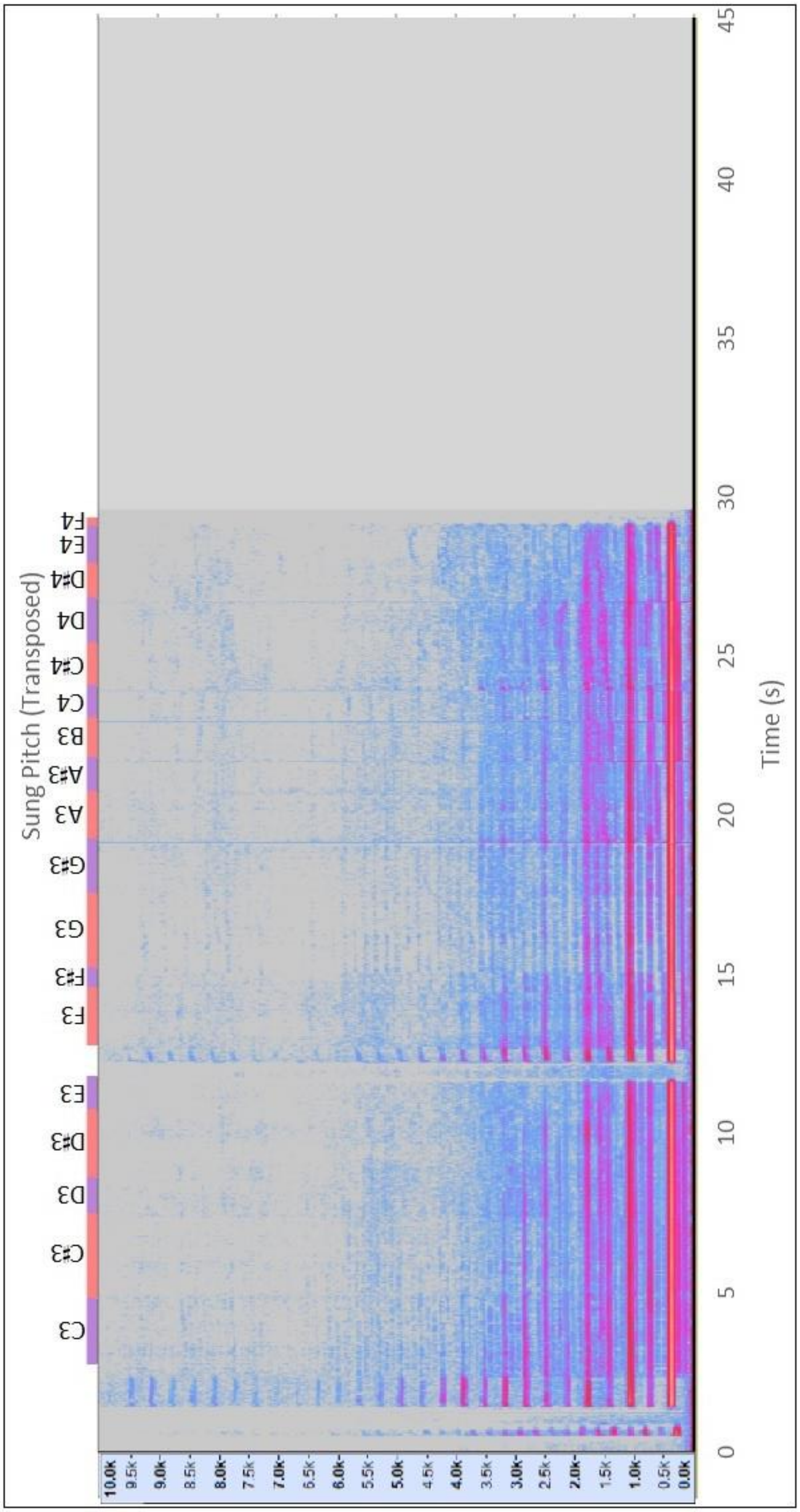


Figure B.40. Spectrogram for play loud, sing soft, G_4.

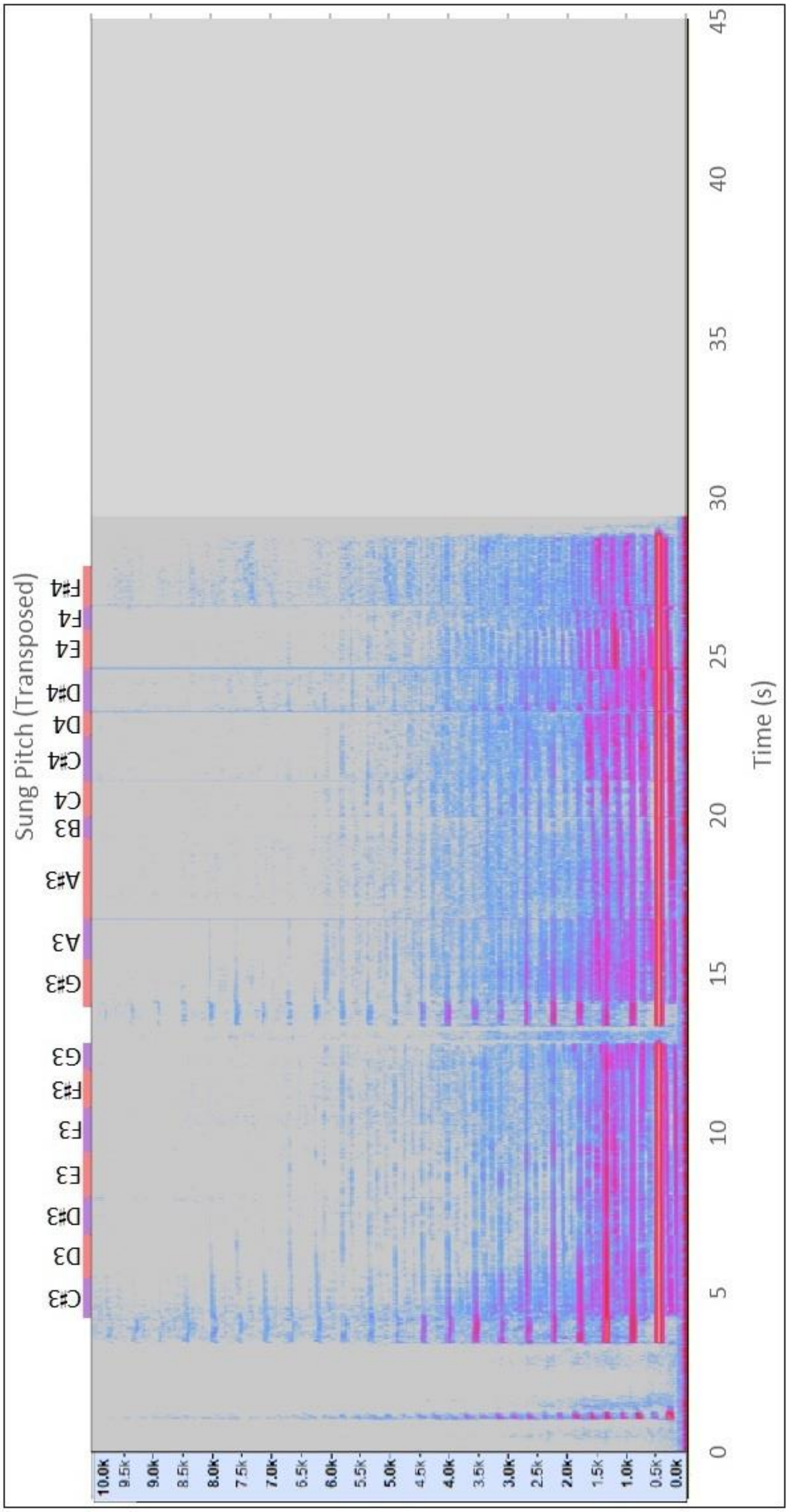


Figure B.41. Spectrogram for play loud, sing soft, B4.

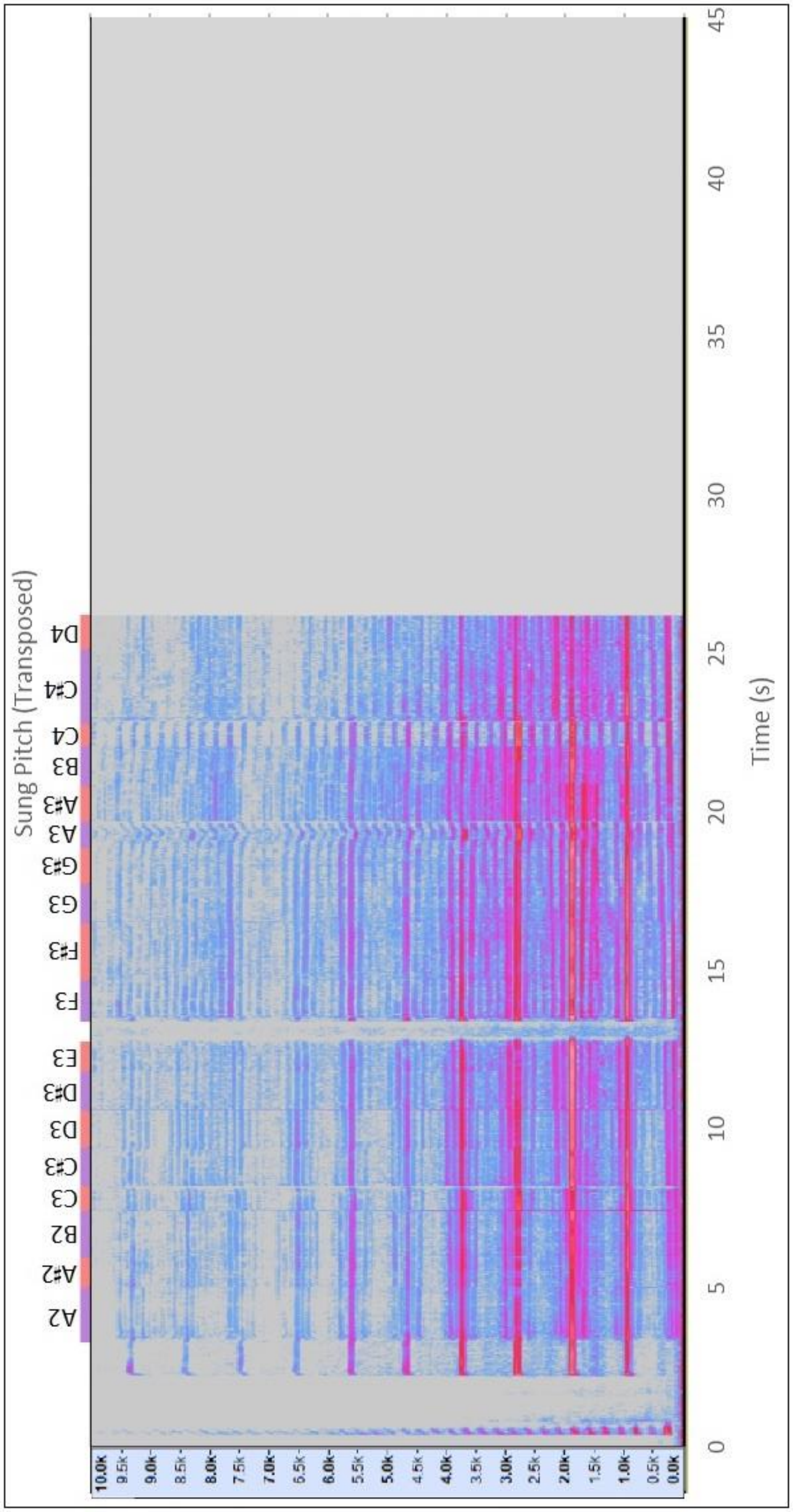


Figure B.42. Spectrogram for play loud, sing soft, C_6.

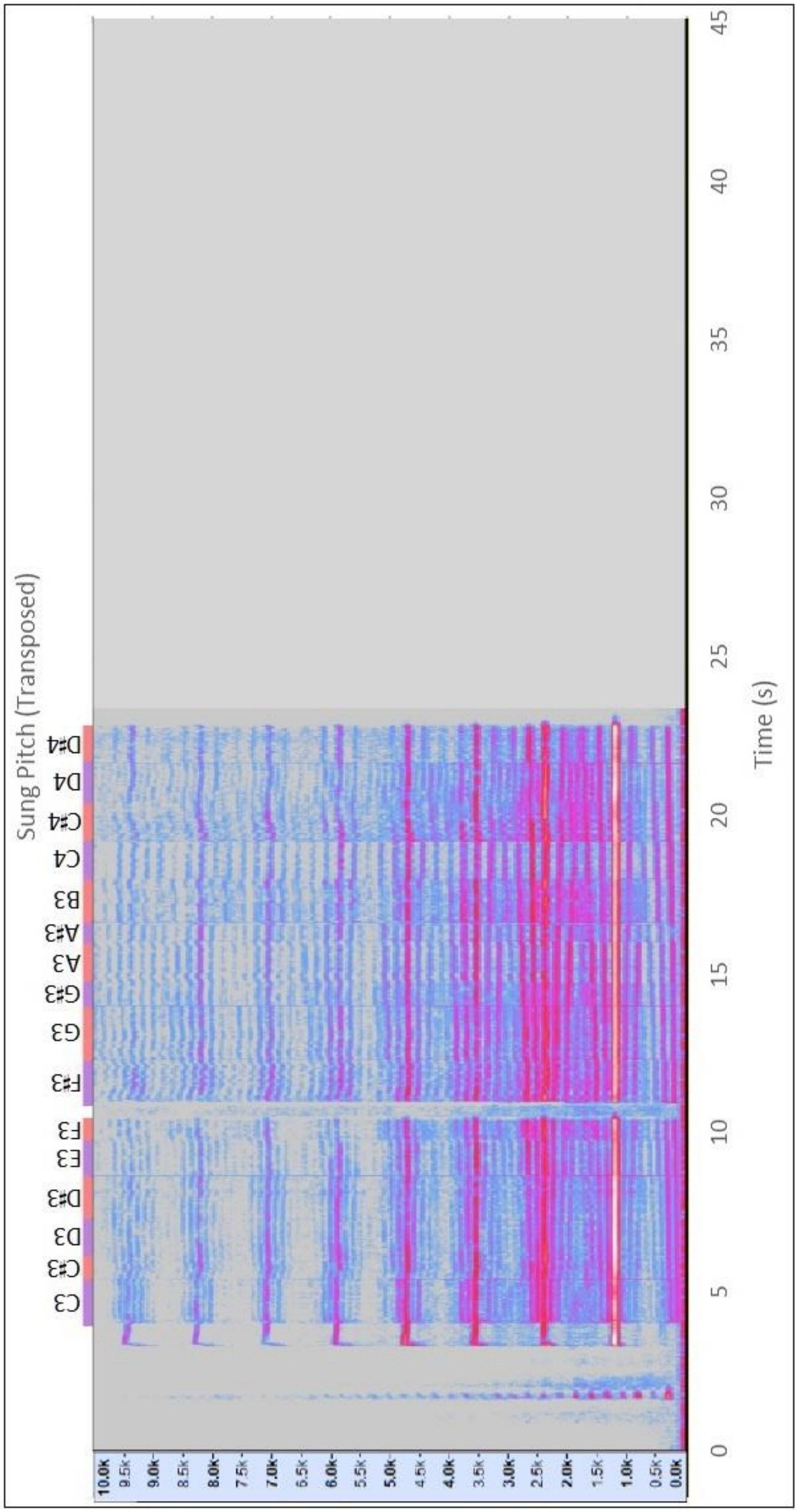


Figure B.43. Spectrogram for play loud, sing soft, E6.

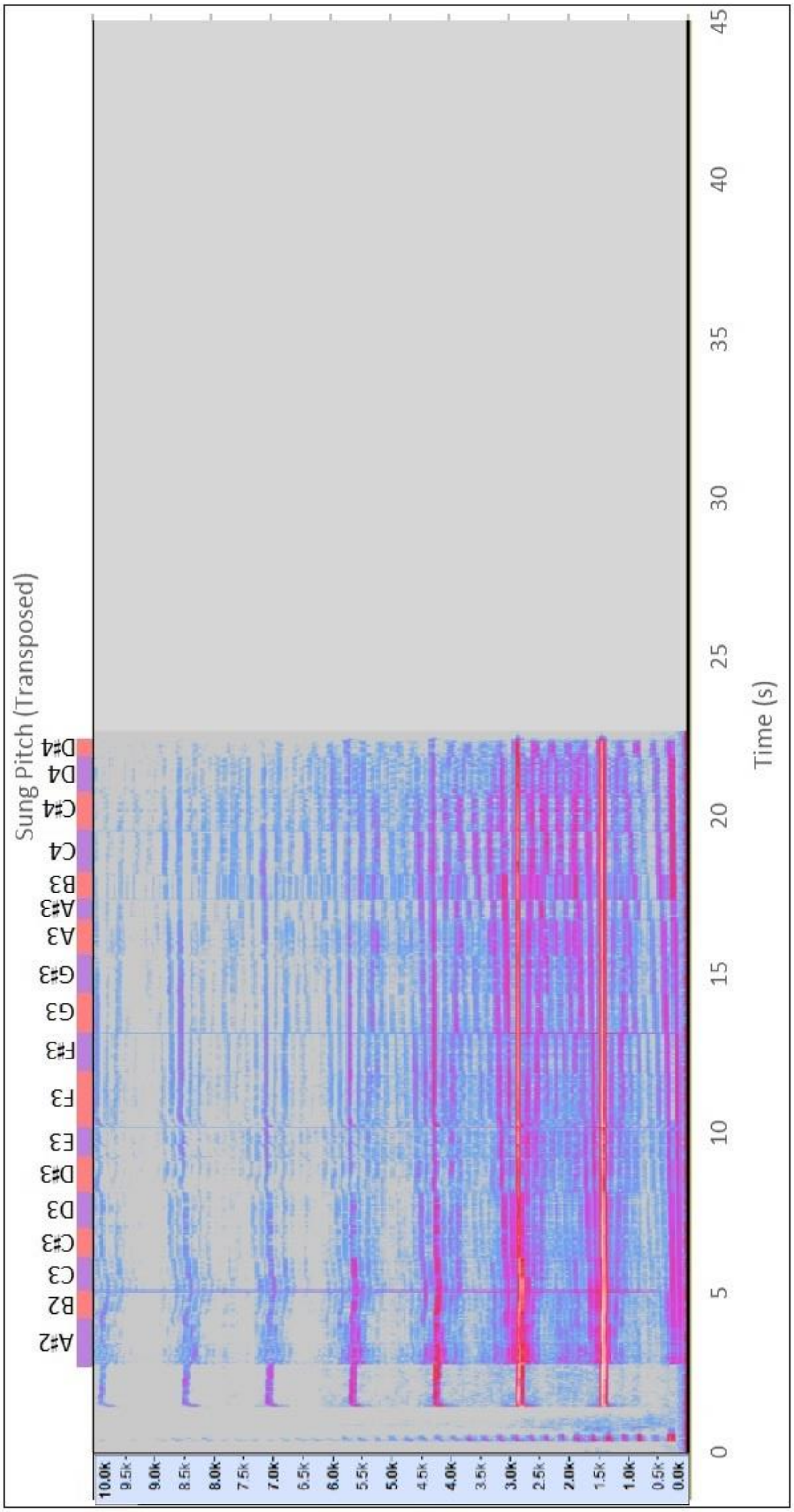


Figure B.44. Spectrogram for play loud, sing soft, G_6.

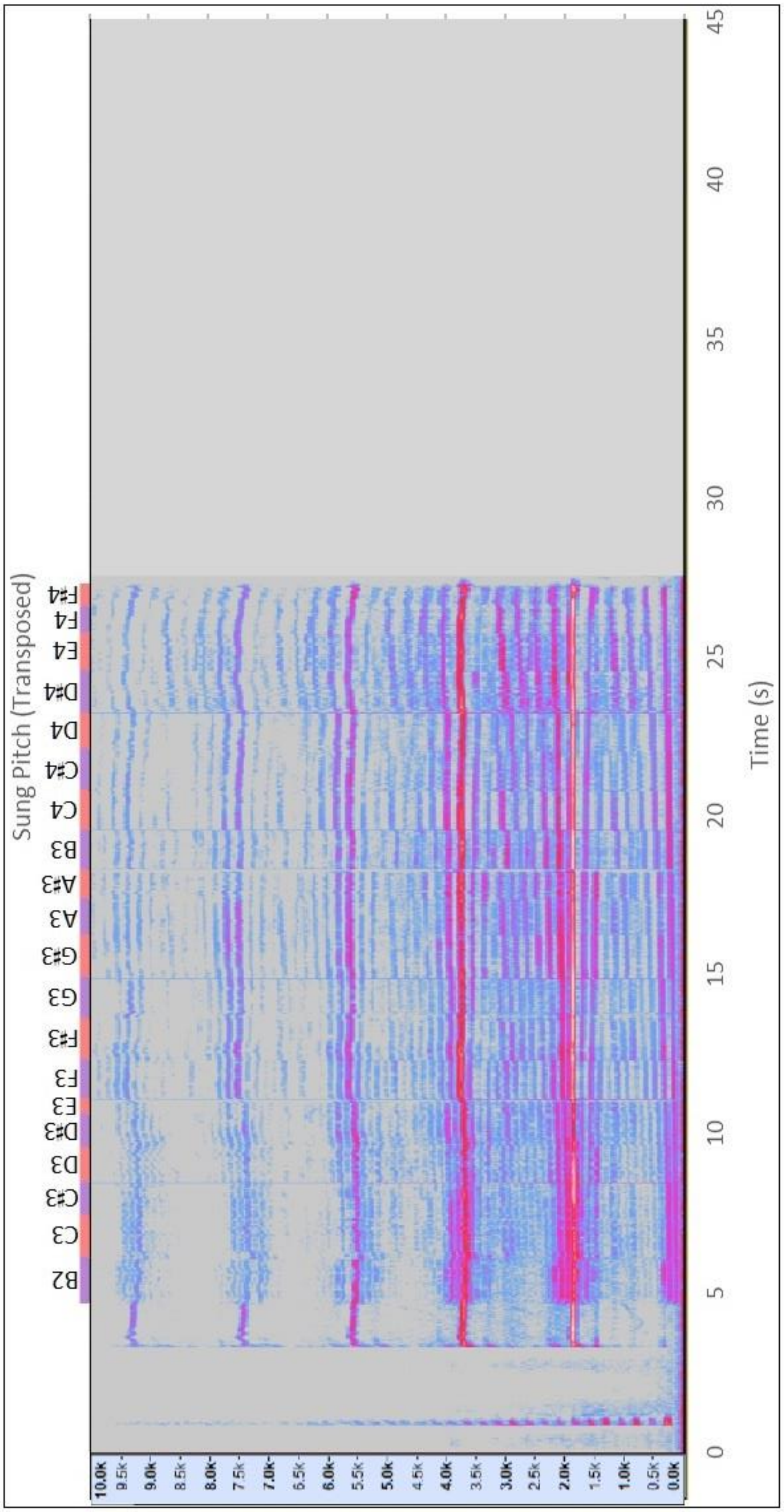


Figure B.45. Spectrogram for play loud, sing soft, C_7.

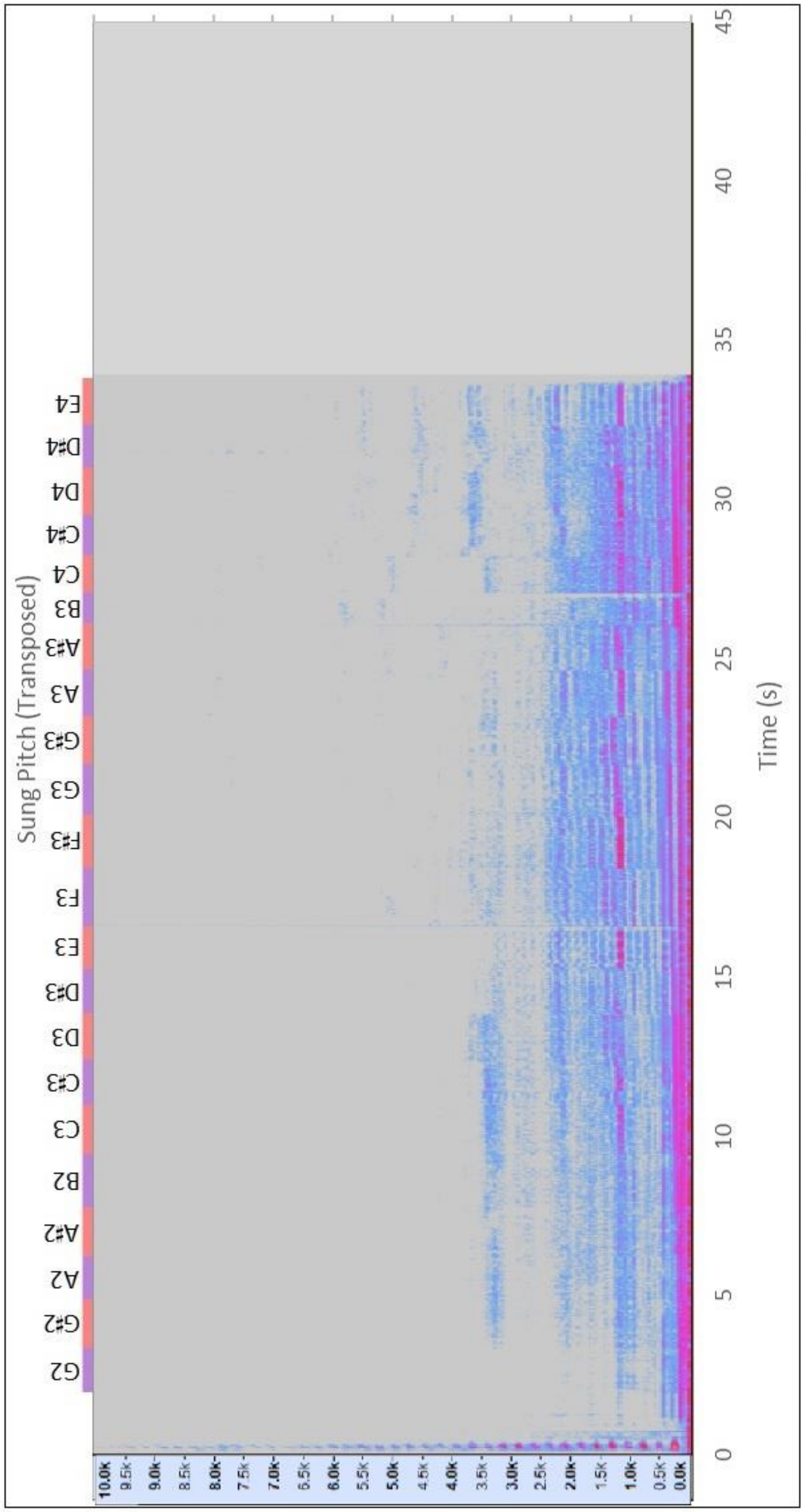


Figure B.46. Spectrogram for play soft, sing loud, E_3.

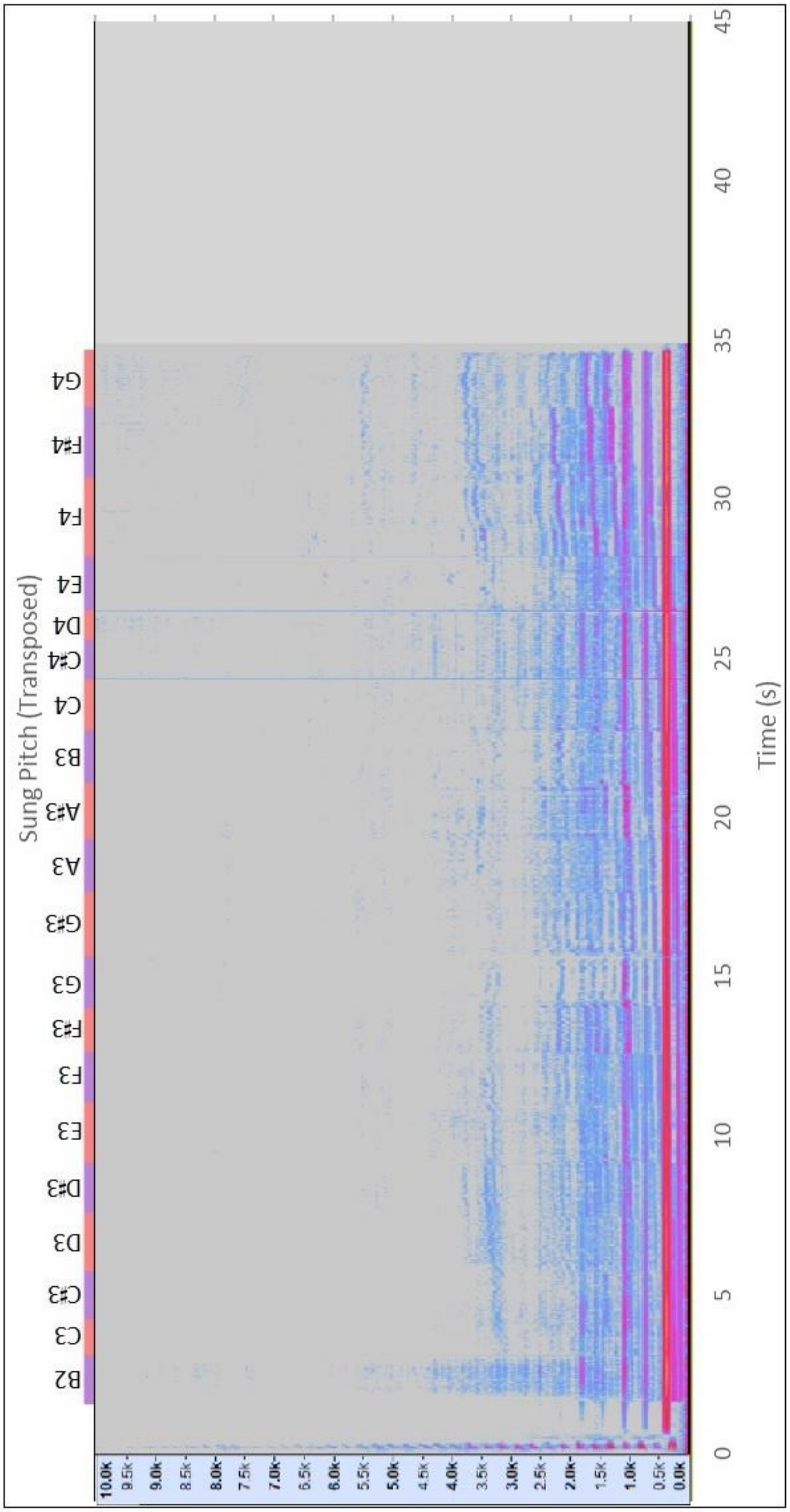


Figure B.47. Spectrogram for play soft, sing loud, G4.

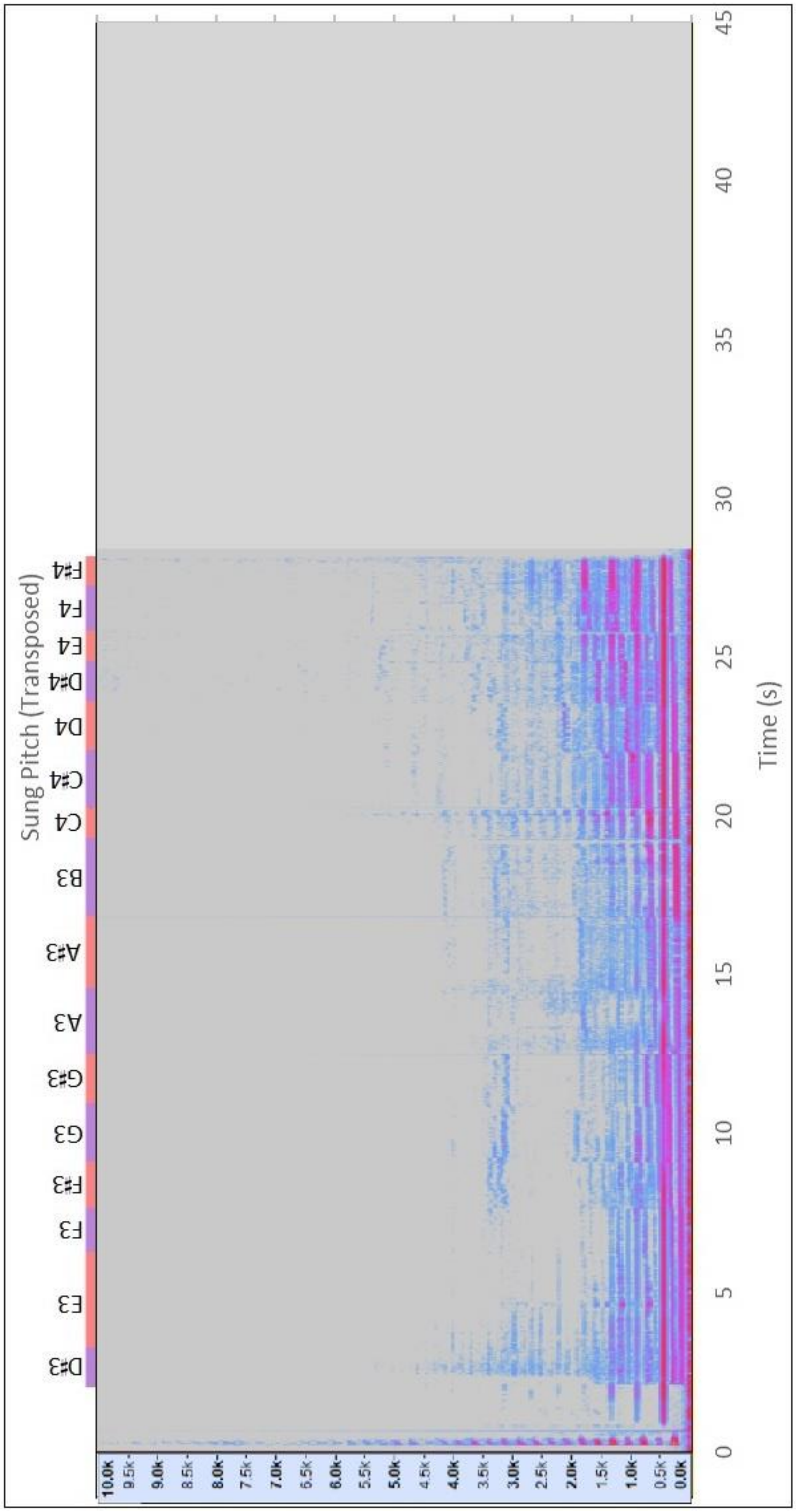


Figure B.48. Spectrogram for play soft, sing loud, B4.

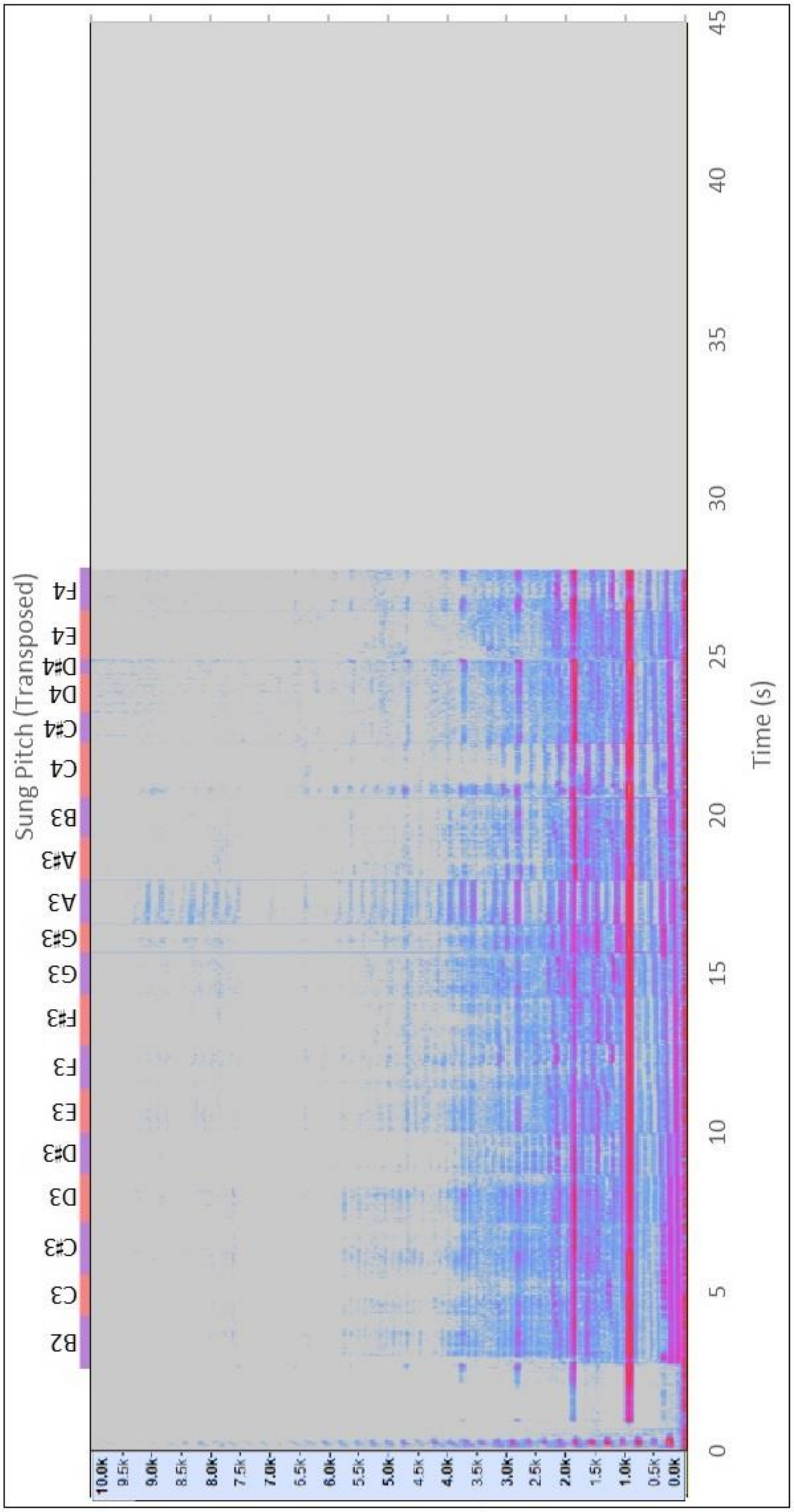


Figure B.49. Spectrogram for play soft, sing loud, C_6.

