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I. Solo Recital: Saturday, February 23, 2013, 7:30 p.m., Recital Hall. *Canzonetta, Op. 19* (Gabriel Pierné); *Cantilène* (Louis Cahuzac); *Introduction et Rondo, Op. 72* (Charles-Marie Widor); *Sonata for Solo Clarinet, Op. 41* (Miklós Rózsa); *Tango Études Nos. 3 and 4* (Astor Piazzolla); *Fantasia di La Traviata, Op. 45* (Donato Lovreglio).

II. Solo Recital: Saturday, October 26, 2013, 7:30 p.m., Recital Hall. *Fantasia da Concerto su motivi del Rigoletto* (Luigi Bassi); *Sonata for Clarinet Solo* (Edison Denisov); *Sonata for Clarinet and Piano in Eb Major, Op. 120, No. 2* (Johannes Brahms); *Hillandale Waltzes* (Victor Babin).

III. Solo Recital: Friday, April 24, 2015, 3:30 p.m., Recital Hall. *Grand Duo Concertant in Eb Major, Op. 48* (Carl Maria von Weber); *Concerto for Clarinet Solo* (Valentino Bucchi); *Histoire du Tango* (Astor Piazzolla); *Concerto for Clarinet* (Artie Shaw).

IV. D.M.A. Research Project. EFFECTS OF MATERIALS ON THE ACOUSTIC PROPERTIES OF CLARINET BARRELS, (2015). This project was intended to provide empirical data to determine if materials (e.g. Cocobolo, Mopane, Grenadilla, Delrin, and Purpleheart) used to make clarinet barrels have an effect on sound quality and response. The following questions were addressed in this study: For clarinet barrels, do different types of exotic hardwoods and plastics have a measurable effect on the sound qualities

(timbre) of the clarinet? Do different materials used to manufacture clarinet barrels have a measurable effect on the response (immediacy of tone and vibration to the player) of the instrument? Do different materials have a measurable impact on the intensity (volume/projection) of the clarinet? Will participants have a preference for specific materials tested? Results indicated that 25% of participants chose Mopane, 25% of participants chose Grenadilla, 25% of participants chose Delrin, and 25% of participants chose Purpleheart, meaning no material was preferred by a majority of the participants. No participant chose Cocobolo. Though there were commonalities among recordings of each material, the findings were not substantial enough to determine true differences in timbre, response to articulation, or intensity.

EFFECTS OF MATERIALS ON THE ACOUSTIC PROPERTIES OF CLARINET BARRELS

by

Mark James Cramer

A Dissertation Submitted to
the Faculty of The Graduate School at
The University of North Carolina at Greensboro
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of the Requirements for the Degree
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Approved by

Kelly J. Burke
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To my father, Brian J. Cramer, whose generosity and support has helped me reach many milestones in my life. These accomplishments would not have been possible without his willingness to share his time and talents.

APPROVAL PAGE

This dissertation, written by Mark James Cramer, has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Co-Chairs	Kelly J. Burke
	Sandra Teglas
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CHAPTER I

INTRODUCTION

Introduction

Many professional musicians are searching often for equipment with which to deliver musical concepts naturally through the instrument. Many classically trained clarinetists have had a fascination with developing their personal interpretation of an ideal clarinet sound that possesses balance, beauty, and the flexibility to play a wide range of repertoire. Although some have had other areas of prime concern, sound is almost universally a consideration. Typically, the professional classically trained clarinetist spends years searching for equipment that helps them serve the music and meet their technical demands. When purchasing a piece of equipment, some believe that there should not have any trade-offs between quality of sound and efficiency of sound production. For example, some mouthpiece makers struggle continually with balancing immediacy of articulation response with tonal depth. It is not uncommon for professional musicians to customize standardized equipment to achieve the individualized balance.

Because equipment choice is personal and can be influenced by marketing, the major clarinet manufacturers have devoted considerable time and attention to product research and design. Regardless of the various industry manufacturing changes, Grenadilla wood has remained the most widely accepted material used for the manufacture of clarinets. Since the establishment of the Boehm System clarinet in 1835, the major changes in clarinet design that impact sound production have focused on the design of the bore, which make an obvious difference in sound quality and immediacy of response. However, there are very few comparative studies of quality for reference. Research into bore design has been done largely by for-profit companies; therefore, these particular research and design studies are usually closely guarded proprietary secrets.

Although there has been little available research conducted on various clarinet bores, there have been several studies conducted involving the clarinet mouthpiece. Clarinet mouthpiece research has included every variable of the mouthpiece, including material of construction. However, there are other factors that may have an impact on the development of the sound. Because the mouthpiece functions as a gateway to the sound and influences pitch and response, it is understandable that the mouthpiece has received so much attention. A study on mouthpiece baffles and bores conducted by Walter Whener illustrates how mouthpiece dimensions can affect sound production. Whener (1963) states:

> When an analysis was made on the effect of various bore taper sizes on intonation, it was found that as the taper was increased in size the intonation was gradually raised. Although the intonation in the chalumeau register was satisfactory when using bore sizes of less than 0.030 of an inch, the upper registers were quite flat. With bore taper sizes larger than 0.060 of an inch, the intonation was quite sharp especially in the chalumeau and the acute registers. The selection of mouthpieces with bore taper sizes between 0.030 of an inch and 0.050 of an inch would appear to be best for overall intonation accuracy. (p. 133)

This is only one of the many examples of work done on construction technique that may have an impact on sound, but more work needs to be done on measuring the impact of materials on sound.

Although research has been performed on the topic of the effectiveness of material on the different components of the instrument,[1] much debate remains. Arthur H. Benade has stated that the material from which an instrument is made does not affect the quality of sound produced, though most performing clarinetists would disagree (Benade, 1960, p. 500). In support of Benade's statement, there have been several well-known studies comparing various materials and equipment. One such example is a study comparing different metal alloys for the body of the flute, resulting in the conclusion that material does not necessarily make a difference (Jenny Foutch, 2010, p. 39).

Another example of a study testing the effect of material is one conducted by Dr. Roger McWilliams, who tested the effect of material on the mouthpiece of the tenor saxophone. The researcher used two, identical mouthpieces (one made of metal and one made of plastic), and one additional metal mouthpiece made by another manufacturer for his study. Results of the study showed that the two identical mouthpieces made of metal and plastic showed little to no difference in the plot spectrums created from a lower frequency (A3 = 220 Hz), but a major difference of spectrums of the mouthpieces at a higher frequency (C4 = 261.63 Hz). The third mouthpiece in the study created a very different spectrum plot, proving that mouthpiece dimension has a strong impact on sound

[1] Although there are not many examples of research regarding the different components of the clarinet and their respective materials of construction, there are related examples of research done on the effect of materials on other instruments. Examples of this research are: *"The Differences"* by Jenni Foutch, *"Does Saxophone Mouthpiece Material Matter?"* by Dr. Roger McWilliams, and *"Trumpet Timbre: A Comparative Investigation of the Tone Quality of Two Professional C Trumpets"* by Frank E. Hanson III.

(http://www.philbarone.com/blog/saxophone-news/post/does-saxophone-mouthpiece-material-matter).[2]

Although these studies document that material does not necessarily make a difference, perception remains in the professional clarinet community that material of construction does matter. Part of the difference in opinion over the subject as to whether material has an effect on sound production is due to the perspective of the performer. An observer may be able to see minute differences in the plot spectrum between materials, but they may not be able to hear a difference in material. However, a musician playing different materials has the ability to perceive the added gradation of the feel and response of a material, which to many is equally as important as the scientific measurements of the sound being created.

These observational studies still have not persuaded the perception among professional clarinet players. Many players still insist that the material of construction greatly influences the sound and response. However, there are other areas of research into sound production where by the measurable results and the perceptions of clarinetists are in alignment. The disconnect between measurable results and perception may exist because more empirical work is needed to determine if different types of material (e.g., exotic hardwood) have an impact on the sound quality, response, and projection of the clarinet. It would be helpful to persuade the performing clarinetists as to the efficacy of a particular material if these empirical studies were undertaken by clarinetists and written in a language understood by the performing clarinetist.

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[2] Other examples of studies on material of construction are listed in the bibliography.

Overview of Clarinet Acoustics

The methodology of this study is dependent on a basic understanding of the acoustic properties of a characteristic clarinet sound. There are enough acoustic anomalies with the clarinet that warrant a brief overview to better understand and evaluate the spectrum plots.

The clarinet is a single reed instrument, possessing a cylindrical bore, which is consistent throughout, except for a conical flare towards the bottom of the lower joint, along with the flared bell. Due to the characteristics of the bore, the clarinet creates a recognizable spectrum that possesses a predominance of odd harmonics in the chalumeau and lower clarion registers (see Figure 1).

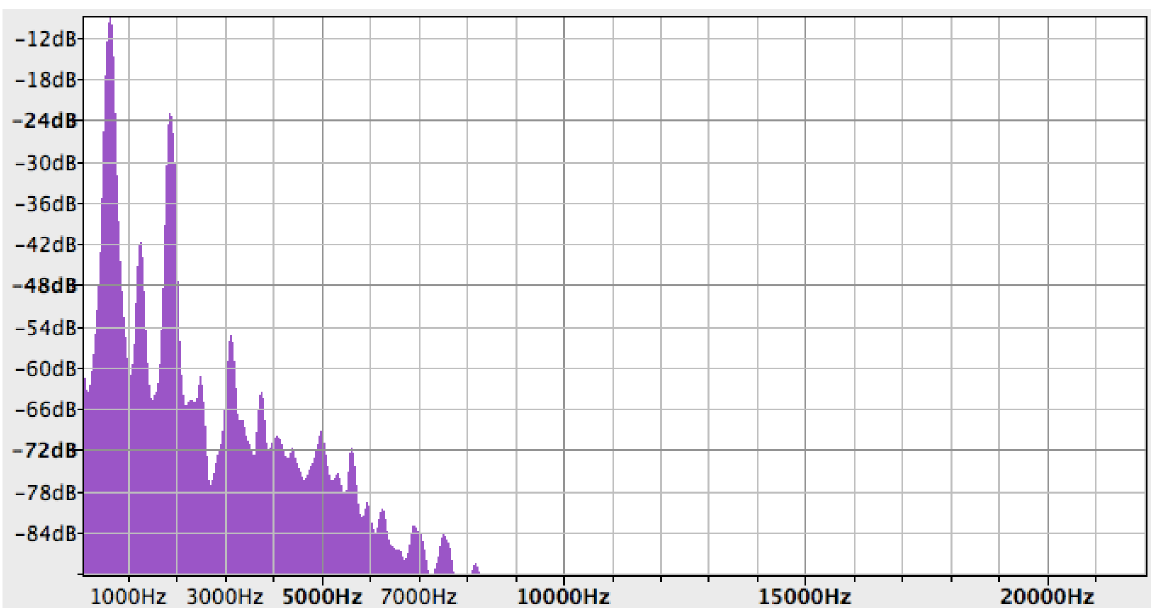

Figure 1. Characteristic Plot Spectrum of the Clarinet with Diminished Presence of the 2nd and 4th Harmonics (Plot Spectrum Produced by the Researcher).

The characteristic tone quality of the clarinet is rich in harmonics, and has a recognizable chalumeau register that produces a plot spectrum with virtually no presence of the second harmonic (Fletcher & Rossing, 1998, p. 417). Additionally, the clarinet has a diminished presence of the 4th harmonic. These characteristic spectra are created from the lowest notes of the clarinet, up to a written, top line F-natural. After this note, the harmonics begin to show an increasingly more equal presence. There is no indication of a predominance of the odd harmonics at written, top line C-natural (Gibson, 1994, p. 17).

Resembling the reed of an organ pipe, the clarinet reed vibrates against the facing of the mouthpiece, similar to how an organ reed beats against the shallot (Hall, 1991, p. 260). The flare of the bore in the lower joint of the clarinet presents some intonation inconsistencies with long-tube notes in that the chalumeau notes tend to be flat, while the overblown musical 12ths in the clarion register tend sharp. There has been a great deal of experimentation with the clarinet's length of the right-hand joint in order to find the correct lowest frequency (Backus, 1977, p. 237). The bore of the clarinet is unique to all woodwinds and has the most influence over the action of the reed when referring to pitch (Benade, 1960, p. 201). John Roederer perhaps best sums up the clarinet as "a stopped cylindrical pipe . . . the mouthpiece with the reed behaves as the closed end, the bell or the first open finger hole defining the open end" (Roederer, 1995, p. 132). Due to the unique cylindrical bore, which overblows upward to the musical interval of a 12th, the fundamental pitch of a note played on the instrument lies one octave lower than the same corresponding note and air column length of that of a flute or oboe, qualifying it as an alto voice in the woodwind section (Roederer, 1995, p. 132). Due to the fact that the clarinet overblows a 12th, the instrument requires at least 18 tone holes in order to successfully complete a chromatic scale (Levarie & Levy, 1980, p. 130).

The History of the Adjusted Clarinet Barrel

Although there are many parts of the clarinet that may have an impact on sound production, and need additional empirical research, this study focuses on the clarinet barrel. Therefore, some background information is necessary.

The French or Boehm System clarinet of today was developed in the mid-1800s and has undergone very few major revisions since that time. In 1950, Robert Carrée and the Buffet-Crampon company introduced an improved bore design (R-13), which was the premiere clarinet of its time and is considered the standard in clarinet design to this day. While the R-13 clarinet was much improved, there were still a few vital adjustments that needed to be made in order to make the instrument perform better in tune.

Hans Moennig, a repairman in Philadelphia was the center for state of the art woodwind repair in the U.S from the late 1930s through the early 1980s. Mr. Moennig worked with virtually every major principal clarinetist in the U.S. and much of his work was quite innovative for his time. Not only did he set the industry standard for re-padding and key adjustments, he also took great interest in adjusting the acoustics of the instrument. Moennig is responsible for developing a way of reshaping tone holes for better intonation and more even scale of the clarinet and was incredibly skilled at adjusting the bore if it was incorrect due to weather changes and warping. Moennig is most famous for his development of hand-fabricated clarinet barrels.

During the late 1940s, Ralph McLane, then principal clarinetist of the Philadelphia Orchestra, was a frequent visitor Hans Moennig's shop in Philadelphia. Known for his wonderful rich tone, McLane still wanted his instrument to be better, and together he and Moennig experimented with a variety of bore measurements for barrels. McLane would spend hours in Moennig's shop testing, comparing, and listening critically. The outcome of this experimentation with McLane was a set of barrel specifications, which Moennig began to reproduce for other players to try. Subsequently, many clarinetists liked these newly designed barrels and began playing them exclusively. This particular barrel and interior dimension is still copied and in use today.

The demand for Moennig's barrels continued to increase over the next several years, and eventually the Buffet-Crampon Company began manufacturing a Moennig style barrel available as an accessory item. Although these barrels were close to Moennig's specifications, they were not ideal because of variations in production or changes due to wood instability and individual error. As is still the case today, discerning players looking for barrels with true Moennig bores had to depend on knowledgeable repairmen with correctly tapered reamers to check and adjust their barrels on a custom basis.

Traditionally, a 67 mm barrel for the B-flat clarinet and a 66 mm barrel for the A clarinet are appropriate for A-440 tuning (Hite, 1997). It is the experience of the author and many other professional players, that a longer barrel gives more depth and richness to the sound. Therefore the longest barrel which also comfortably meets their tuning requirements is preferred.

New instruments tend to have a greater internal resistance and therefore, tend to be lower in pitch. As an instrument is played over time, the internal resistance lowers, making the pitch rise slightly (Hite, 1977). Consequently, a 66mm length barrel is customary in the beginning of the instrument’s cycle. The A clarinet usually will need a 65mm barrel in the beginning.

To offset the bore instability problems, manufacturers have made barrels of hard rubber, plastic, or aluminum. Some have gone to the trouble of putting a rubber or plastic liner inside a wooden barrel. These solutions have proven useful in certain seasons and climates, especially in the ever-changing Midwest. But for many discerning players, the sound produced by a solid wood barrel remains superior.