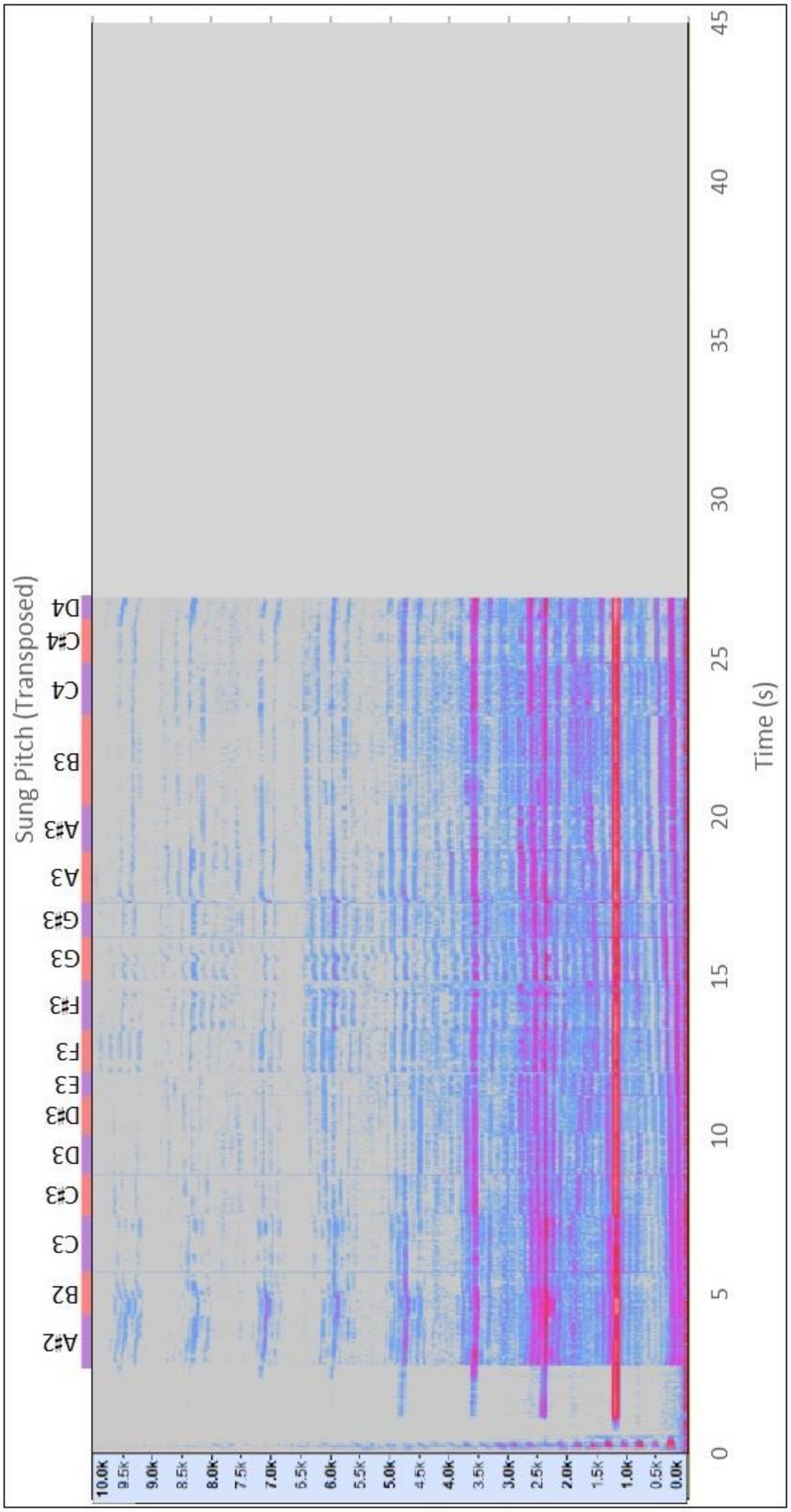


Figure B.50. Spectrogram for play soft, sing loud, E_6.

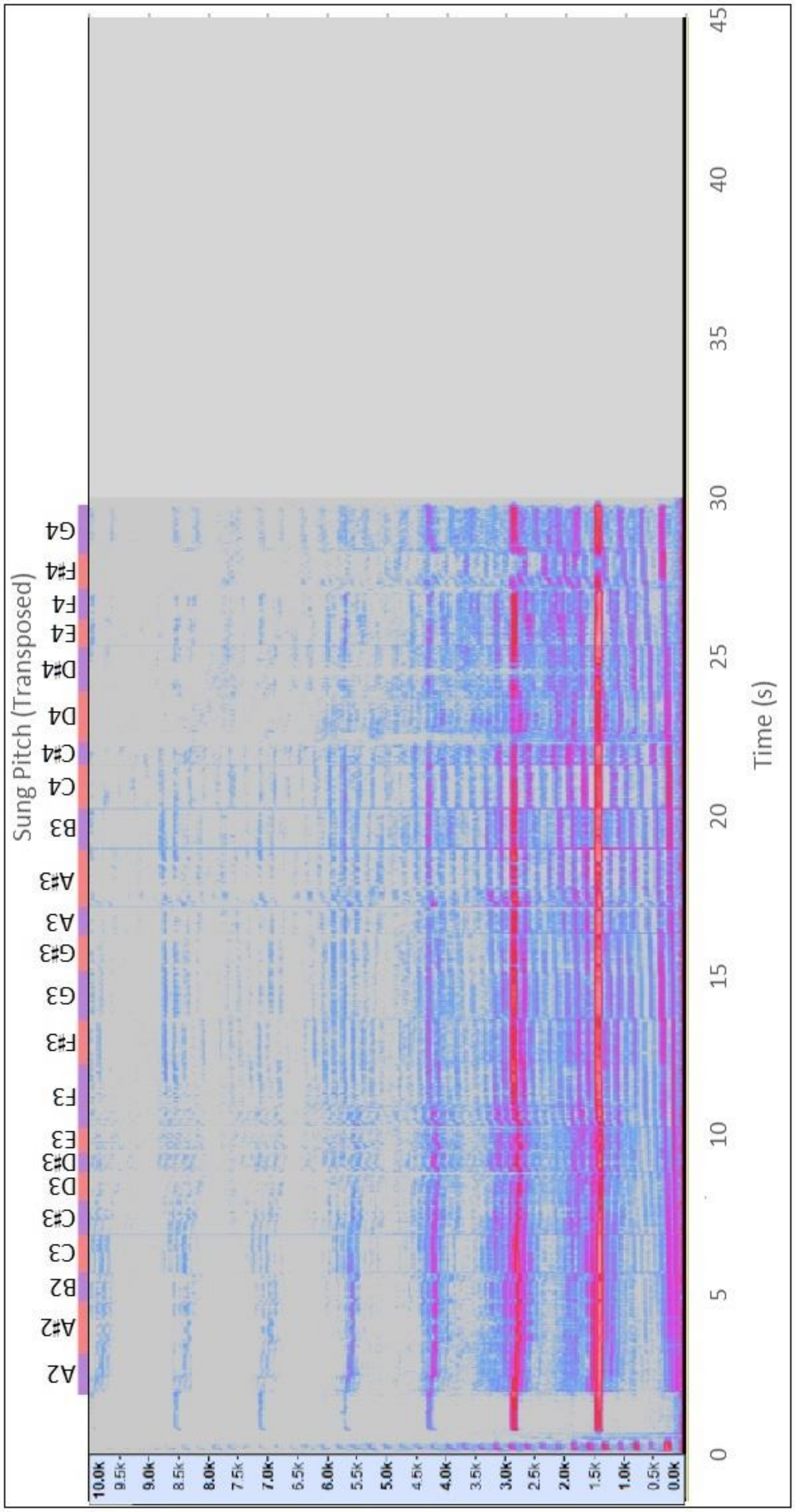


Figure B.51. Spectrogram for play soft, sing loud, G_6.

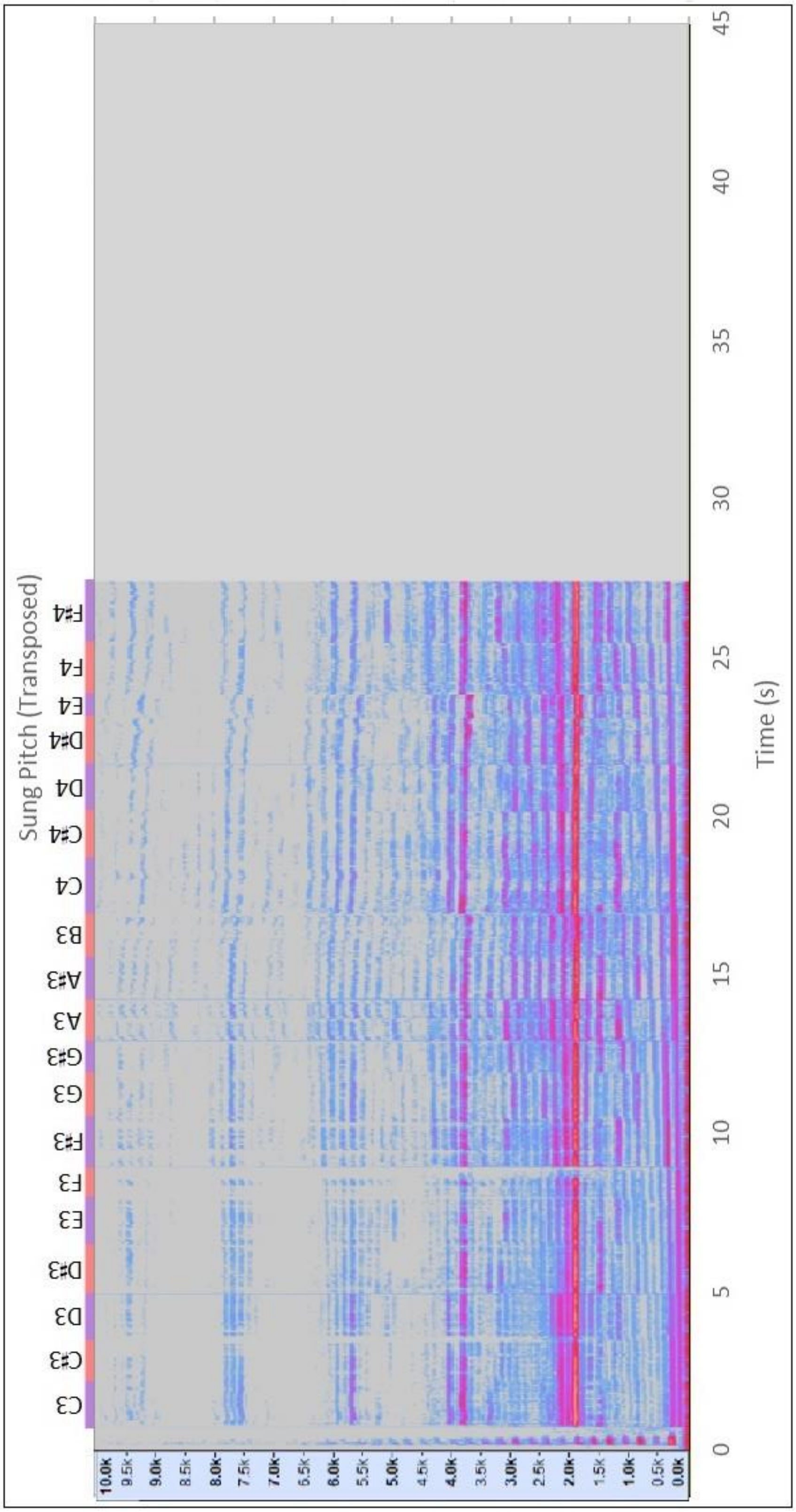


Figure B.52. Spectrogram for play soft, sing loud, C_7.

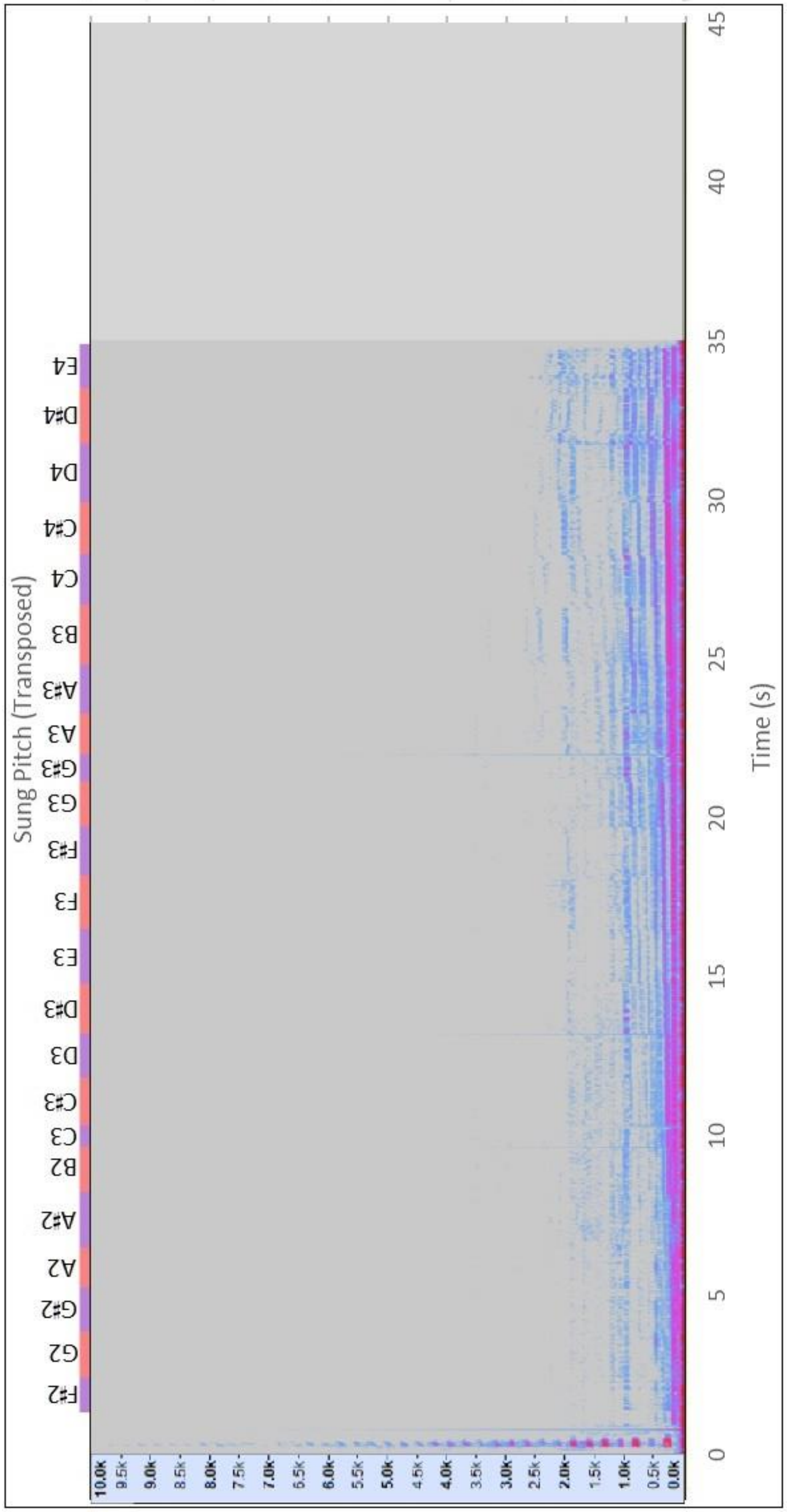


Figure B.53. Spectrogram for play soft, sing soft, E_3.

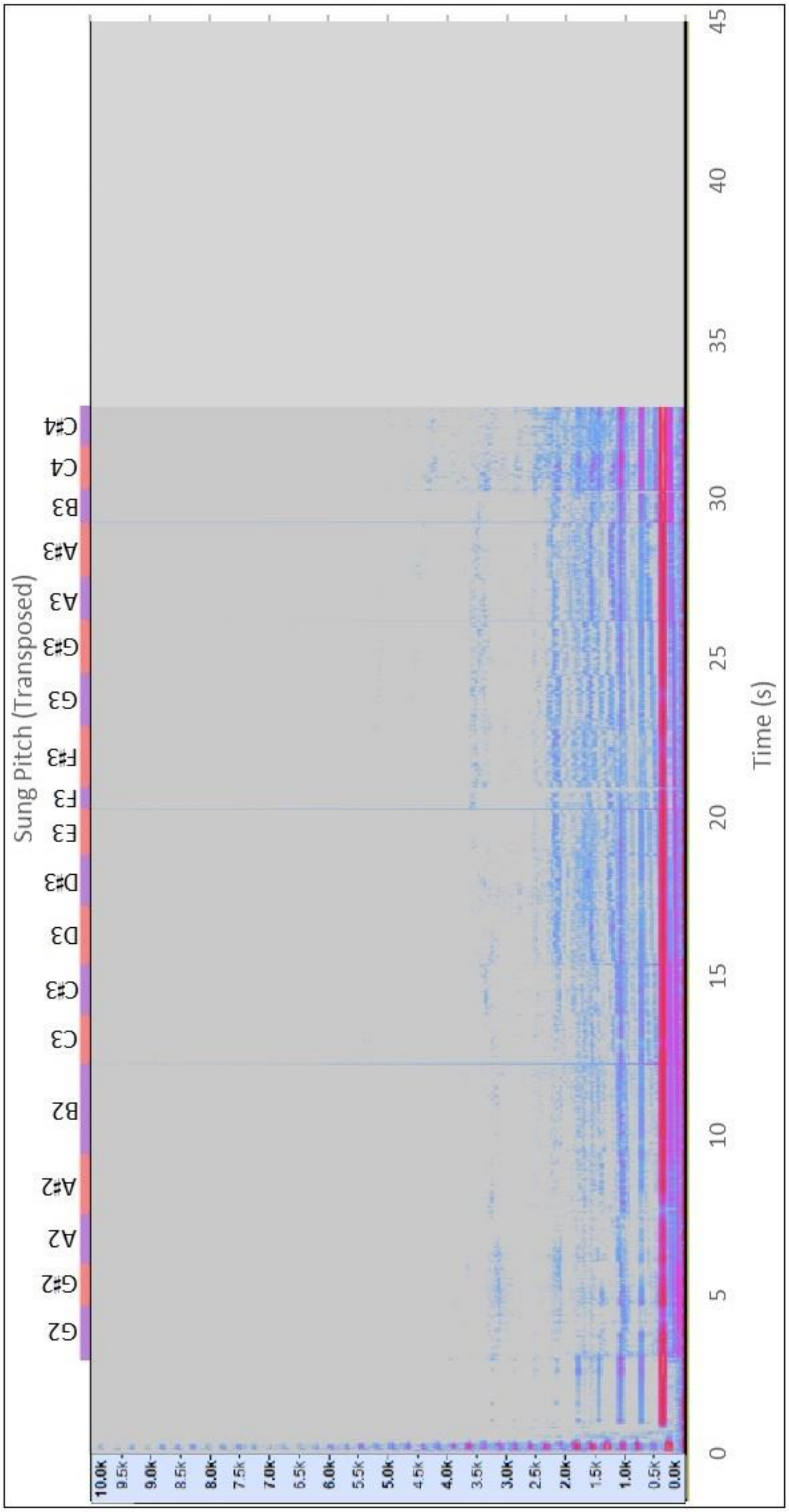


Figure B.54. Spectrogram for play soft, sing soft, G_4.

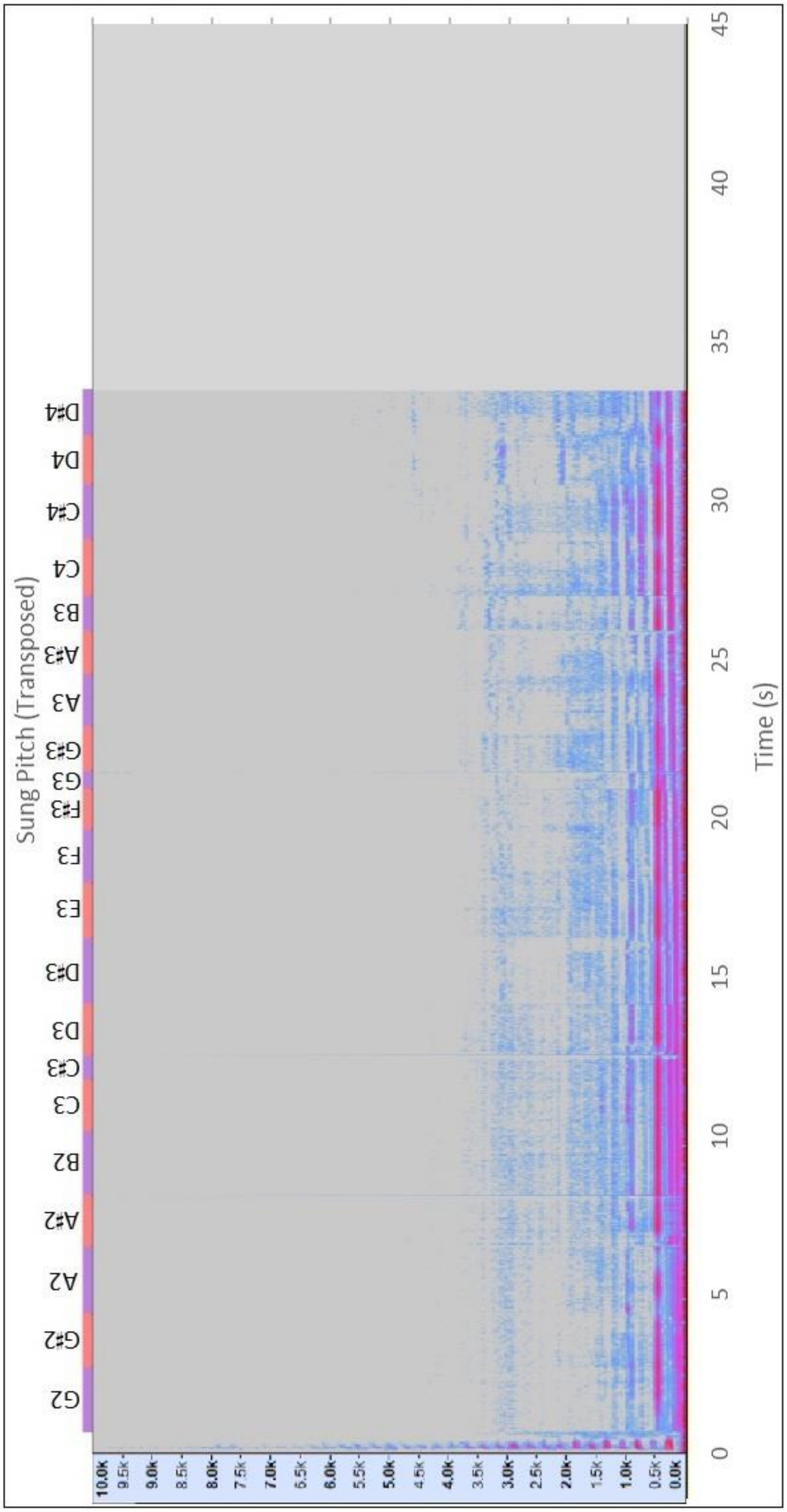


Figure B.55. Spectrogram for play soft, sing soft, B4.

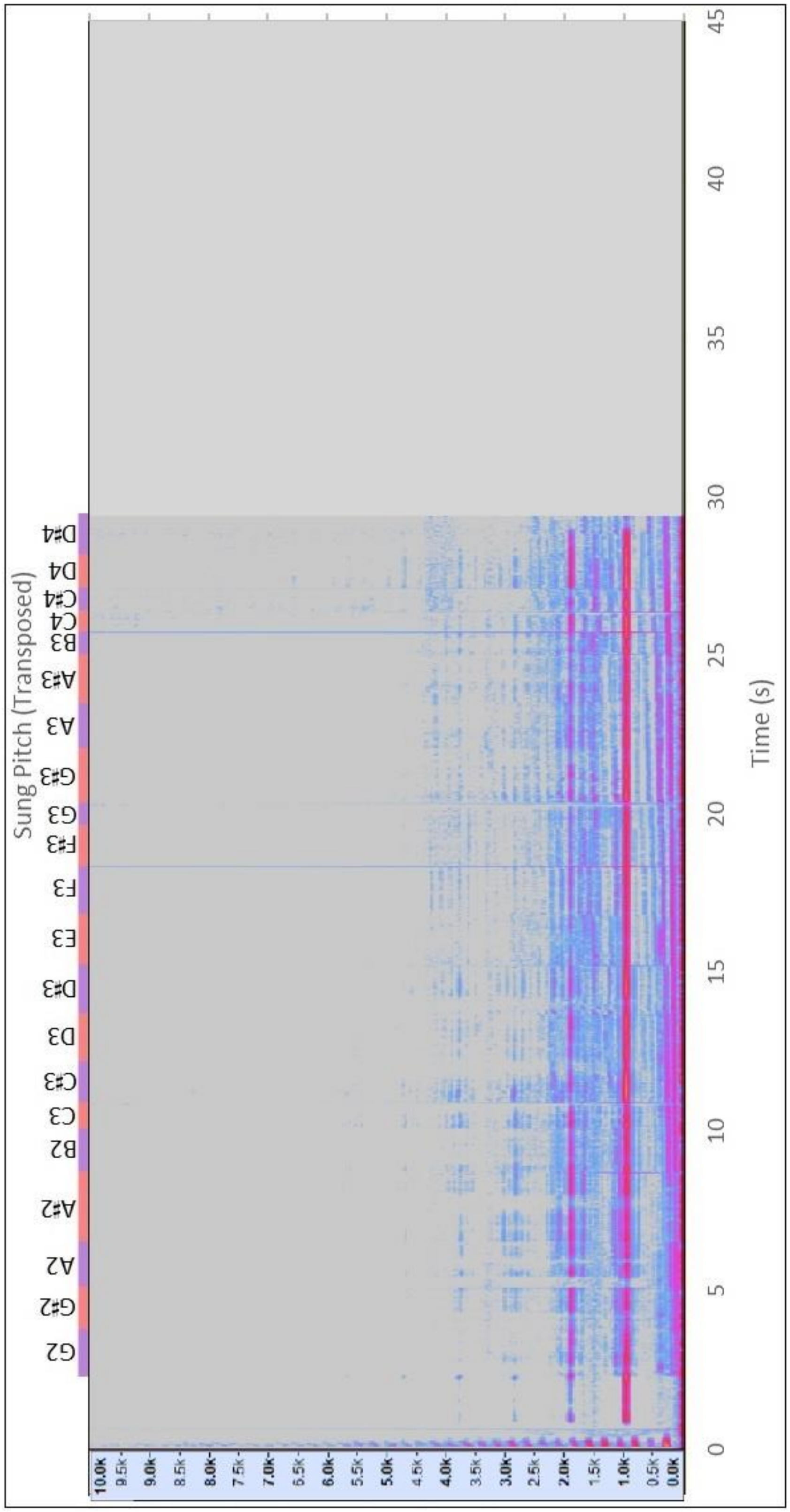


Figure B.56. Spectrogram for play soft, sing soft, C_6.

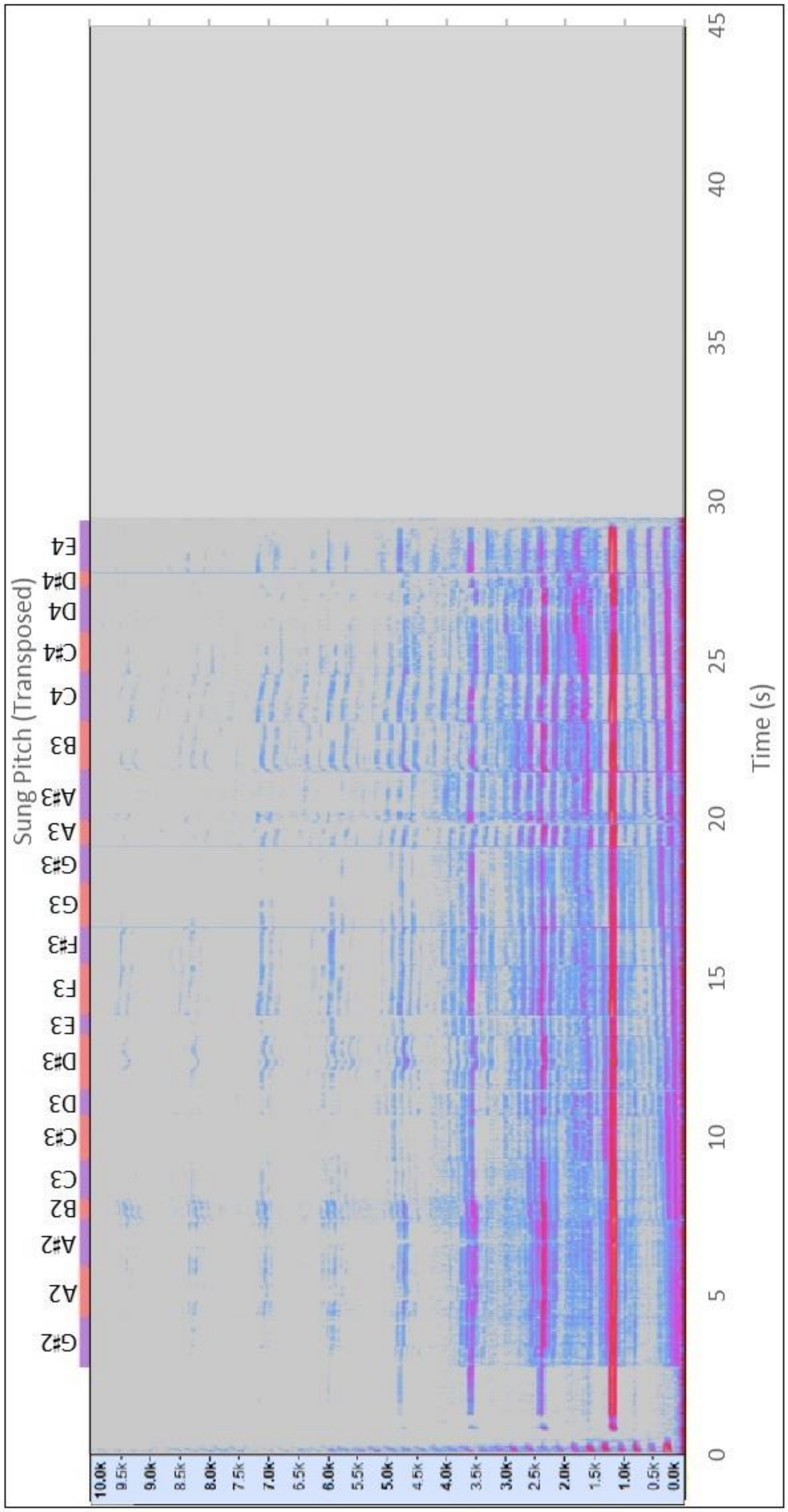


Figure B.57. Spectrogram for play soft, sing soft, E_6.

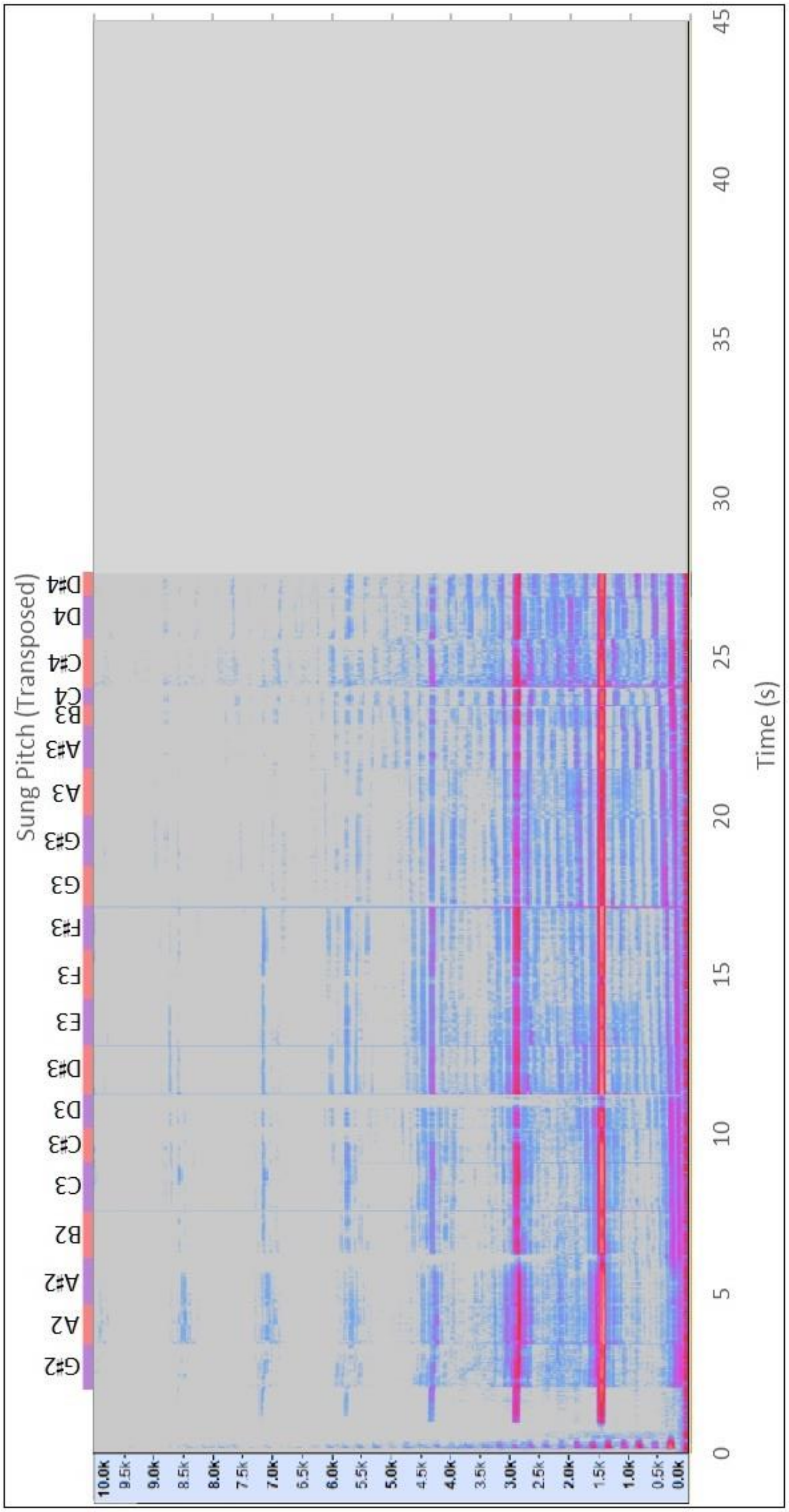
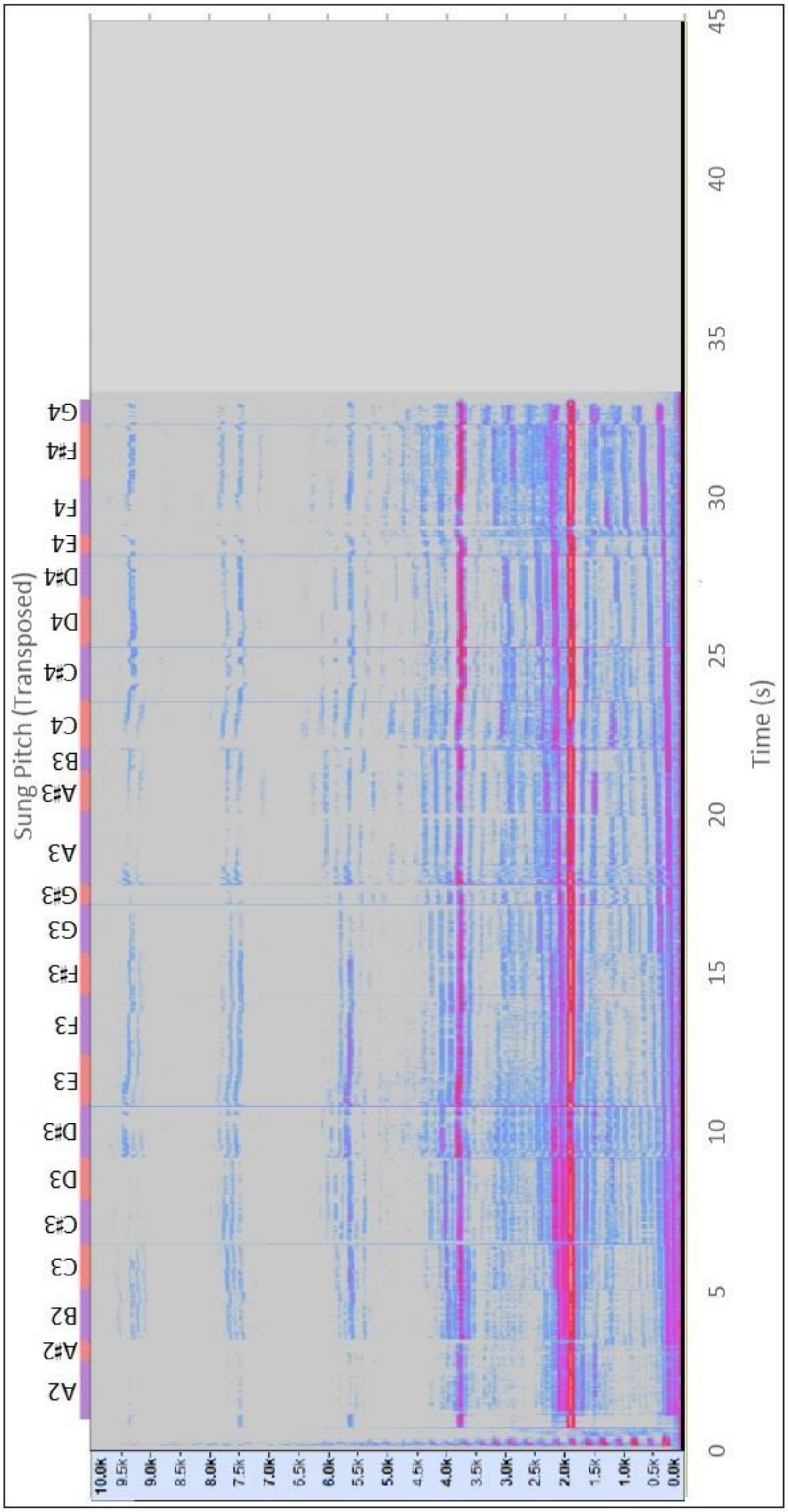


Figure B.58. Spectrogram for play soft, sing soft, G_6.