The dimension of a properly measured Moennig style barrel should be: 0.589" at the top, tapering down to 0.580” at the bottom for the Bb clarinet. The A clarinet was found to improve greatly in tone, response and tuning balance when it was bored 0.004" smaller than the Bb (Hite, 1997). Ideally, therefore, it is necessary to use a different barrel for each clarinet. Using a different barrel for each clarinet may prove to be an inconvenience when switching from Bb to A clarinet in order to facilitate a quick change between clarinets without disturbing the reed and ligature. The improvement in the A clarinet is dramatic enough to justify the extra effort of switching, or possibly investigating an option of using a ligature which is less prone to slip when making a quick change.

Clarinetists who have adopted a barrel with Moennig’s specifications believe it produces a distinctly better, fuller, richer sound than the industry supplied stock barrel when played with most mouthpieces generally in use now and in earlier days. For well-trained and experienced clarinetists, the preference has been nearly universal.

M'pingo

When choosing an instrument, modern day clarinetists have multiple brands to choose from. Not only are there several massed-produced, quality instrument models, there are an increasing number of boutique manufacturers gaining in popularity. For generations, the industry standard material in clarinet manufacturing has been M'pingo, (also known as African Blackwood or Grenadilla). This species of timber is native to Africa, where it spans a wide range of the continent, from northern Ethiopia to Angola, and from Senegal to Tanzania (http://www.fauna-flora.org/species/mpingo-tree/). This particular wood is considered valuable, as it is in high demand for making other musical instruments such as the oboe, flute, and bagpipes. Demand for wood instruments has resulted in rapid consumption of these trees.

Due to the depletion of this natural resource, woodwind manufacturers are seeking alternative materials with "similar acoustic properties." With the concerns of the environment, instrument manufacturer Buffet-Crampon has made strides at harnessing the sound qualities of M'pingo by introducing their Green-line products. This new material is pressure formed and is made by a process of combining 95% M'pingo wood powder with resin. This material is favorable, as it has the same acoustic properties of this hardwood in its natural form, but does not require a large piece of wood in order to make a larger musical instrument and is less vulnerable to changes in temperature or humidity (http://www.blackwoodconservation.org/greenline.html).

In addition to Buffet, woodwind manufacturers and boutique makers are working to find alternative materials that harness the qualities of the M'pingo wood that has been used for generations. Although the companies and individual makers that are crafting fine clarinets, barrels, and mouthpieces are having growing success with alternative materials, among many clarinetists there is still a stigma associated with clarinets made from materials other than Grenadilla.

Many contemporary woodwind accessory craftsmen have built on the pioneering barrel work of Hans Moening. But most of this work has focused on the development of the bore and overall design, not material of construction. For years, barrel craftsmen have been constructing barrels with a multitude of exotic hardwoods, including the industry standard African Grenadilla wood, but empirical studies on these materials have not been conducted. The research and information gathered from this study is intended to provide objective information to help choose equipment that has the perceived acoustic properties desired by the professional clarinet community and ease of use. Additionally, this information may persuade manufacturers to consider an alternative to a resource facing possible depletion.

Statement of Purpose and Research Questions

The purpose of this empirical study is to determine if the material (e.g., exotic hardwoods and plastics) used to make the clarinet barrel has an effect on sound quality and response. Although not the focus of the study, it may be possible to suggest that there are acceptable alternative materials to Grenadilla for the use of manufactured clarinet barrels.

The following questions are addressed in this study:

1. For clarinet barrels, do different types of exotic hardwoods and plastics have a measurable effect on the sound qualities (timbre) of the clarinet?
2. Do different materials used to manufacture clarinet barrels have a measurable effect on the response (immediacy of tone and vibration to the player) of the instrument?
3. Do different materials have a measurable impact on the intensity (volume/projection) of the clarinet?
4. Will participants have a preference for specific materials tested?

Identifying the effects of exotic woods and plastics on the tone (timbre), response (immediacy of tone and vibration to the player) and intensity of the clarinet is the main intent of the study. As stated earlier in this document, there is much debate on the topic of the effect of material on performance. While there is a great deal of speculation on the acoustical differences of the resonance properties of a given material, there is physical evidence that can be gathered to measure differences. This study did not control the type of mouthpiece, ligature, reed or reed strength, or manufacture and model of clarinet used by the participants in the study, and this experiment is only intended to test the effects of materials used to construct the clarinet barrel.

CHAPTER II

PROCEDURES

Barrel Materials and Manufacture

Several species of exotic hardwoods and plastics were considered for inclusion in this study. The materials chosen for the study (Cocobolo, Mopane, Grenadilla, Delrin, and Purple Heart) are being used increasingly in musical instrument manufacturing, are readily obtainable, and include viable alternatives to Grenadilla. The materials are presented below in the same order as they were presented in the experiments of the study. Delrin was placed strategically in the middle of the experiment since it is a different material from hardwood. Participants were aware that a synthetic material was included, but due to the single-blind methodology, they were unaware of the order. Therefore, potential for bias was mitigated.

Cocobolo

Dalbergia retusa, more commonly known as Cocobolo wood, is a product of Central and South America. This hardwood is a member of the rosewood family and has a characteristically reddish-brown color with an instantly recognizable wood grain. Cocobolo is a relatively light hardwood and is fairly porous and oily (www.cookwoods.com, 2012). This wood is in abundant supply and relatively manageable to work with and is one of the most used materials by fine instrument and barrel craftsmen. Exposure to the dust generated by cutting and sanding Cocobolo can cause irritation and nausea, due to the presence of dalbergione compounds in the wood. These compounds are also known as quinones, which are naturally occurring chemicals found in several species of rosewood. Quinones are produced as defensive agents which help protect these trees from fungus or insects (http://wiki.bme.com/index.php?title= Wood_Hazards). Many people are allergic to these natural, chemical compounds, often resulting in a rash on the skin. This is an area of concern, particularly to boutique barrel craftsmen and instrument manufacturers, as contact with the dust produced by Cocobolo during the manufacturing process can cause an allergic reaction.

Mopane

Colophospermum mopane, usually abbreviated as Mopane, is a product of the hot, dry, low-lying areas in the northern parts of southern Africa and South Africa. In particular, Mopane is found in Zimbabwe, Mozambique, Botswana, Zambia, Namibia, Angola and Malawi (www.cookwoods.com, 2012). This dense hardwood is being used increasingly in the construction of musical instruments, particularly woodwinds, as suitable quality Grenadilla wood is becoming harder to find. Mopane is fairly oily, similar to Cocobolo wood, and seldom cracks during the curing process.

Grenadilla

Dalbergia melanoxylon, otherwise known as Grenadilla, African Blackwood, or M'pingo, is a product native to the seasonally dry regions of Africa located in Senegal, as far east as Eritrea, and as far south as the northern regions of South Africa. This incredibly dense wood has been the main hardwood used by clarinet and oboe craftsmen since the mid-19th century and is known for its characteristically dense grain, beautiful dark patina, and strength and durability (www.cookwoods.com, 2012). Due to over-harvesting, M'pingo trees are severely threatened in certain regions of Africa. M'pingo conservation practices are needed most urgently in Kenya; M'pingo crops in Tanzania and Mozambique are also in desperate need of conservation attention. The trees in these areas are being harvested at an unsustainable rate, partly because of illegal smuggling of the wood, but also because the tree takes upwards of sixty years to mature and is not being replaced at the same rate as it is being harvested. For these reasons, Grenadilla wood is becoming particularly difficult to obtain, especially stock of superior quality.

Delrin

Polyoxymethylene (or Delrin), is an engineering thermoplastic used in precision parts manufacturing that require high stiffness, low friction, and excellent dimensional stability. As with many other synthetic polymers, it is produced by several chemical firms using slightly different formulas, and therefore it is sold under various commercial names like Delrin, Celcon, and Hostaform (http://www.plasticsintl.com, 2012). Delrin is approved by the Food and Drug Administration as a plastic that is fit for use in kitchenwares, because its density and non-porous characteristics make it highly resistant to bacterial growth. Due to its similarity in construction characteristics to dense hardwood, ease of use, and availability and affordability, instrument, barrel, and mouthpiece craftsmen have used Delrin for years.

Purpleheart

Peltogyne, most commonly referred to as Purpleheart, is known for its natural purple hue and incredible density and durability. This wood is the densest of the hardwoods chosen for this study. Because of the risk of shattering, working with Purpleheart requires the use of a sharp, carbide blade (www.cookwoods.com, 2012). This wood it is often used by high-end craftsmen for fine inlay work, woodturning, cabinetry, flooring, and furniture. Overharvesting has caused this species to become endangered in areas of South America where the species was historically abundant (http://www.maderasdesudamerica.com, 2008). Like Cocobolo, Purpleheart also has a presence of dalbergione compounds, which irritate the skin of many people when they come in contact with dust created during manufacturing process.

Barrel Crafting Process

Prior to conducting the study, the researcher had nearly ten years of experience crafting and refining custom-made clarinet barrels. The taper used is based on a traditional Moennig-style, reverse taper, modified to measurements that have been carefully tested by the researcher and several professional clarinetists over the years. Since the goal of this study is to discern the preferences among different materials, the Moennig-style bore was used because its intonation and resistance would likely be reliable and familiar to the participants. For the same reason, the same bore measurements were used for all barrels in the study, to keep the focus on the acoustic properties of the material and not on the qualities of the researcher's design. The barrels were made with the assistance of machinist Brian Cramer. He has over 30 years of experience using the required machinery necessary for detailed work on clarinet barrels.

The first step in manufacturing a barrel was to carefully select plugs of wood and cut them down to three-inch lengths. Wood samples were selected for their evenness of grain pattern, and the absence of cracks, knots and visible signs of warping. After the wood plug was cut to size, a rough, internal bore was reamed. Next, the upper joint tenon socket was reamed (this tenon socket fits over the tenon of the top joint of the clarinet). The exterior contour for the lower part of the barrel was cut. This process was then repeated on the upper portion of the barrel, the upper tenon socket was reamed (which fits over the tenon of the mouthpiece) and the exterior contour was applied. After this was process was completed, the barrels were left to age for approximately six months. This process was necessary in order to account for warping of the material due to drying from exposure to the air. After the aging process was completed, the barrels received the final, reversed-taper bore and were measured several times by both the researcher and Brian Cramer, in order to ensure that the proper tolerances were met.

Due to the speed at which the lathe rotated, the friction of the cutting blades created a great deal of heat that could have interfered with the integrity of the material. Because of this, it was necessary to allow the barrels to sit and cool in between each step so that too much material was not removed because of swelling due to expansion from heat.

After the barrels received the final bore, the wood was sealed with almond oil, which was applied with a 100% cotton, lint-free towel, and left to sit for approximately two days. Because the woods have different densities and inherent differences of natural oils, some barrels needed extra time both to allow the wood to absorb the oil and for the curing process. After the barrels were completely dry, carnauba wax was applied to the exterior, the tenon sockets, and the bore with the same lint-free cotton in order to waterproof the product. See Figures 2–14.

Figure 2. Pre-machined Piece of Delrin.

Figure 3. Delrin is Cut to 3” in Length.

Figure 4. Delrin after Being Reduced to 3” in Length

Figure 5. Delrin Receiving Rough Bore.

Figure 6. Picture of Barrel with Rough Bore.

Figure 7. Barrel after Receiving Appropriate Top Joint Tenon Socket Measurements.

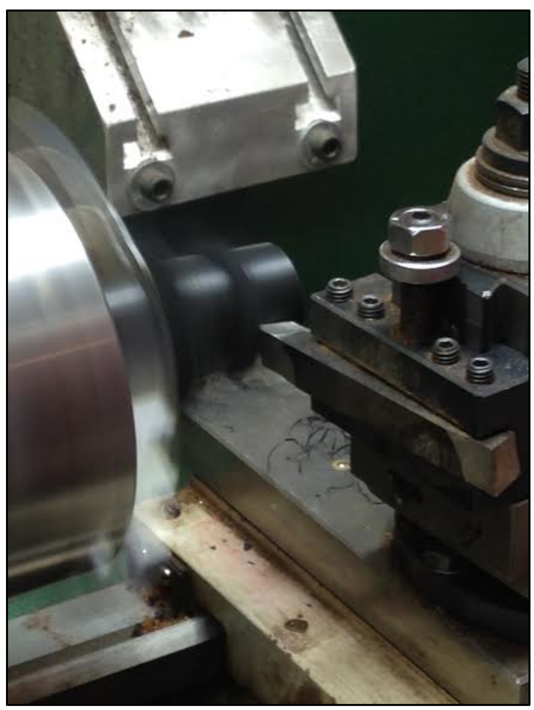

Figure 8. Shaping of Barrel Exterior Contour.

Figure 9. Barrel after Being Contoured

Figure 10. Barrel Being Prepared to Receive Exterior Contour and Mouthpiece Tenon Socket.

Figure 11. Barrel after Completion of Top and Bottom Exterior Contouring and Respective Tenon Measurements.

Figure 12. Barrel Receiving Final, Reverse-Taper Bore.

Figure 13. Finished Barrel after Receiving Final Bore Measurements.

Figure 14. Finished 66-Millimeter Barrels Used in Pilot Study. From Left to Right: Grenadilla, Mopane, Purpleheart Wood, Cocobolo, and Delrin.

Research Design

The research design was an experimental study of the effects of materials on the acoustic properties of clarinet barrels, utilizing a researcher designed, three-part survey and recordings of eight participants performing on six different materials.

Due to the fact that many professionals have prior experience playing the materials used in the study, the tests performed in the study were conducted using a single-blind method. This method was intended to minimize or eliminate participant bias, which could alter the measurements or the outcome of the experiment, making the data or results invalid.

Subjects and Selection Process

The subjects for this study were selected as world-renowned professional clarinetists from the Southeastern and Midwestern regions of the United States. Participants of this caliber were chosen for this study in order to ensure consistency of sampling. Among those who were asked to perform in the study were musicians from professional symphony orchestras and/or educators at major universities and conservatories. A total of eight professionals participated in the study and completed the *Clarinet Barrel Material Preference Survey.*

Procedures

Prior to the official study, the researcher launched an identical pilot study, using highly accomplished graduate students from The University of North Carolina at Greensboro. The purpose of the pilot study was to diminish variables by determining if all barrels crafted for the experiment were necessary for research, due to the possibility of naturally occurring inconsistencies in organic materials. For the purposes of this study, the subjects were labeled as participants 1, 2, and 3, and results from the data collected in the pilot study was not used in the official study. The official study only analyzed data from participants 4-11.

The researcher crafted fifteen barrels, composed of the five listed materials (three barrels made of each material), in order to determine if there was a measurable difference in the presence of overtones and rate of articulation response within a single species of hardwood. If the tests confirmed that there was not a measurable difference within each species of hardwood, the researcher would use only one barrel of each hardwood. The researcher chose to address this question in the pilot study, in order to shorten the participation time for each participant in the official study.

The researcher employed a single-blind method in order to eliminate bias from the subjects, since the participants may have had some pre-formed opinions about the materials from previous experience. In order to keep the identity of the barrel unknown to the participant, a cone constructed of stiff felt and Velcro was wrapped around the participants' mouthpieces. The cone was carefully placed each time, so that it did not come in contact with the barrel, ensuring that it did not affect the vibration of the material.

The examiner was responsible for changing the materials being tested as well as each participant's clarinet, mouthpiece, reed and ligature configuration. The participants performed four blind-tests on the five different materials, as well as their personal equipment, controlling as many acoustic variables as possible. Following their performance of each task, the participants were asked a survey question.

Upon conclusion of the pilot study, the researcher determined there was not a considerable amount of variance among barrels composed of the same material, and he selected five barrels (one of each material) for use in the official study. These barrels were selected due to their large frequency of response and presence of overtones, which was consistent for all three participants of the pilot study. The process of choosing barrels with a higher resonance was intended to potentially eliminate the confounding variables of inconsistencies or poor quality of material, thus altering the recordings and preferences of the participants in the official study.