Figure B.59. Spectrogram for play soft, sing soft, C_7.



APPENDIX C

WAVEFORM dB DATA

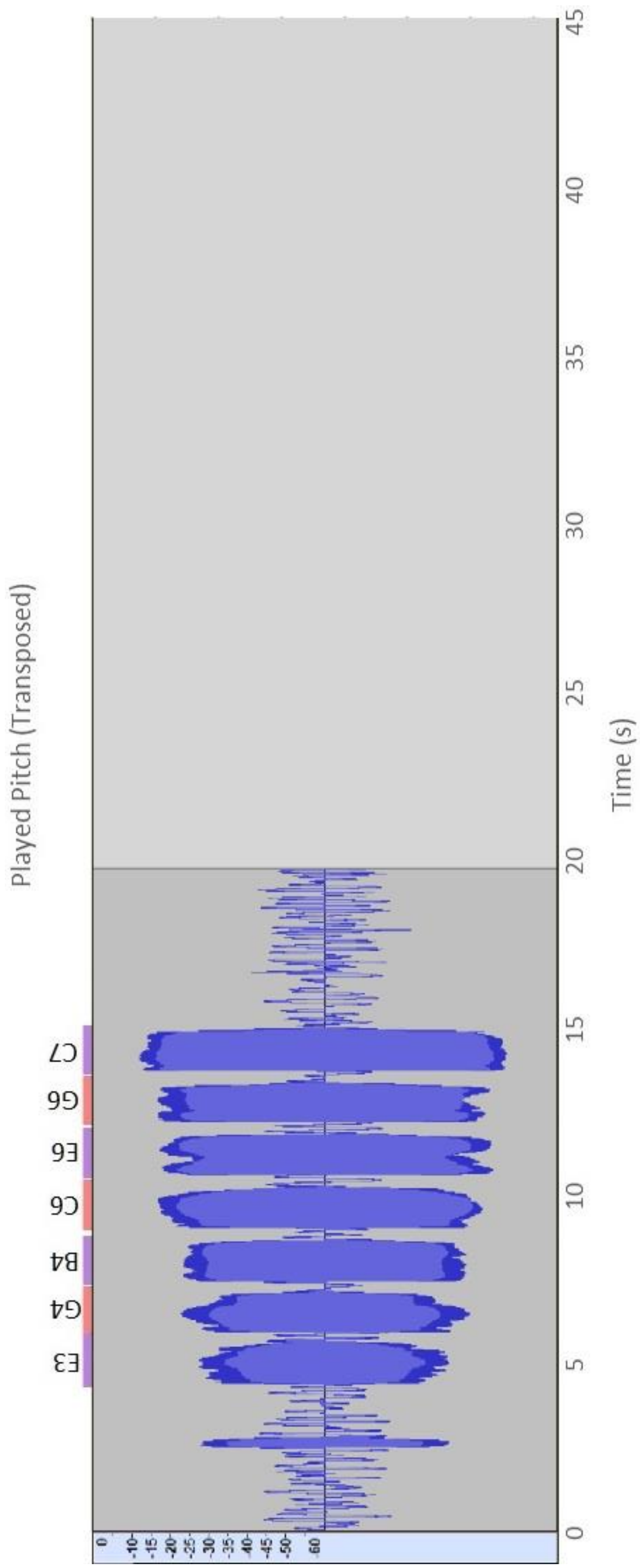


Figure C.1. Waveform dB view, play loud, no vocalization, all pitches.

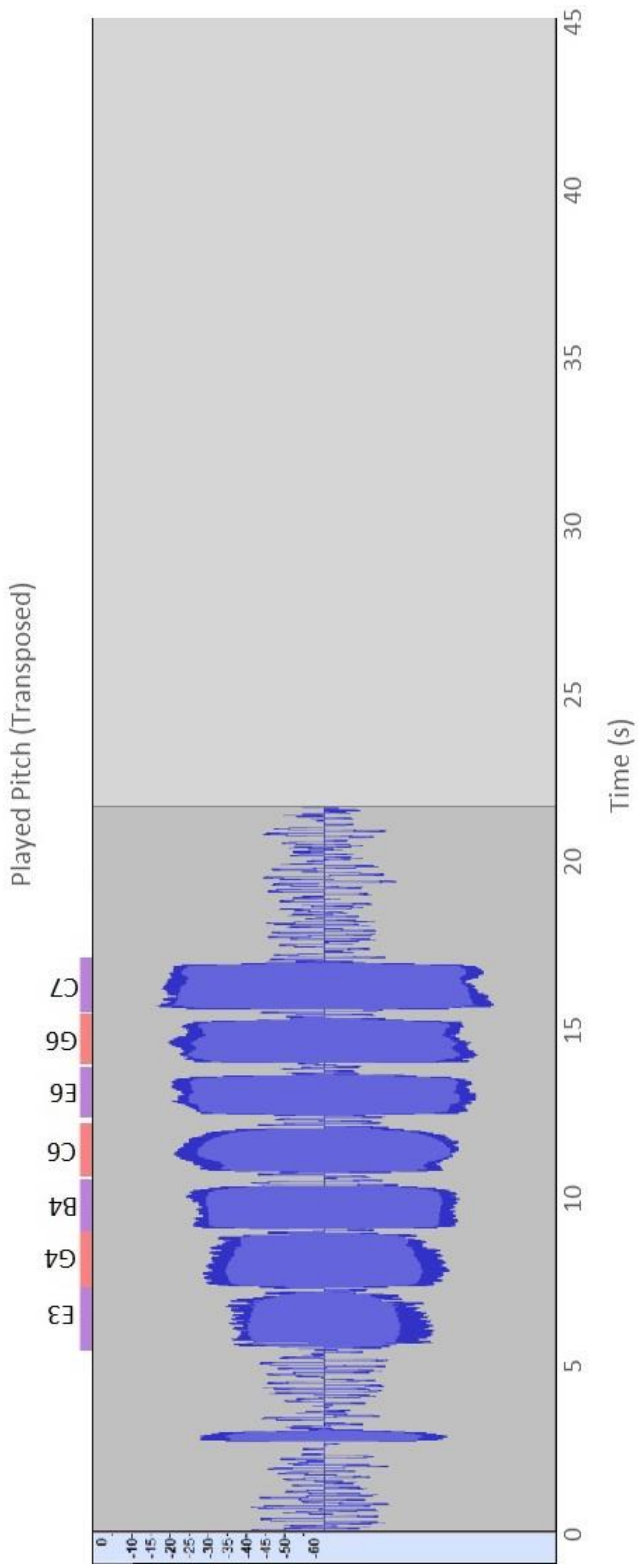


Figure C.2. Waveform dB view, play medium, no vocalization, all pitches.

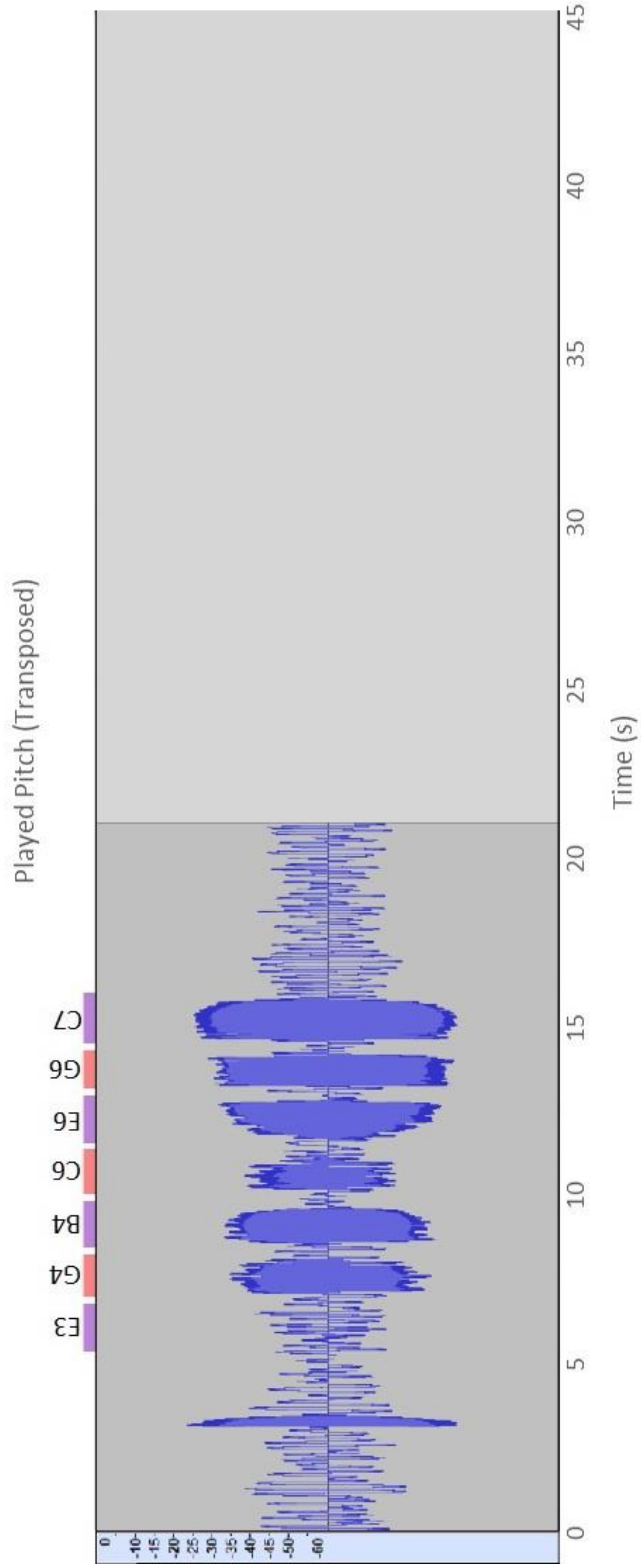


Figure C.3. Waveform dB view, play soft, no vocalization, all pitches.

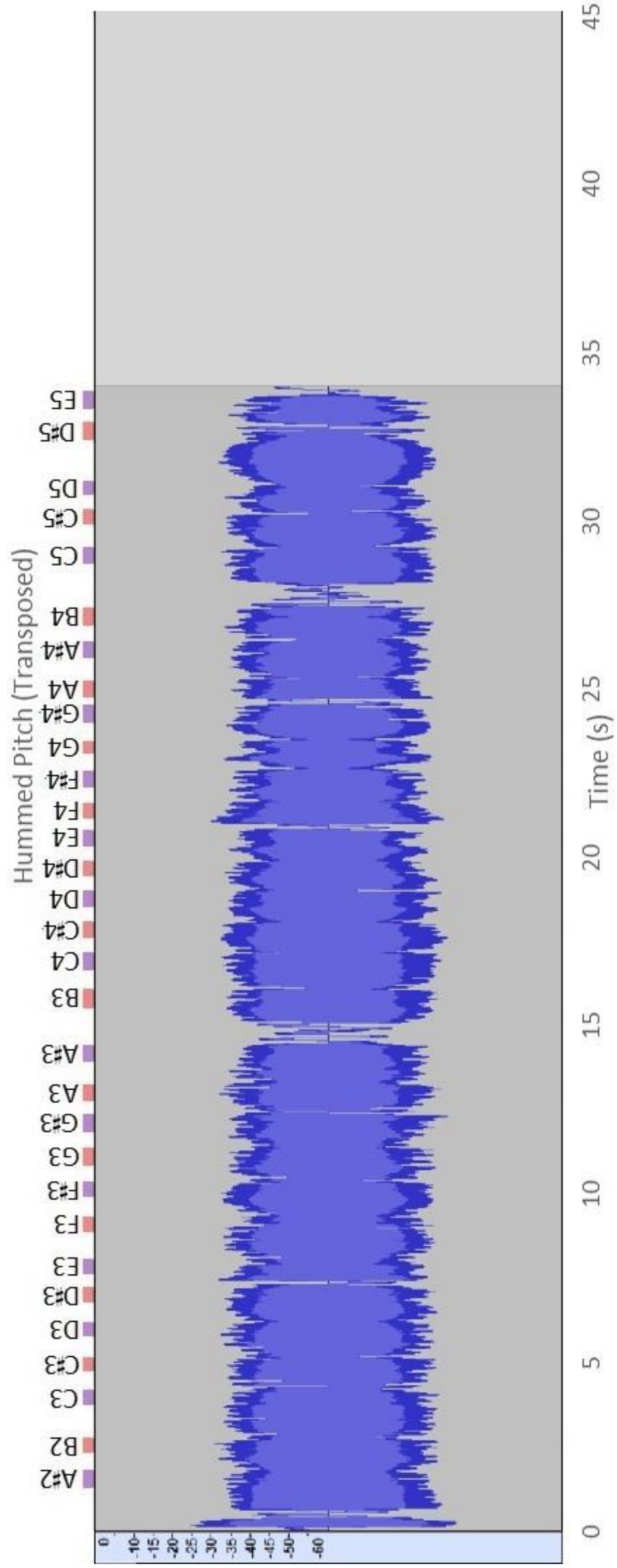


Figure C.4. Waveform dB view, play loud, hum loud, E_3.

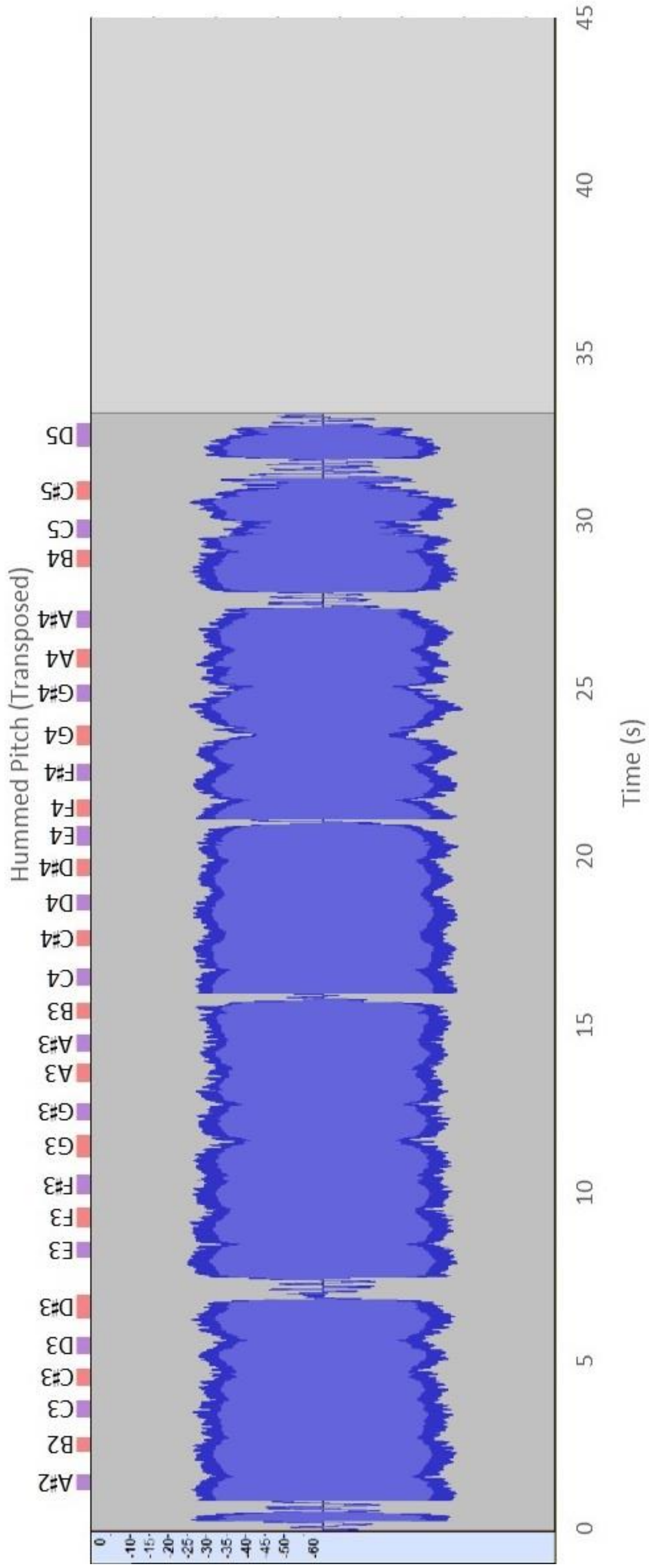


Figure C.5. Waveform dB view, play loud, hum loud, G_4.

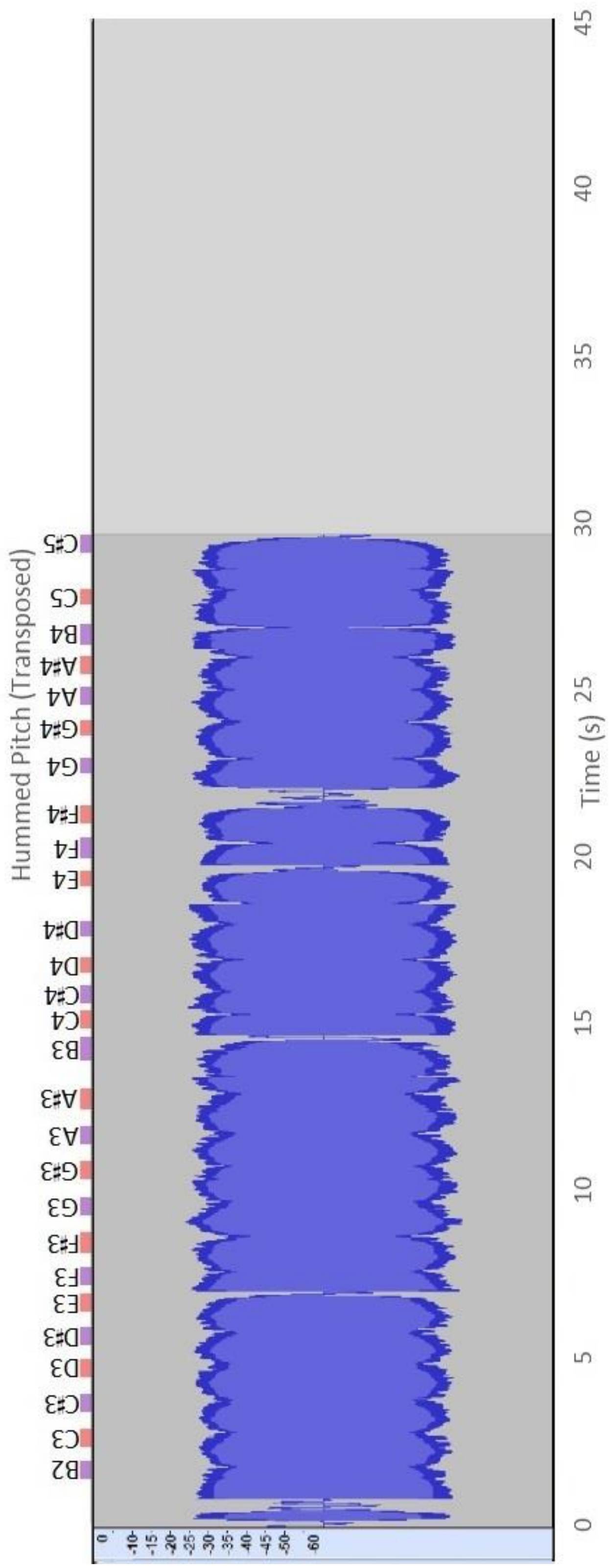


Figure C.6. Waveform dB view, play loud, hum loud, B4.

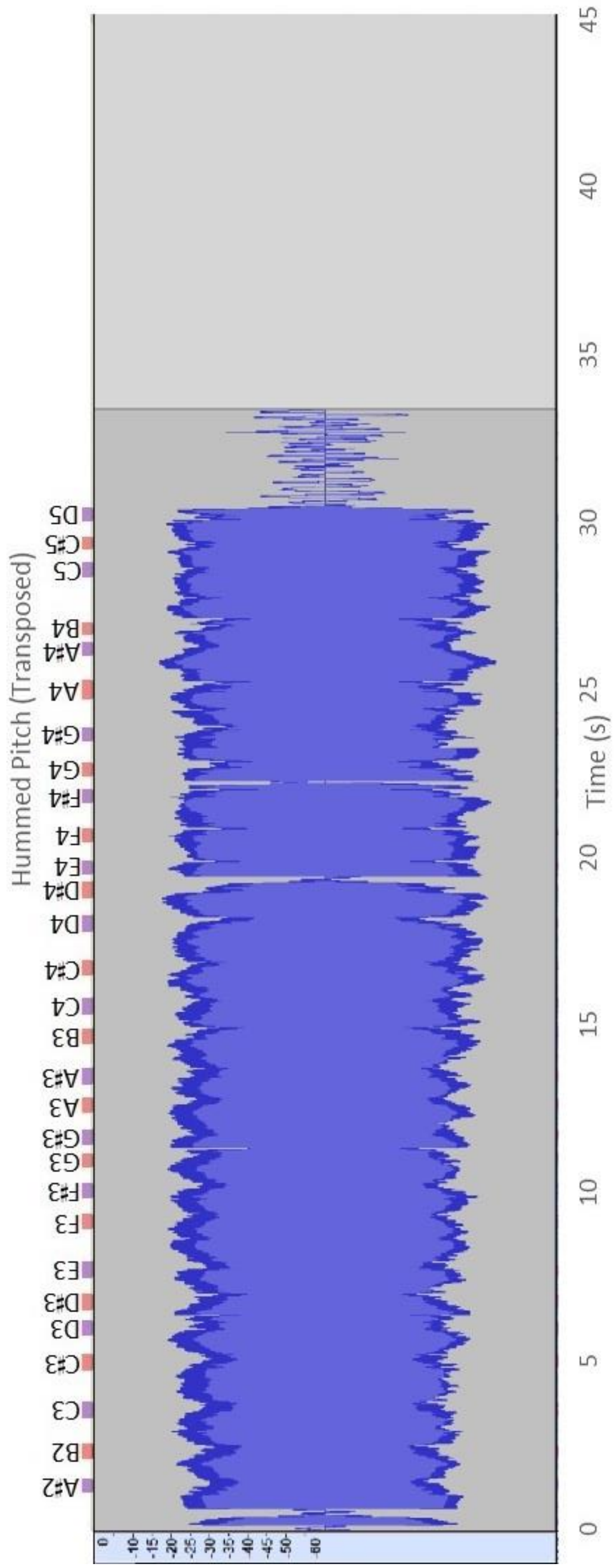


Figure C.7. Waveform dB view, play loud, hum loud, C_6.

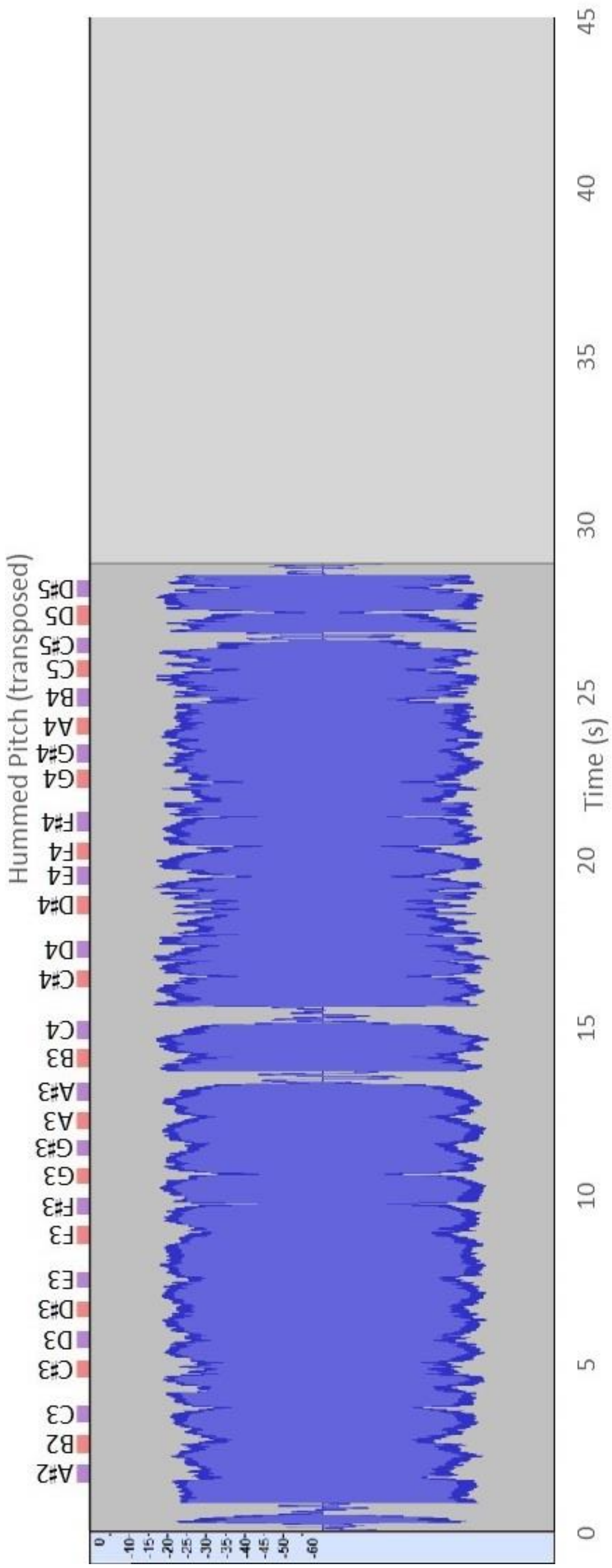


Figure C.8. Waveform dB view, play loud, hum loud, E_6.

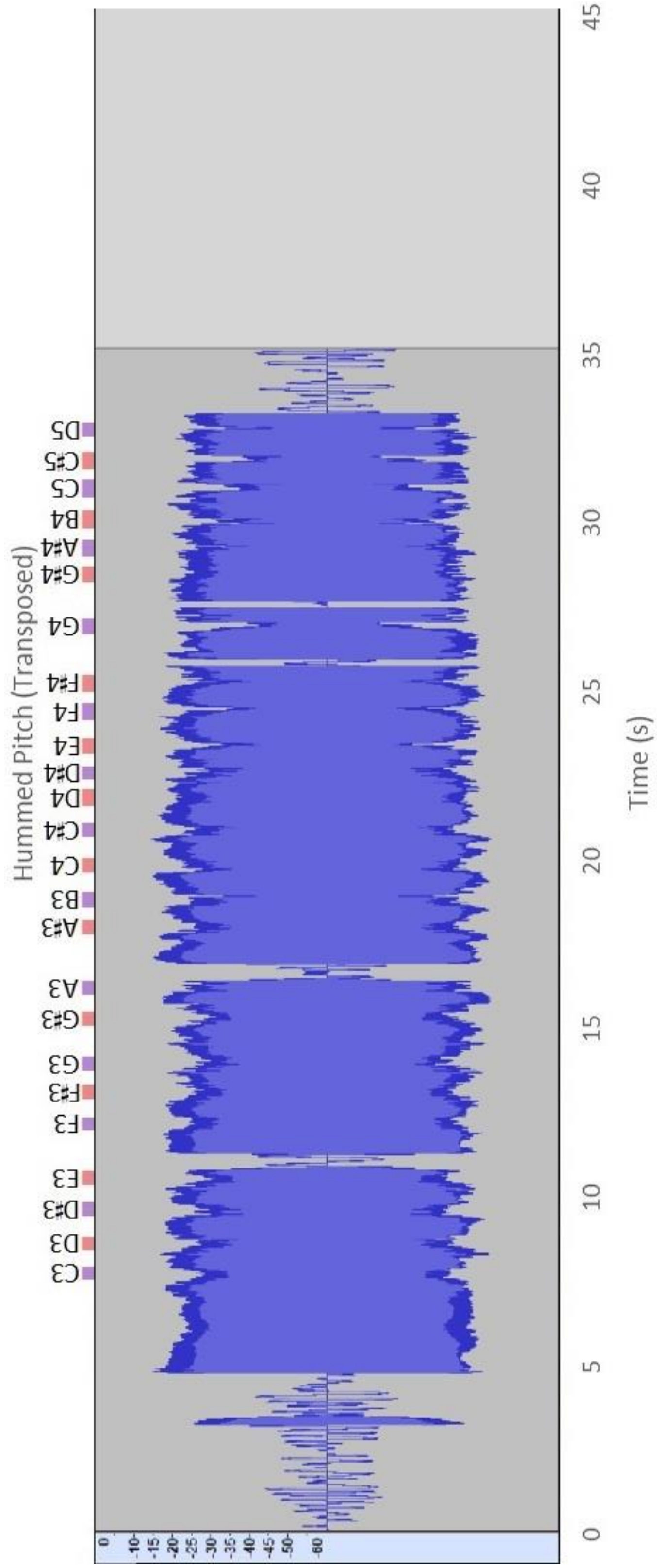


Figure C.9. Waveform dB view, play loud, hum loud, G_6.

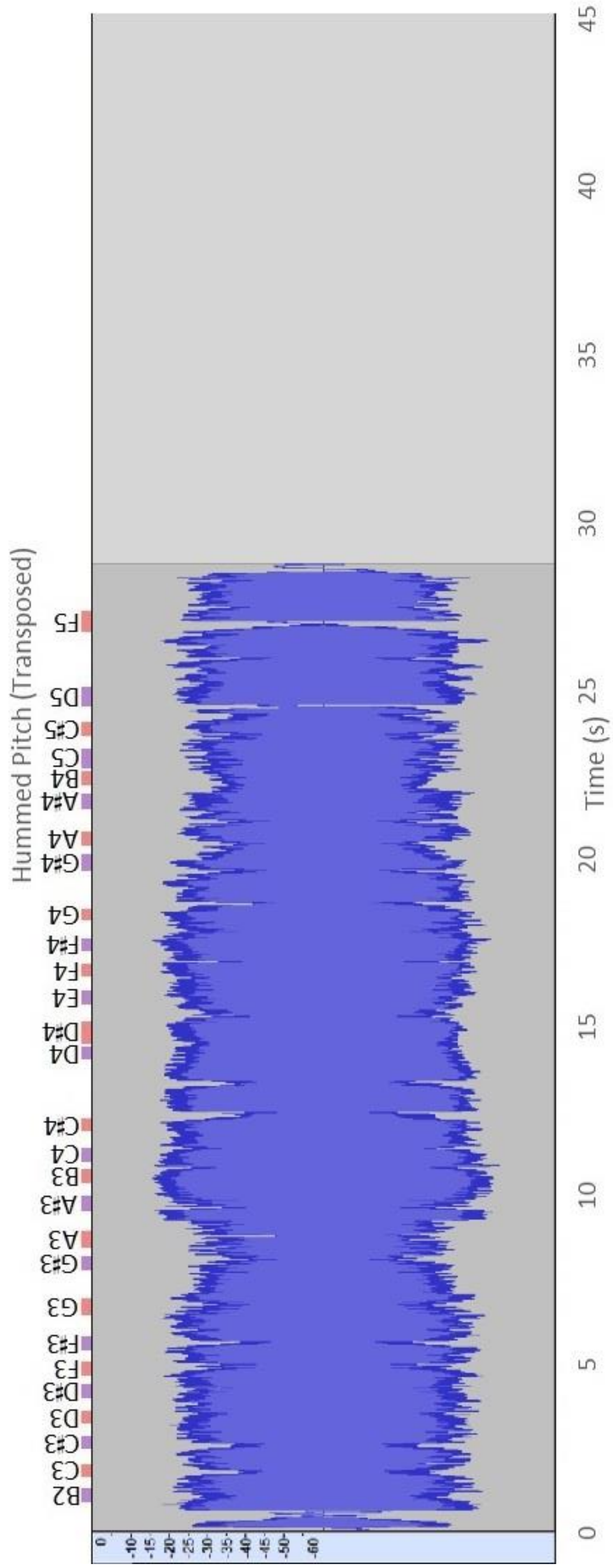


Figure C.10. Waveform dB view, play loud, hum loud, C_7.

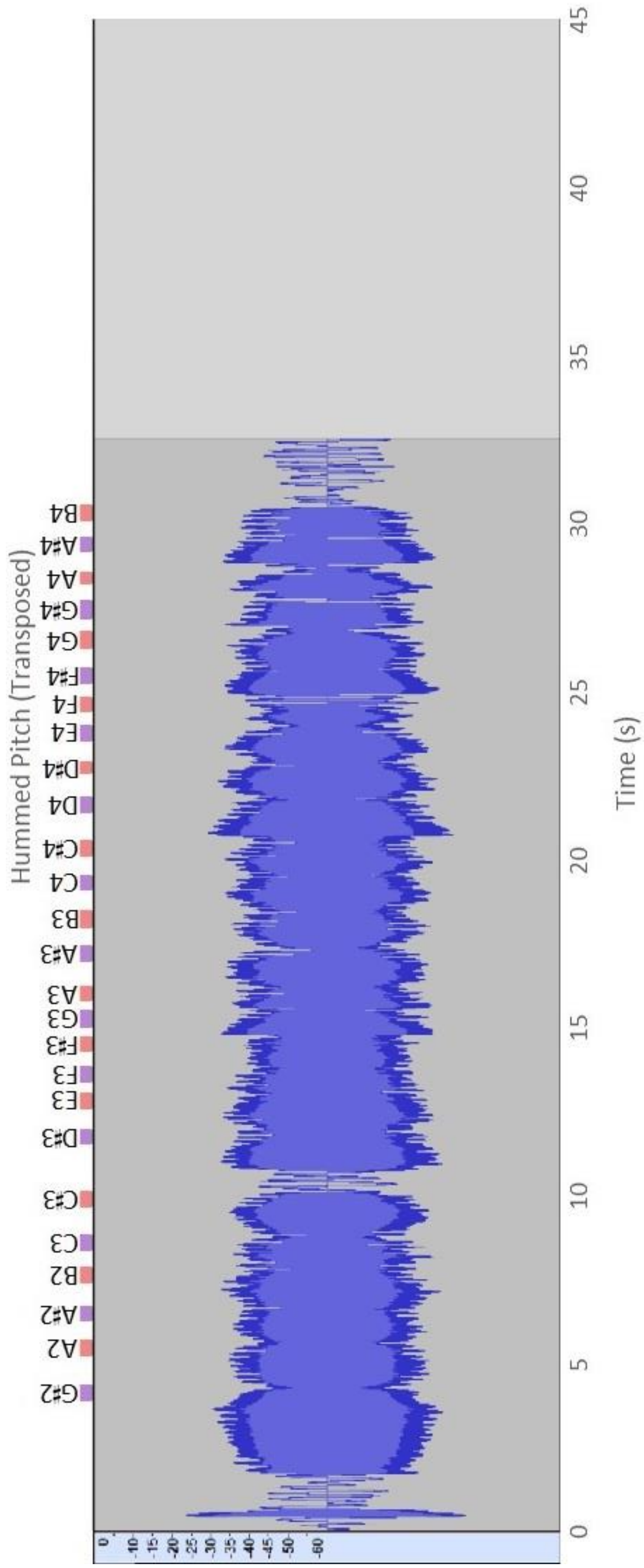


Figure C.11. Waveform dB view, play loud, hum soft, E3.