The participants in both the pilot and official study performed four brief tasks in order for the researcher to take measurements of the acoustical properties of the various types of wood. Audio was recorded for later spectrographic and sound envelope comparison.

Each subject performed the test on his or her personal mouthpiece, reed, and ligature combination. Using each of the five materials and the subject's personal barrel, the subjects completed the following four tasks:

Task I

The participant was asked to play a clarion register F-natural[3] at a *forte* dynamic (91 dB) into the decibel meter and recording device and sustain the note for one second. It was concluded that a distance of five feet from the equipment was the ideal range and

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[3] Throughout this document and the survey instrument, pitches are notated as written for the B-flat clarinet. Therefore, register F-natural sounds as concert E-flat (622.25 Hz).

placement for recording each participant's clarinet in order to effectively determine intensity and timbre. The decibel meter was necessary in this task in order to obtain consistent measurement for comparing the sound envelopes.

After the task was performed, the participant was asked to rate their experience performing the task. Using a five-point scale (1 = "very difficult", 5 = "very easy"), the participant was asked to rate their effort level needed in order to achieve the desired decibel level. The purpose of this task was to allow the participant a "practice" run of obtaining the desired dynamic level, and acquire an initial, first impression of the timbre of the material.

Additionally, the participant was asked to rate their experience, using the same five-point scale, to rate the barrel relative to achieving their idea of a characteristic clarinet sound.

Task II

Next, the participant was asked to play a clarion register F-natural in to the decibel meter and recording device and to reach and maintain a volume level 91 dB for three seconds. After the task was performed, the participant was asked to give a rating based on their perception of effort needed to maintain the desired decibel level, using the same five-point scale from the previous task.

Task III

The participant was asked to play the first three measures of a brief orchestral excerpt (Gounod's "Faust – Ballet Music"). See Figure 15. After the participants performed the excerpt, they were asked to rate the barrel relative to ease of response to articulation using the 5-point scale.

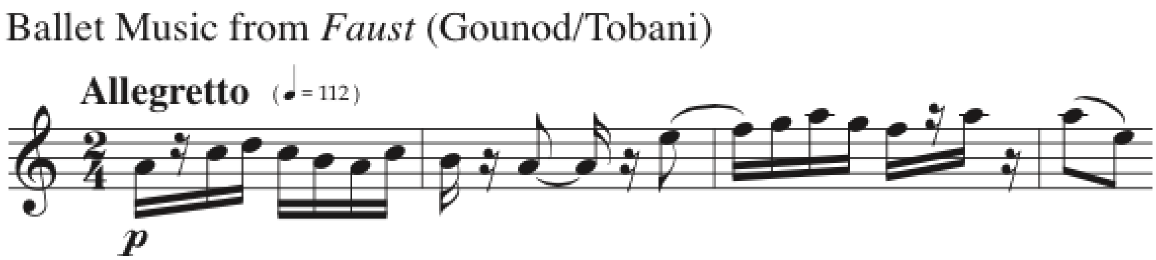

Figure 15. Excerpt Used to Measure Participant Perception to Material Response to Articulation.

Task IV

After all three steps were performed on the six materials, participants were guided through a "single elimination, simple bubble sort" procedure that aimed to determine their preferred material. In order to do this, the participant was asked to play a short passage of their choosing (a solo passage or personal technical composition). It was important that the participant play the same passage(s) on all five materials (this step only required using the barrels belonging to the study and not the participant's personal barrel) in order to make a fair comparison. As stated earlier in this document, this study was only intended to test the effects of materials used to construct the clarinet barrel. It was not the intent of the researcher to compare the barrels manufactured for this study to other barrels on the market. Because Task IV involved ratings of player preference, it was not necessary to include the participant barrels in this portion of the experiment, as these barrels possessed different dimensions from the barrels manufactured for the study.

The procedure in Task IV was modeled after the standard practice of vision tests, conducted by opticians. Vision tests are performed at a quick pace, not apportioning enough time for the eye to adjust to differences between types of lenses. Professional clarinetists are highly adaptable to many factors, including changes in environment and equipment. Due to the flexibility of professionals, the researcher purposely designed a procedure that was brief in duration, with the consideration that each participant would perform on all materials at an exceptionally high level. This technique is practiced commonly by mouthpiece craftsmen, who suggest that the most effective way of selecting an appropriate mouthpiece is by choosing a facing that offers an immediate improvement of response. Due to this fact, it was critically important that the participant keep the passage of their choosing short in duration, preferably under 5 seconds, as the preference was to be determined by basis of their initial impression of the material and not after having a long period of time to adjust to differences.

The order of the barrels in Task IV intentionally was neither the same as the previous tasks nor the same between participants. The reason for this was to remove potential bias from the previous set order of barrels. After the order was chosen, the researcher simply took the upper joint and mouthpiece configuration from the research subject, put on the barrel, reapplied the cone to keep the material's identity blind, and handed back the clarinet to the participant. After the participant played the passage, the researcher quickly replaced the first barrel with another barrel. After the participant played the passage, they were asked which barrel they preferred. The barrel that was determined to be less favorable to the participant was then eliminated from the procedure. This process was completed until only one barrel remained.

All participants in the study were highly accomplished clarinet players who possessed the capabilities of making most any material sound exceptional after a period of time. It was the researcher's intention to record the immediate impression of the material, and not have time to adjust to any abnormalities in the material. One of the main objectives of the study was to determine if there were similarities or differences between player perception and acoustical reality.

The necessary materials for conducting this study included: the five barrels crafted for the study, the participant's personal barrel, a decibel meter, a high-quality recording device (Zoom recorder), sound spectrum analysis software (Audacity), and the proper materials required to maintain consistent distance from the equipment while performing the experiments and to keep the material identity unknown. The data was collected through analysis of the sound spectrum software. The findings were organized using a combination of figures and tables to demonstrate the frequency of vibration and the shape of sound envelopes.

Recording Process

The researcher established a triangulation between the clarinet bell, recorder (on the right), and the sound pressure meter (on the left), using a pre-measured loop of string (see Figures 16 and 17) using the following measurements: support of left music stand to tenon between the lower joint and clarinet bell = 5 feet; support of right music stand to tenon between the lower joint and clarinet bell = 5 feet. Both the sound pressure meter and recording device were placed on identical Manhasset music stands, and were also separated at a distance of three feet from each other using a pre-measured string in hopes of further controlling the acoustic setting.

Figure 16. Player Setup Showing Triangulation.

This triangulation served as a method of keeping consistent distance from the microphone and sound pressure meter as well as to keep the participant and their instrument stationary while performing the tasks in the experiment.

Each test was recorded using a Zoom H2 digital recorder with the microphone gain set at “high.” In order to maintain consistency in volume for each test, players were asked to visually monitor their volume using a decibel meter. Several sound pressure meters were considered, but for portability and consistency of replication and response, the researcher chose “Decibel,” an application for iPhone 5.

Figure 17. Triangulation—Right Shoulder View (Sound Pressure Meter Not Shown)

The note chosen for the playing test, clarion register F-natural, was chosen with several factors in mind. This note in particular is a stable note in resistance and intonation for most professional B-flat clarinets. Also, it was decided that a note in the middle of the clarinet’s overall range was best.

Variables

The study investigated the effects of independent variables; Cocobolo, Mopane, Grenadilla, Delrin, Personal Barrel, and Purpleheart on the dependent variables in the captured recordings. The dependent variables include; timbre, response, intensity, and preference. As a control, the researcher tested the participant's personal barrel in order to establish a baseline measurement for the individual. In order for the participants to feel the most comfortable while performing the tasks in the procedure, and to determine their material of preference, the type of mouthpiece, ligature, reed brand and strength, and clarinet were not controlled (see Table 1).

The pilot and official studies consisted of several controls. Fifteen barrels (three barrels of each material) using identical structural measurements were crafted for the study. Other controls were the maintenance of a standardized distance between the participant and the decibel meter and recording device, using a set of strings measuring five feet in length. Additionally the same type of music stands were used in each experiment, which were separated using a set of strings measuring three feet in length. A sound level meter and metronome was used in order to control the volume and tempo required of the participants playing each task. For the participants who participated in the study using the facilities at UNCG, consistent placement of the recording device and decibel meter within the room was maintained for all experiments. With these controls, it was the researcher's intention to get as accurate and consistent of a recording as possible for later comparison and analysis.

The study had several confounding variables including the make and model of instrument, mouthpiece, ligature, and reed and reed strength used by the subject. The recording space was also a confounding variable, as the test was conducted in six completely different acoustic environments.

Table 1

Participant Mouthpiece, Ligature, Reed Brand and Strength, Personal Barrel, and Clarinet Used in the Study

Participant	**Mouthpiece**	**Ligature**	**Reed Brand**	**Reed Strength**	**Personal Barrel**	**Clarinet Brand**
4	Frank Kaspar Cicero	BG Super Revelation-Gold Plated	Vandoren V12	3.5	Stock 66 mm	Buffet R13
5	Vandoren B40 Lyre (13 Series)	Ishimori	Vandoren V12	3.5	Stock 66 mm	Buffet Tosca
6	Richard Hawkins R Model	Ishimori	D'Addario Classic Reserve	3.5+	Stock 65.5 mm	Selmer Privilege
7	Richard Hawkins G Model	Rovner-Versa	Legere Signature	3.75	Zinner 66 mm	Buffet R13
8	Henri Chediville	Ishimori	Gonzalez FOF	3.75	Buffet-Moennig	Buffet Tosca
9	Vandoren M30 (13 Series)	Kaspar	Vandoren V12	4	Paulus and Schuler GbR	Buffet R13
10	Vandoren M13 Lyre (13 Series)	Bonade-Regular	Vandoren V12	4.5	Buffet-Muncy 66 mm	Buffet R13
11	Johnston H3 Model	Spriggs	Vandoren Traditional	3.5	Buffet-Muncy 65 mm	Buffet Tosca

The model of mouthpiece, type of ligature, brand and strength of reed, brand and model of clarinet, the disposition of the participant, and location of the experiment (as traveling to some of the participants was required) could not be controlled. This complicated the data analysis, as the measurements *between* participants were not the same. Because each participant was asked to perform each task in the procedure on their personal barrel, the researcher was able to establish a baseline measurement for the participants.

The Survey

Subjects played five materials in an identical, pre-selected order. Each test was conducted blind, with the researcher handling the participant's personal mouthpiece, reed, ligature and upper joint of their clarinet. After conducting the pilot study, it was determined that due to the amount time required to re-set the triangulation, the participant would hand-off the upper-joint, mouthpiece/ligature/reed combination, and barrel (covered with cone) to the researcher in hopes of limiting the amount of time between tasks. The researcher worked as quickly as possible to remove and replace each barrel so that the participant could compare barrels in the third portion of the survey.

For the second portion of the survey, the researcher prompted each participant with a question, asking them to rate the barrel according to a 5-point scale.

Analysis of Data

The researcher took an average of the recordings of all eight participants in the experiment. The data that was of particular importance was the harmonic makeup of the sound/timbre produced by each material (specifically; the fundamental, 3rd, and 5th harmonic) and the difference in response/ease of articulation of each material (by comparing the spectrogram of the Gounod excerpt). Using graphs and tables, the researcher was able to organize and demonstrate the difference in measurement of each material.

CHAPTER III

RESULTS

First Research Question

The first research question referred to both player perception and acoustic reality of timbre: For clarinet barrels, do different types of exotic hardwoods and plastics have a measurable effect on the sound qualities (timbre) of the clarinet? Perception was self-rated by the participants after completing Task I of the procedure of the study. In the *Clarinet Barrel Material Preference Survey*, the subjects were asked to "Rate the barrel relative to ease of achieving a characteristic clarinet tone quality" after playing a clarion register F-natural at 91 dB for one second. This score was intended to document the participant's initial impressions of the timbre of the material. Participants rated Purpleheart the highest of the materials tested that most easily allowed them to achieve their concept of an ideal sound, with a score of 36. Rated slightly lower, Grenadilla, Delrin and the participants' personal barrels were rated sum scores of 35. Mopane and Cocobolo were rated scores of 32 and 30, respectively (see Tables 2–7).

Table 2

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Cocobolo

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Cocobolo	5
5	Cocobolo	4
6	Cocobolo	5
7	Cocobolo	5
8	Cocobolo	3
9	Cocobolo	2
10	Cocobolo	5
11	Cocobolo	1
	Total = 30	

Table 3

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Mopane

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Mopane	5
5	Mopane	3
6	Mopane	5
7	Mopane	5
8	Mopane	3
9	Mopane	3
10	Mopane	4
11	Mopane	4
	Total = 32	

Table 4

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Grenadilla

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Grenadilla	4
5	Grenadilla	2
6	Grenadilla	5
7	Grenadilla	5
8	Grenadilla	5
9	Grenadilla	4
10	Grenadilla	5
11	Grenadilla	5
	Total = 35	

Table 5

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Delrin

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Delrin	5
5	Delrin	5
6	Delrin	4
7	Delrin	5
8	Delrin	4
9	Delrin	2
10	Delrin	5
11	Delrin	5
	Total = 35	

Table 6

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Personal Barrel

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Personal Barrel	5
5	Personal Barrel	3
6	Personal Barrel	5
7	Personal Barrel	5
8	Personal Barrel	4
9	Personal Barrel	3
10	Personal Barrel	5
11	Personal Barrel	5
	Total = 35	

Table 7

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving Characteristic Tone for Purpleheart

Participant	Material	Ease of Achieving Characteristic Tone Rating
4	Purpleheart	3
5	Purpleheart	5
6	Purpleheart	4
7	Purpleheart	5
8	Purpleheart	5
9	Purpleheart	5
10	Purpleheart	5
11	Purpleheart	4
	Total = 36	

Plot spectrums were isolated from the recordings of the participants in the study for analysis of the differences in the presence of harmonics among the barrels. All materials in the study demonstrated an inconsistency of plot spectrums. Some materials did not produce consistent examples of plot spectrums that are typically recognized as characteristic of the clarinet, in which the odd harmonics are most prominent. This may be the case because the harmonics produced by the clarinet begin to show an increasingly equal presence, starting at written, top line F-natural (Gibson, 1994, p. 17). This was the note the participants were asked to play in Tasks I and II.

The following sections present the characteristics observed by the researcher after viewing and comparing the harmonic spectrums created by each participant on all materials that were tested (plot spectrums located in Appendix A).[4]

Cocobolo

The plot spectrums sampled for Cocobolo did not generally produce a harmonic spectrum typically recognized as characteristic of the clarinet: the odd harmonics were not most prominent. For five of the participants in the study (participants 4, 6, 7, 8, and 10), Cocobolo created a very prominent 2nd harmonic. This was not the circumstance for participants 5, 9, and 11, who produced a harmonic spectrum with prominent odd harmonics. Another common observation showed that 7 of the participants (participants 4, 6, 7, 8, 9, 10, and 11) had a dramatically diminished presence of the 4th harmonic. This was not true for participant 5, who created a more steady presence of all harmonics.

[4] The researcher based his comparisons on the assumption that a characteristic harmonic spectrum was the desired result. However, there is no evidence to suggest that participants would find a sound that possesses a harmonic spectrum with more prominent 3rd and 5th harmonics most appealing.

Additionally, participants 5 and 9 demonstrated an increased presence of upper harmonics between 15,000 Hz and 20,000 Hz. A spectrum plot of a clarinet sound considered characteristic of the instrument indicates a prominence of the fundamental, and odd numbered harmonics (Benade, 1960, p. 230). Figure 18 (produced by the researcher) provides a visual representation of a typical harmonic spectrum of the clarinet and can be used to make comparisons of plot spectrums collected in the study.

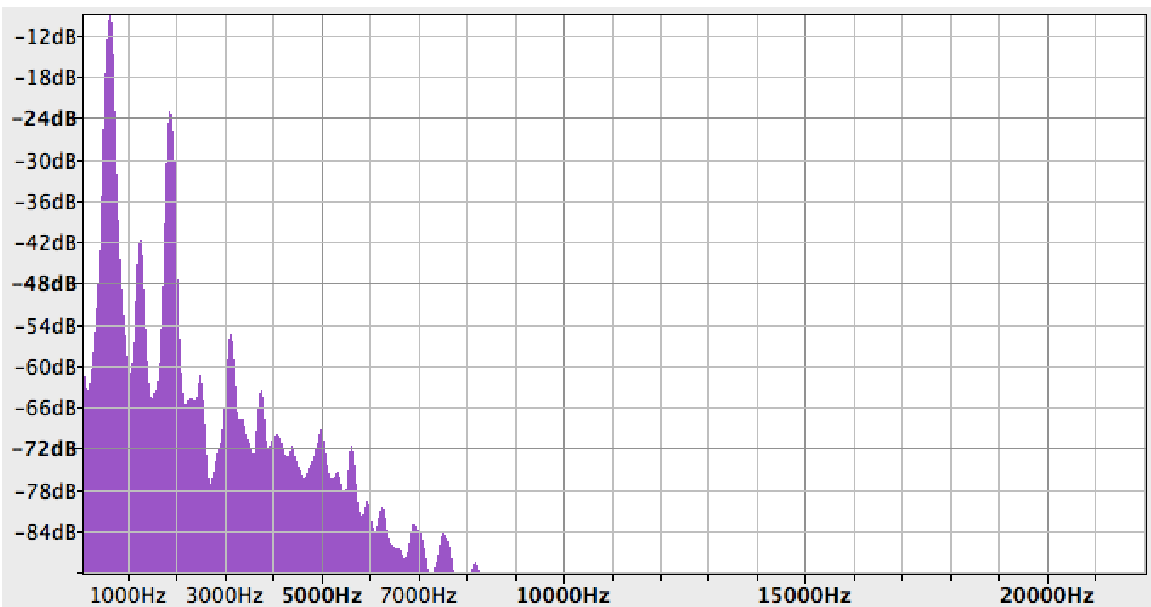

Figure 18. Characteristic Plot Spectrum of the Clarinet with Prominent Odd (3rd and 5th) Harmonics.

Mopane

Similar to the observations made of Cocobolo, Mopane did not produce a harmonic spectrum typically recognized as characteristic of the clarinet. This was true for all participants, with the exception of participant 11, who produced a plot spectrum that demonstrated a larger presence of odd harmonics. Participants 4, 5, 6, 7, and 9 all produced a similar plot spectrum that possessed especially present 2nd and 3rd harmonics. Mopane was generally very resonant for most participants. Specifically, participants 4 and 11 showed particularly active upper harmonics (up to 20,000 Hz for participant 4 and 15,000 Hz for participant 11).

Grenadilla

Plot spectrum observation of Grenadilla showed that four participants produced a harmonic spectrum typically recognized as characteristic of the clarinet, with a slightly more present 3rd harmonic (participants 4, 5, 10, and 11). Additionally, Grenadilla showed a high degree of resonance for participants 4, 5, and 9.

Delrin

With the exception of participant 5, Delrin did not produce a harmonic spectrum typically recognized as characteristic of the clarinet. One trait common to the plot spectrums of the participants for Delrin, excluding participants 4, 5 and 9, was a more severe decline in the presence of the 4th harmonic. Interestingly, the participants who did not show a severe decline in the 4th harmonic, demonstrated a higher degree of resonance of upper harmonics.

Personal Barrel

Due to the fact that each barrel belonging to the participants possessed a different bore and varied in age, material, and length, it was not surprising that there were no common empirical observations of plot spectrums. Excluding participant 5, no participant (participants 4, 6, 7, 8, 9, 10, or 11) demonstrated the full harmonic spectrum typically recognized as characteristic of the clarinet on their personal barrels. With the exception of participants 4, 5, 9, and 11, there was no harmonic activity above 10,000 Hz. However, the participants who demonstrated a higher degree of resonance of upper harmonics did show a commonality of a more gradual and consecutive decline in the 2nd, 3rd, and 4th harmonics.

Purpleheart

Common among all participants, the 2nd and 3rd harmonics were the most prominent in the plot spectrums demonstrated by Purpleheart. Similarly to Cocobolo, Mopane, Grenadilla, Delrin and the participants' personal barrels, Purpleheart did not create a harmonic spectrum that demonstrated more prominent odd harmonics (excluding the spectrum produced by participant 5).

Second Research Question

The second research question referred to both player perception and acoustic reality of the materials' response to articulation: Do different materials used to manufacture clarinet barrels have a measurable effect on the response (immediacy of tone and vibration to the player) of the instrument? Task III of the procedures, which required the participants to play the excerpt from Gounod's "Faust – Ballet Music," was intended to capture and define differences in the response to articulation profile of the materials tested in the study.

According to the results of the survey, Delrin received the highest rating of response to articulation, with an average rating of 4.375. Cocobolo, Mopane, and the participants' Personal Barrels received the same rating, with an average score of 4.125. Purpleheart scored just below, with an average score of 4.0, and Grenadilla scored the lowest, with an average score of 3.5. The researcher believes that there is a possibility that these scores are skewed, as player perception of poor response is often confused with their perception of resistance. See Tables 8–13.

Articulation profiles were isolated from the recordings of the participants in the study for analysis of the immediacy of response to articulation. Empirical observation of the articulation profiles of all the materials did not show any commonalities among materials. However, there were consistencies of articulation based on the type of mouthpiece used by the participants. Participants 5, 9, and 10 played Vandoren mouthpieces, which consistently produced articulation that was less defined than participants 4, 6, 7, 8, and 11, who played either Vintage or custom-made, Zinner blank-based mouthpieces (articulation profiles located in Appendix B).

Table 8

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Cocobolo

Participant	**Material**	**Response Rating**
4	Cocobolo	5
5	Cocobolo	4
6	Cocobolo	4
7	Cocobolo	5
8	Cocobolo	4
9	Cocobolo	3
10	Cocobolo	5
11	Cocobolo	3
	Total: 33	

Table 9

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Mopane

Participant	Material	Response Rating
4	Mopane	5
5	Mopane	2
6	Mopane	4
7	Mopane	4
8	Mopane	5
9	Mopane	4
10	Mopane	5
11	Mopane	4
	Total: 33	

Table 10

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Grenadilla

Participant	Material	Response Rating
4	Grenadilla	4
5	Grenadilla	2
6	Grenadilla	5
7	Grenadilla	5
8	Grenadilla	3
9	Grenadilla	3
10	Grenadilla	4
11	Grenadilla	2
	Total: 28	

Table 11

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Delrin

Participant	Material	Response Rating
4	Delrin	5
5	Delrin	5
6	Delrin	4
7	Delrin	5
8	Delrin	4
9	Delrin	3
10	Delrin	5
11	Delrin	4
	Total: 35	

Table 12

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Personal Barrel

Participant	Material	Response Rating
4	Personal Barrel	5
5	Personal Barrel	4
6	Personal Barrel	4
7	Personal Barrel	5
8	Personal Barrel	5
9	Personal Barrel	2
10	Personal Barrel	5
11	Personal Barrel	3
	Total: 33	

Table 13

Clarinet Barrel Material Preference Survey Scores for Response of Articulation for Purpleheart

Participant	Material	Response Rating
4	Purpleheart	4
5	Purpleheart	4
6	Purpleheart	4
7	Purpleheart	4
8	Purpleheart	5
9	Purpleheart	2
10	Purpleheart	5
11	Purpleheart	4
	Total: 32	

Third Research Question

The third research question addressed player perception of dynamic intensity and control: Do different materials have an impact on the intensity (volume/projection) of the clarinet? The results of this question are in reference to the ratings given by the participants after being asked to rate each barrel relative to ease of achieving 91 dB for both one and three seconds while playing a clarion register F-natural (see Tables 14–19).

The results of the *Clarinet Barrel Material Preference Survey* determined that Grenadilla scored the highest, with a sum score of 75, meaning that most participants felt that Grenadilla was the easiest to achieve and maintain the requested decibel level. Purpleheart received the second highest rating with a sum score of 72. Delrin and the participants' Personal Barrels received the same combined score of 71, and Mopane and Cocobolo received scores of 69 and 60, respectively.

Table 14

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Cocobolo

Participant	**Material**	**Rating: 91 dB for One Second**	**Rating: 91 dB for Three Seconds**
4	Cocobolo	4	4
5	Cocobolo	4	3
6	Cocobolo	5	5
7	Cocobolo	5	5
8	Cocobolo	3	4
9	Cocobolo	2	4
10	Cocobolo	5	5
11	Cocobolo	1	1
Total = 60			

Table 15

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Mopane

Participant	**Material**	**Rating: 91 dB for One Second**	**Rating: 91 dB for Three Seconds**
4	Mopane	5	5
5	Mopane	3	4
6	Mopane	4	5
7	Mopane	4	5
8	Mopane	4	4
9	Mopane	4	4
10	Mopane	5	5
11	Mopane	4	4
Total = 69			

Table 16

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Grenadilla

Participant	**Material**	**Rating: 91 dB for One Second**	**Rating: 91 dB for Three Seconds**
4	Grenadilla	4	5
5	Grenadilla	5	5
6	Grenadilla	5	5
7	Grenadilla	5	5
8	Grenadilla	5	5
9	Grenadilla	3	5
10	Grenadilla	4	4
11	Grenadilla	5	5
Total = 75			

Table 17

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Delrin

Participant	**Material**	**Rating: 91 dB for One Second**	**Rating: 91 dB for Three Seconds**
4	Delrin	4	5
5	Delrin	5	5
6	Delrin	4	5
7	Delrin	5	5
8	Delrin	5	5
9	Delrin	3	3
10	Delrin	4	4
11	Delrin	5	4
Total = 71			

Table 18

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Personal Barrel

Participant	Material	Rating: 91 dB for One Second	Rating: 91 dB for Three Seconds
4	Personal Barrel	5	4
5	Personal Barrel	4	5
6	Personal Barrel	4	5
7	Personal Barrel	5	5
8	Personal Barrel	5	5
9	Personal Barrel	4	1
10	Personal Barrel	5	5
11	Personal Barrel	5	4
Total = 71			

Table 19

Clarinet Barrel Material Preference Survey Scores for Ease of Achieving and Sustaining 91 dB for Purpleheart

Participant	Material	Rating: 91 dB for One Second	Rating: 91 dB for Three Seconds
4	Purpleheart	4	4
5	Purpleheart	5	5
6	Purpleheart	5	5
7	Purpleheart	5	5
8	Purpleheart	4	5
9	Purpleheart	4	4
10	Purpleheart	4	5
11	Purpleheart	5	4
Total = 72			

Fourth Research Question

The fourth research question refers to the results of Task IV of the procedure, when the participant was asked to determine their top choice material by playing a short and identical passage of their choosing: Will participants have a preference for specific materials tested? The results in this study yielded no clear favorite. Participants 6 and 10 chose Mopane, participants 5 and 11 chose Grenadilla, participants 7 and 8 chose Delrin, and participants 4 and 9 chose Purpleheart. No participants chose Cocobolo, which paralleled the results of the survey, with Cocobolo receiving the lowest overall score of all materials.

Additional Observations and Limitations of the Study

As with many studies involving experimental research, this particular study had several limitations. Ideally, this research would have been conducted in an environment that was consistent, including the same acoustic sampling space, same mouthpiece, ligature and reed combination, and instrument in order to control as many variables as possible. Because it was not possible to fund the travel of each subject that participated in the study, the acoustic environments of each individual experiment were not the same, likely affecting the results collected by the recording device. This study was designed to accommodate for these uncontrolled variables in that the researcher was looking for intra-subject responses as well as any impact of cumulative data.

One component of the data collection was intra-player preference. In order to obtain an accurate measure of a participant's material preference, it was necessary for each subject to play on a setup with which they were most comfortable. Due to this limitation, no two mouthpieces, ligatures, reed brands/strengths, or even instrument brands were the same between participants, altering the plot spectrum and articulation profile collected from the experiments. However, this study had several elements that could be controlled, including the internal barrel dimensions, the type of wood selected, the distance of each participant from the decibel meter and recording device, and the fact that each test was performed blind.

There is a great deal of similarity between the plot spectrums of the individual participant's preferred material and the plot spectrums of their personal barrel. Perhaps some participants preferred barrels most similar to their own or responded favorably to barrels best suited to their personal mouthpiece, reed, and ligature configuration.

While there are some consistencies within the plot spectrums of each type of material, there are too many variables to quantify the results. Because the materials were tested on each participant's personal setup, the plot spectrums and articulation profiles were found to be inconsistent. Perhaps the variable most responsible for the lack of consistencies among recordings of all the participants was the fact that there were eight different mouthpieces used in this study. Within an individual experiment (i.e., only the test completed by participant 4), it was possible to see a difference in the harmonic spectrum and articulation profile of each barrel, but because no two participants played the same mouthpiece, this is not enough information to accurately identify the characteristics of each material.

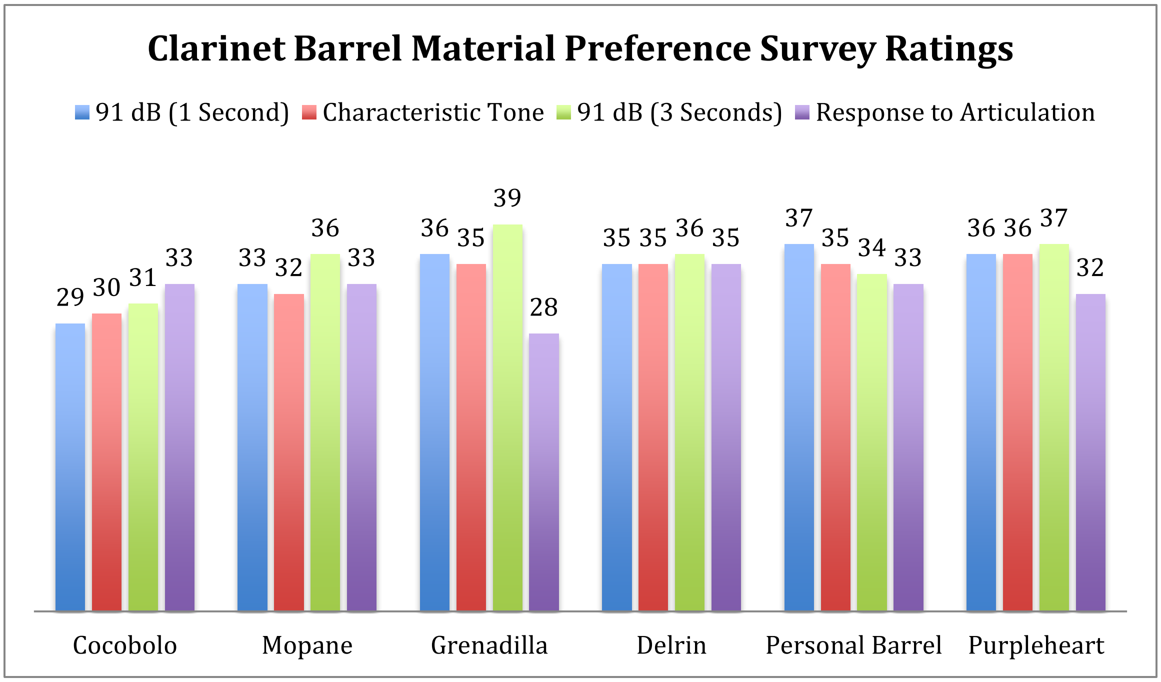

Figure 19. Overall Ratings Collected from the Clarinet Barrel Material Preference Survey.