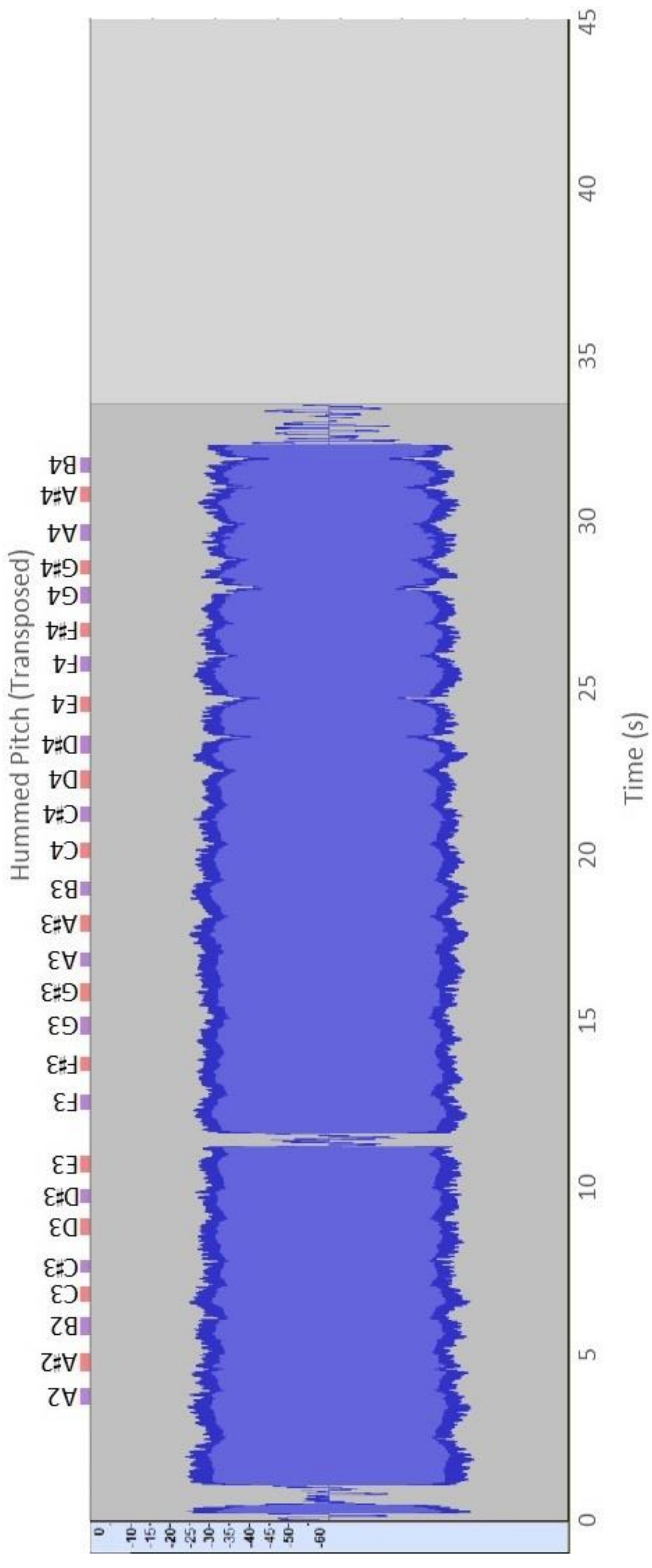


Figure C.12. Waveform dB view, play loud, hum soft, G_4.

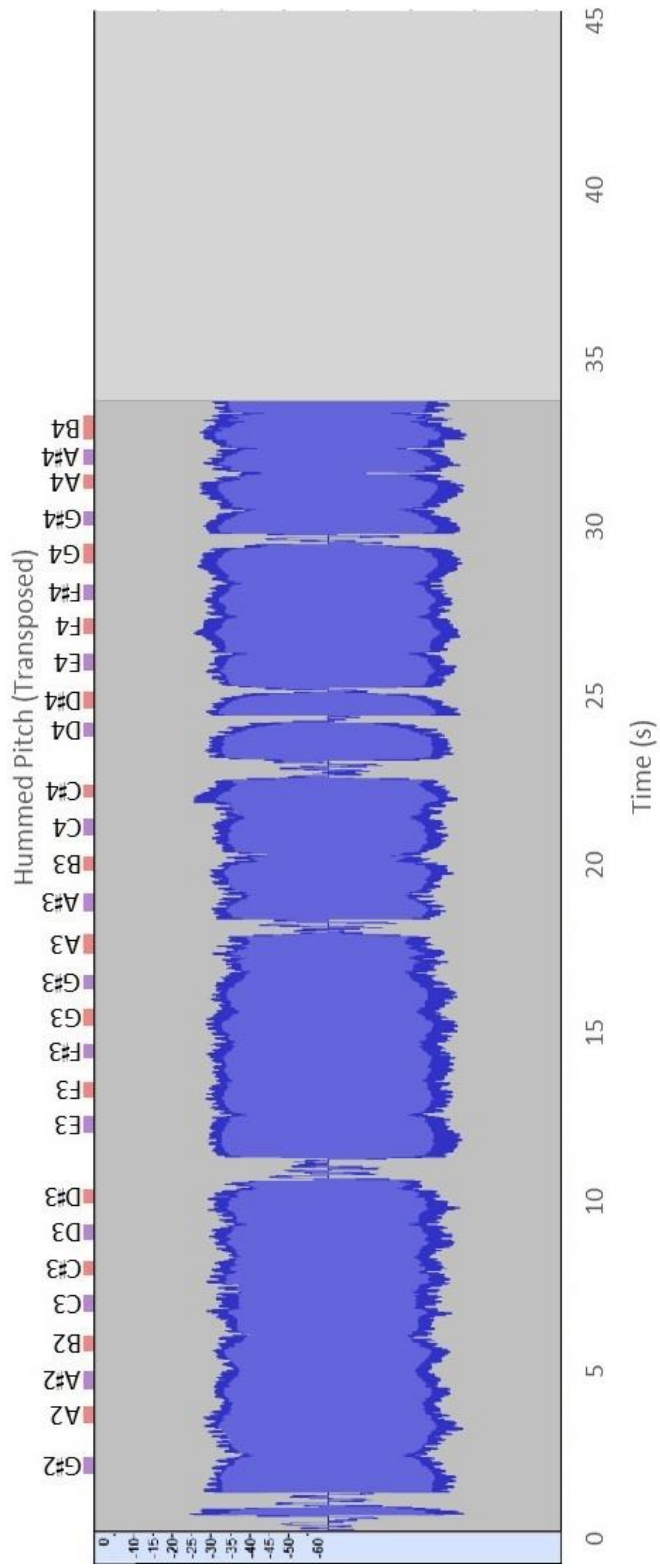


Figure C.13. Waveform dB view, play loud, hum soft, B_4.

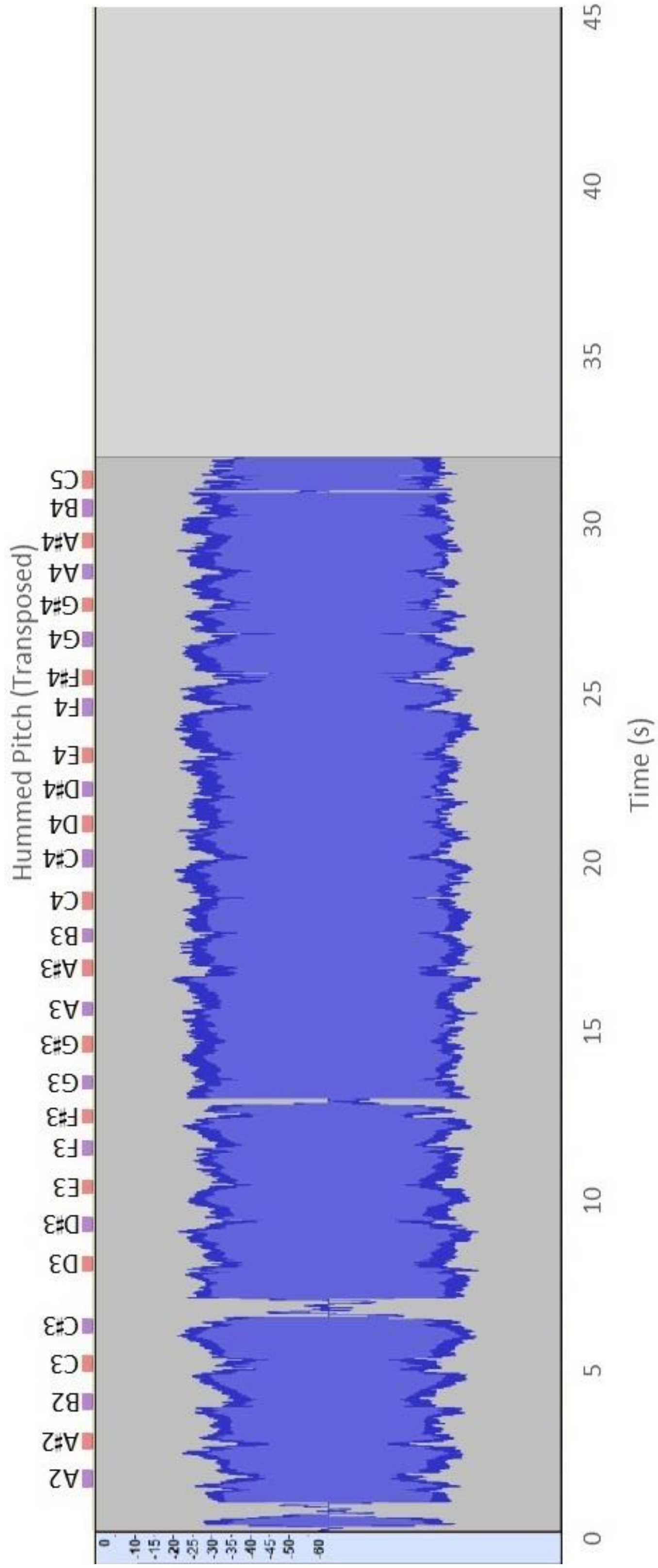


Figure C.14. Waveform dB view, play loud, hum soft, C_6.

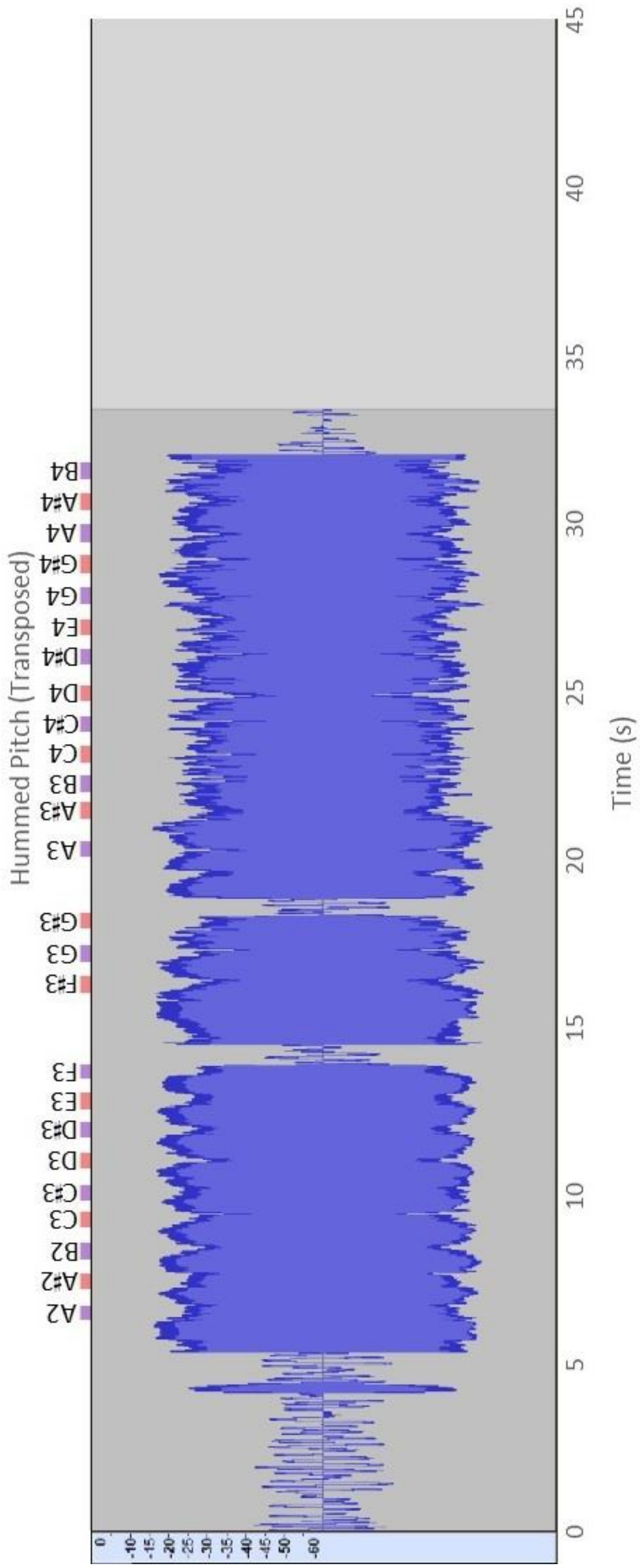


Figure C.15. Waveform dB view, play loud, hum soft, E_6.

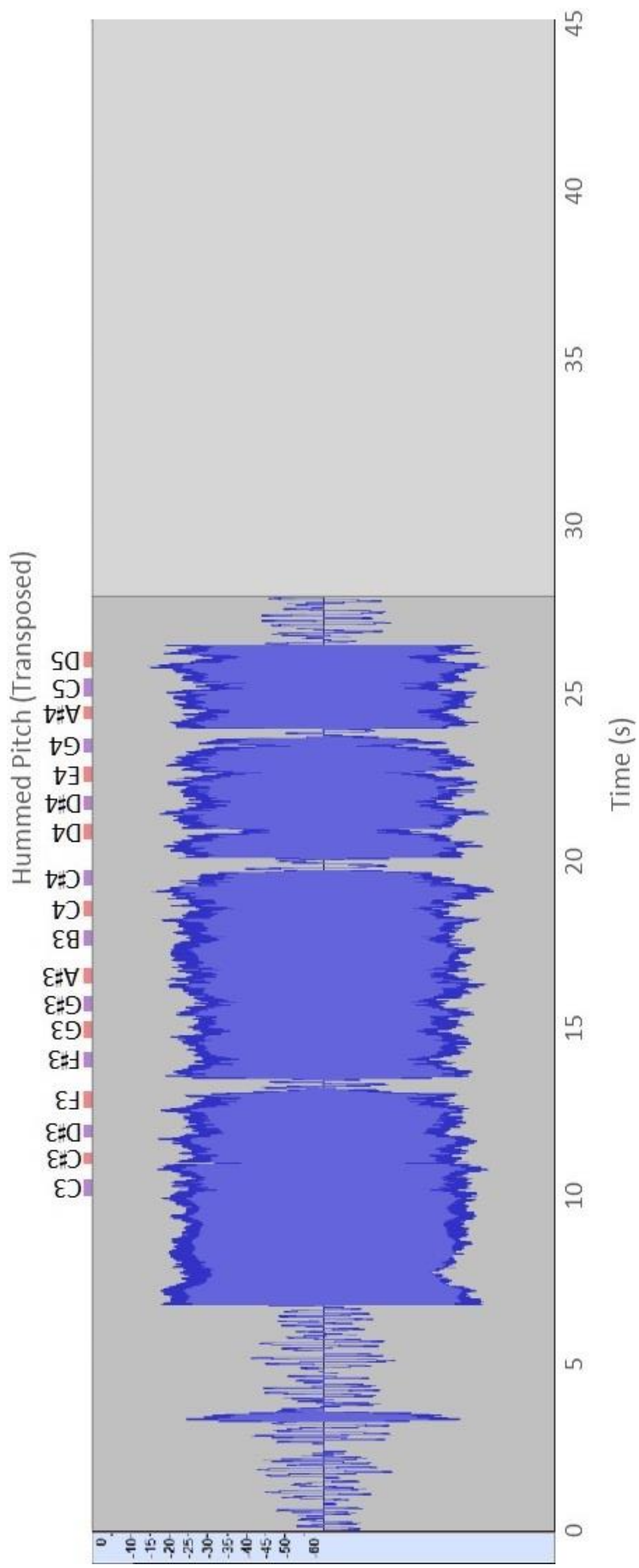


Figure C.16. Waveform dB view, play loud, hum soft, G_6.

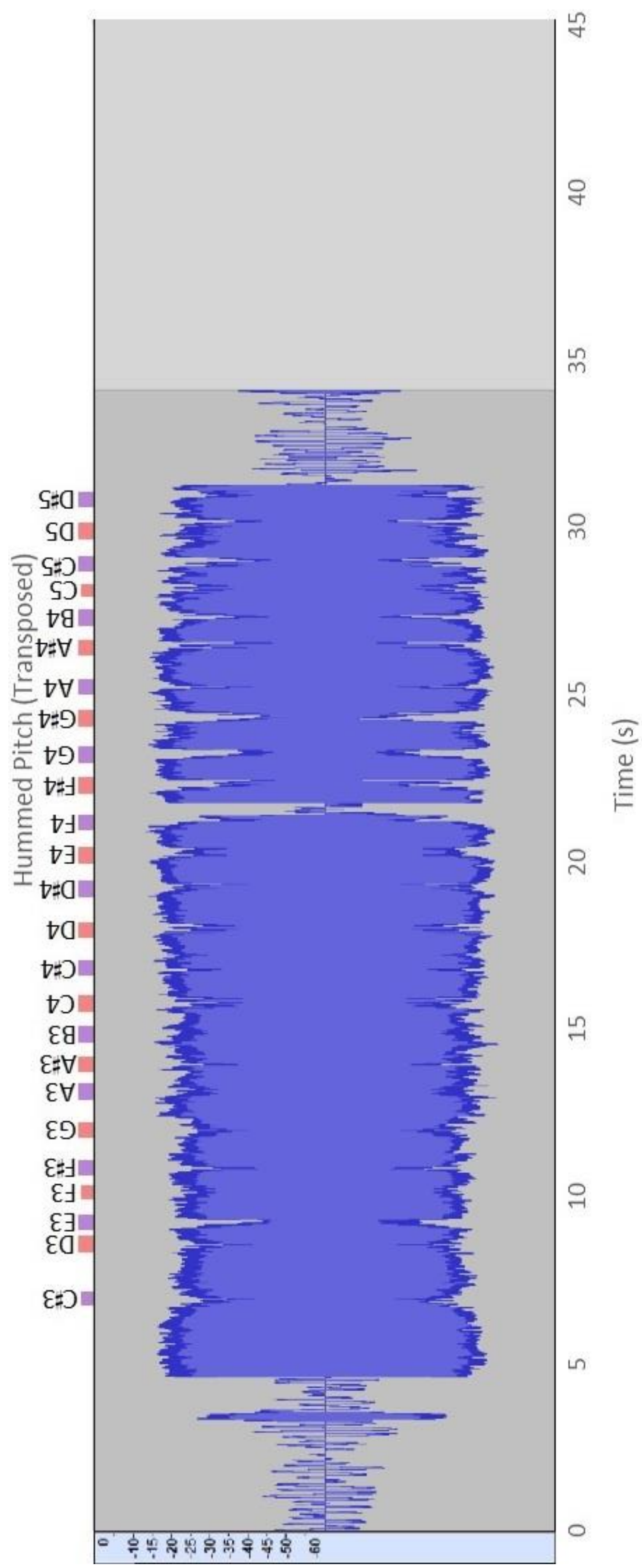


Figure C.17. Waveform dB view, play loud, hum soft, C_7.

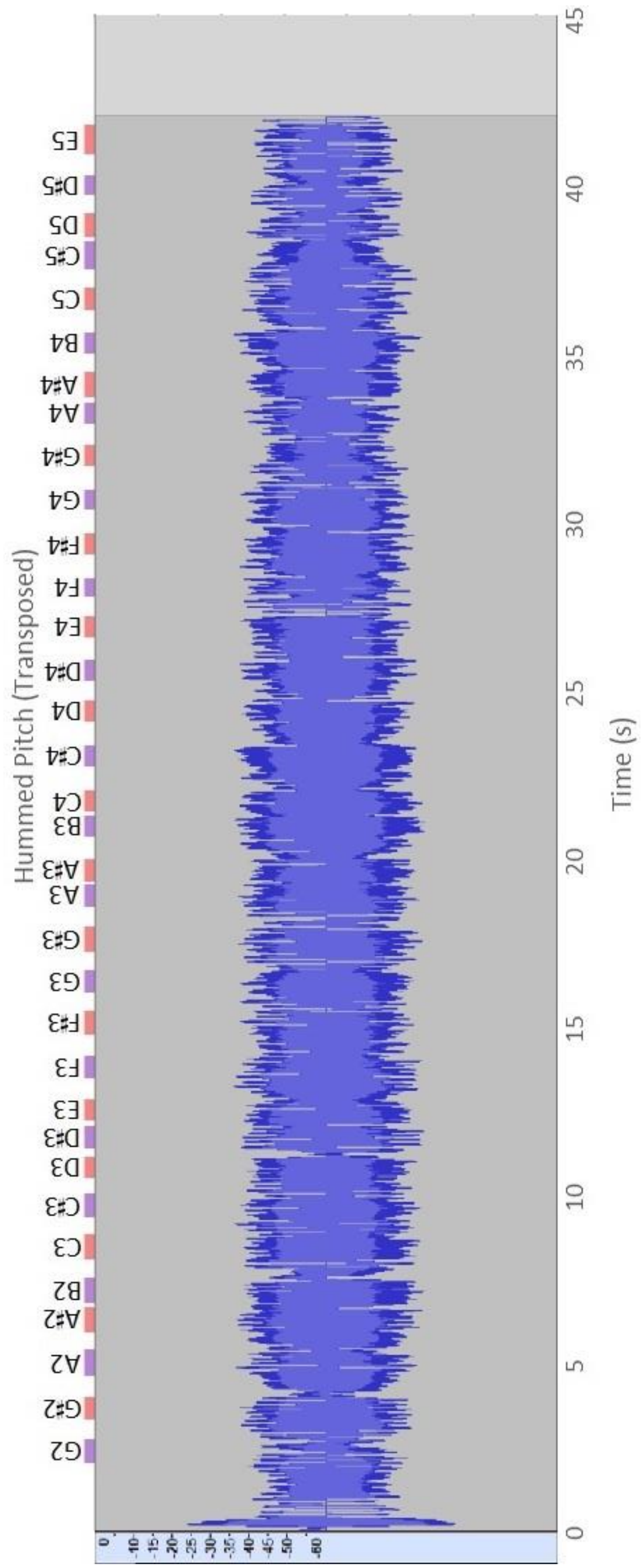


Figure C.18. Waveform dB view, play soft, hum loud, E_3.

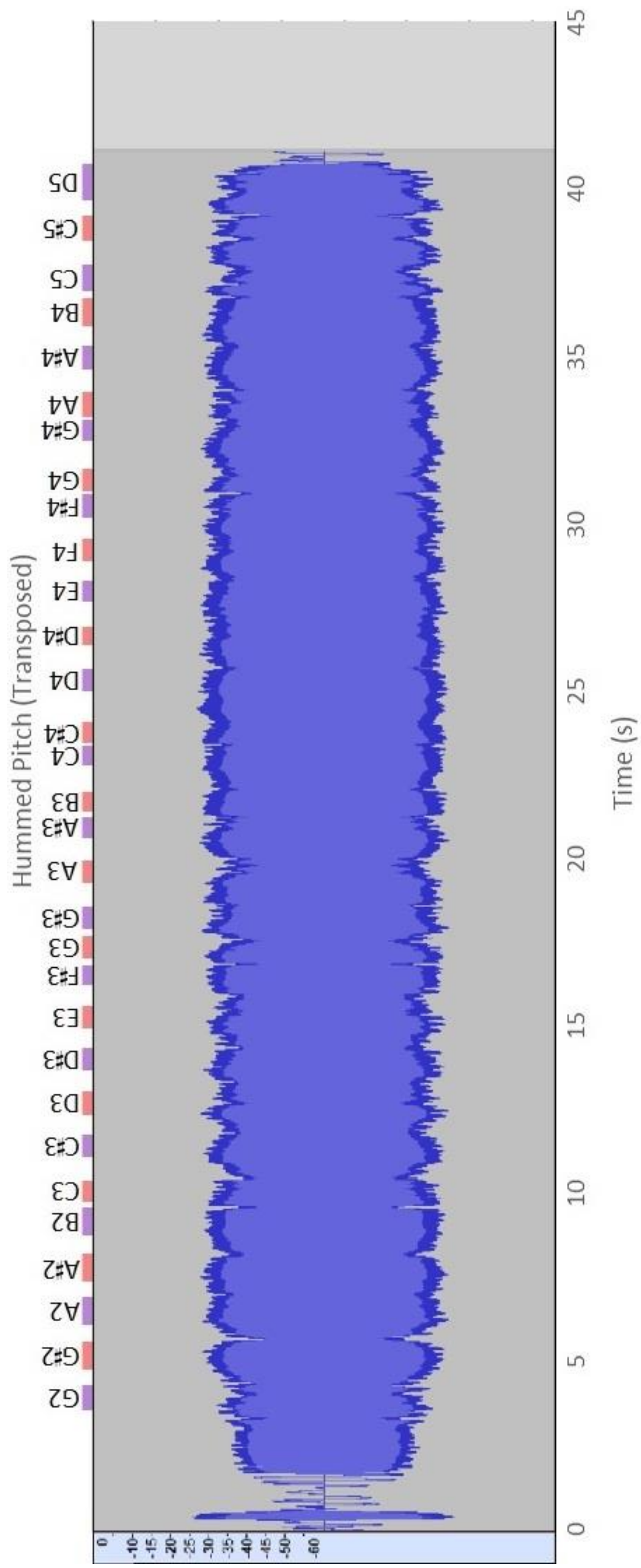


Figure C.19. Waveform dB view, play soft, hum loud, G_4.

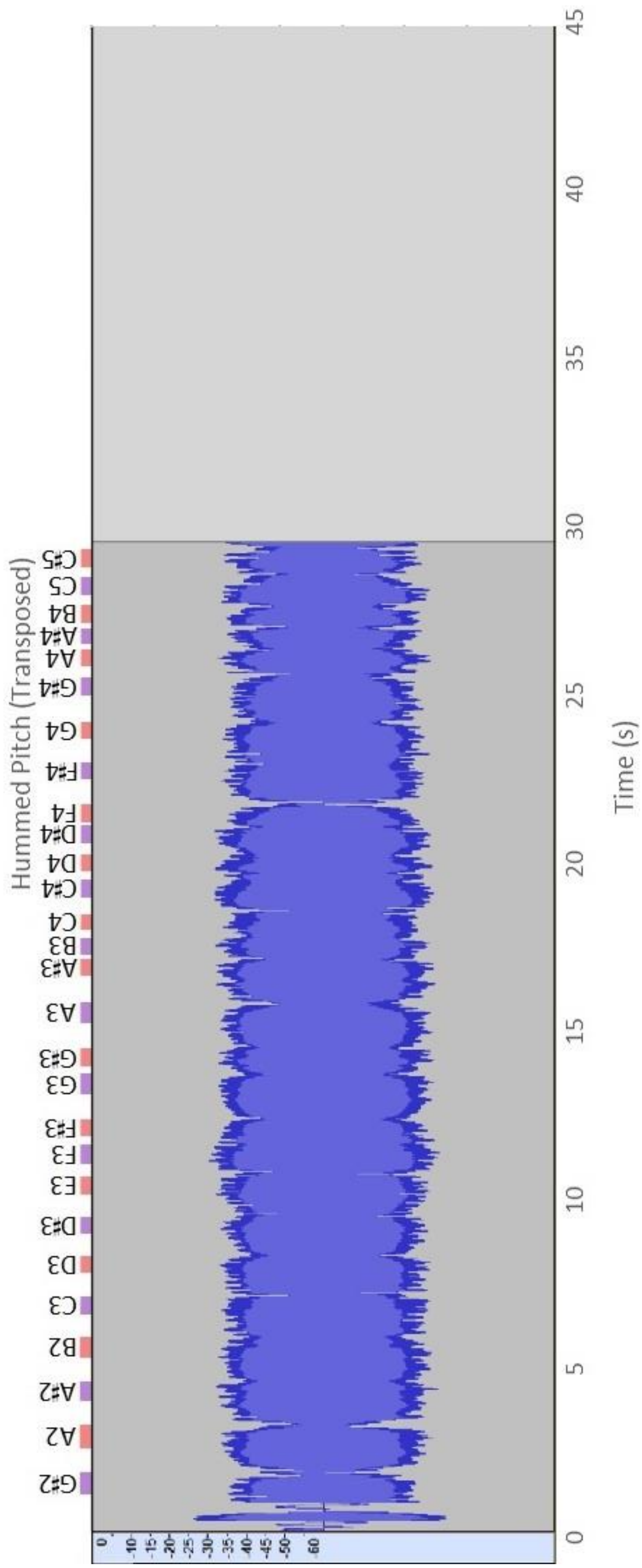


Figure C.20. Waveform dB view, play soft, hum loud, B$_4$.

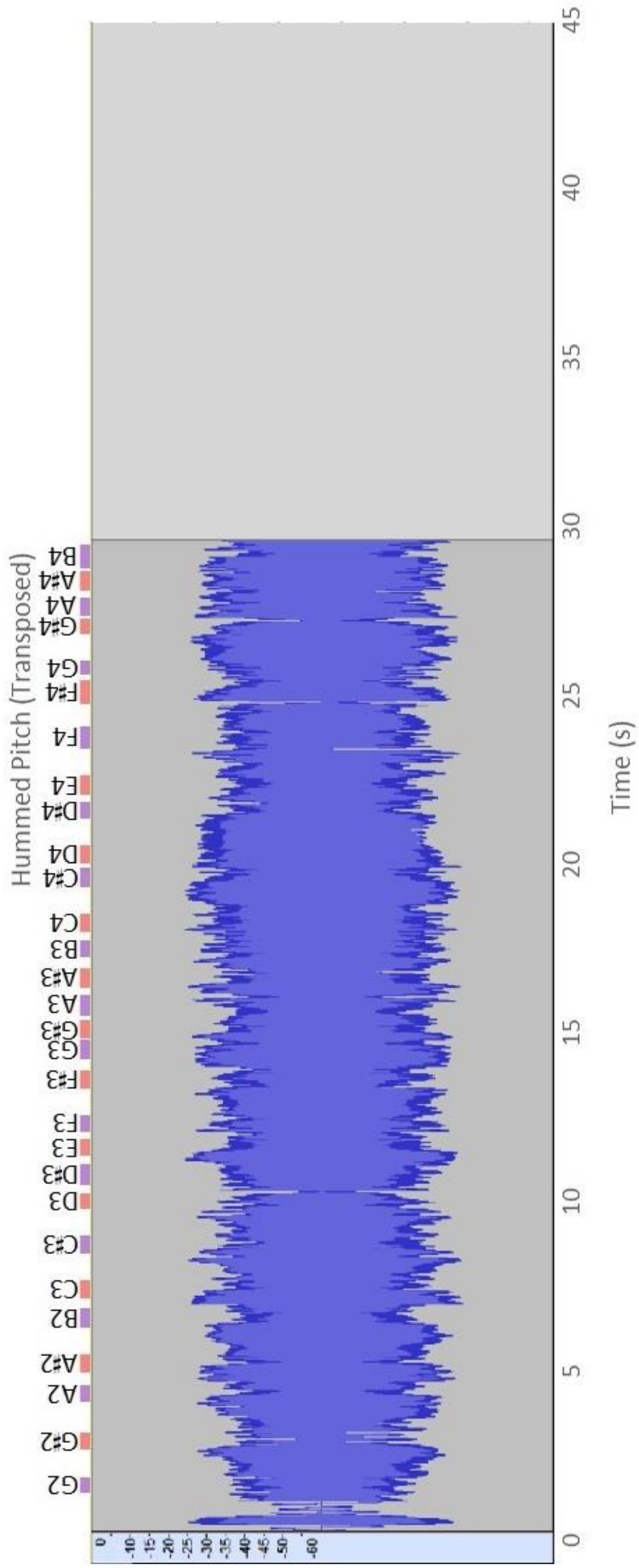


Figure C.21. Waveform dB view, play soft, hum loud, C_6.

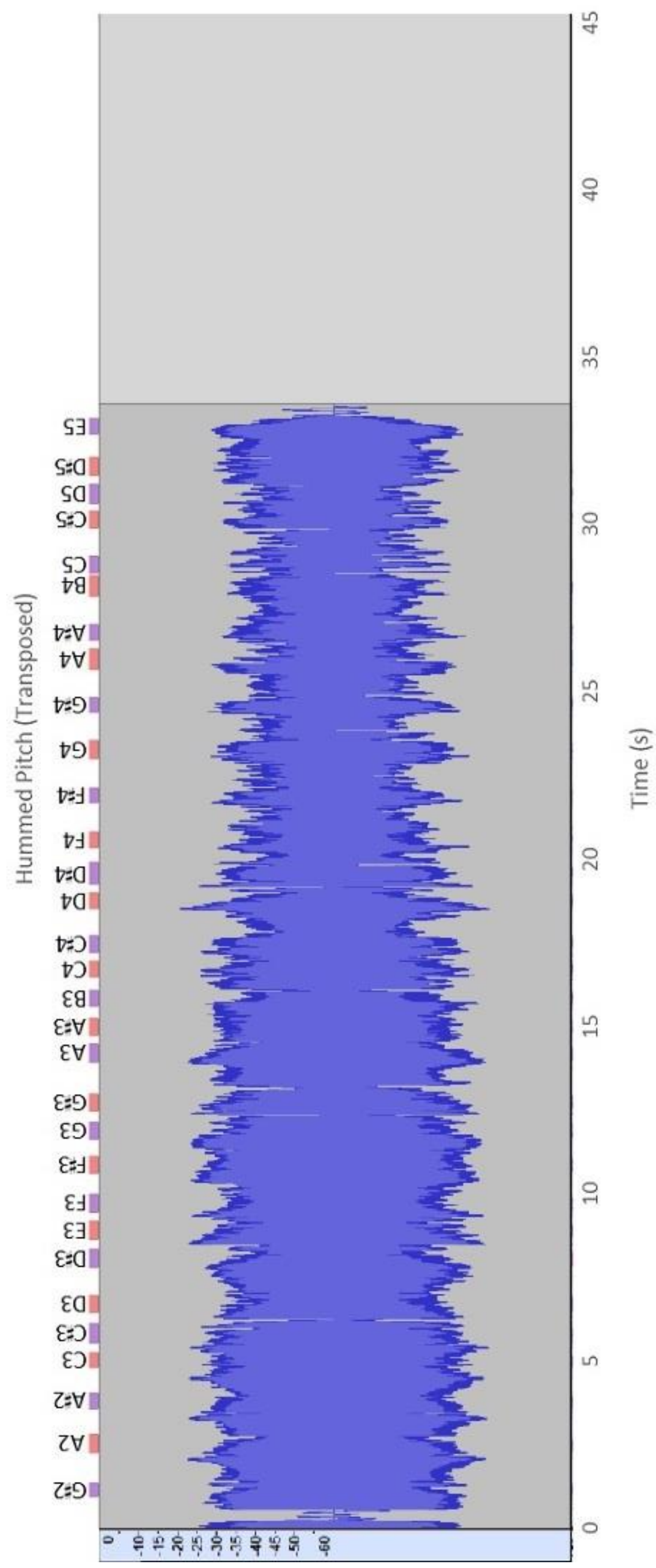


Figure C.22. Waveform dB view, play soft, hum loud, E_6.

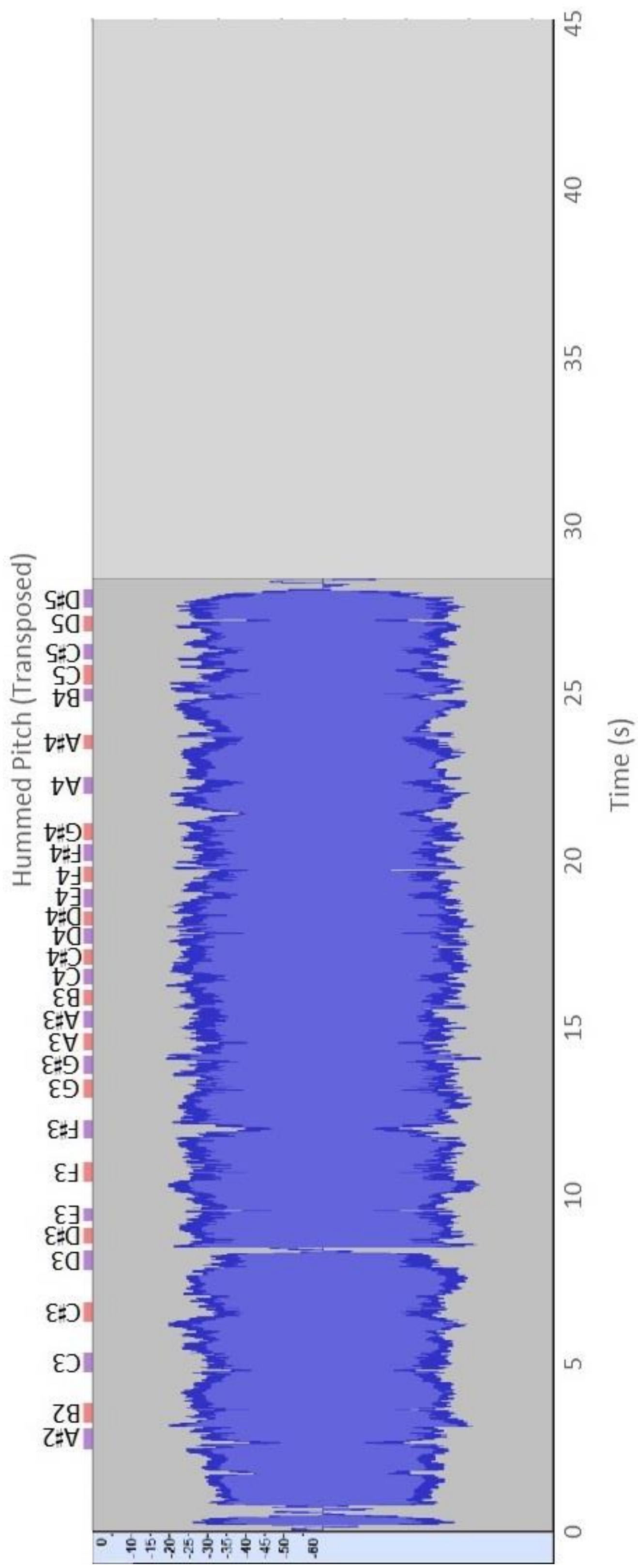


Figure C.23. Waveform dB view, play soft, hum loud, G_6.