CHAPTER IV

CONCLUSIONS

This study was the first of its kind and was the first step toward identifying the acoustic qualities of clarinet barrels made with exotic hardwoods and plastics and the tone quality preferences of participants. The results of the *Clarinet Barrel Material Preference Survey* indicated that Purpleheart was rated slightly above other materials in terms of participant observation of ease of achieving a characteristic clarinet tone quality. Delrin was rated the highest regarding participant observation as to which material demonstrated the most ease of response to articulation. Results of the survey indicated that Grenadilla was the material that was rated the highest regarding participant perception of ease of achieving and maintaining the desired decibel level. When participants were asked to play an excerpt of their choice in order to determine a preferred material, 25% of participants chose Mopane, 25% of participants chose Grenadilla, 25% of participants chose Delrin, and 25% of participants chose Purpleheart, meaning no material was preferred by a majority of participants. No participant chose Cocobolo.

The researcher made preliminary predictions as to whether materials would have an effect on the acoustic quality of clarinet barrels. Though there were commonalities among recordings of each material, the findings are not substantial enough to determine the true differences in the timbre, response to articulation, or intensity of the tested materials. This may be due to the need for more areas of control for the experiment.

There is a possibility that the group of barrels selected at the conclusion of the pilot study had an influence on the outcome of the official study. Because the individual barrels chosen for use in the official study were selected due to their large frequency of response and presence of overtones, it is possible that some of the barrels were constructed using materials that possessed uncharacteristic physical properties. In order to determine if this were a contributing factor to the outcome, additional research that tests a larger quantity of each material, testing the densities of individual samples, would be required.

Recommendations for Future Research

While this study did not determine enough acoustic differences among differing materials or conclude that one material is superior, it may inspire additional research on the subject.

Future research could include a study that controls more variables. Because this study did not control the acoustic environment, mouthpiece, type of ligature, brand and strength of clarinet reed, or the manufacture and model of clarinet, a replication study that controls more variables would be more accurate. Ideally, a study in the same acoustic setting, using the exact same mouthpiece, ligature, reed, and clarinet would be the most ideal scenario. Due to the fact that reeds made of cane are prone to warping because of the changing environment, an even more accurate measure of the differences of clarinet barrels would employ the use of a synthetic reed, which may be less vulnerable to changes in climate.

Given that the barrels manufactured for the study where handmade, inherently there was a degree of variability in the measurements of each individual barrel. Future studies could be done using barrels made by 5-axis CNC machinery, which could control tolerances to a higher degree.

Equipment is only one layer of control. In order to truly document an accurate reading, a study using a robot that can perfectly replicate each task, while keeping the same air and lip pressure on the reed, would most likely be the only accurate means of seeing the differences of material. This concept could motivate a more comprehensive study that includes the capturing of the harmonic spectrum of clarinet barrels made of differing materials using a wider range of pitch and decibel level.

This study recorded the initial impressions and evaluations of participants of the materials in the experiment. Further research could include a study that that records participant preference of material over a longer period of time, as initial impressions and preferences of material are not always maintained in a longer trial period. Additionally, future studies could compare the physical and dimensional integrity of materials after intense performance trials, cost-benefit analysis, and the ease of workability of individual materials used in the manufacturing process of clarinet barrels.

As stated in the introduction of this document, the research of Arthur H. Benade suggests that the material from which an instrument is made does not affect the quality of sound produced (Benade, 1960, p. 500). While this study may be an additional example of data in support of Benade's research, clarinetists will continue to debate that material of construction makes an audible difference. Although it was observed that this study did not demonstrate an outcome of an optimal or consistently measurable favorite material, it does provide evidence that there are many alternatives to the dwindling M'pingo resource.

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APPENDIX A

PARTICIPANT PLOT SPECTRUM

Cocobolo

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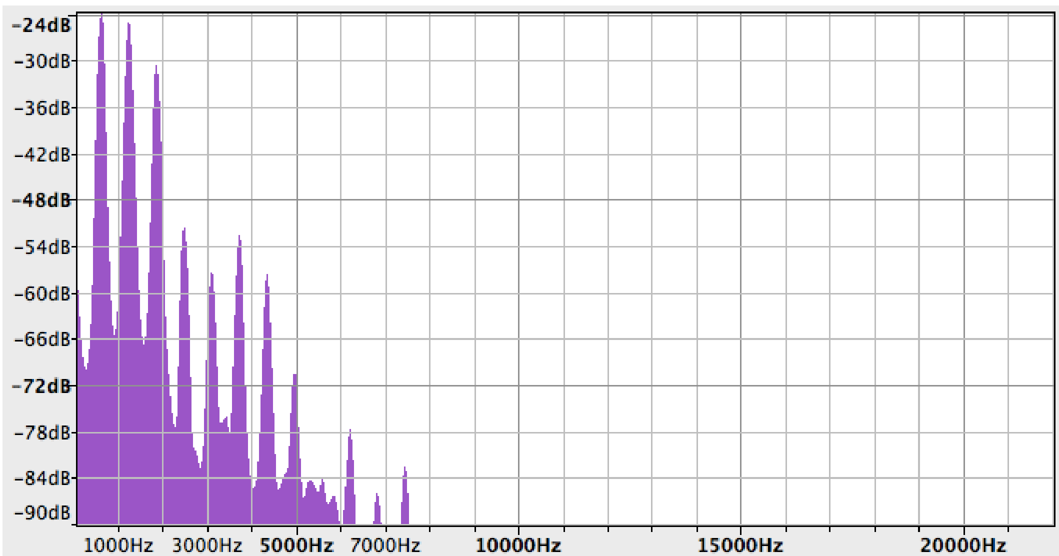

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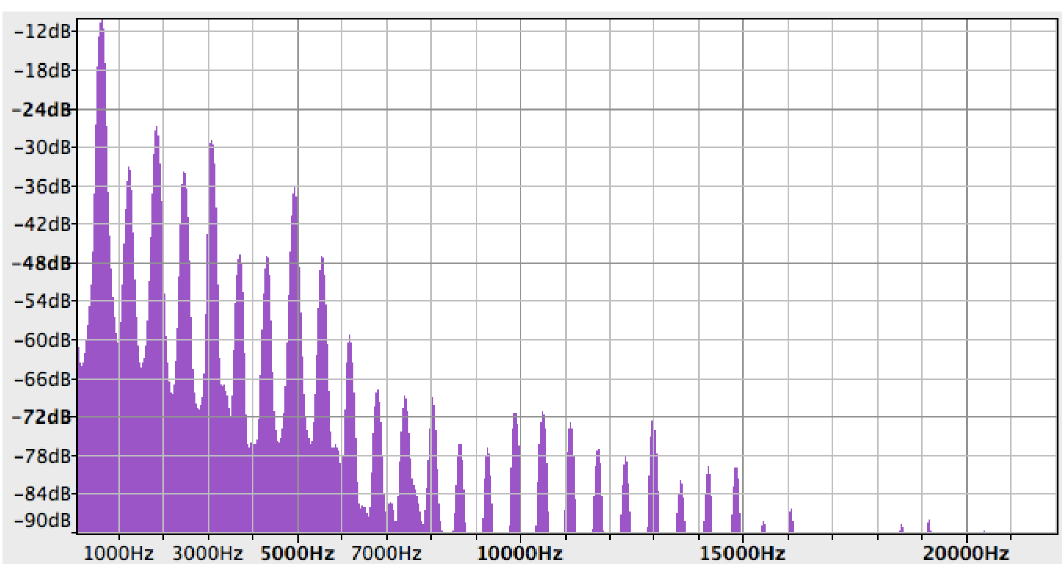

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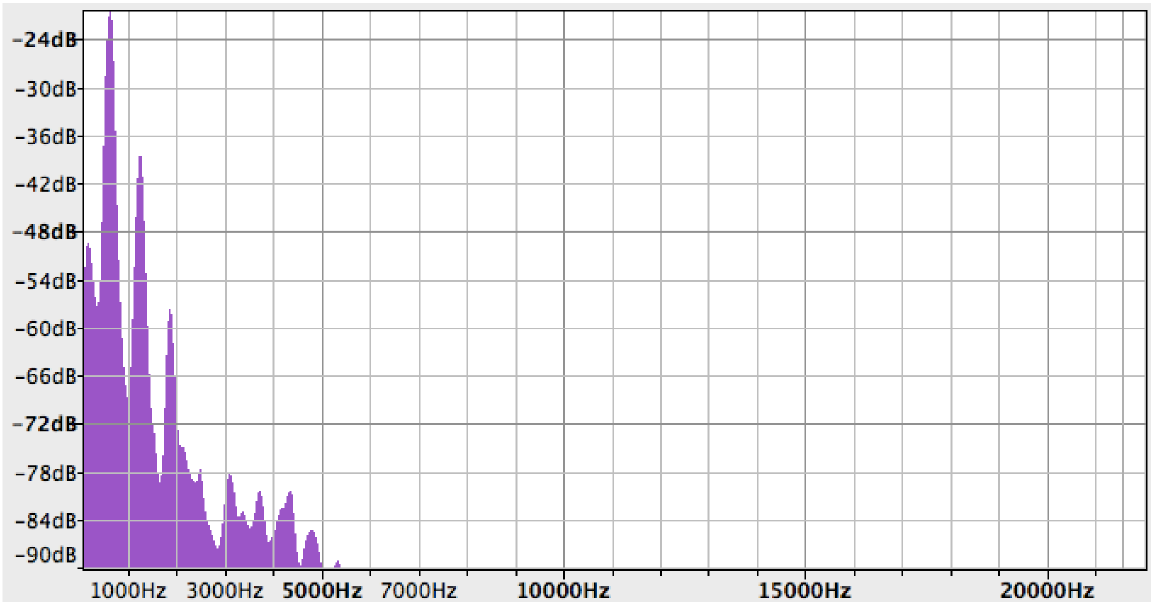

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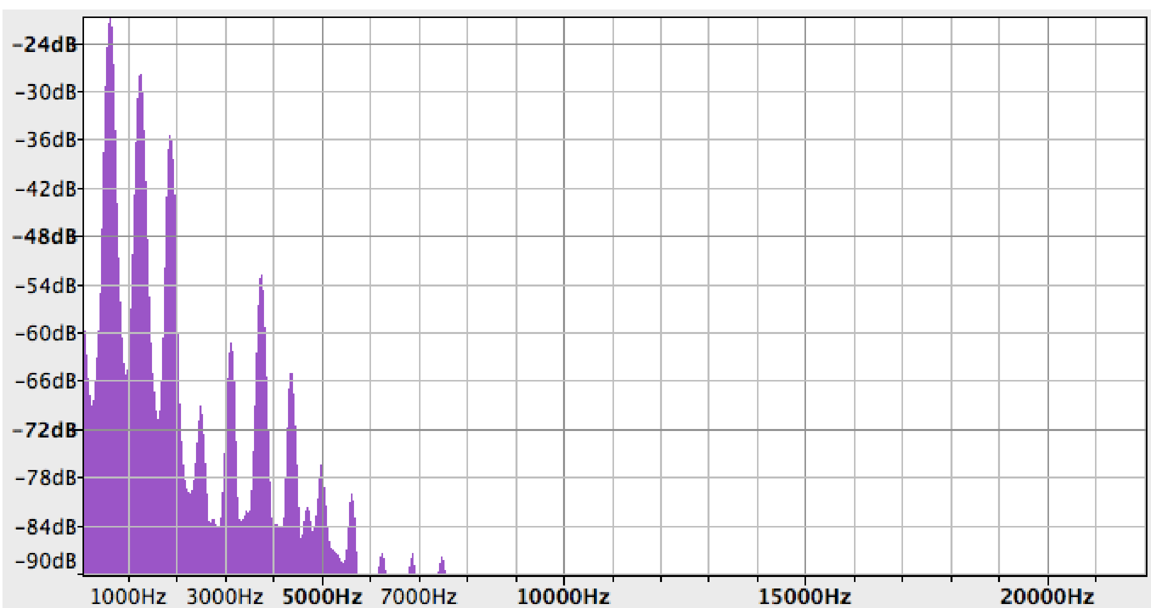

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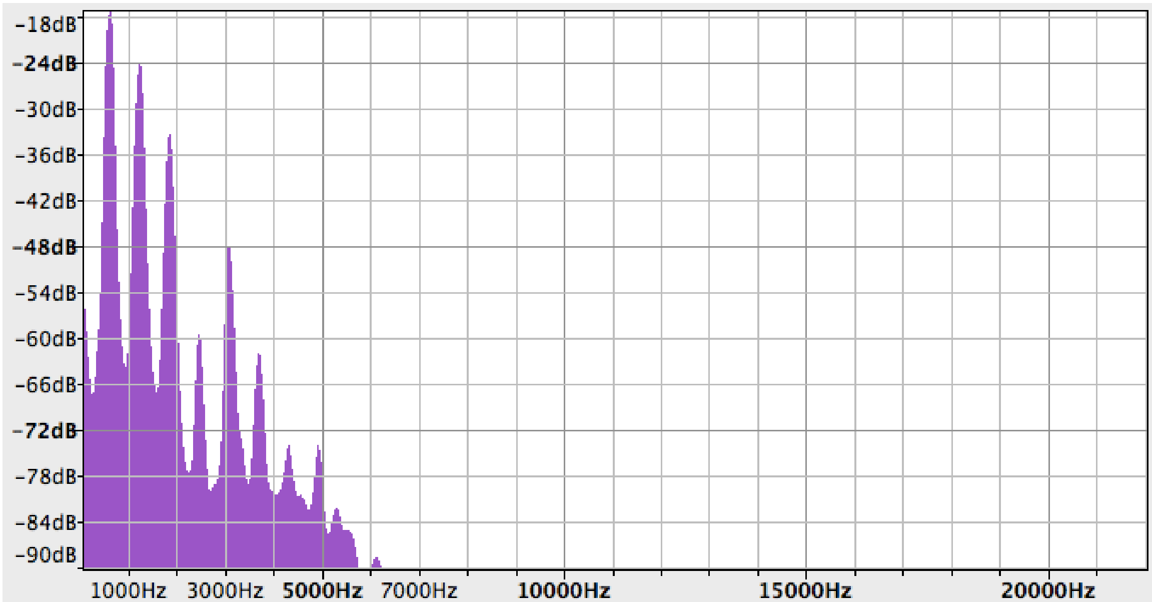

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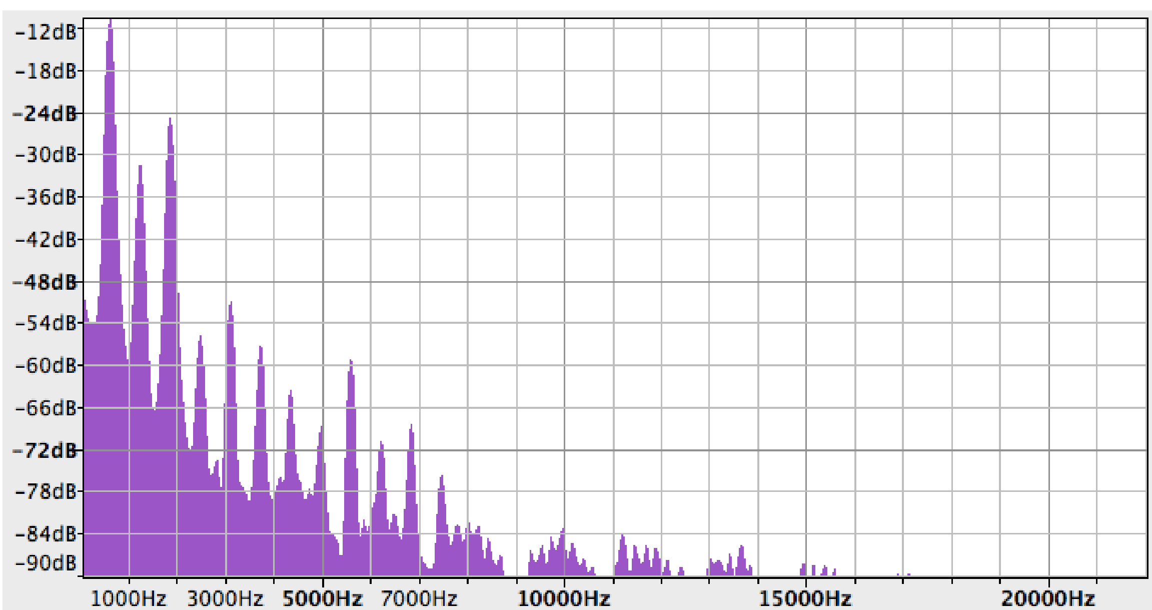

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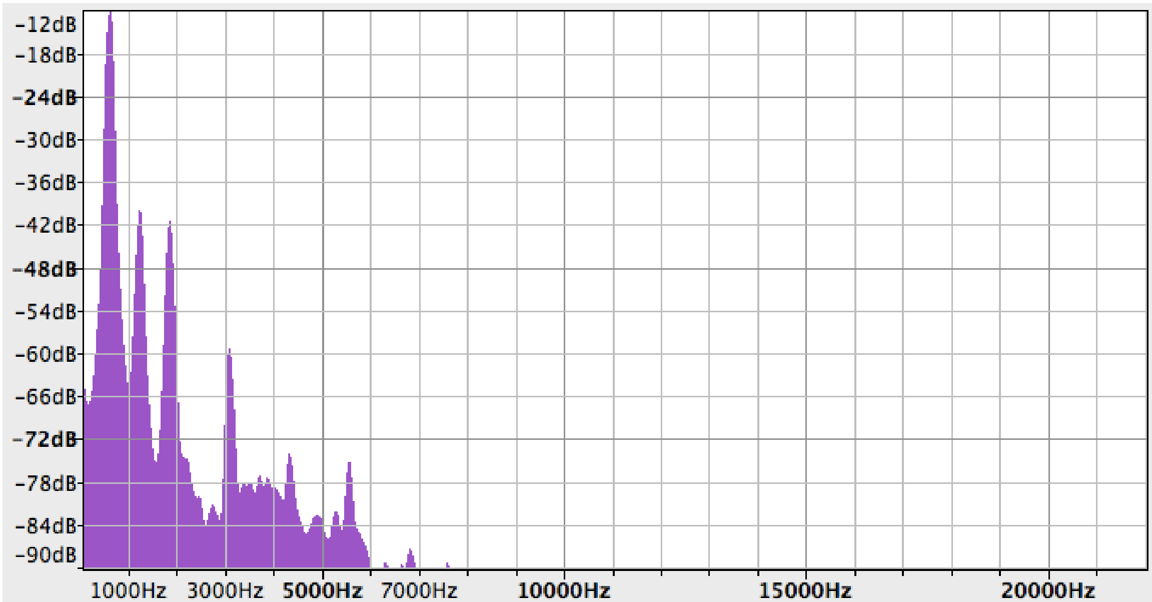

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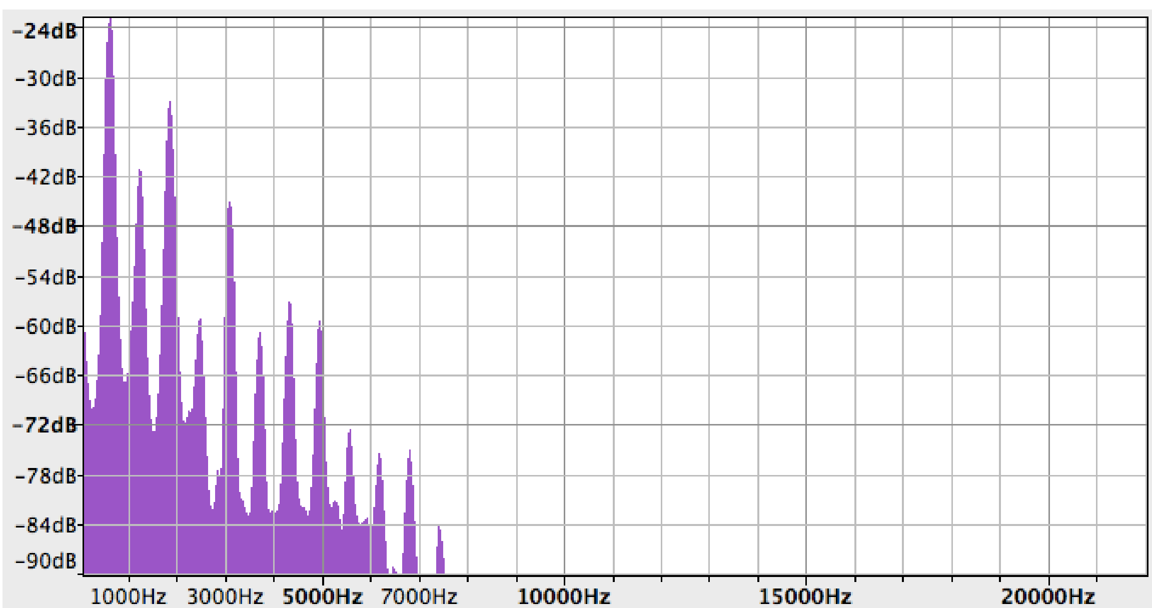

Mopane

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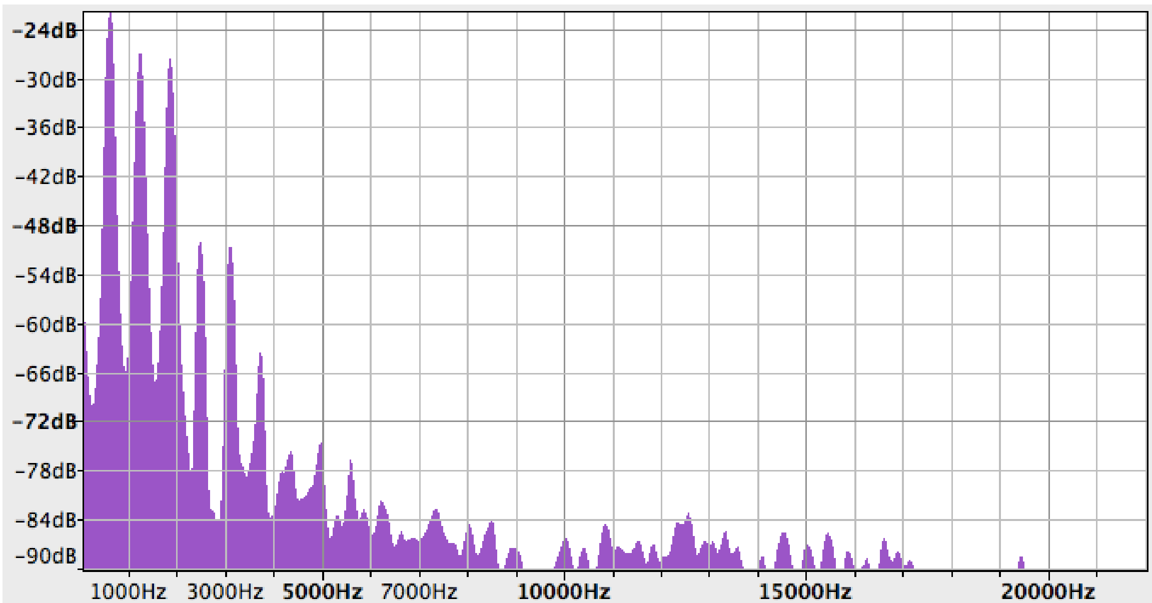

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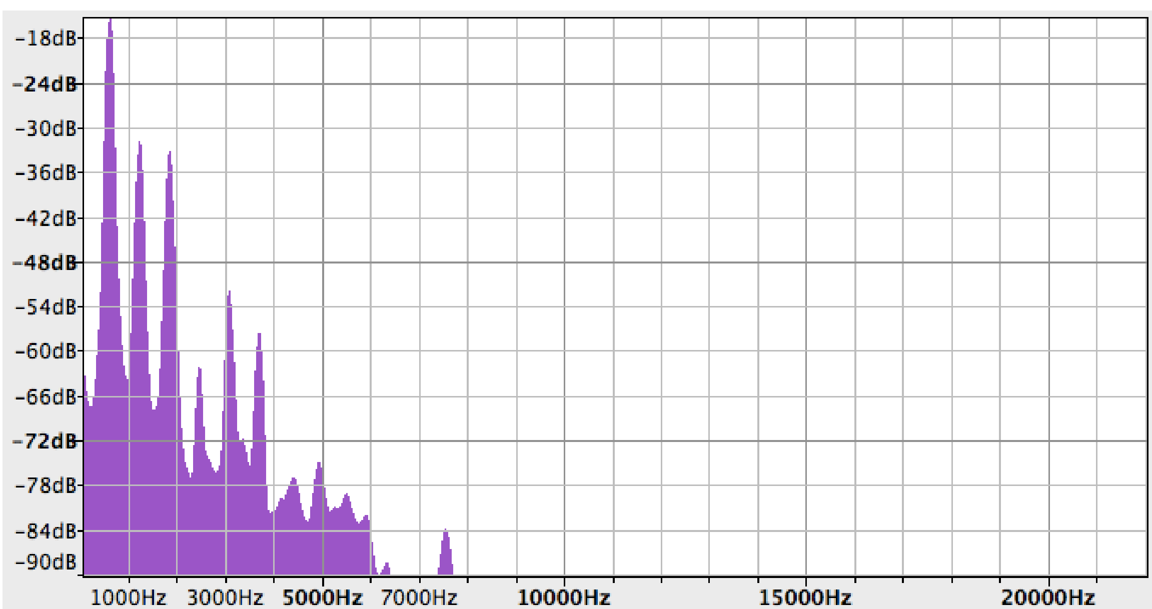

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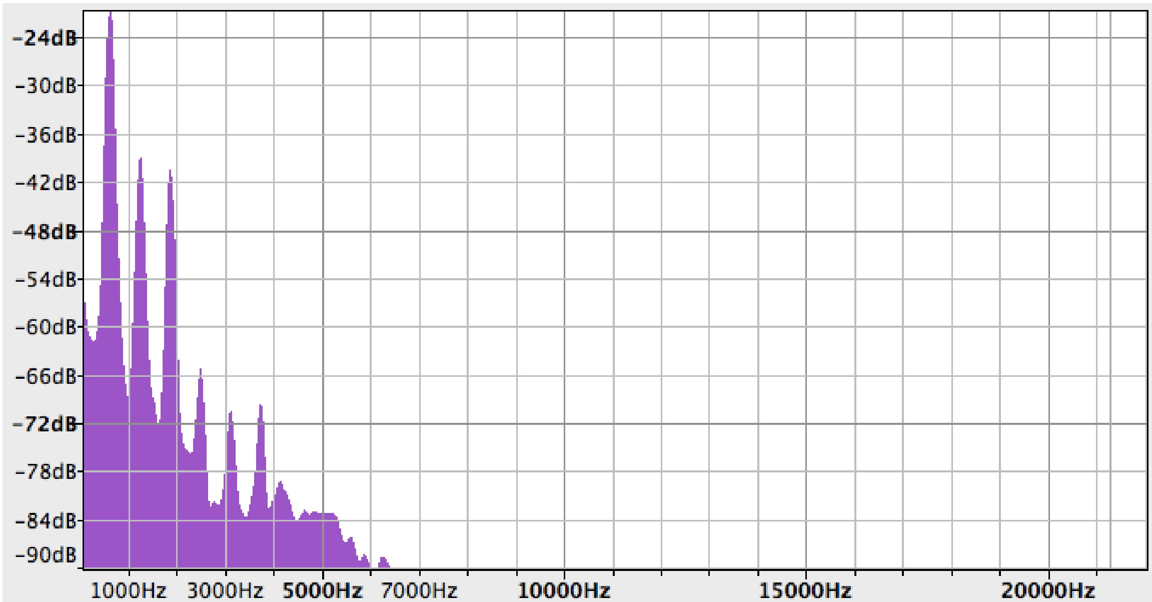

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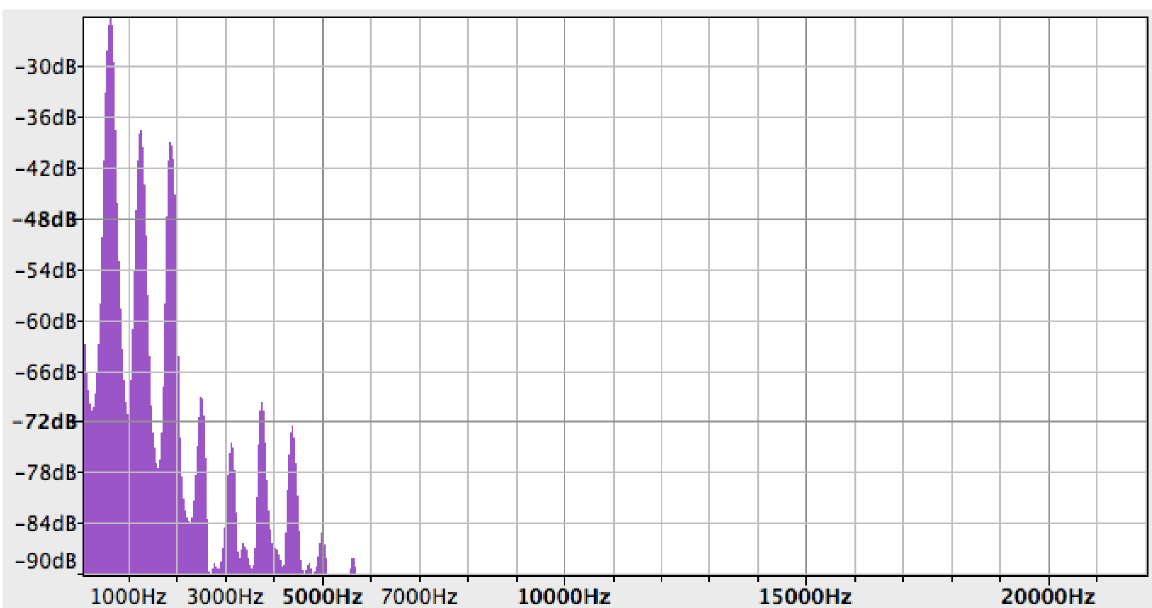

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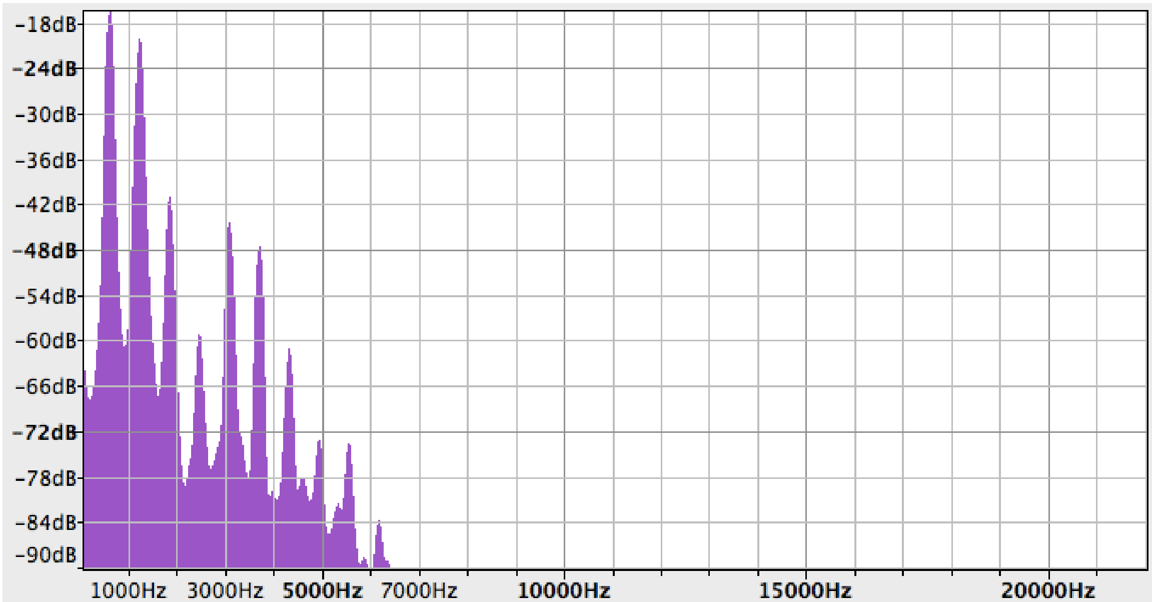