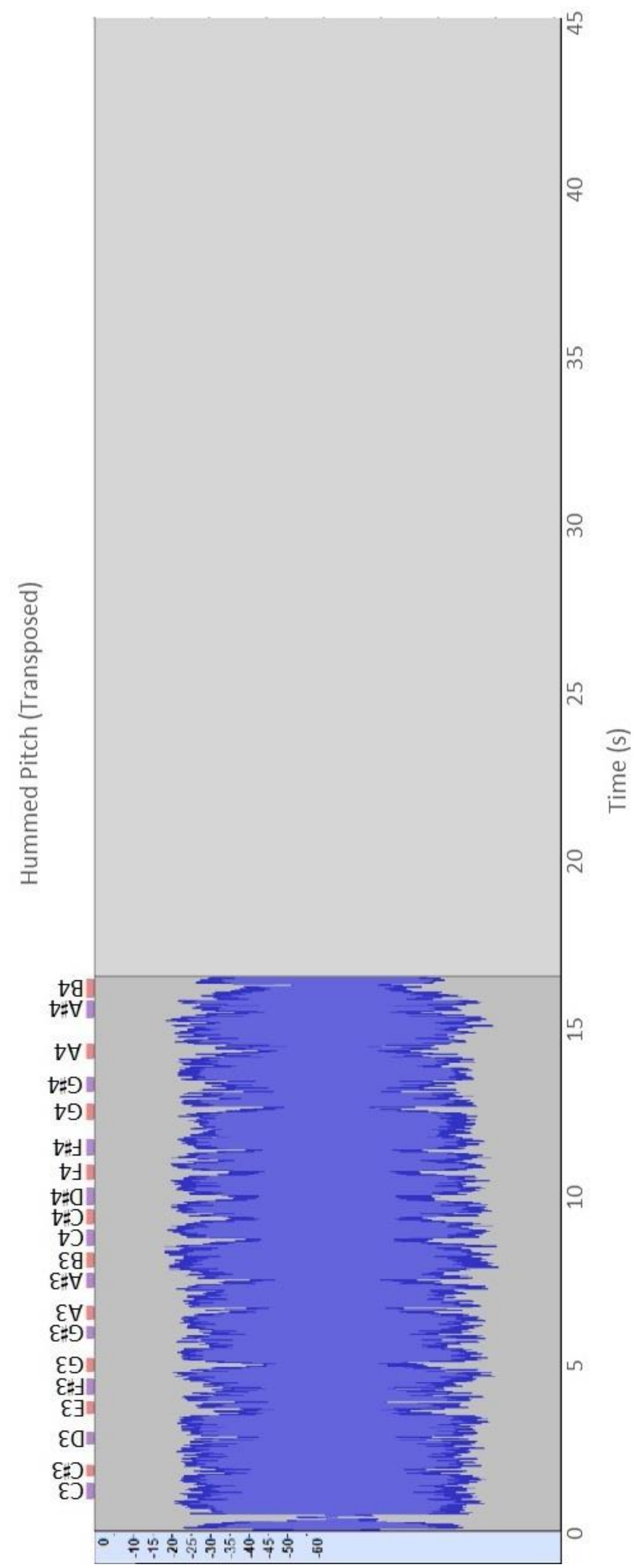


Figure C.24. Waveform dB view, play soft, hum loud, C_7.

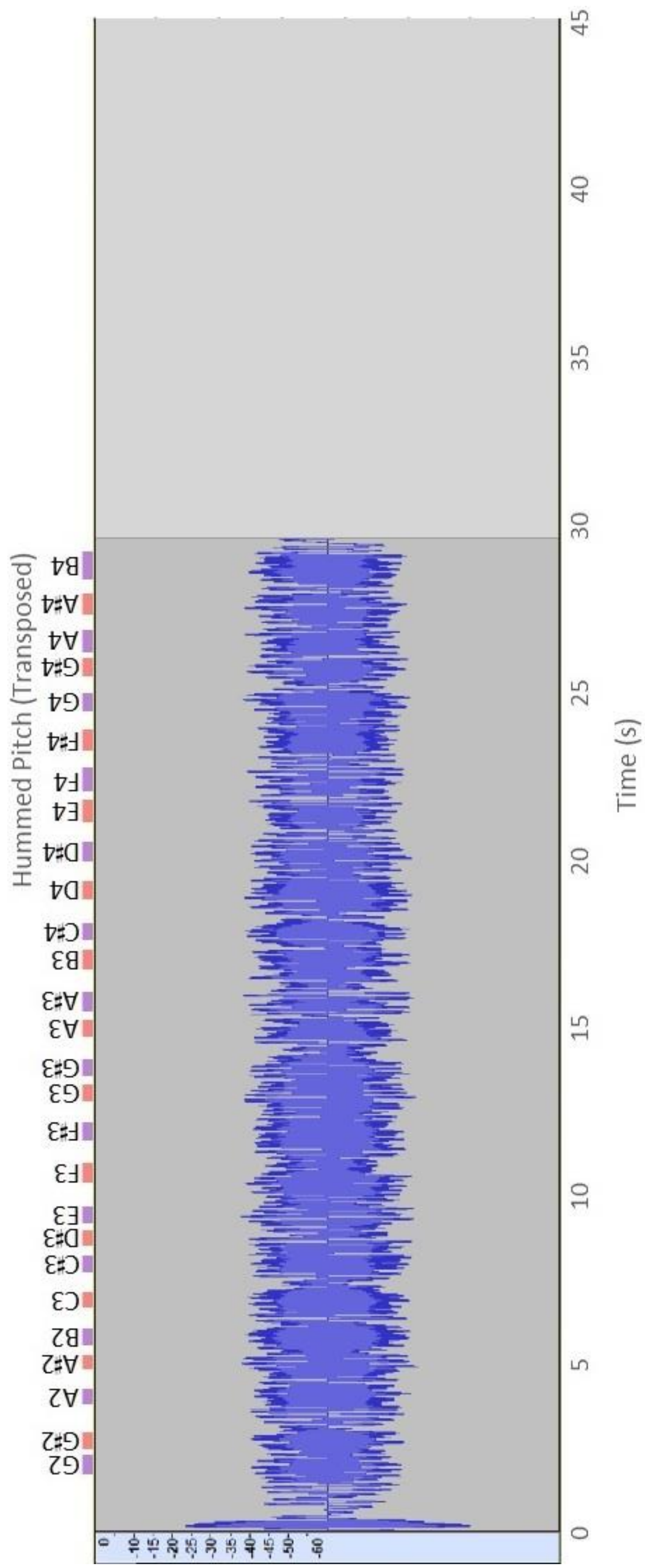


Figure C.25. Waveform dB view, play soft, hum soft, E_3.

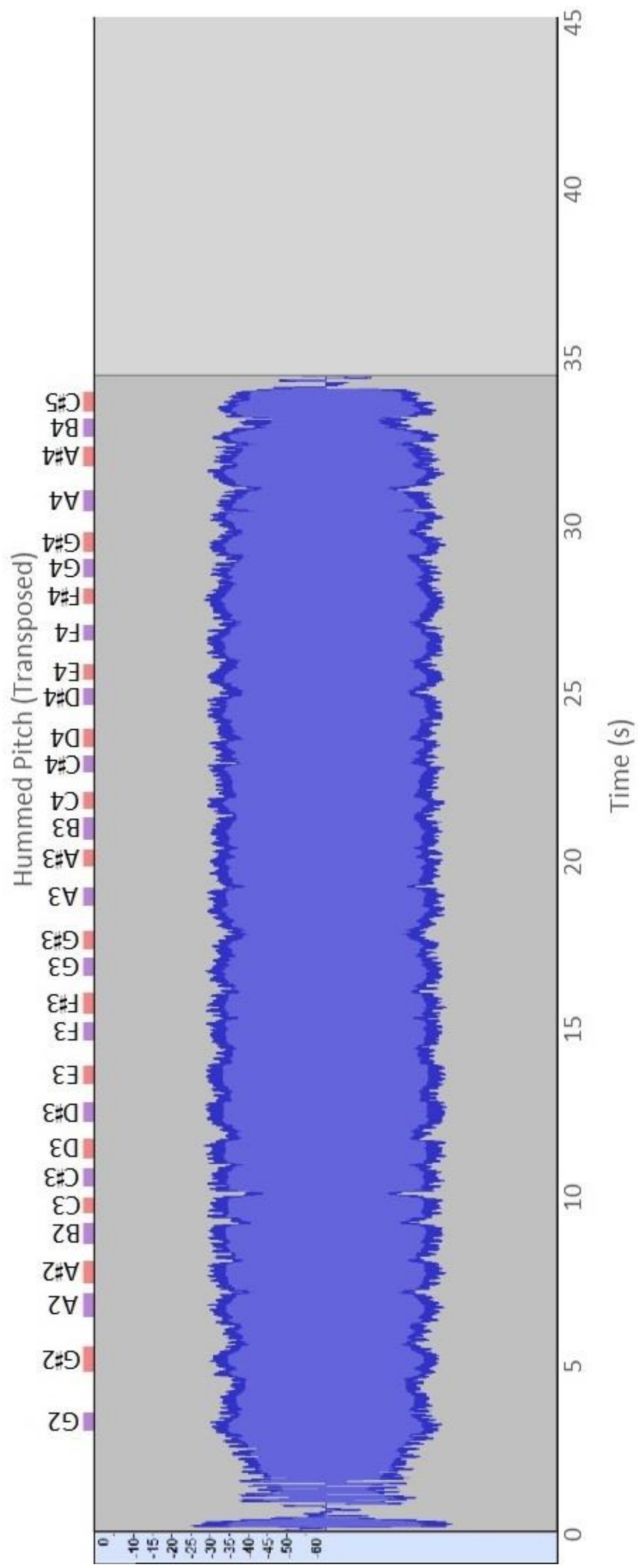


Figure C.26. Waveform dB view, play soft, hum soft, G_4.

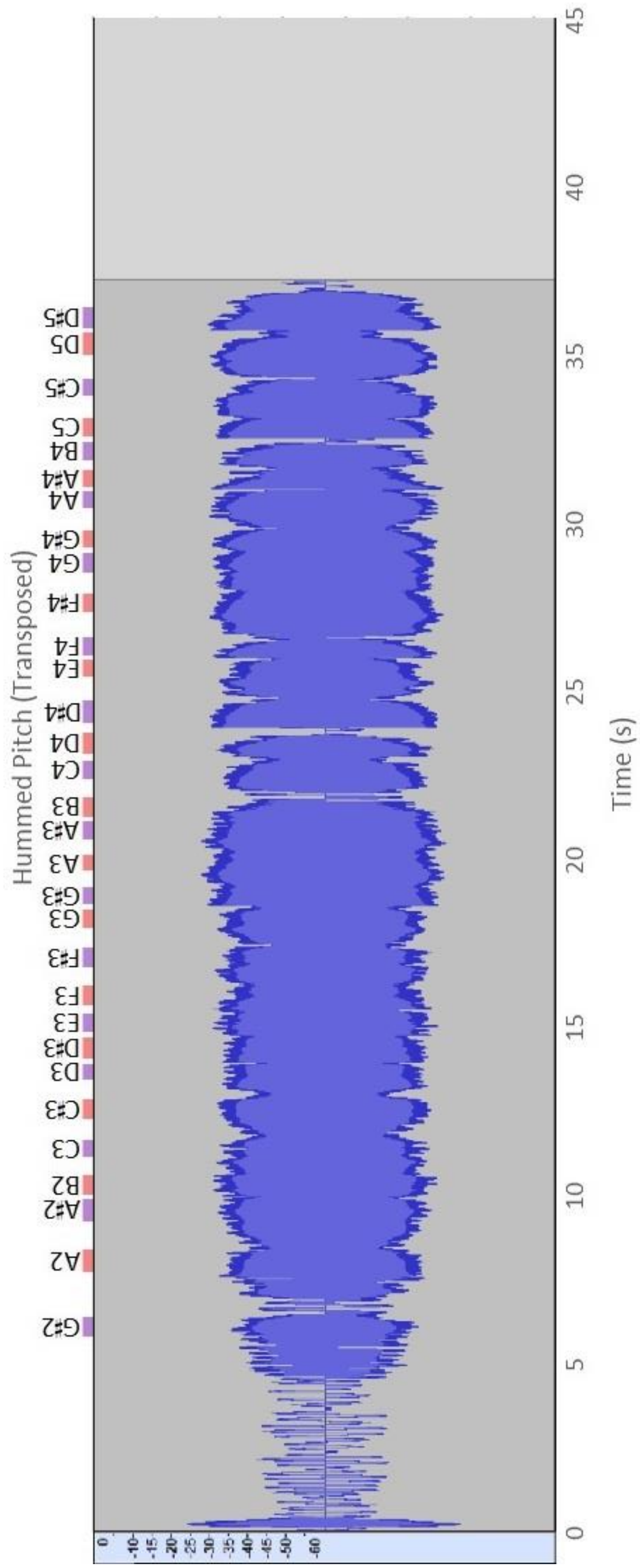


Figure C.27. Waveform dB view, play soft, hum soft, B4.

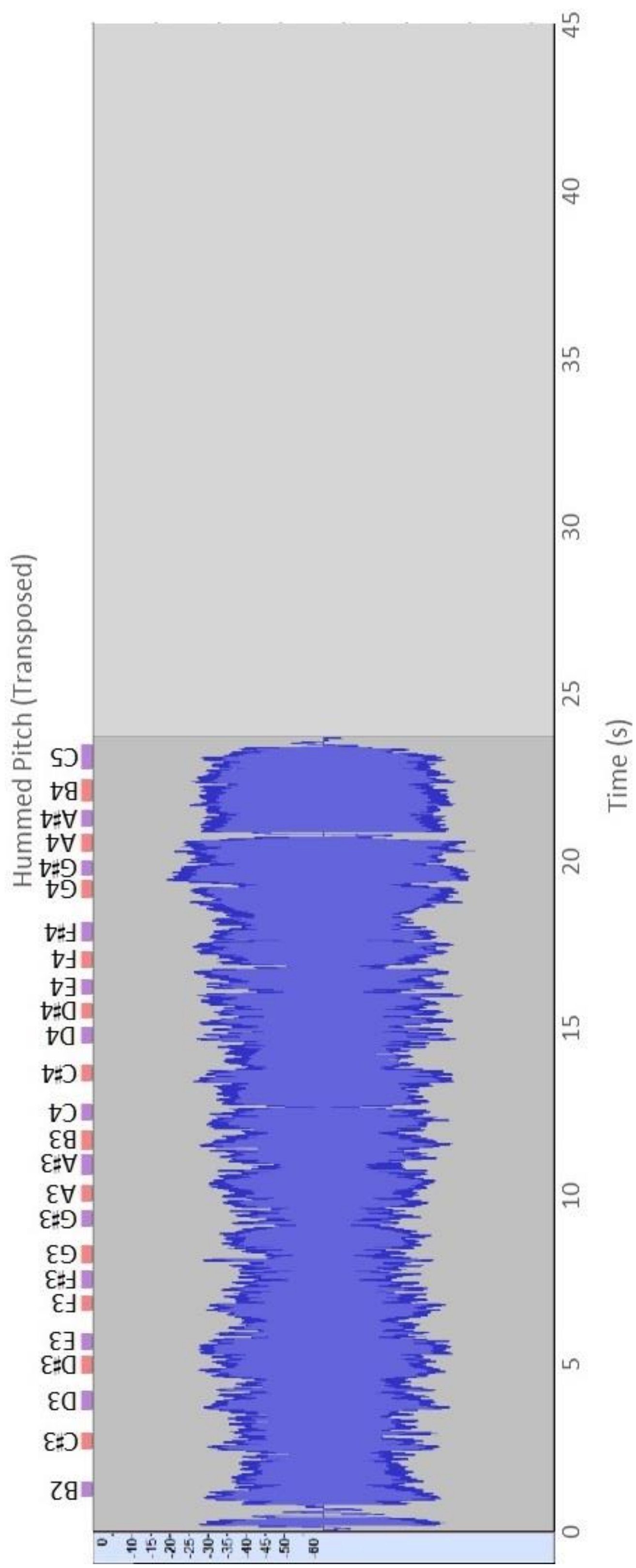


Figure C.28. Waveform dB view, play soft, hum soft, C_6.

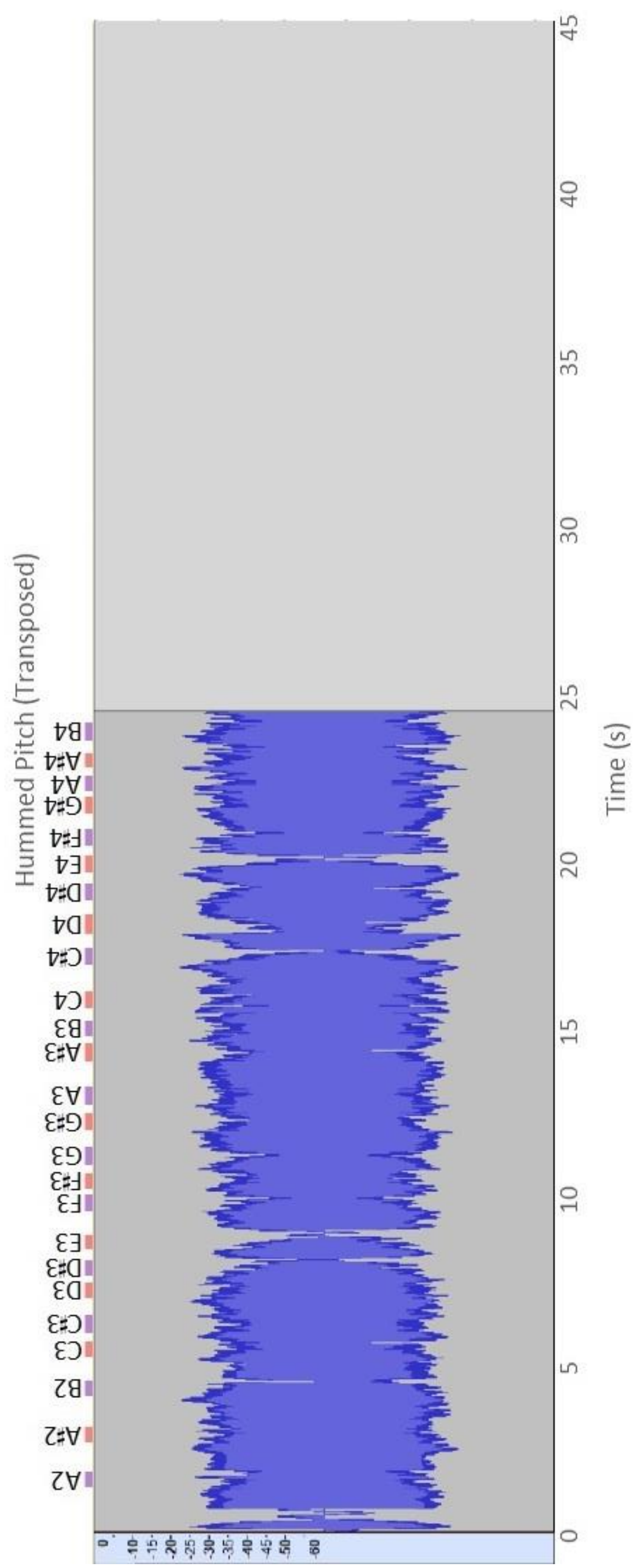


Figure C.29. Waveform dB view, play soft, hum soft, E_6.

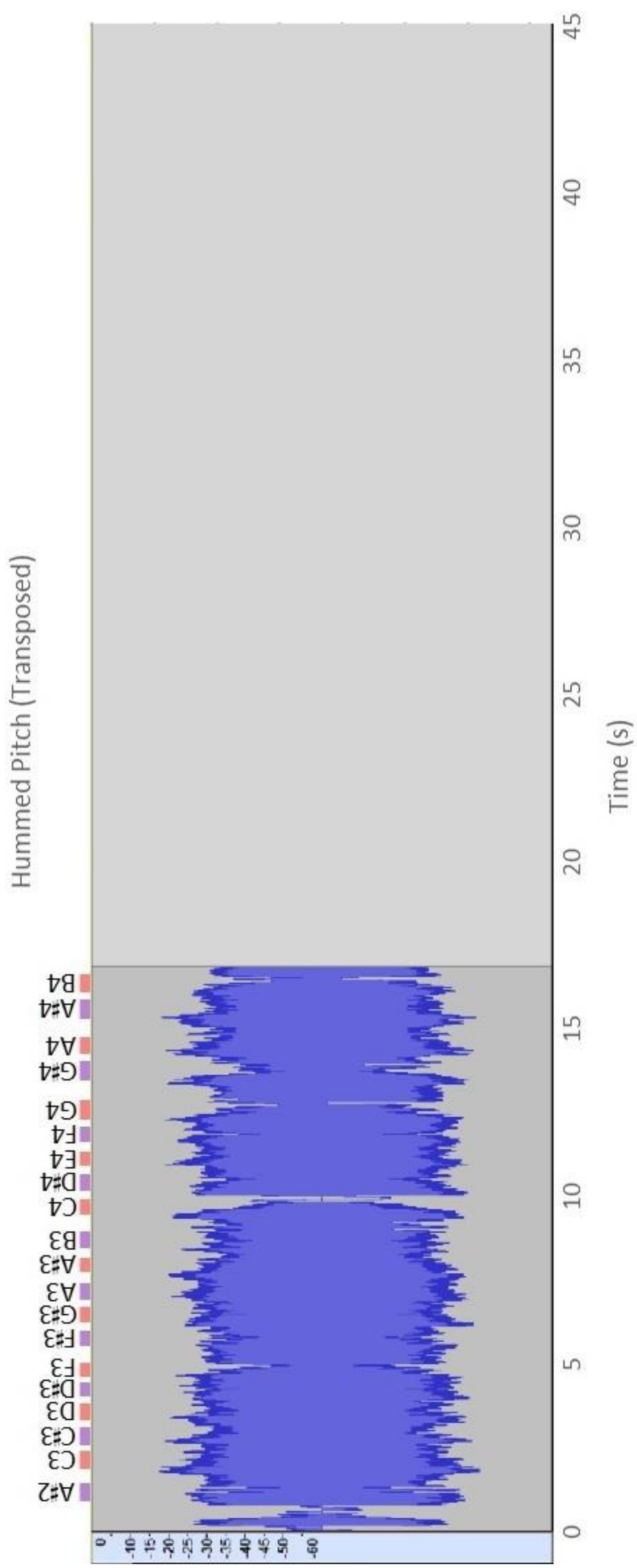


Figure C.30. Waveform dB view, play soft, hum soft, G_6.

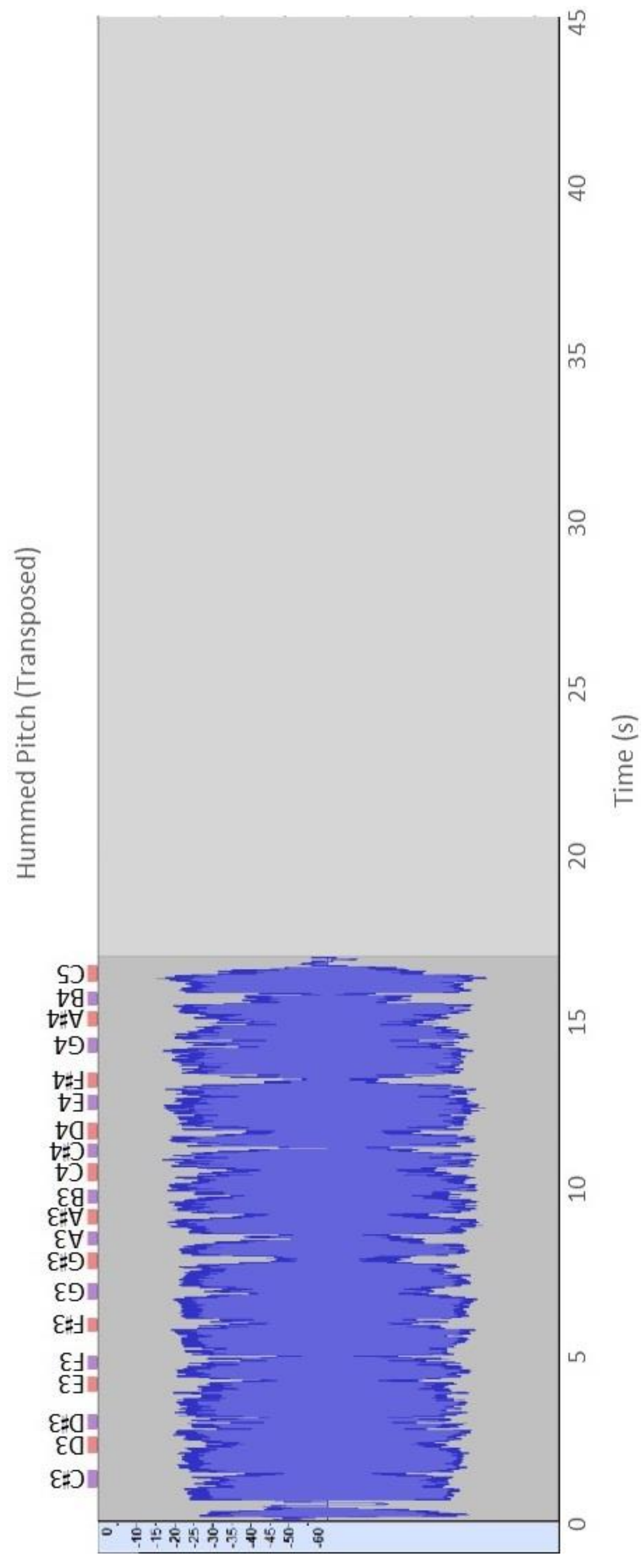


Figure C.31. Waveform dB view, play soft, hum soft, C_7.

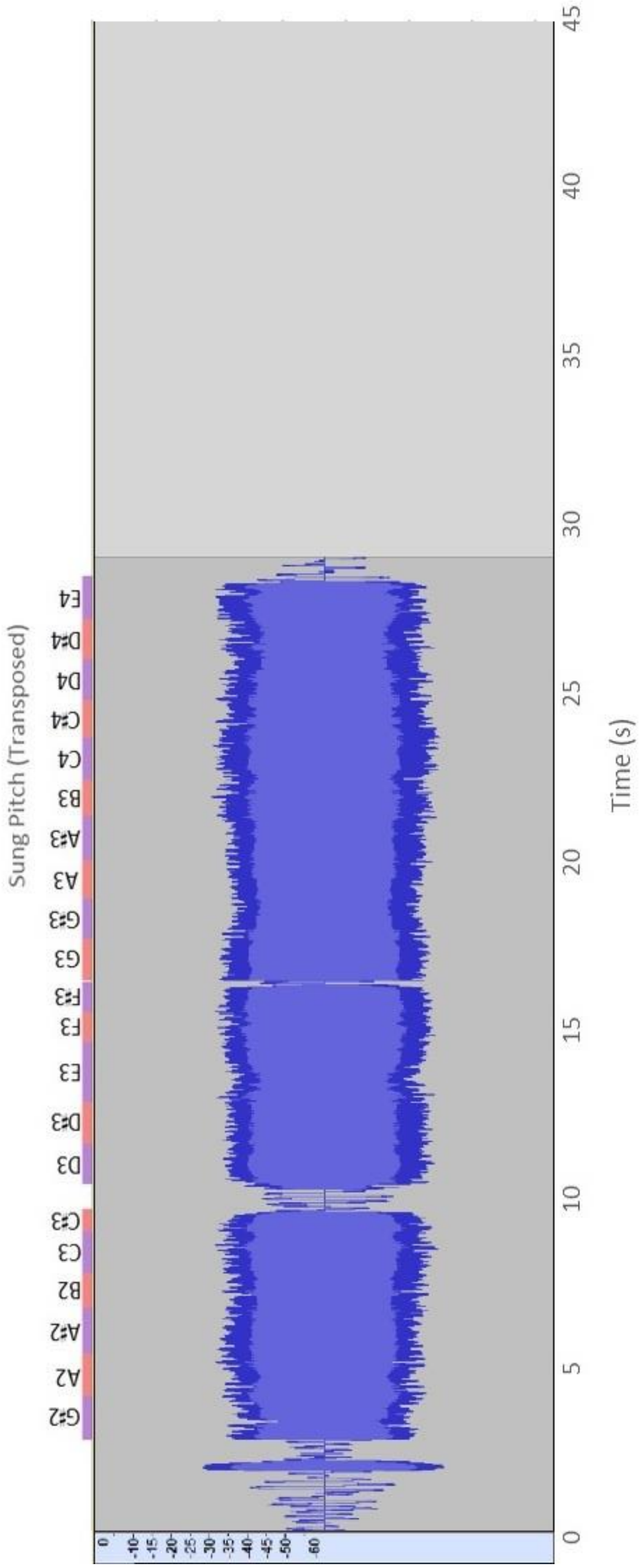


Figure C.32. Waveform dB view, play loud, sing loud, E_3.

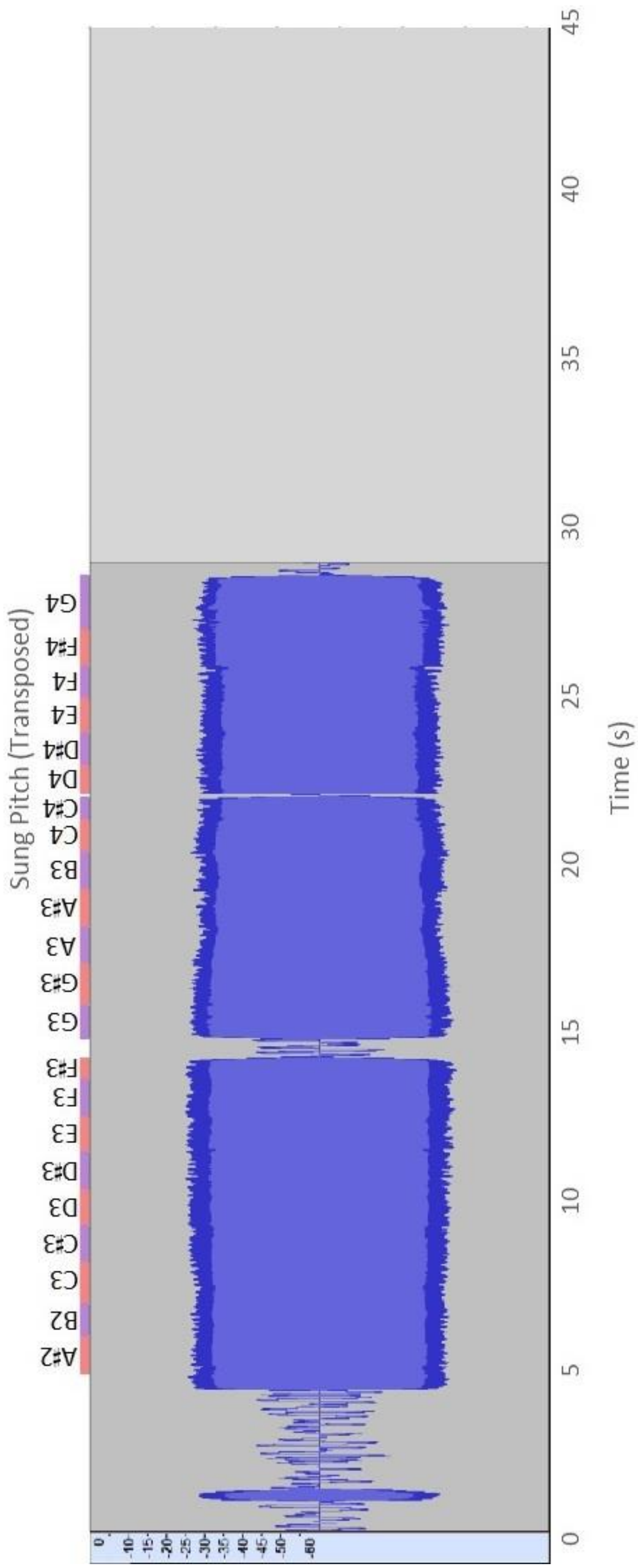


Figure C.33. Waveform dB view, play loud, sing loud, G4.

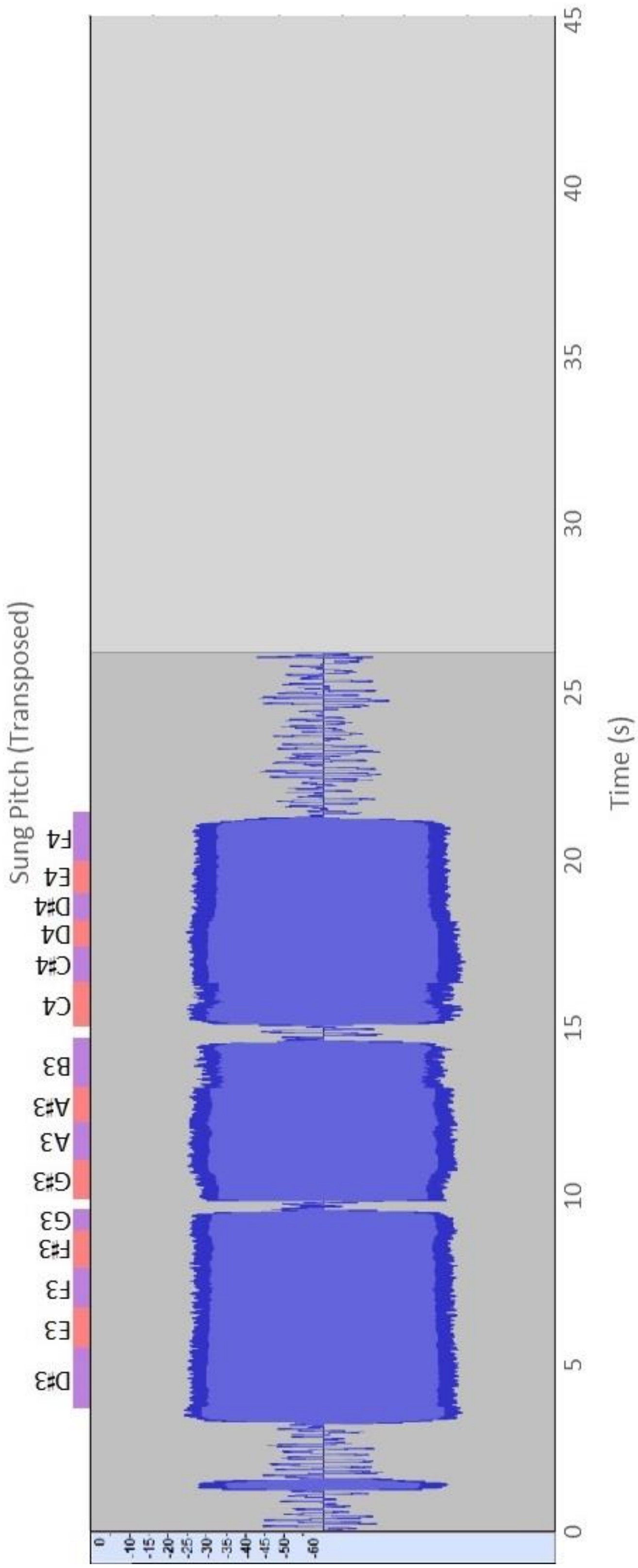


Figure C.34. Waveform dB view, play loud, sing loud, B4.