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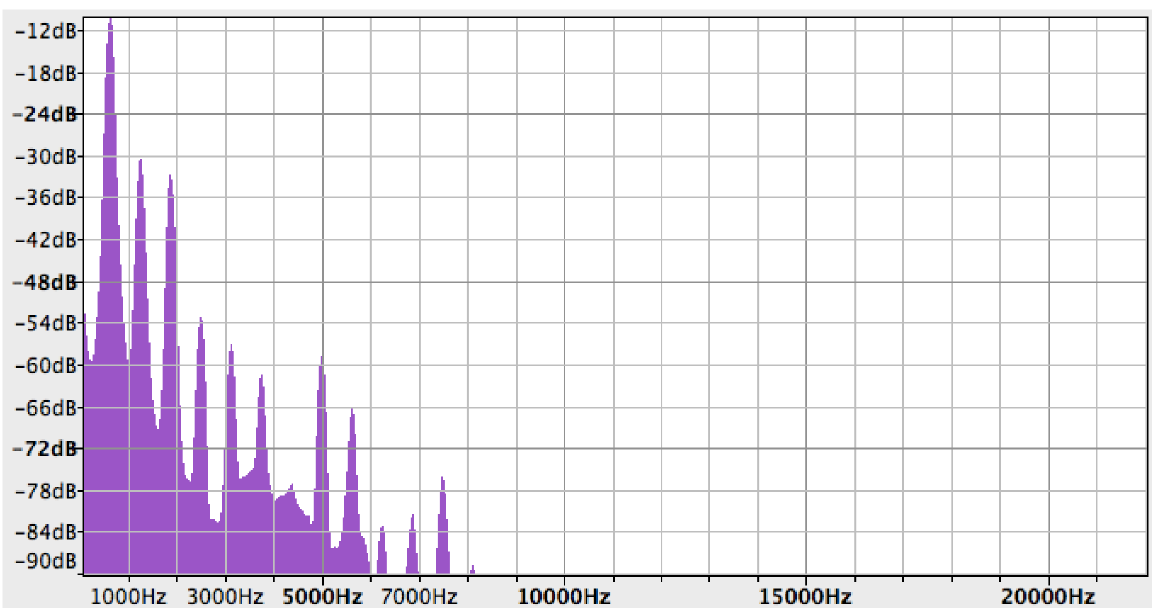

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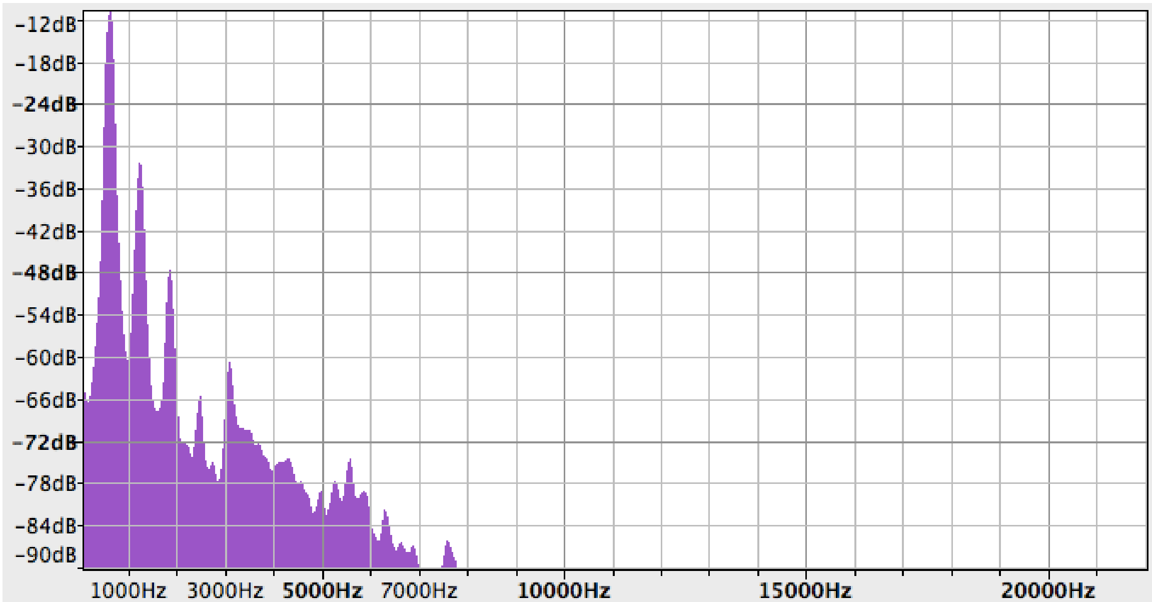

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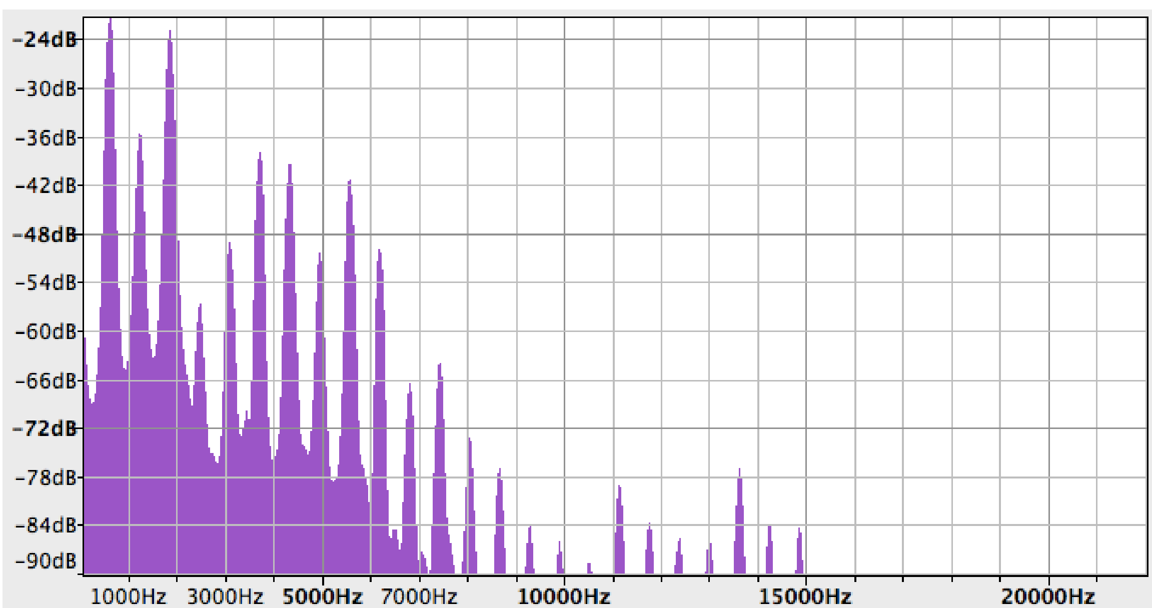

Grenadilla

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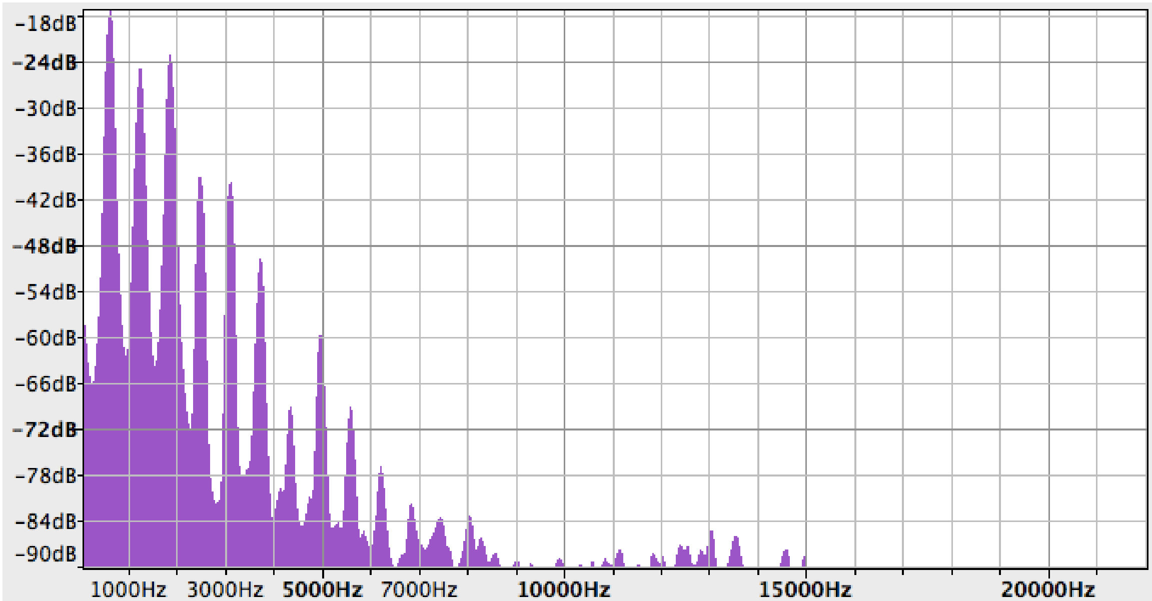

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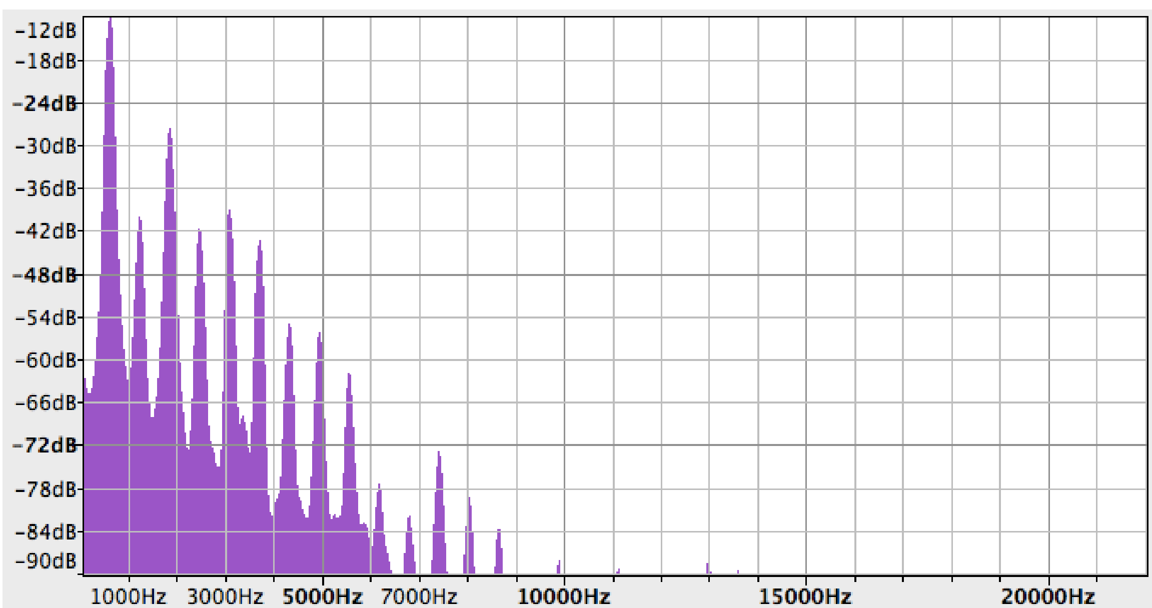

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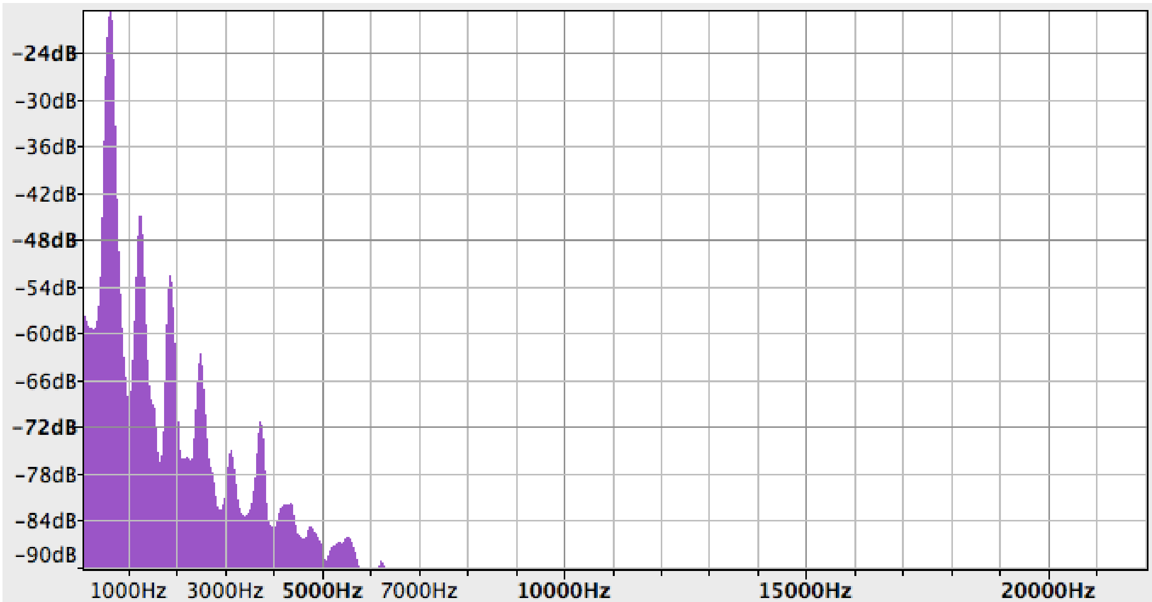

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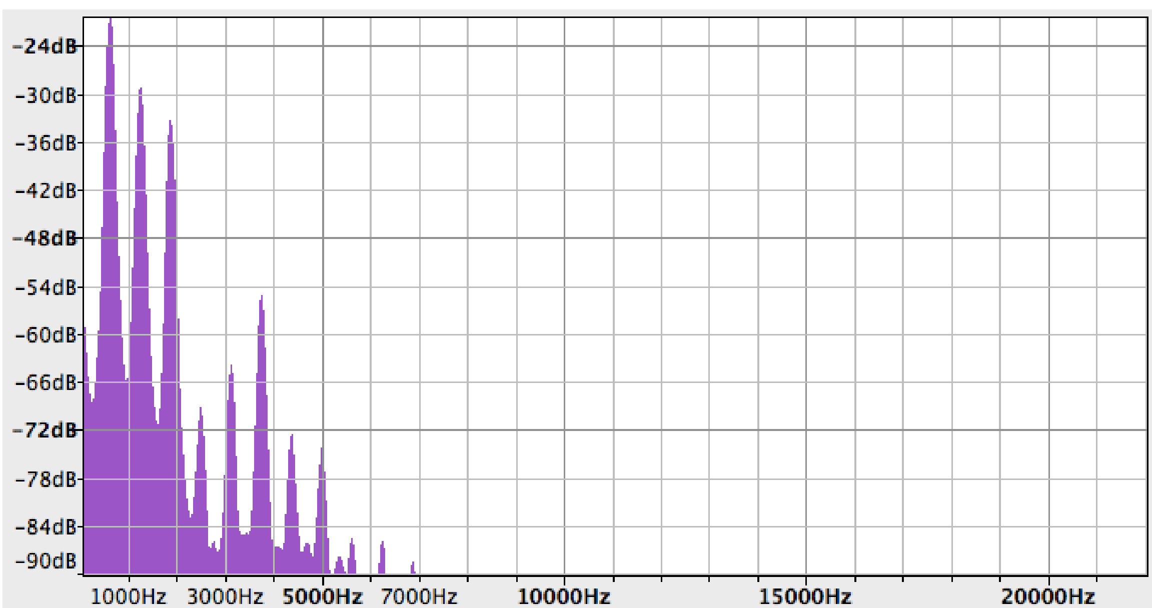