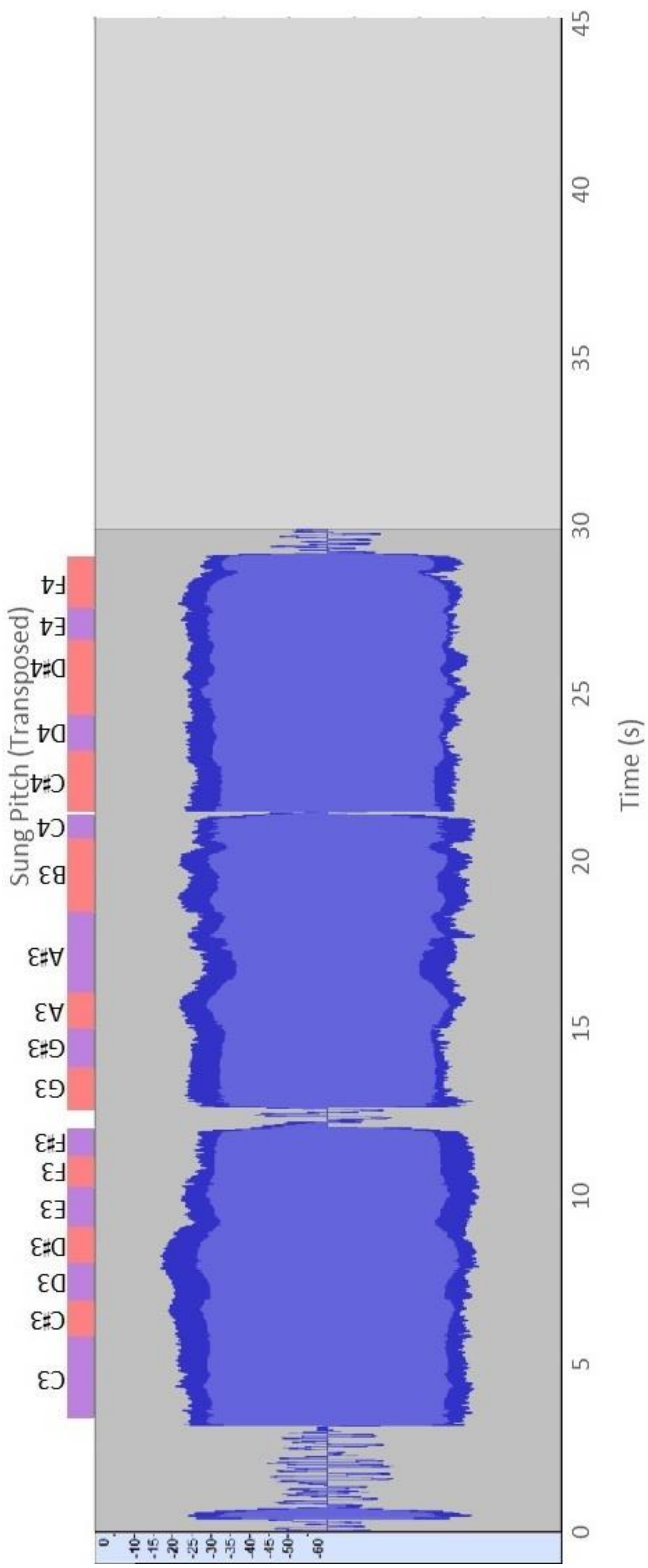


Figure C.35. Waveform dB view, play loud, sing loud, C_6.

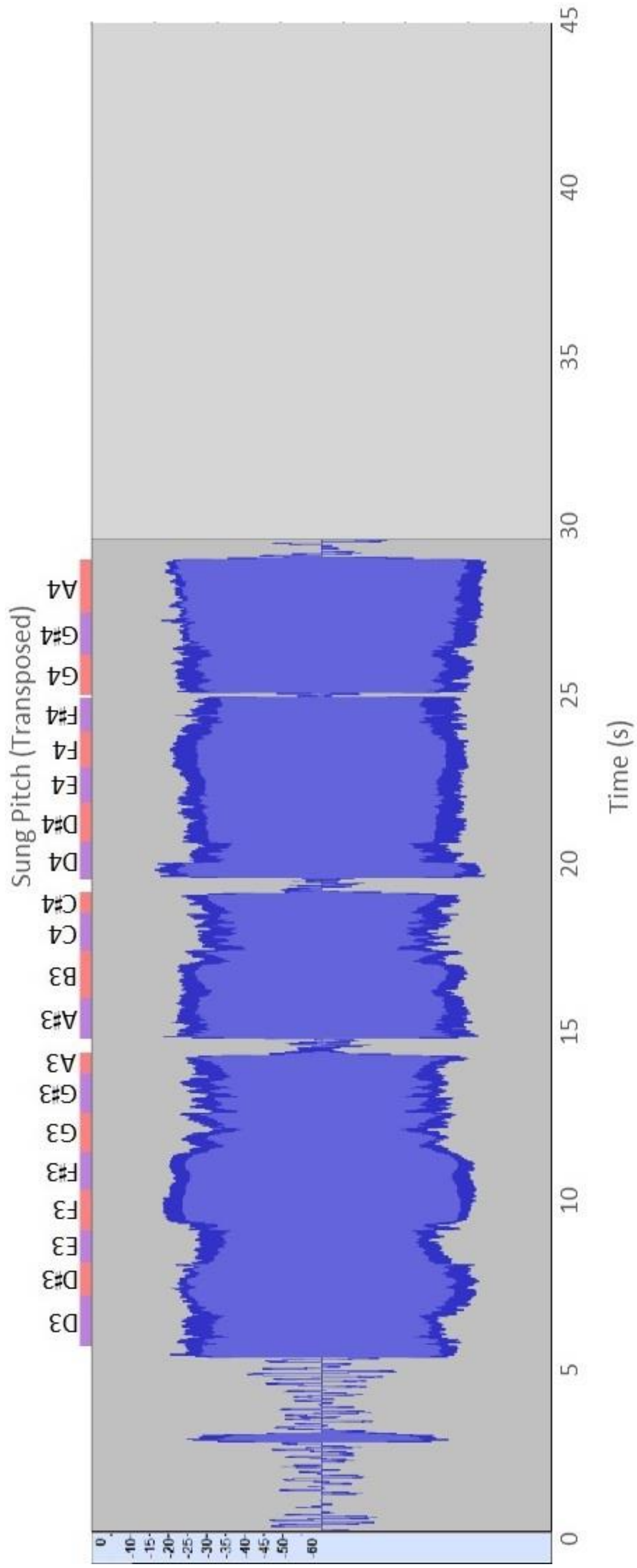


Figure C.36. Waveform dB view, play loud, sing loud, E_6.

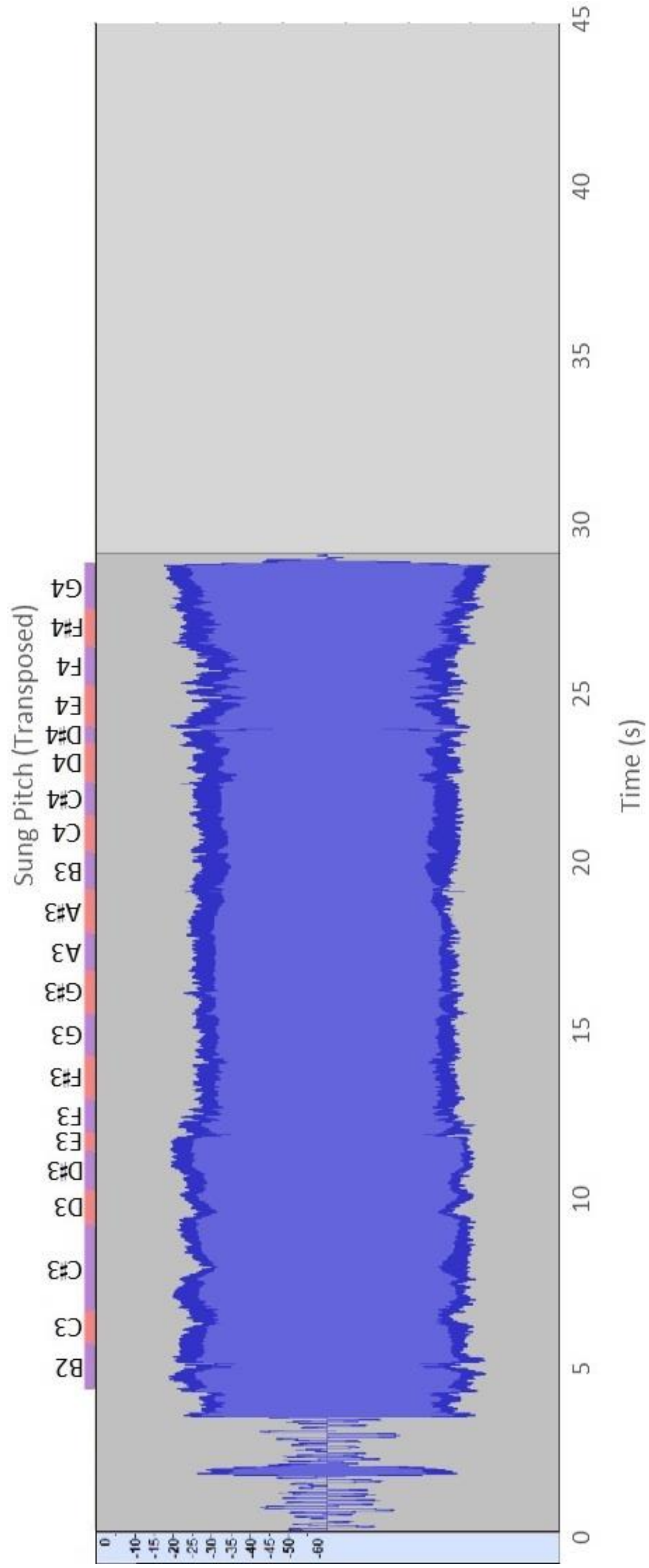


Figure C.37. Waveform dB view, play loud, sing loud, G_6.

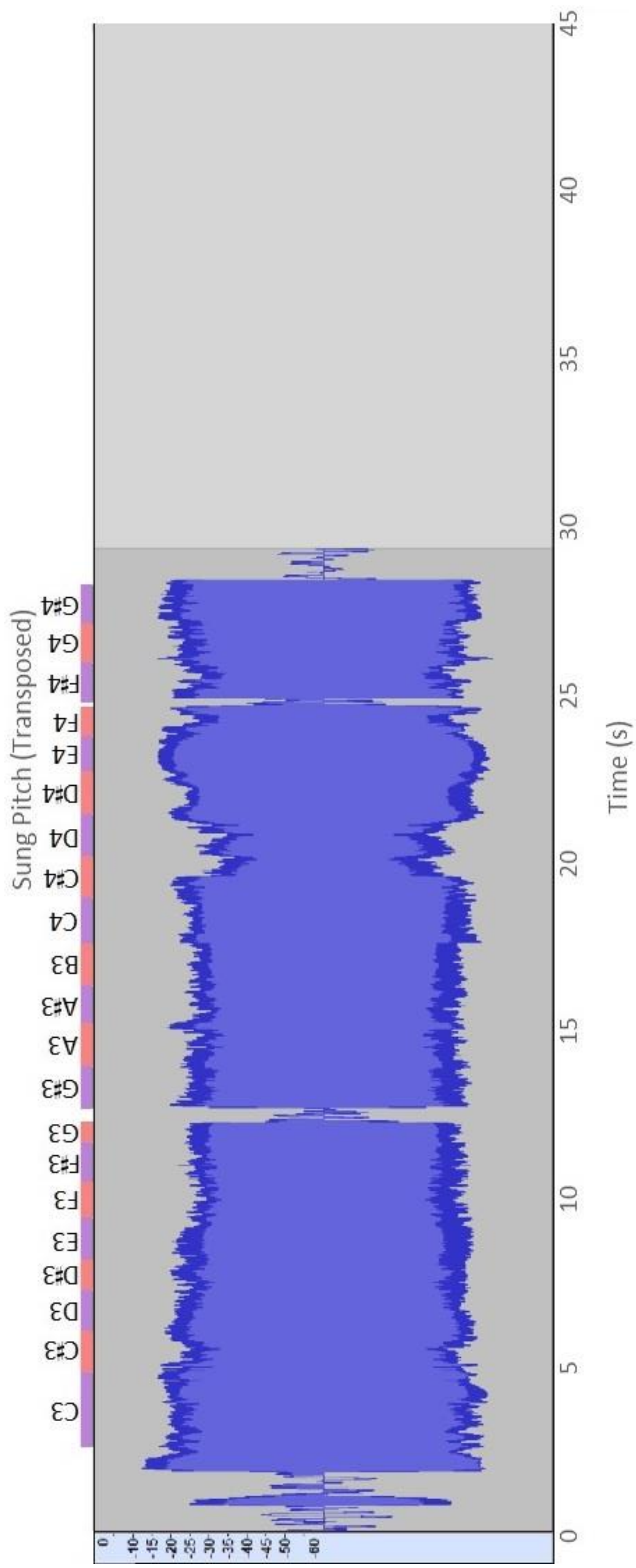


Figure C.38. Waveform dB view, play loud, sing loud, C_7.

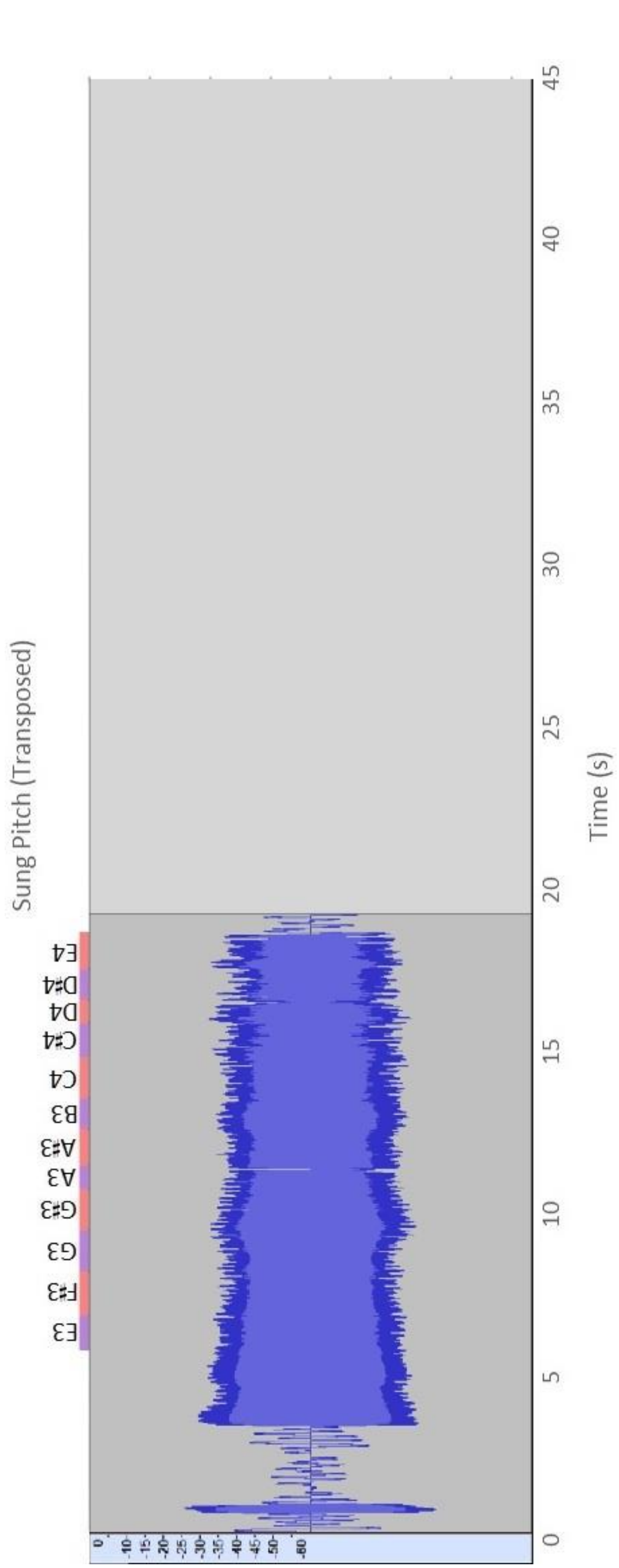


Figure C.39. Waveform dB view, play loud, sing soft, E3.

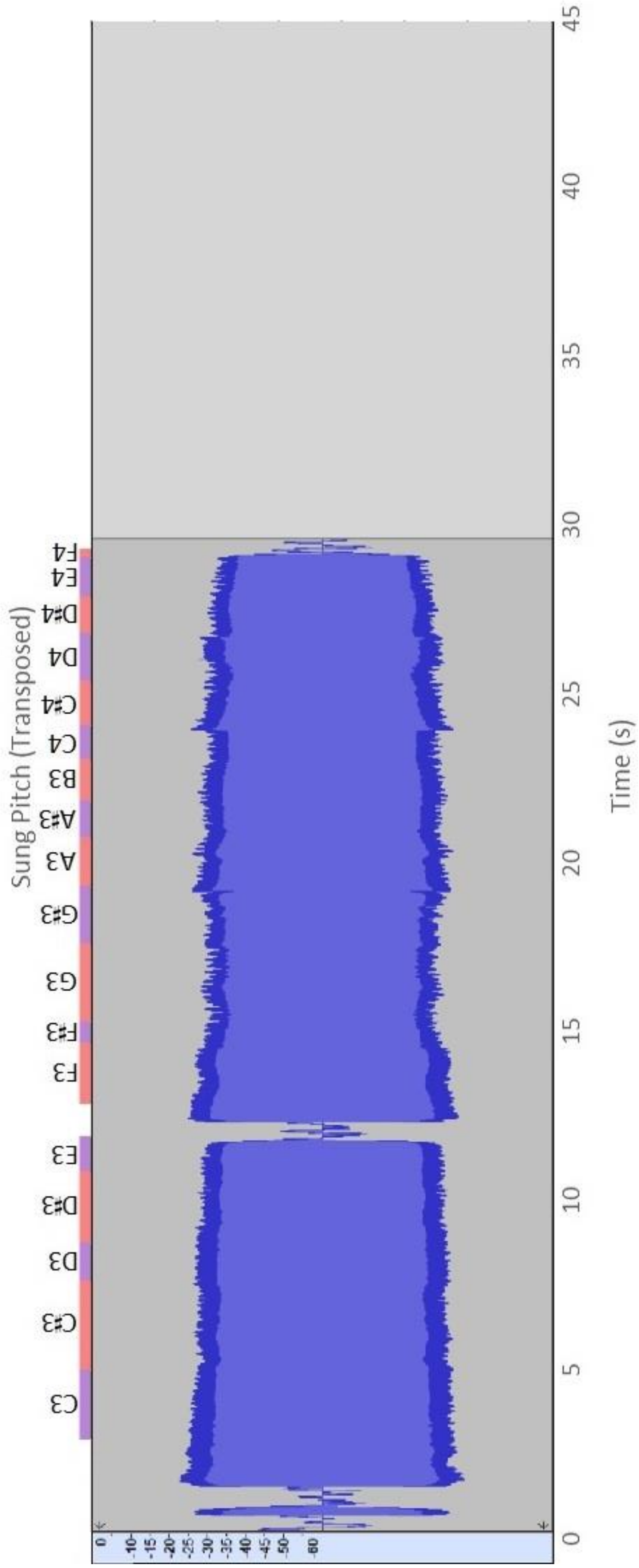


Figure C.40. Waveform dB view, play loud, sing soft, G4.

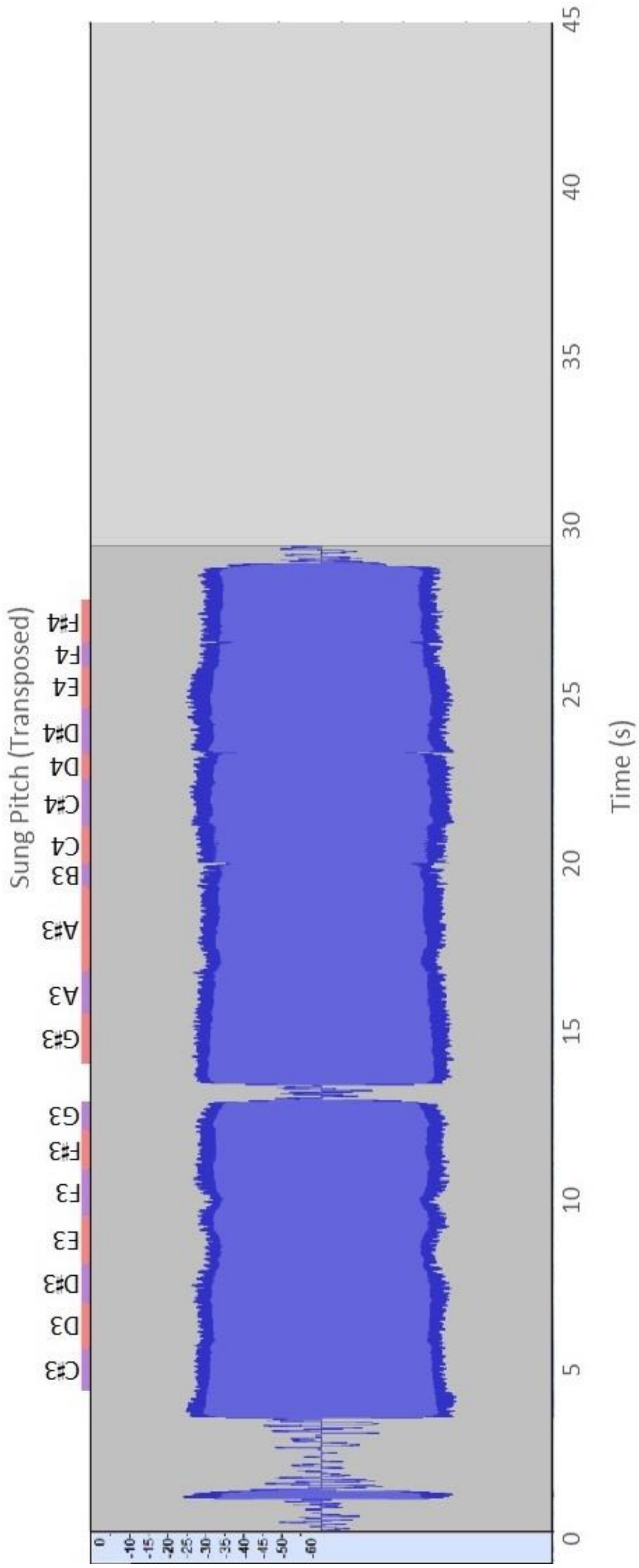


Figure C.41. Waveform dB view, play loud, sing soft, B4.

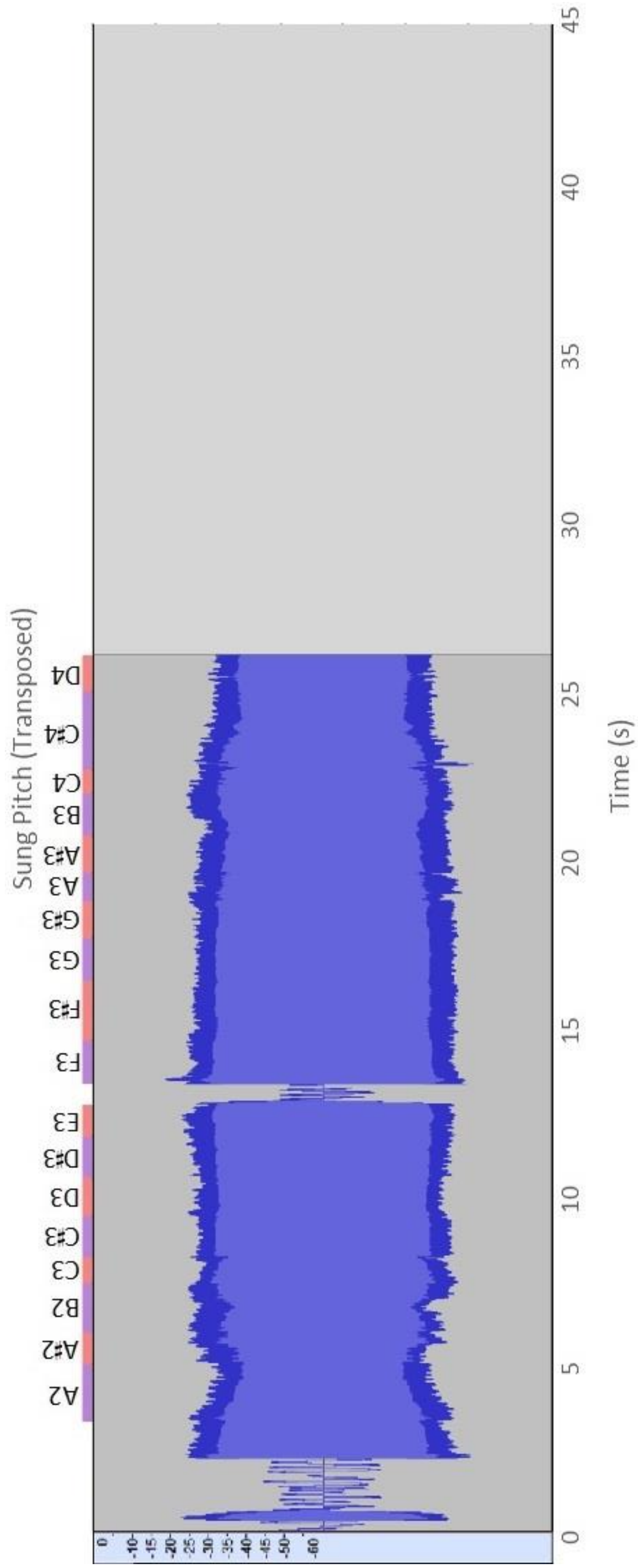


Figure C.42. Waveform dB view, play loud, sing soft, C_6.

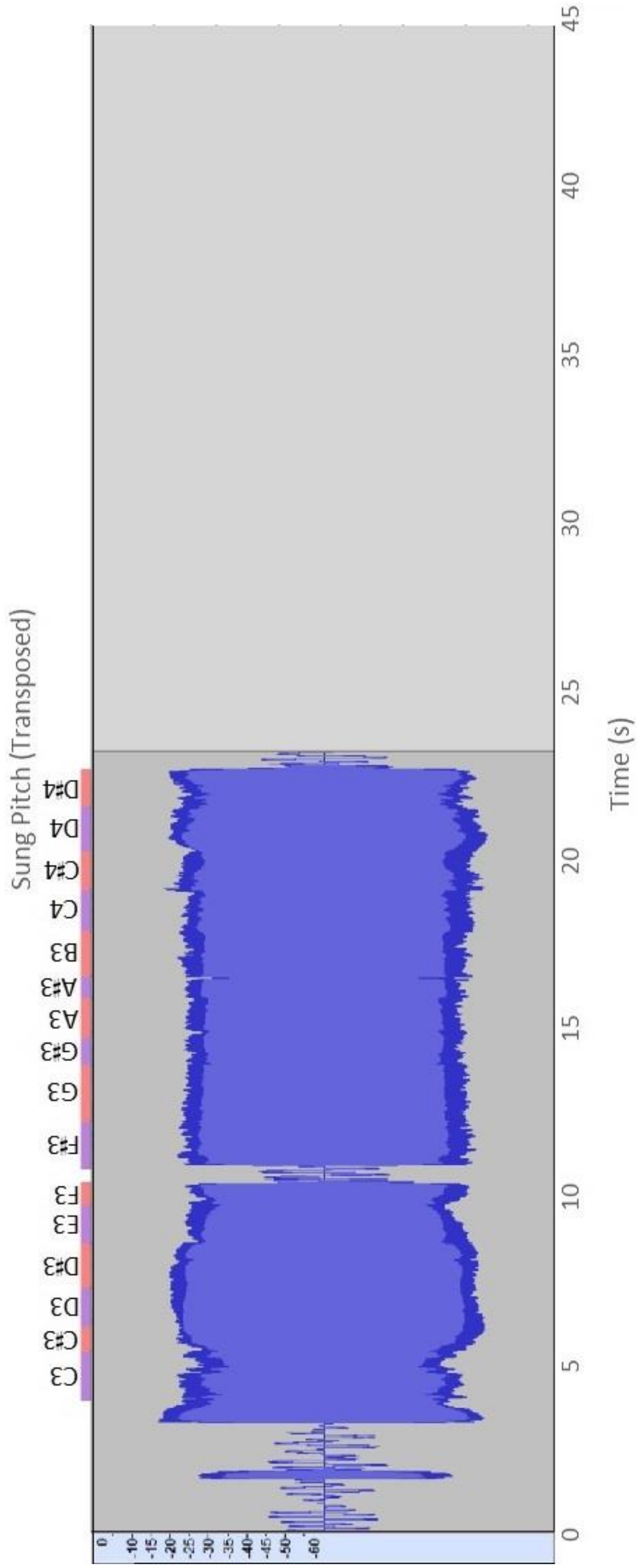


Figure C.43. Waveform dB view, play loud, sing soft, E_6.

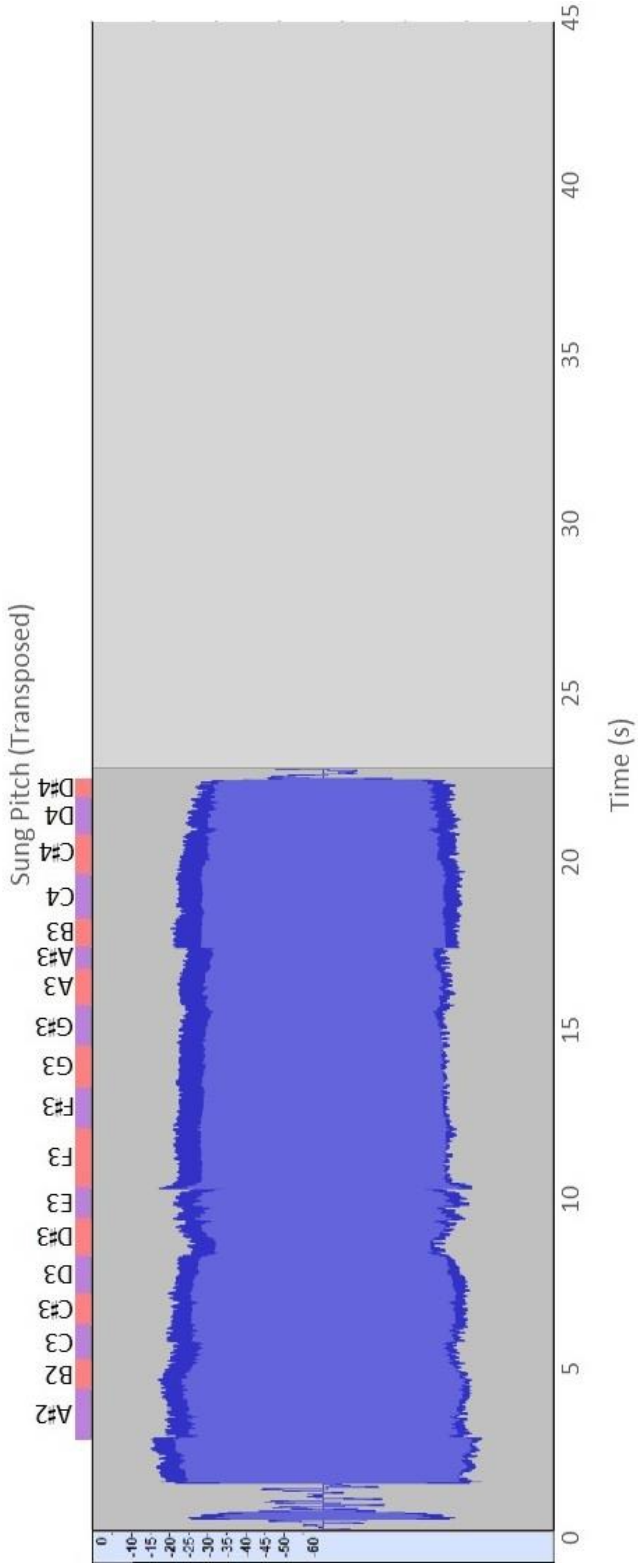


Figure C.44. Waveform dB view, play loud, sing soft, G_6.

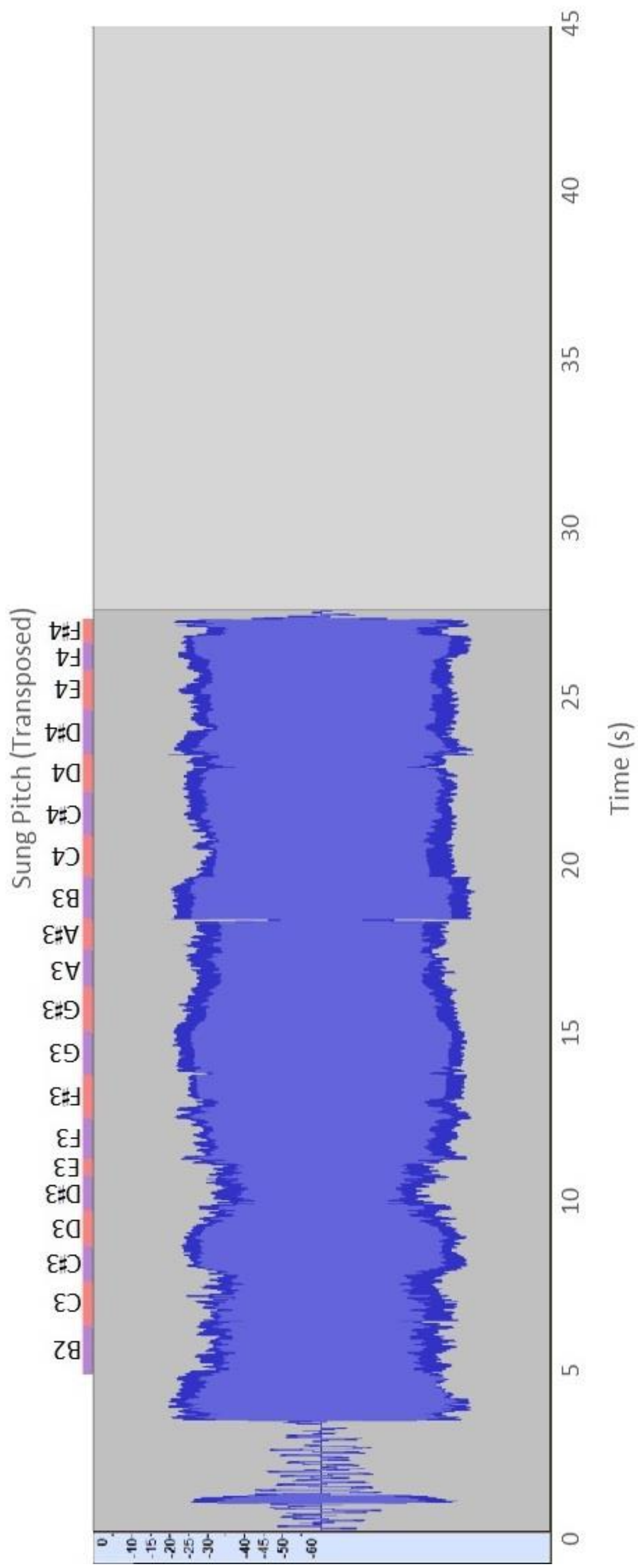


Figure C.45. Waveform dB view, play loud, sing soft, C_7.

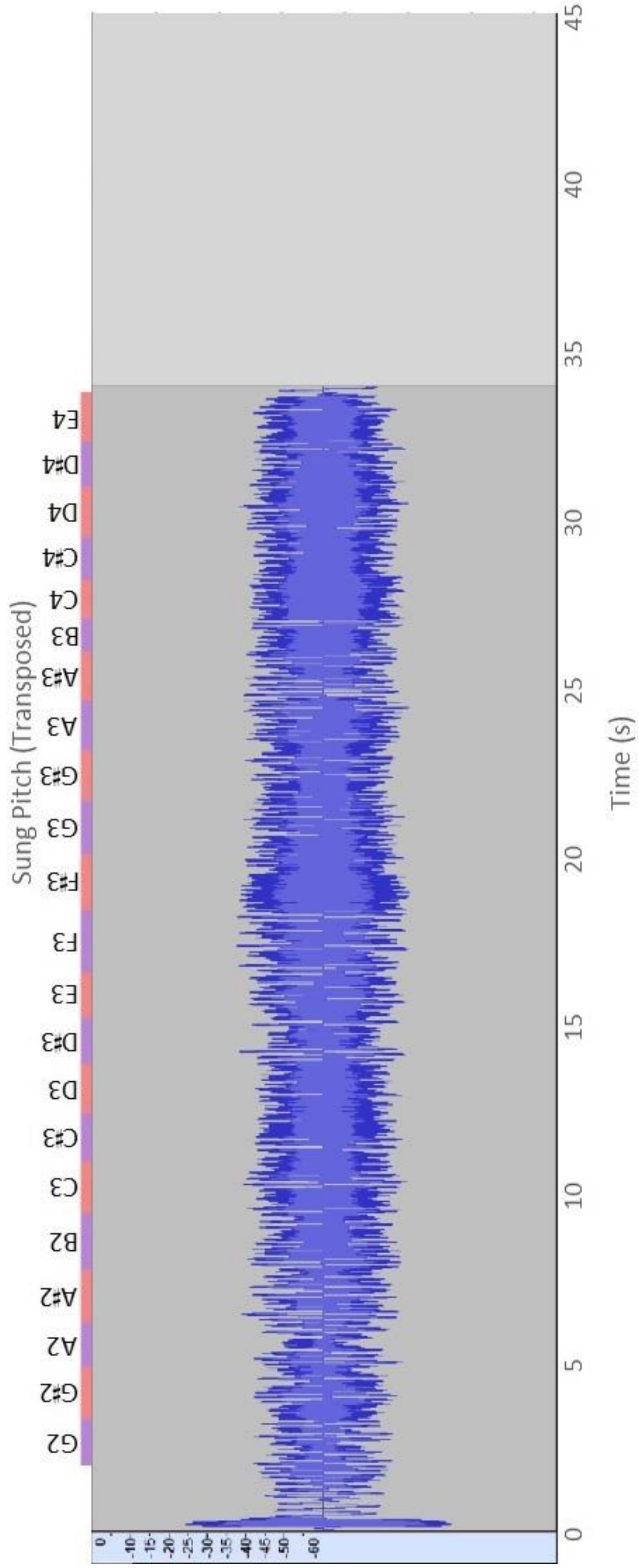


Figure C.46. Waveform dB view, play soft, sing loud, E_3.

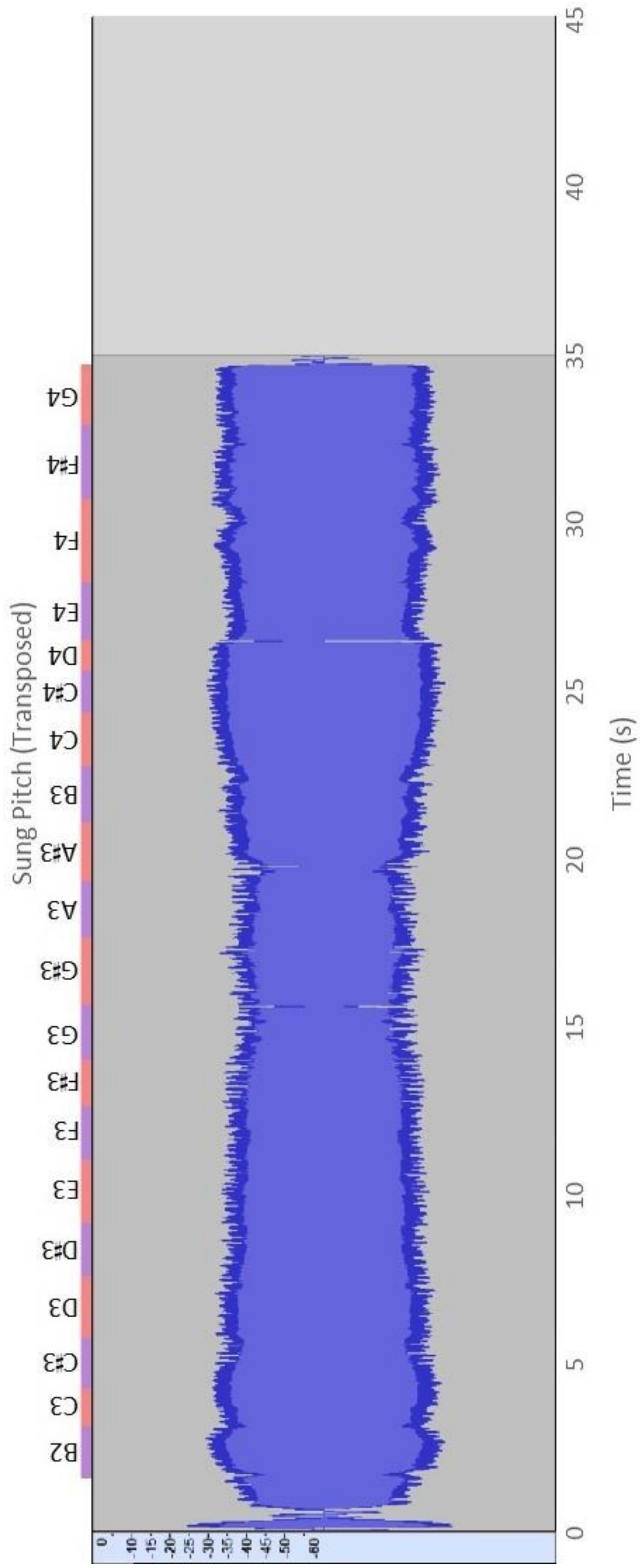


Figure C.47. Waveform dB view, play soft, sing loud, G4.

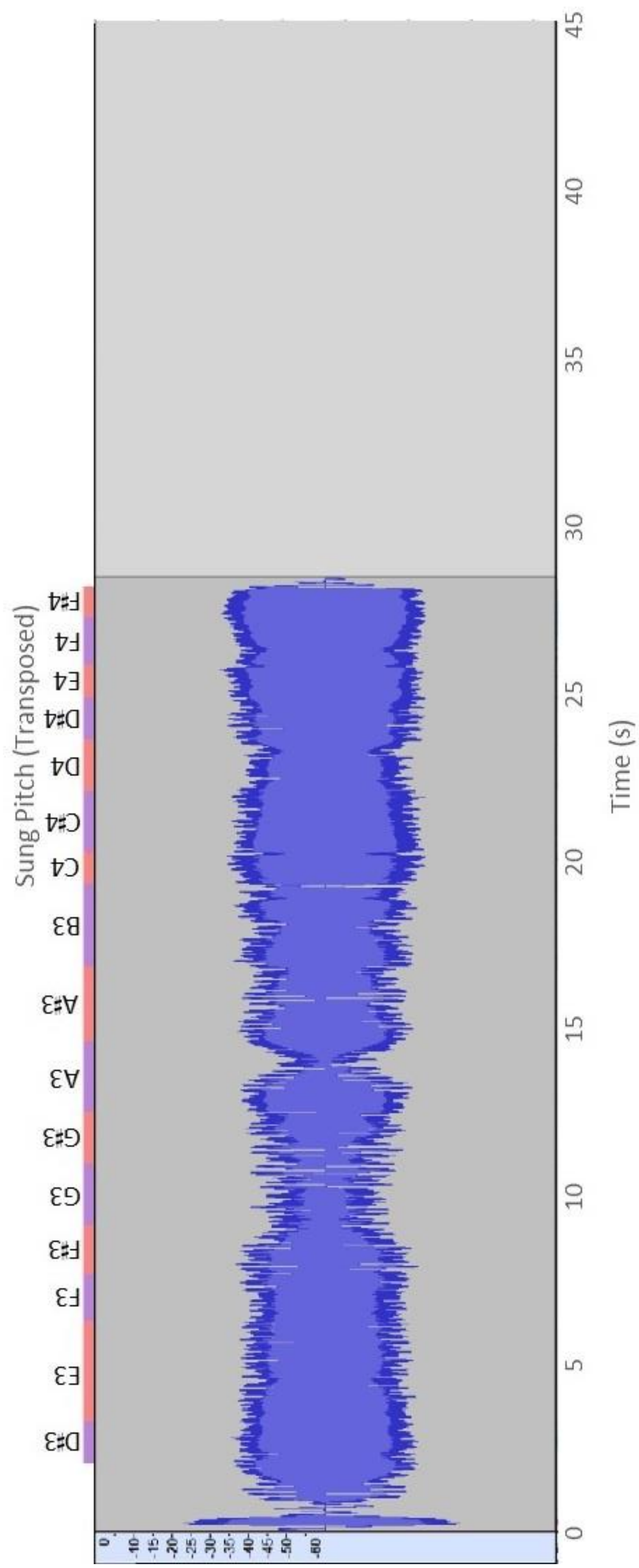


Figure C.48. Waveform dB view, play soft, sing loud, B_4.

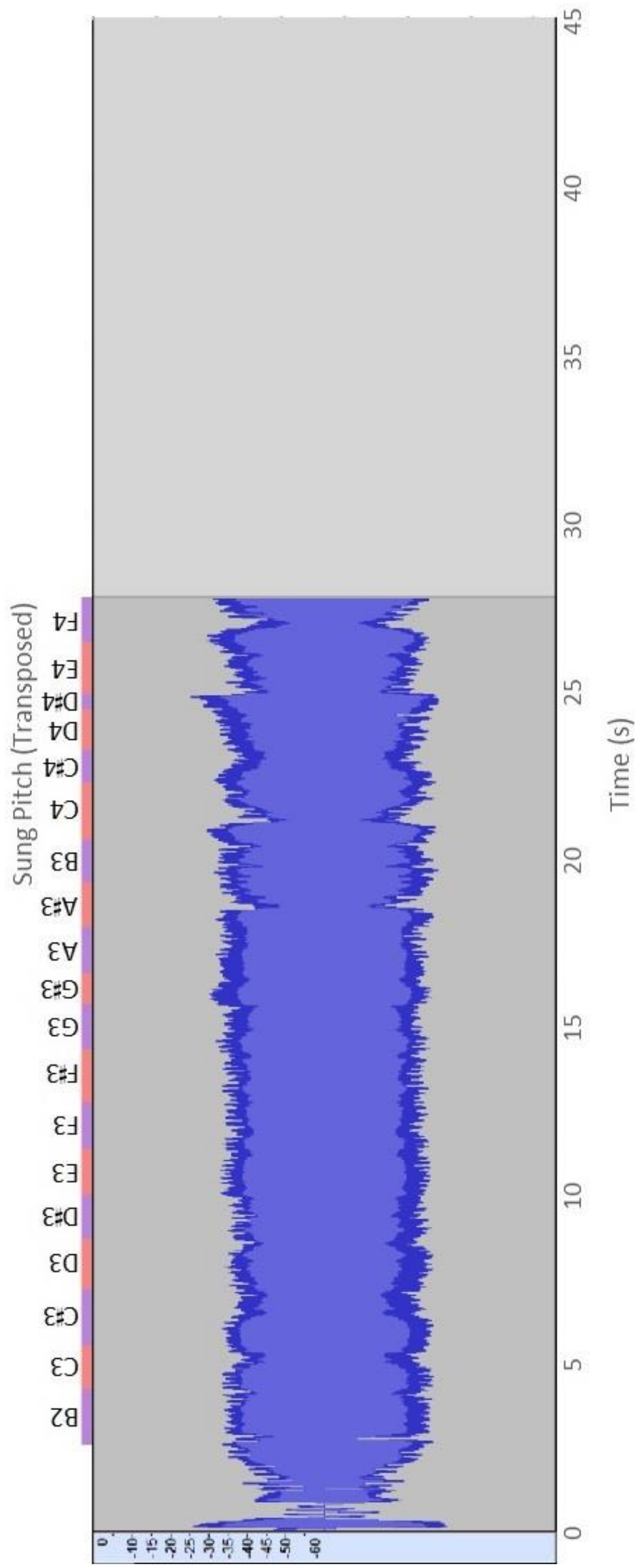


Figure C.49. Waveform dB view, play soft, sing loud, C_6.

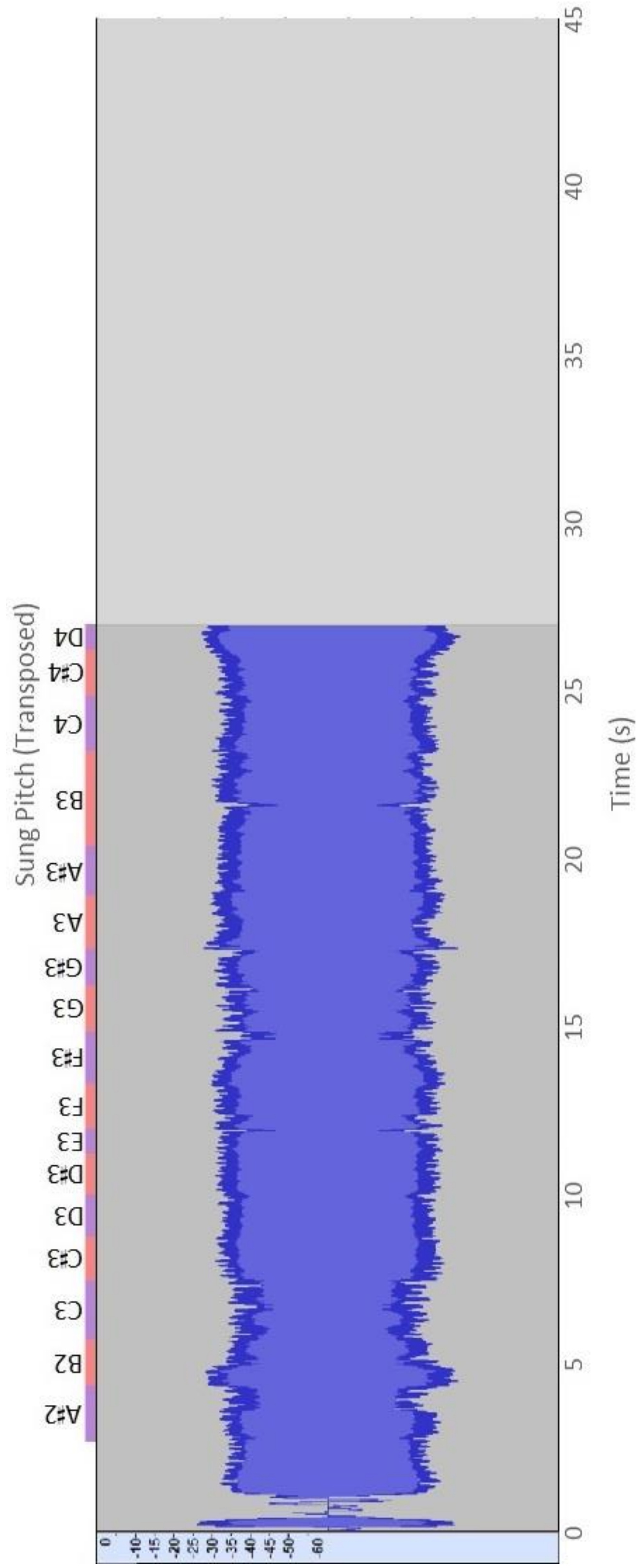


Figure C.50. Waveform dB view, play soft, sing loud, E_6.

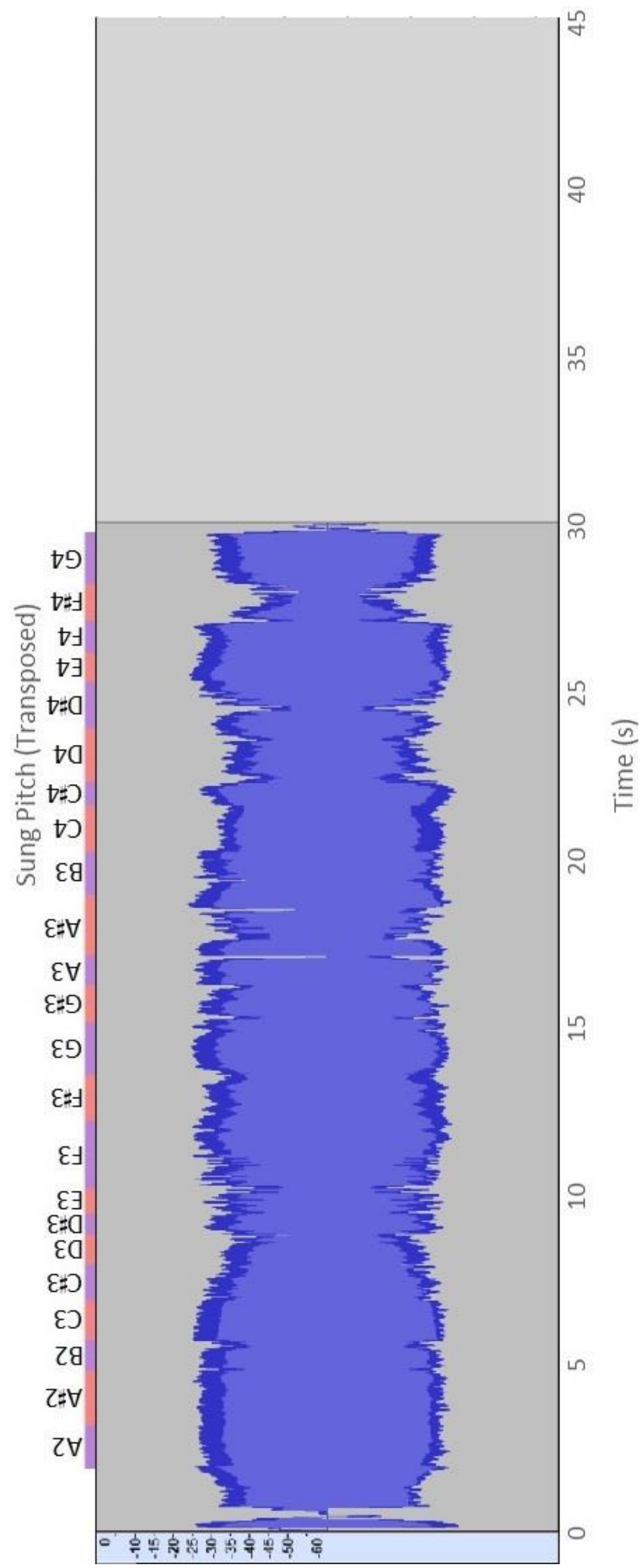


Figure C.51. Waveform dB view, play soft, sing loud, G_6.

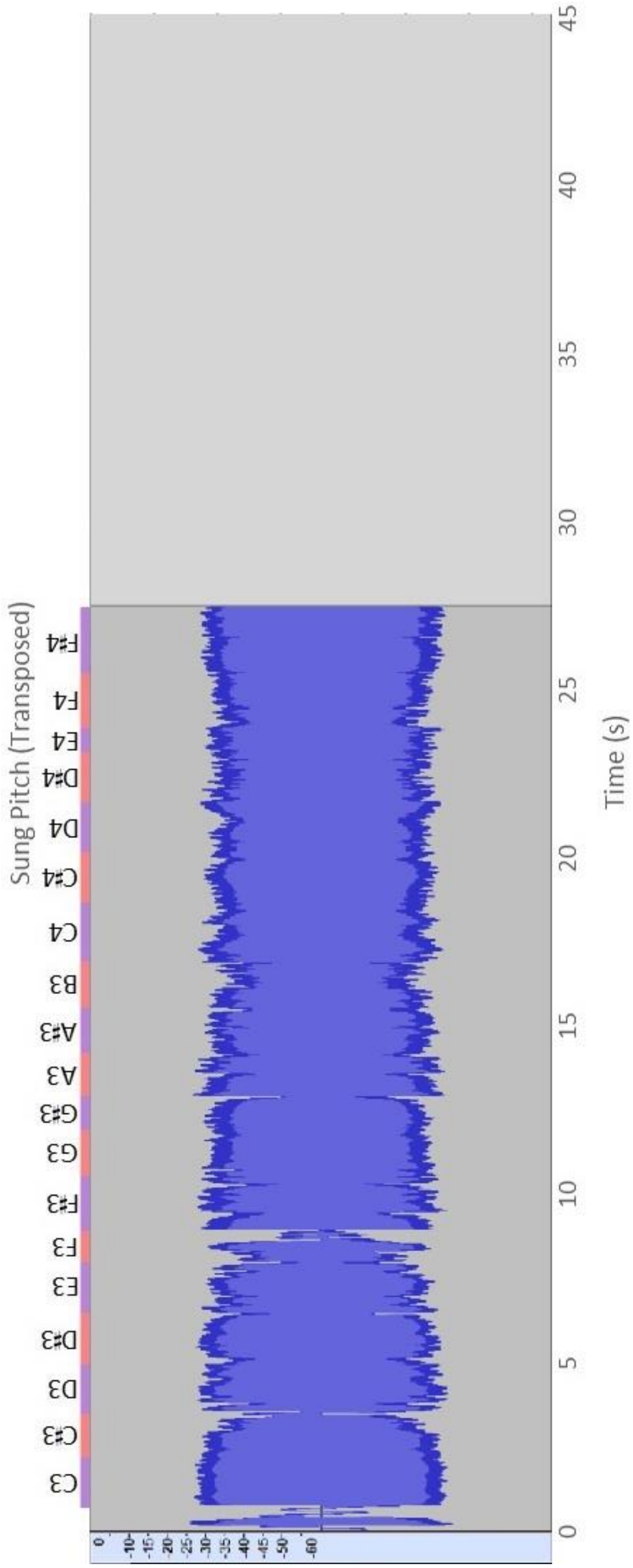


Figure C.52. Waveform dB view, play soft, sing loud, C_7.

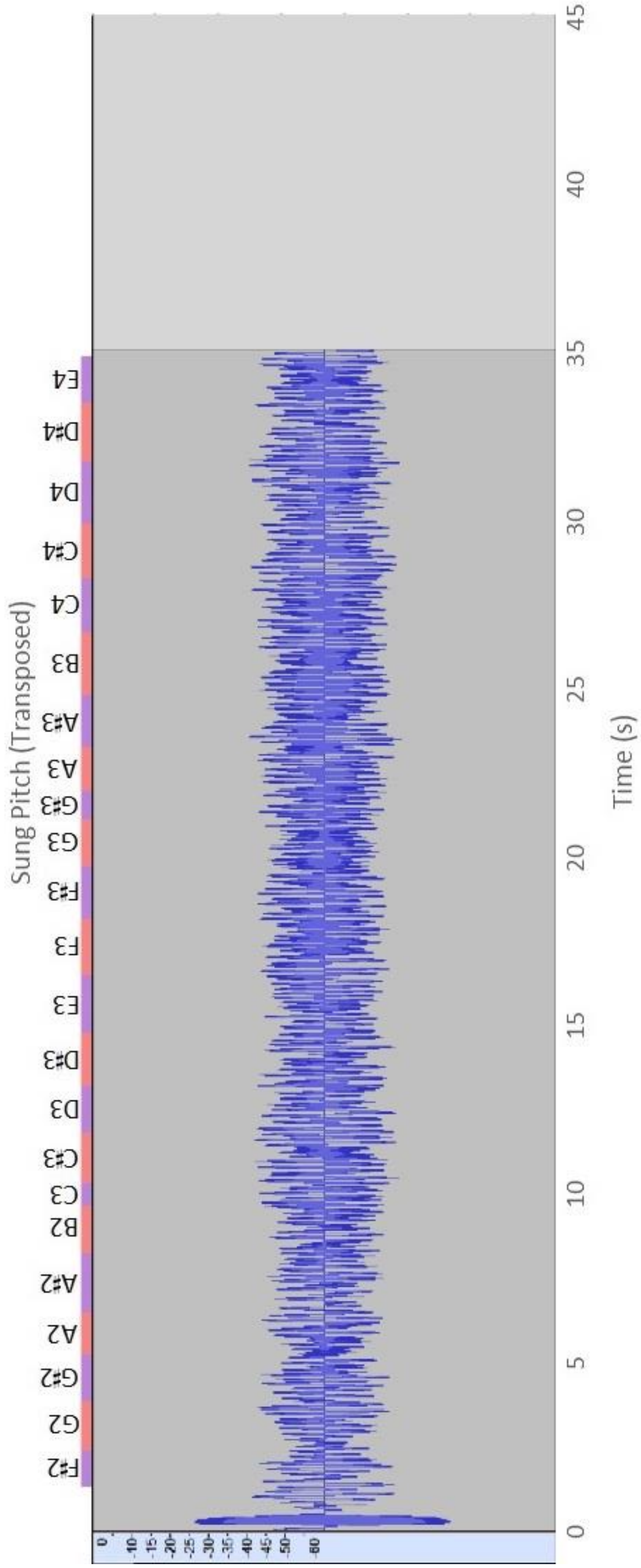


Figure C.53. Waveform dB view, play soft, sing soft, E_3.

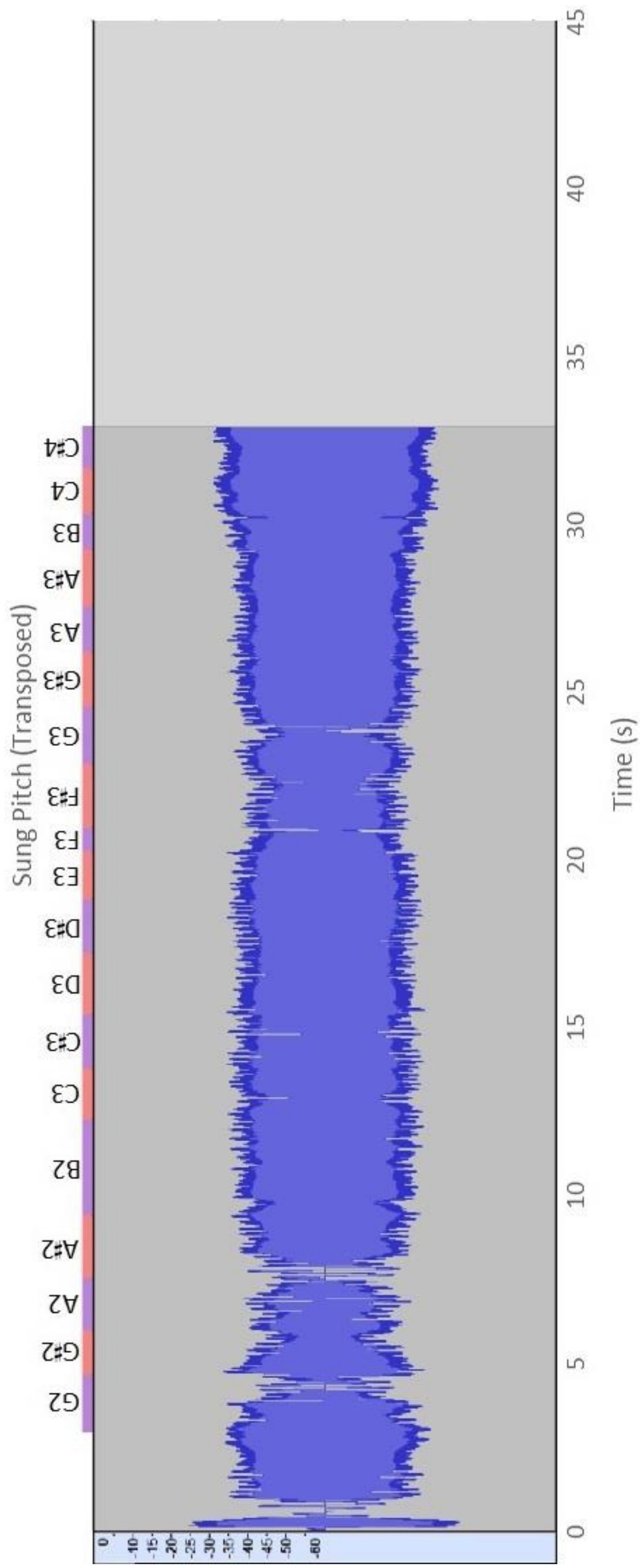


Figure C.54. Waveform dB view, play soft, sing soft, G4.

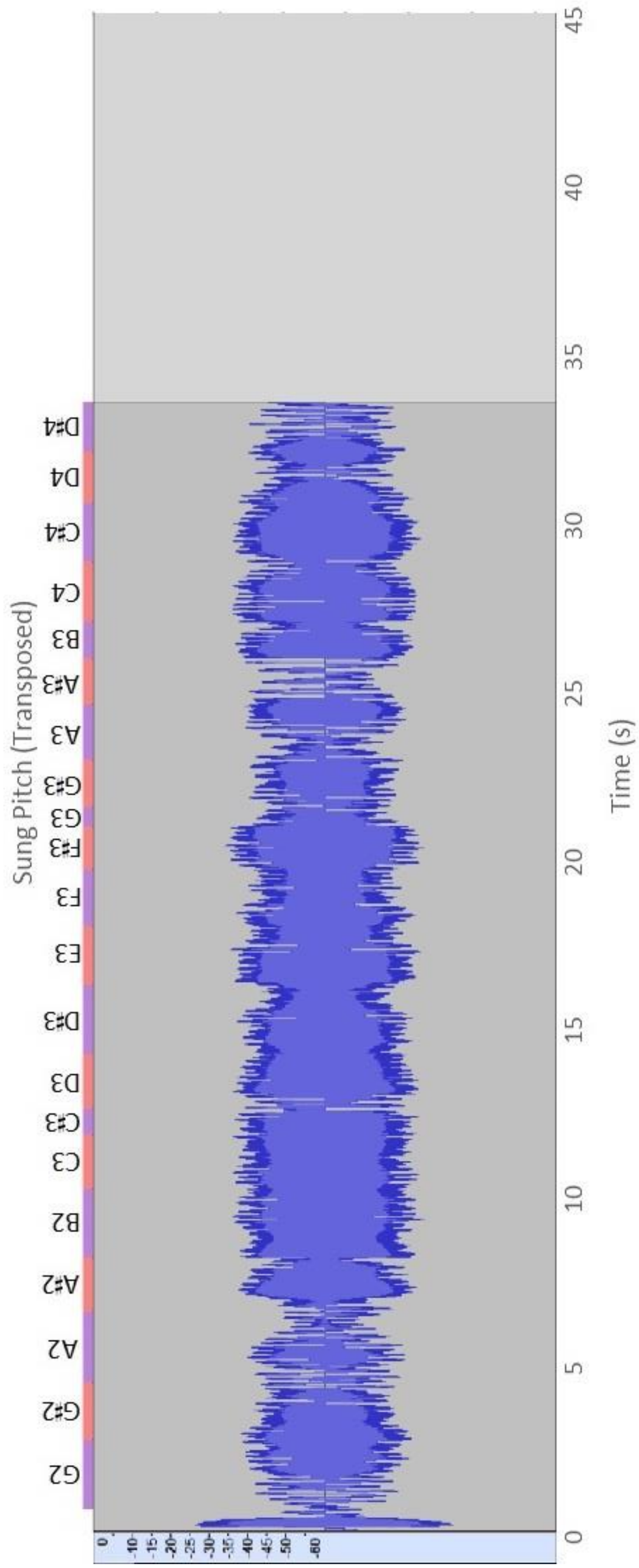


Figure C.55. Waveform dB view, play soft, sing soft, B4.

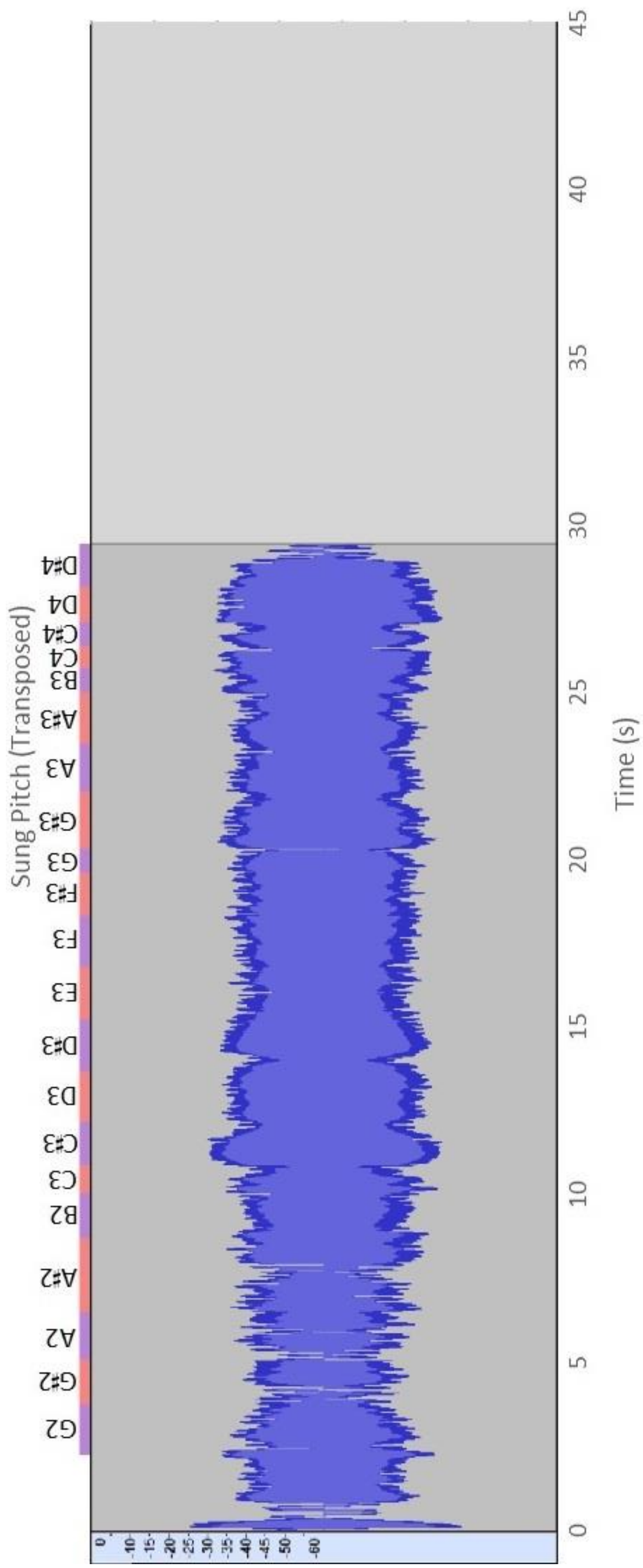


Figure C.56. Waveform dB view, play soft, sing soft, C_6.

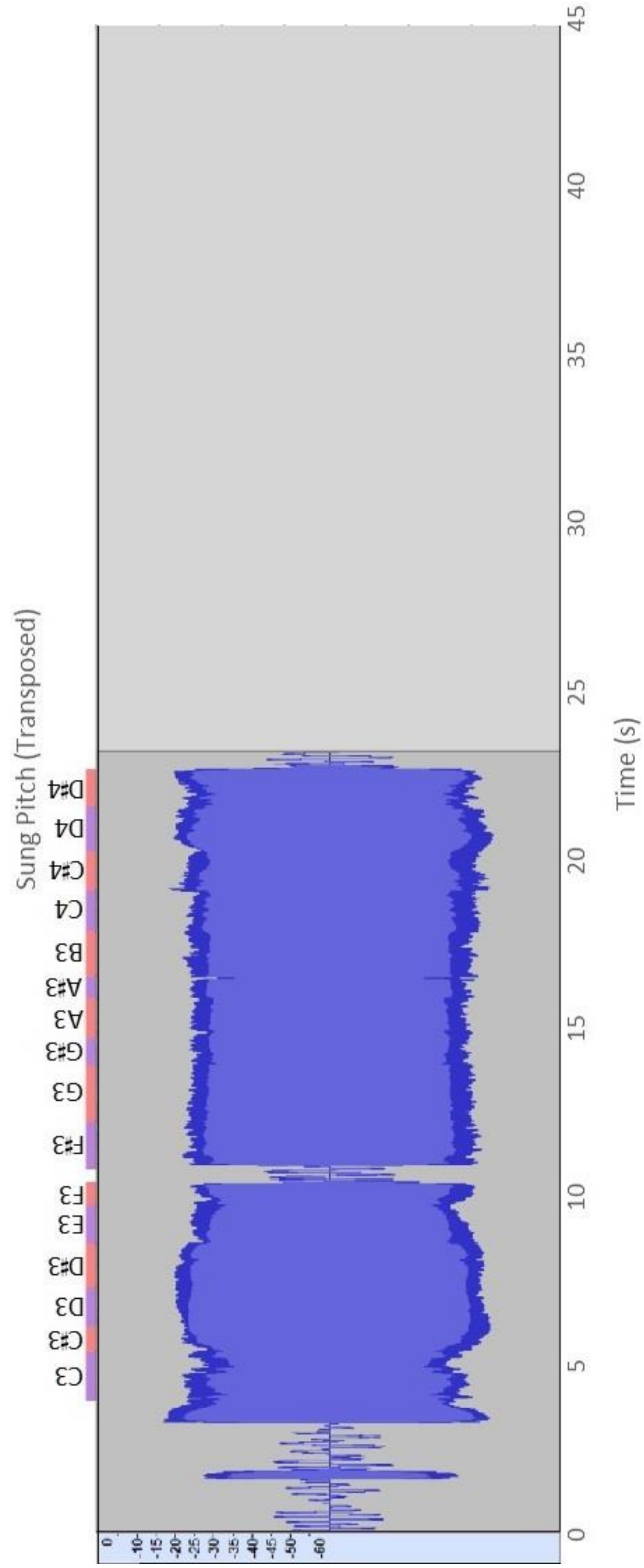


Figure C.57. Waveform dB view, play soft, sing soft, E_6.

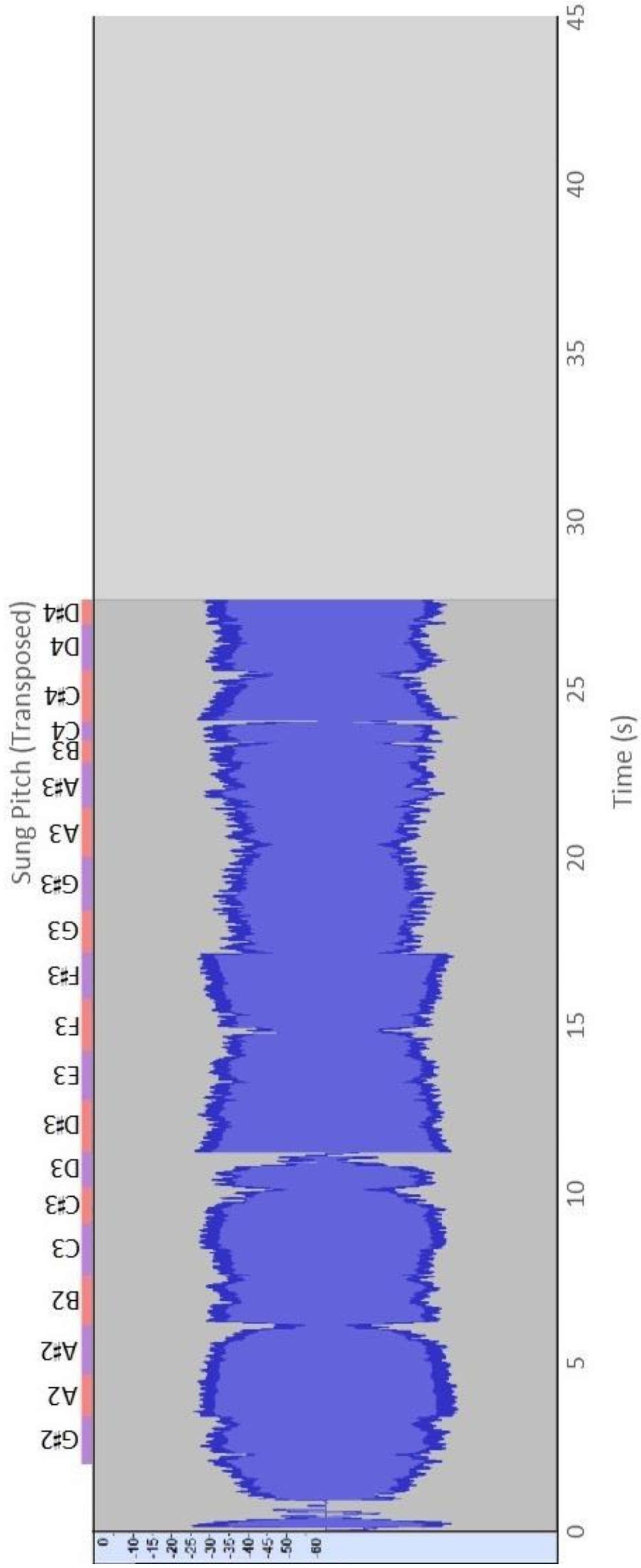


Figure C.58. Waveform dB view, play soft, sing soft, G_6.

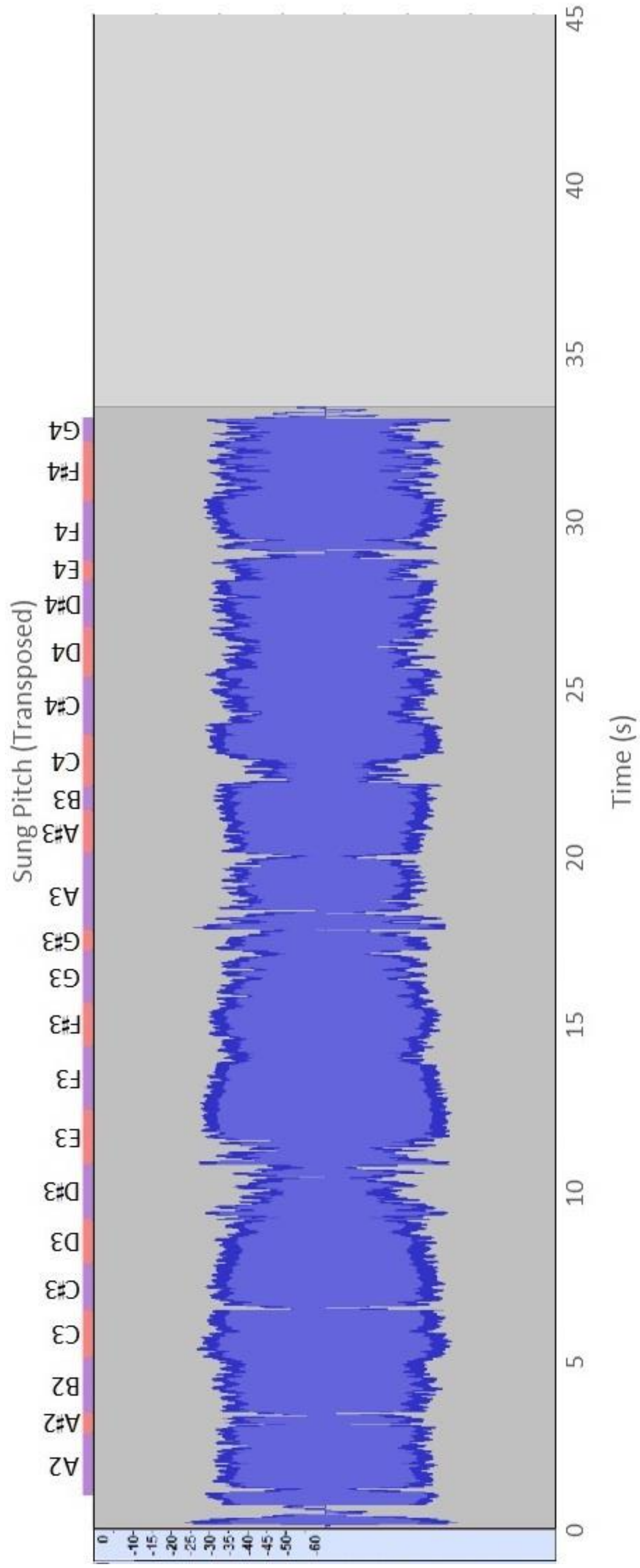


Figure C.59. Waveform dB view, play soft, sing soft, C_7.

APPENDIX D

HUMMING AND SINGING WHILE PLAYING: A METHOD

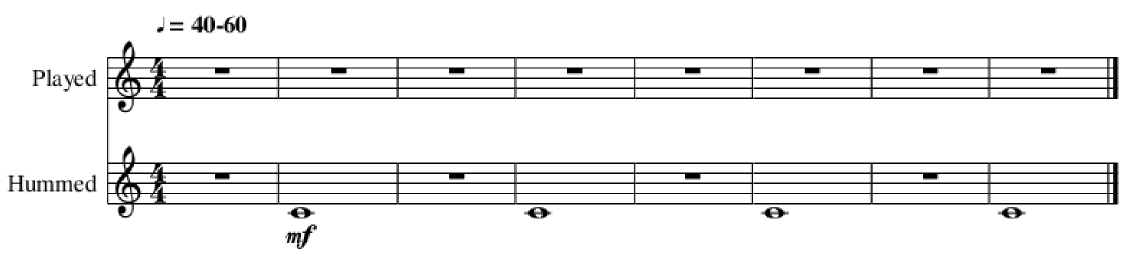
HUMMING AND SINGING WHILE PLAYING: A METHOD

Jeremy Ruth

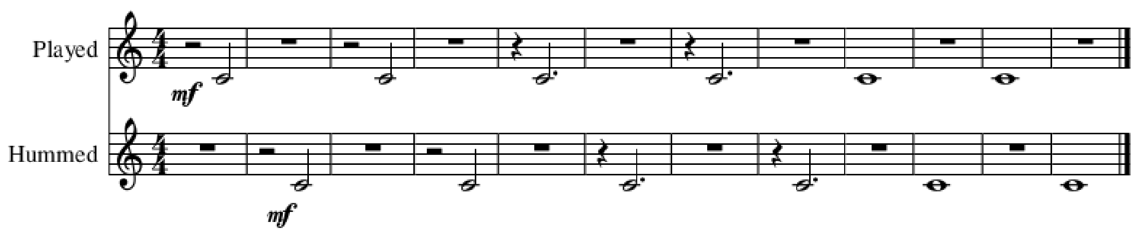
PART 1: HUMMING WHILE PLAYING

Note: At the start, all hummed pitches can be transposed up an octave if it better fits in your comfortable vocal range. Each entire exercise can also be transposed into any key for the same purpose. As you become more comfortable with humming while playing, however, your hummed range should roughly equal your normal vocal range.

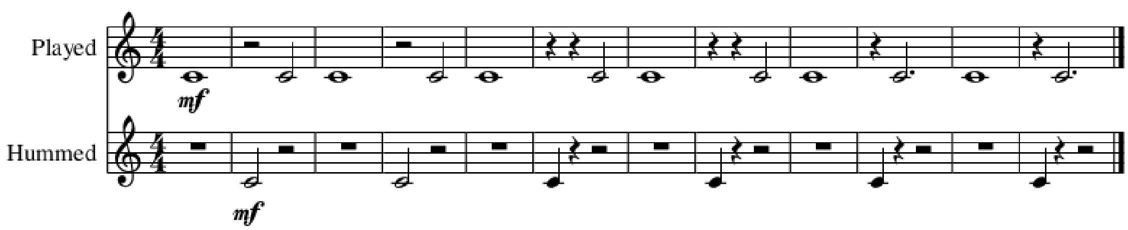
1. This first exercise should be done without the clarinet. Before beginning, close your mouth and puff out your cheeks until they are filled with air. Your tongue and soft palate should move to a position as if you are making an "eng" sound as in the word "cling." Once you have done this, breathe in through your nose during the whole rests in mm. 1, 3, 5, and 7. Without changing anything in your oral cavity, hum out through your nose as indicated in mm. 2, 4, 6, and 8. Note where your tongue and soft palate meet—when adding the clarinet in the exercises that follow, this should feel the same during humming, since the oral cavity must be closed off from the rest of the vocal tract to properly hum and play.



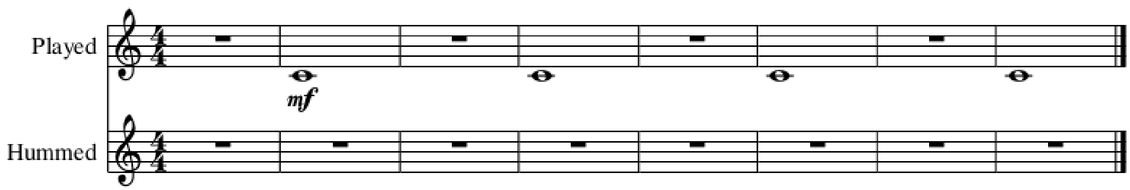
2. Focus on shifting quickly from standard clarinet embouchure to puffed cheeks with the "eng" syllable and back again. In mm. 2 and 4, after puffing your cheeks out, try to inhale through your nose on beat 2. This will ensure that your tongue and soft palate are indeed closing your oral cavity off from the rest of your vocal tract, as you practiced without the clarinet in Exercise 1. As the length of transition time between playing and humming gets shorter and shorter, you will no longer have time to inhale between played and hummed notes. Make sure your cheeks still puff out and your tongue and soft palate meet in an "eng" syllable just as before.



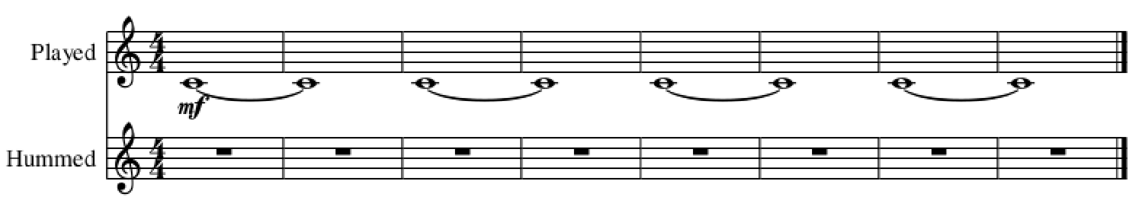
3. In this exercise, focus on being able to quickly produce the hummed pitches and immediately shift back to the regular air stream. As in Exercise 2, you no longer have time to inhale between played and hummed notes.



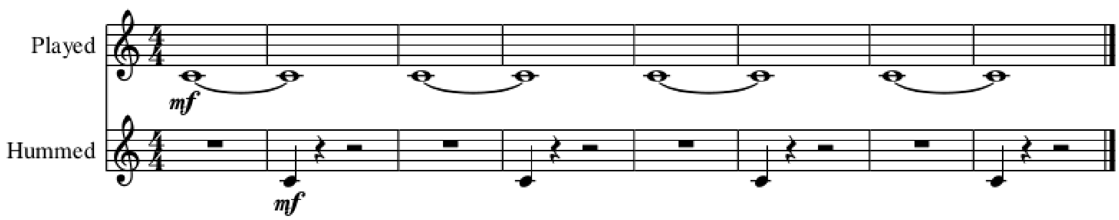
4. In this exercise, puff out your cheeks as in Exercises 1-3, but instead of humming, you will play the clarinet pitch by gradually squeezing the air stored in your oral cavity through the clarinet. Use the whole rests in mm. 1, 3, 5, and 7 to breathe and make sure that your oral cavity is set properly, and then simply play the written pitch without changing from the "eng" syllable. When you run out of air in your oral cavity, the sound should stop. It is okay if you run out of air quickly and cannot play a whole note at first—just practice squeezing the air out with your cheeks slower or faster to change how long you can maintain a played pitch using only "cheek air."



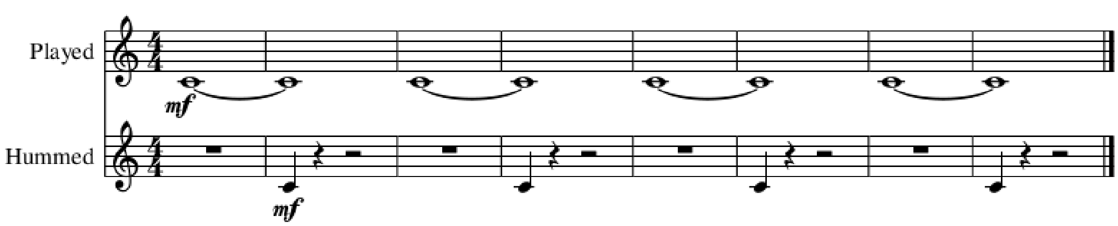
5. The point of this exercise is to transition from playing with a regular air stream to playing with air stored in the oral cavity, as in Exercise 4. The whole notes in mm. 1, 3, 5, and 7 should all begin using a regular air stream. The whole notes in mm. 2, 4, 6, and 8 should all be played using only cheek air. As in Exercise 4, it is okay if you cannot hold the whole notes played with "cheek air" for their full values. Continue to adjust how quickly you expel the air from your oral cavity with your cheeks. In order to smoothly transition from one air stream to another, you must quickly and seamlessly connect three steps that you have already practiced in Exercises 1-4. First, while playing normally, puff your cheeks. Next, while still using the regular air stream with your cheeks puffed out, move your tongue to the "eng" syllable position to seal off the air stored in your oral cavity from the rest of your vocal tract. Finally, as you are finishing the previous step, you must coordinate your cheeks to begin expelling "cheek air" just as your tongue moves to the "eng" position and cuts off the regular air stream. In order to smoothly transition, the final two steps must occur almost simultaneously.



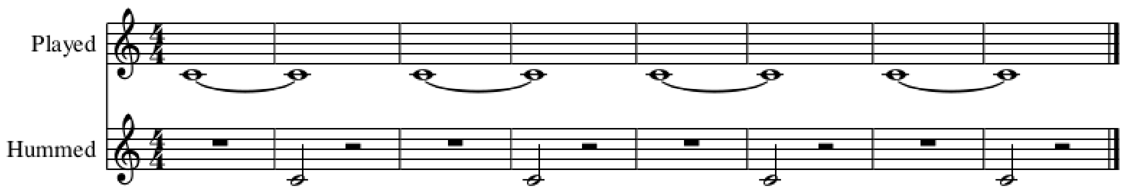
6. The played portion of this exercise should be performed identically to Exercise 5, beginning the whole notes in mm. 1, 3, 5, and 7 with a regular air stream before transitioning to cheek air for the whole notes in mm. 2, 4, 6, and 8. The only difference in this exercise is now every time you switch to cheek air, you must simultaneously hum a pitch for one beat. You have already practiced each isolated element required for Exercise 6 in Exercises 1-5, but now you must simply put them all together.



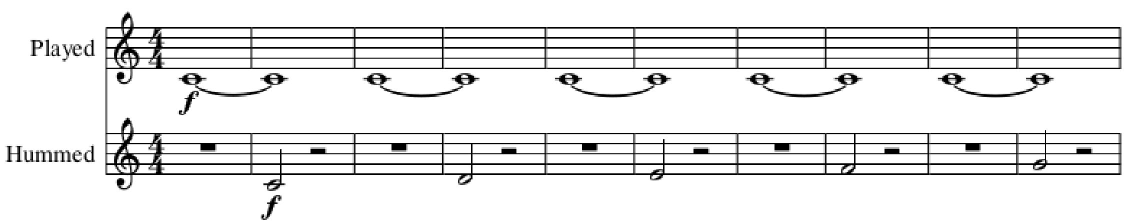
7. In this exercise, you will add the last fundamental element of humming while playing, which is the transition back to the regular air stream. Instead of playing the whole notes in mm. 2, 4, 6, and 8 using only “cheek air,” you will now transition back to the regular air stream as soon as you have hummed the quarter notes on beat one of each of those measures. To transition back, you essentially just reverse the initial transition. As you are expelling cheek air into the clarinet, you will move your tongue away from your soft palate and back to the position it started in when you were playing normally. This will once again connect your oral cavity to the rest of your vocal tract, so you must begin generating a regular air stream just as you start to move your tongue out of the “eng” syllable position.

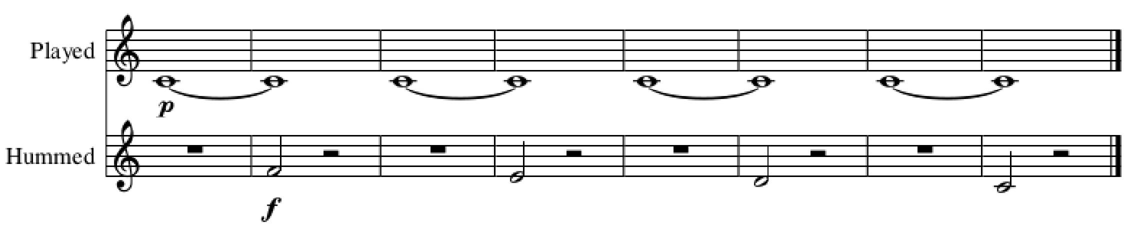


8. Play this exercise using the same principles as in Exercise 7. The hummed note is now longer, so the “cheek air” must also be used for a longer period. Any time you use the humming while playing technique, you must also utilize “cheek air” with a sealed off oral cavity for the duration of the hummed notes.

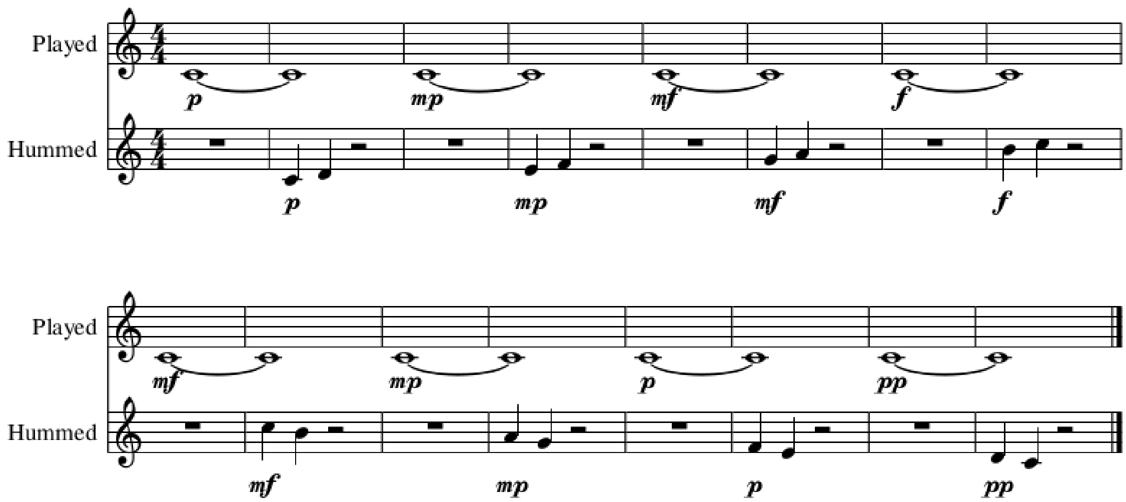


9. Once you are comfortable with the fundamentals of humming while playing, you can then begin to hum and play more complex lines. This exercise keeps the same played pitch, but adds an ascending scale in the hummed line. Also practice adding played dynamic changes while maintaining the forte hummed dynamic.

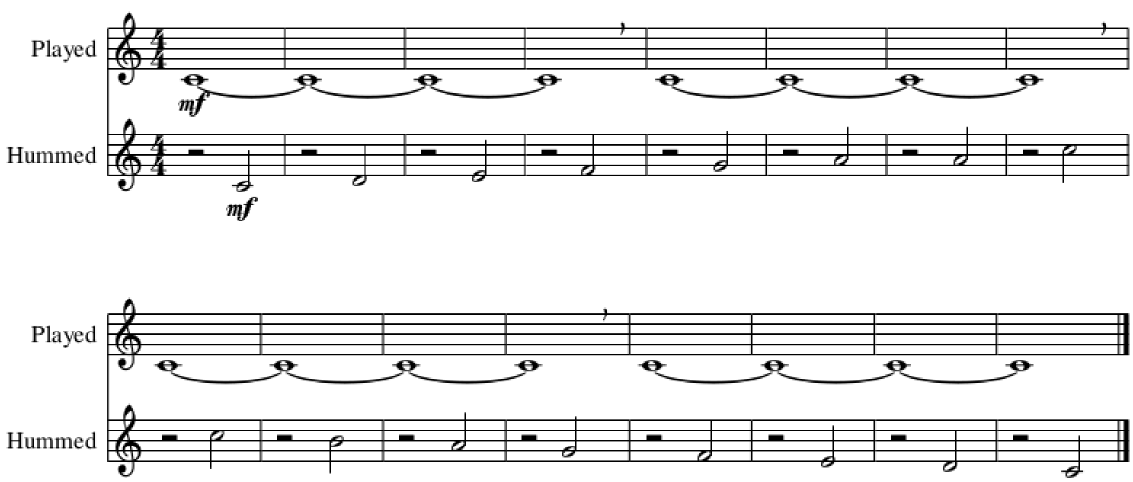




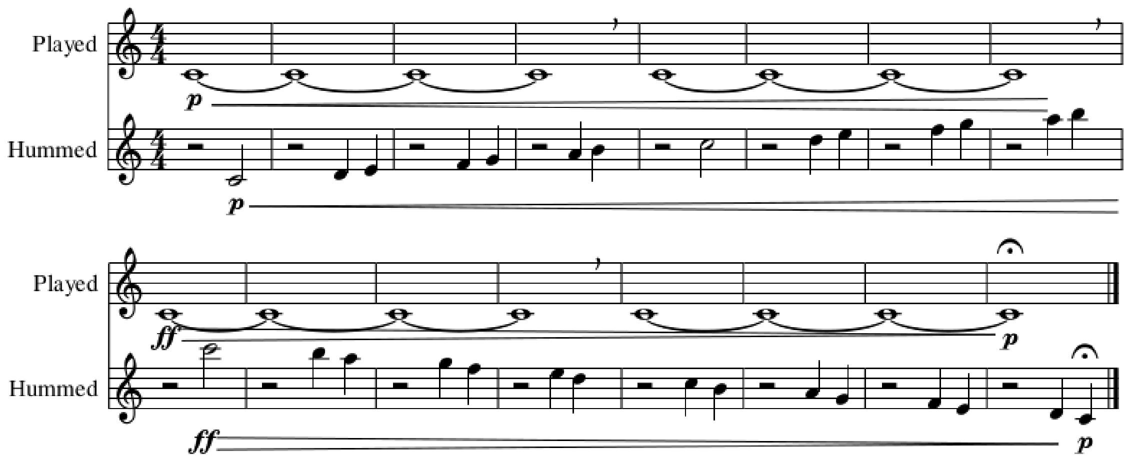
10. This exercise expands the range from Exercise 9, while also fitting two hummed notes into one expulsion of “cheek air.” Focus on quickly and accurately changing hummed notes, but while still humming each one for the full duration. Also try matching the changing played dynamic with your humming each time the played dynamic changes.



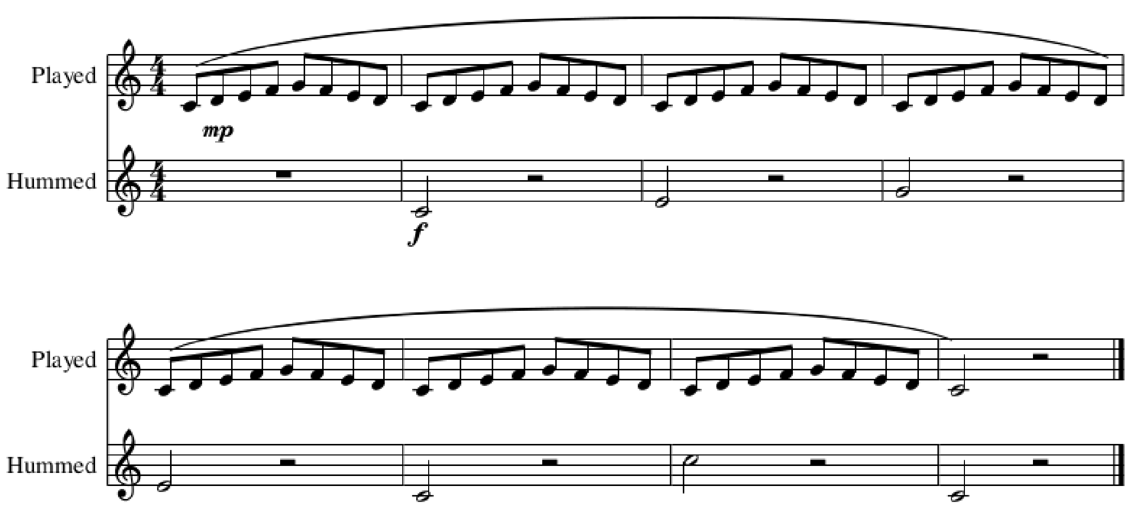
11. This exercise shortens recovery time between each humming section . Try to make each four-measure section between breath marks continuous, and use the half rests to quickly replenish “cheek air” in time to hum the next half note.



12. This exercise combines the shorter recovery times from Exercise 11 with the faster hummed note changes from Exercise 10, in addition to continuing to expand the hummed range and adding hummed octave leaps at the end. Mastering this exercise should make you more comfortable with utilizing more of the technical possibilities of the vocalized element of humming while playing.



13. In this exercise, focus on becoming comfortable with changing played notes while humming. You can repeat the first measure several times at first before moving on to the subsequent measures to get comfortable with the repeated played pattern. Once you can hum and play the pattern together, listen to make sure that your played notes remain even as you shift to and from humming.



14. Focus on making the crescendos and diminuendos in the played part as smooth as possible, just as you make the transitions (particularly at the top of the played arpeggio) between air streams as smooth as possible to eliminate any audible breaks in the sound.

15. Start this exercise slowly, and work to coordinate the played and hummed eighth notes—particularly those in parallel motion in m. 3. Additionally, practice incorporating the breath mark before the last measure so that you can begin the last measure with humming and playing simultaneously, rather than starting with just playing and later adding humming.

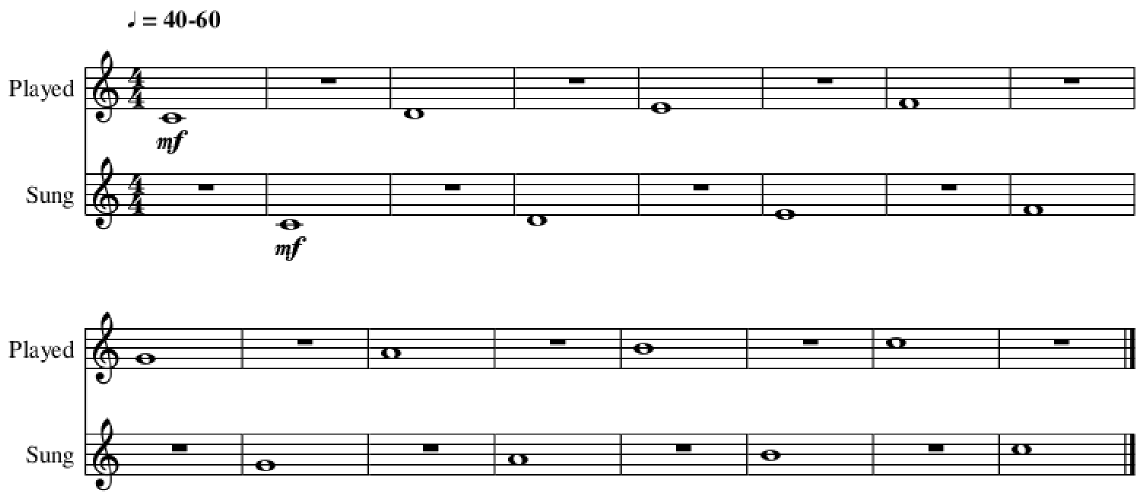
16. In this exercise, work on maintaining independent rhythms in the played and hummed lines. It may be useful to play the hummed line first to ensure that it is in your ear prior to hum it. Quickly reloading “cheek air” is also crucial when you have only an eighth note to replenish your “cheek air” supply.

17. The purpose of this atonal exercise is to prepare you to work on pieces that use humming while playing in more melodically and harmonically challenging ways. Rather than having a simple melody and accompaniment or pedal with scalar patterns, this exercise has two lines that do not fit together in an easily identifiable way. Therefore, it is recommended that you practice each line separately before combining the two to create independence between the hummed and played lines.

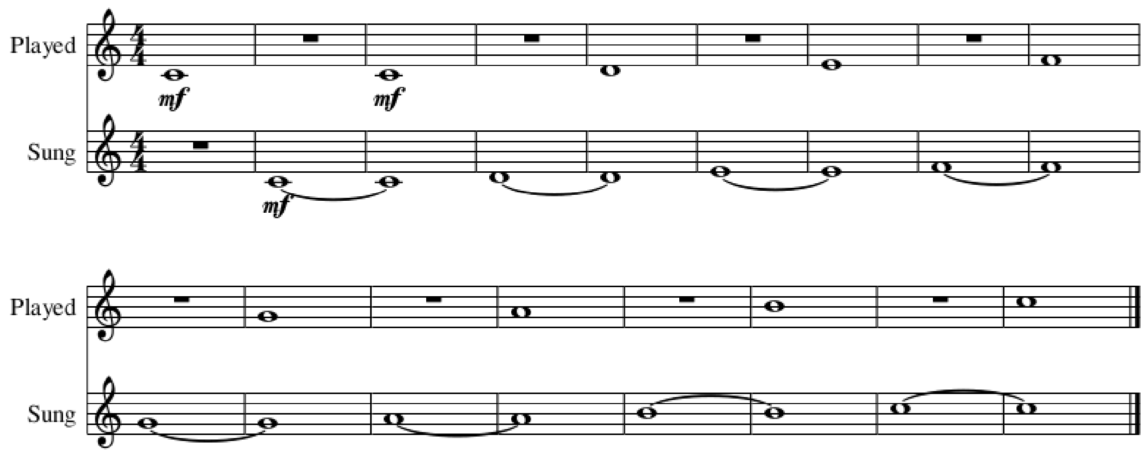
PART 2: SINGING WHILE PLAYING

Note: All sung pitches can be transposed up an octave if it better fits your comfortable vocal range. Each entire exercise can also be transposed to any key for the same purpose. As you become more comfortable with singing while playing, your singing range will likely expand. However, the top of your range will likely not reach as high as in humming while playing, since the increased pressure demands limit the upper range of this technique.

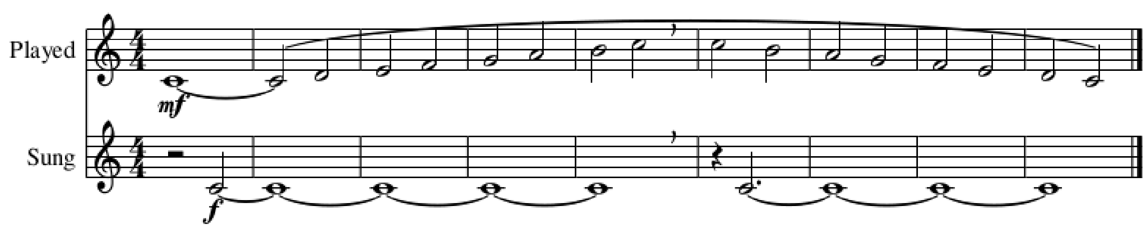
18. This exercise is intended to prepare you for singing while playing. After playing each pitch, keep your mouthpiece in your mouth and avoid making any changes in your oral cavity. Simply switch from playing to singing with the mouthpiece in your mouth. You can think of using an "uh" syllable as in the word "gut" to generate the sung pitch.



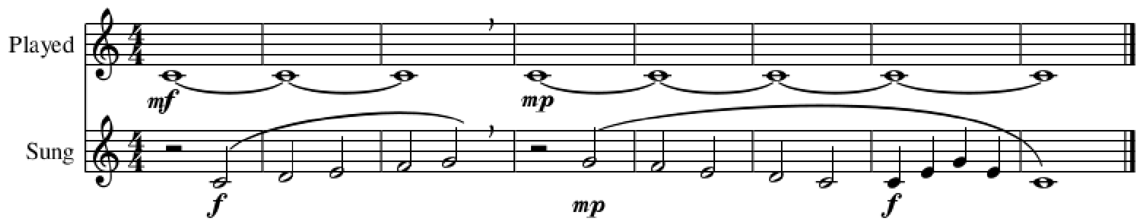
19. You can now combine both singing and playing. The first played pitch is a reference for when you start singing in the second measure. Keep the sung pitch steady, and try increasing the airflow to generate the simultaneous played pitch. It will likely feel like you are exerting significantly more effort to produce the played pitch than in standard playing, since you must generate enough air pressure to make both your vocal folds and your reed vibrate.



20. In this exercise, focus on first being able to generate a sung pitch after the played pitch has started, rather than the other way around. Once you can do this, maintain a steady sung pitch while going up and down the scale in the played part. You should hear the “beating” effect become more or less pronounced as different pitches are played, particularly if you are playing with enough air to generate strong sung and played pitches. After the breath mark, you now have only one beat in the played part to prepare to add the sung pitch. Practice being able to quickly add the necessary air pressure on your vocal folds to be able to generate a sung pitch right in time.

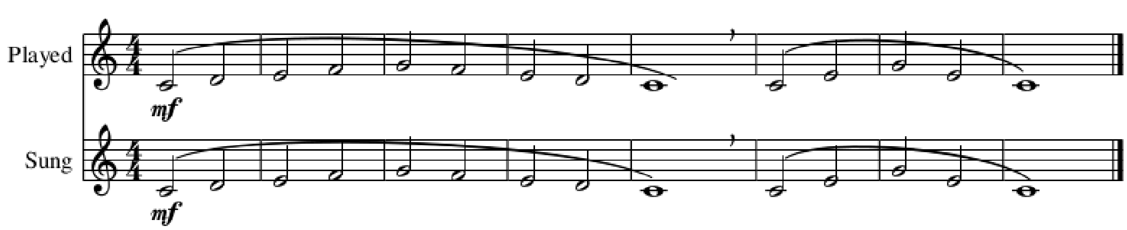


21. For this exercise, practice generating strong sung pitches while keeping the played line steady. Just as in Exercise 20, the "beating" effect will change in intensity as the sung pitches change. Additionally, you may feel yourself having to exert more effort as the sung pitches get higher. This is normal, since singing higher pitches requires more pressure to be applied to the vocal folds.



22. When working on this exercise, focus on matching the played pitch in the sung part each time the sung part ascends. When the played part ascends, keep the sung part steady.

23. Try to start both the sung and played pitches in this exercise together at precisely the same time. To do this, you must be prepared to use enough air pressure from the start. If you need to, you can softly play the first pitch for reference before beginning.



24. As the sung part in this exercise ascends to its peak, you may have difficulty producing the upper notes. When you find the highest note that you can produce without straining, drop an octave when you go beyond this. One of the goals of these exercises is to determine your comfortable singing while playing range, which should be substantially smaller than in regular singing or humming while playing. If you feel yourself straining, do not attempt to push through this, but simply drop the octave.

25. Practice each part in this exercise slowly before putting them together in small chunks of two measures or less. The independence of the lines will likely make this exercise more difficult than the prior exercises. Practice hearing both the horizontal intervals from one sung pitch to the next and the vertical intervals as the sung pitches relate to the played pitches.

26. In this exercise, the sung part moves much faster than in previous exercises, but the repeated chromatic pattern should not be difficult to master. Anticipate the leaps from one half note to the next, and be ready to start the sung pattern again on the new pitch each time.

27. The sung pitches in this exercise should be emphasized for maximum distortion. Each time a sung pitch is present, it was played just two beats prior. You can practice either aurally locking onto that pitch when you play it to prepare yourself to sing it, or simply practice hearing a minor second above or below the played pitch before you produce it. Either way, the end result should be an intensely distorted pitch, until the final consonant interval in the last measure.

APPENDIX E

IRB DOCUMENTATION

NOT HUMAN SUBJECTS RESEARCH DETERMINATION

Joshua Gardner
Music, School of
-
Joshua.T.Gardner@asu.edu

Dear Joshua Gardner:

On 11/8/2018 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Investigation of Intraoral Pressure and Nasalance During Clarinet Playing
Investigator:	Joshua Gardner
IRB ID:	STUDY00009203
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Bioscience Protocol Ruth, Category: IRB Protocol;

The IRB determined that the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.

IRB review and approval by Arizona State University is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether the activities would change the determination, contact the IRB at research.integrity@asu.edu to determine the next steps.

Sincerely,

IRB Administrator

cc: Jeremy Ruth

Joshua Gardner
Jeremy Ruth
Juliet Weinhold

APPENDIX F

RECORDED EXAMPLES

The following video files provide examples of both singing while playing and humming while playing:

01_Singing_While_Playing.mp4

02_Humming_While_Playing.mp4

Other than the vocalization techniques used, the two musical examples are identical.

BIOGRAPHICAL SKETCH

Jeremy Ruth is a freelance clarinetist in the Phoenix area. As an educator, Ruth teaches music history courses at Estrella Mountain Community College and band, orchestra, and chamber music courses at the Desert Marigold School, in addition to private clarinet and saxophone lessons. His performance interests are wide-ranging, but he has a particular interest in contemporary music, performance art, and exploring new extended techniques for the clarinet. Ruth's work has also been published in the *NACWPI Journal*. As a founding member of The Ambassador Trio, Ruth has performed guest recitals at several universities, in addition to being invited to premiere new works at many national and international conferences. He has performed as a soloist with both the Boise State University Orchestra and with the Arizona State University Wind Ensemble. Ruth received a Doctor of Musical Arts degree in 2019 and a Master of Music degree in 2015, both from Arizona State University, studying with Joshua Gardner and Robert Spring. He also received a Bachelor of Music degree from Boise State University in 2013, studying with Leslie Moreau.