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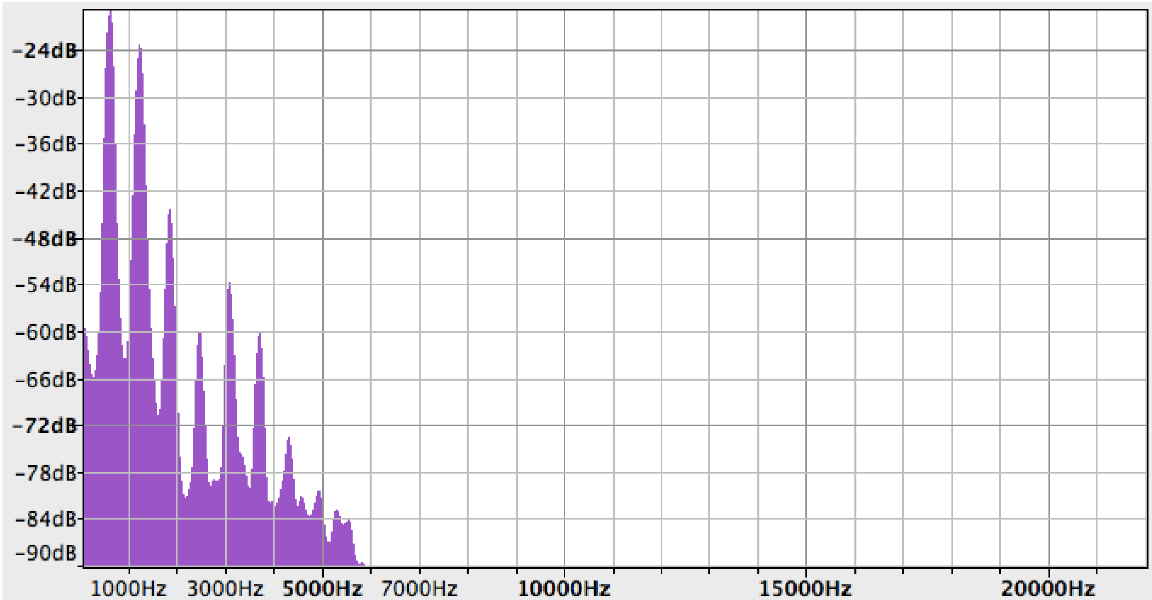

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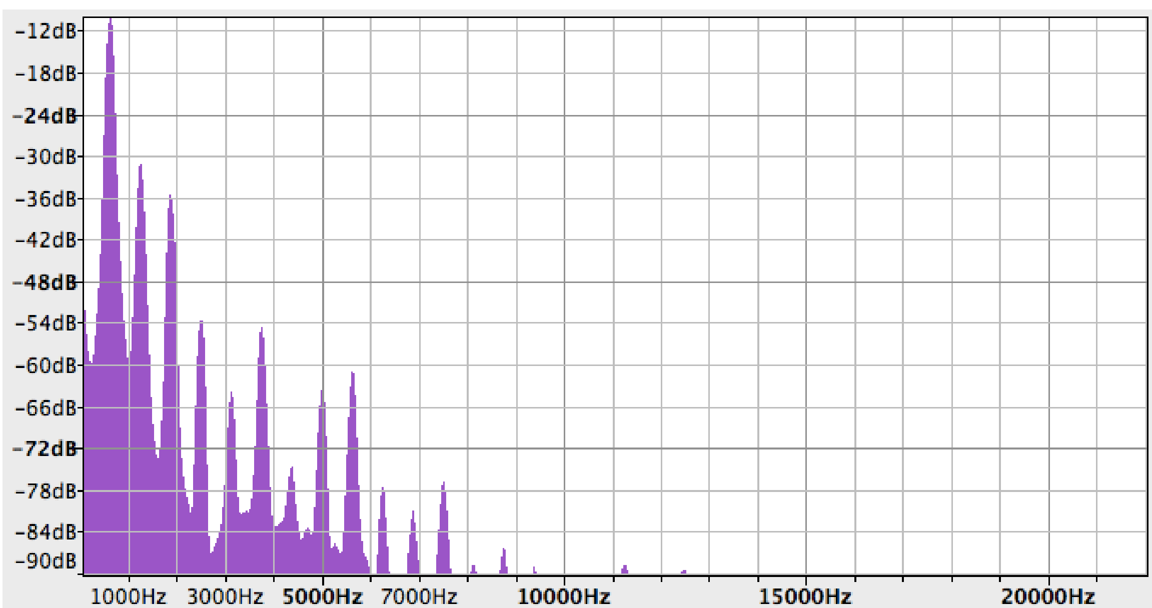

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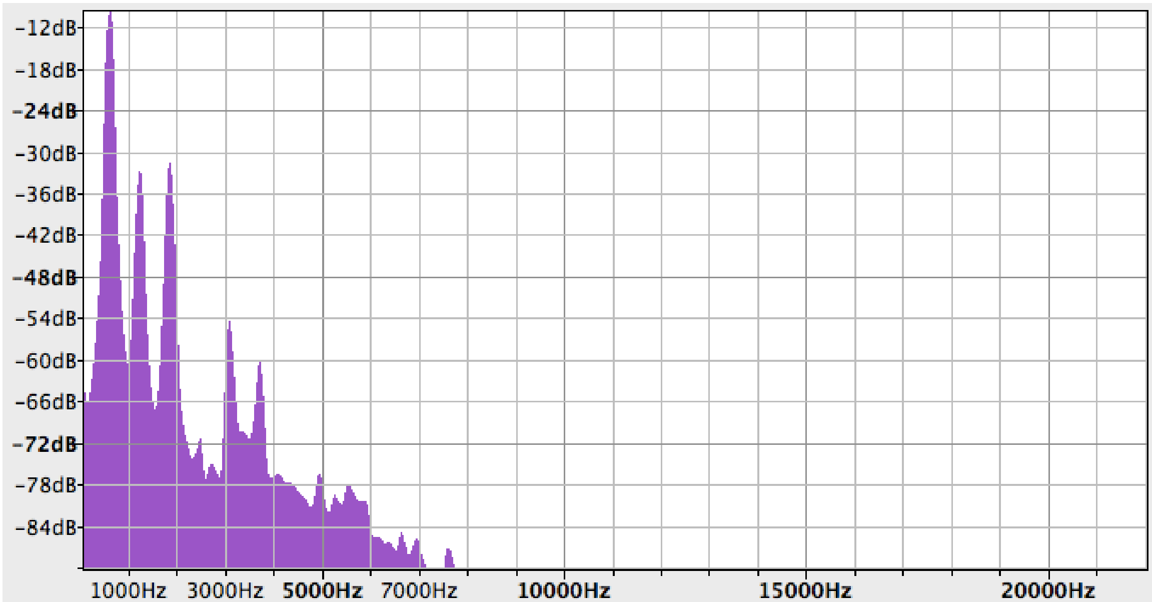

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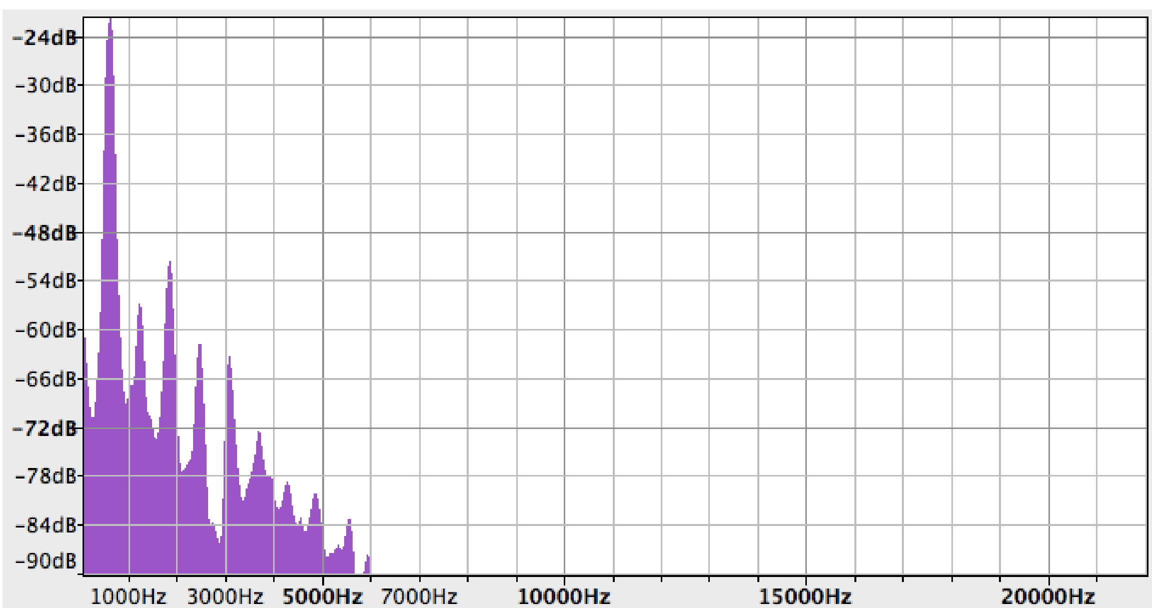

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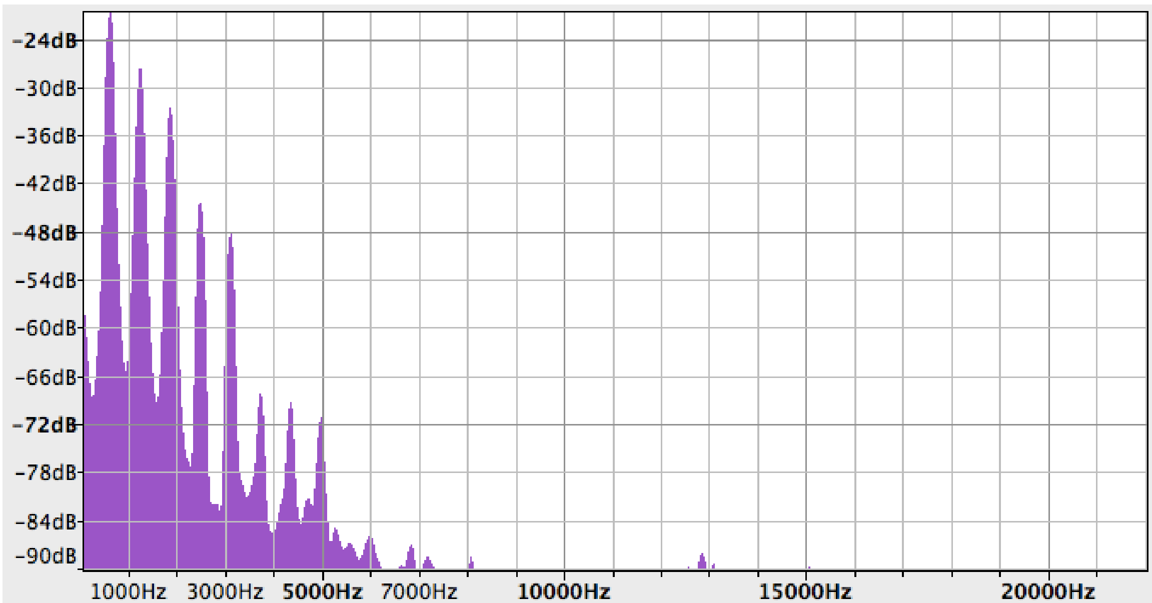

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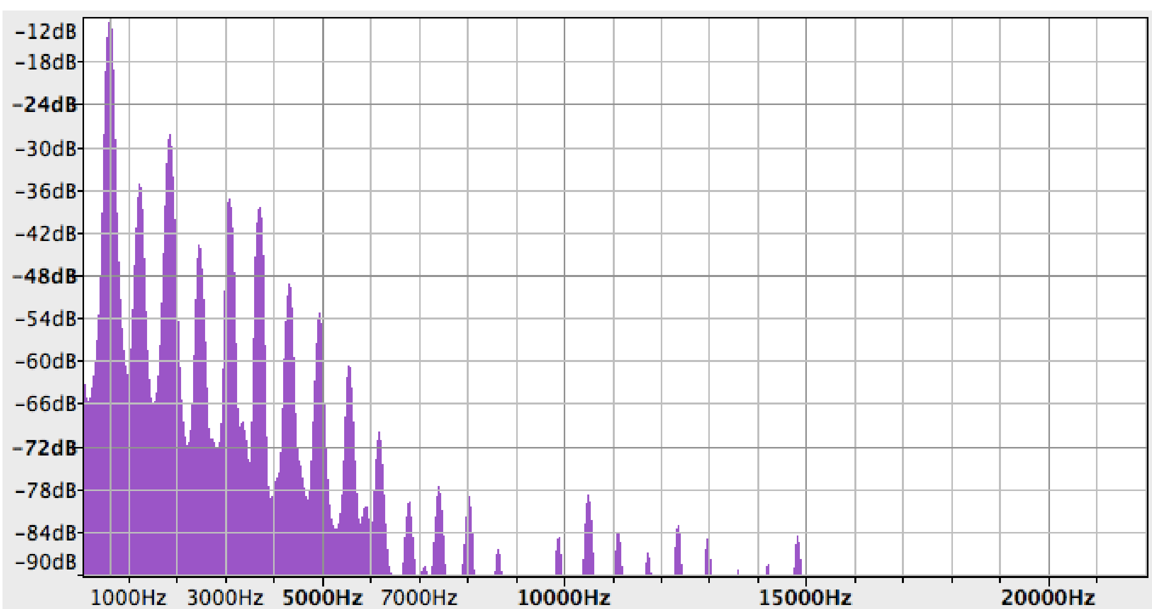

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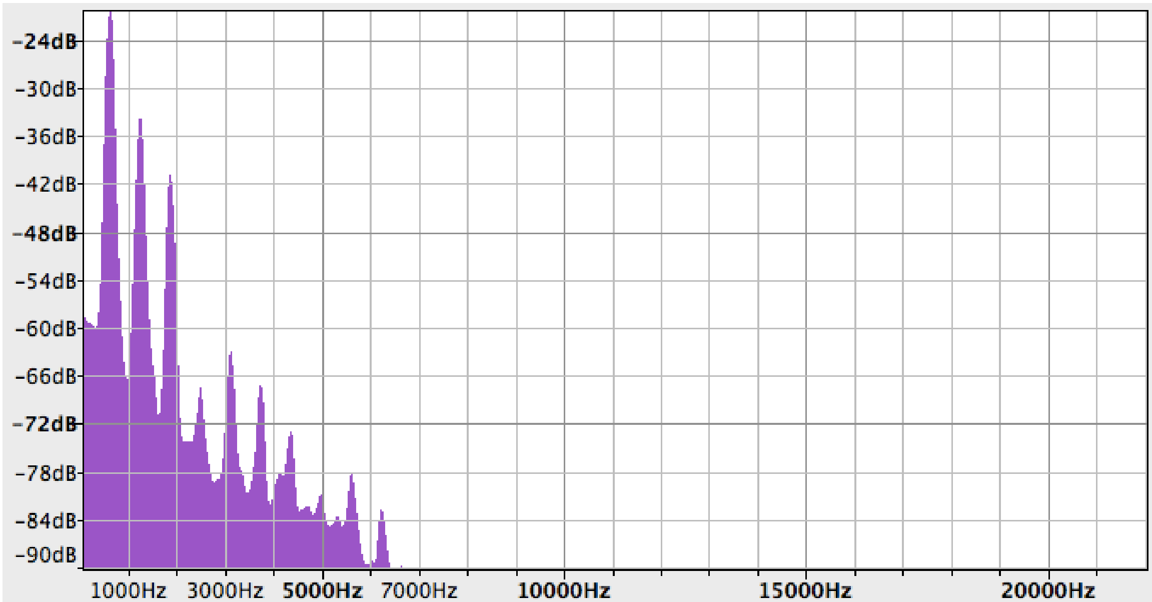

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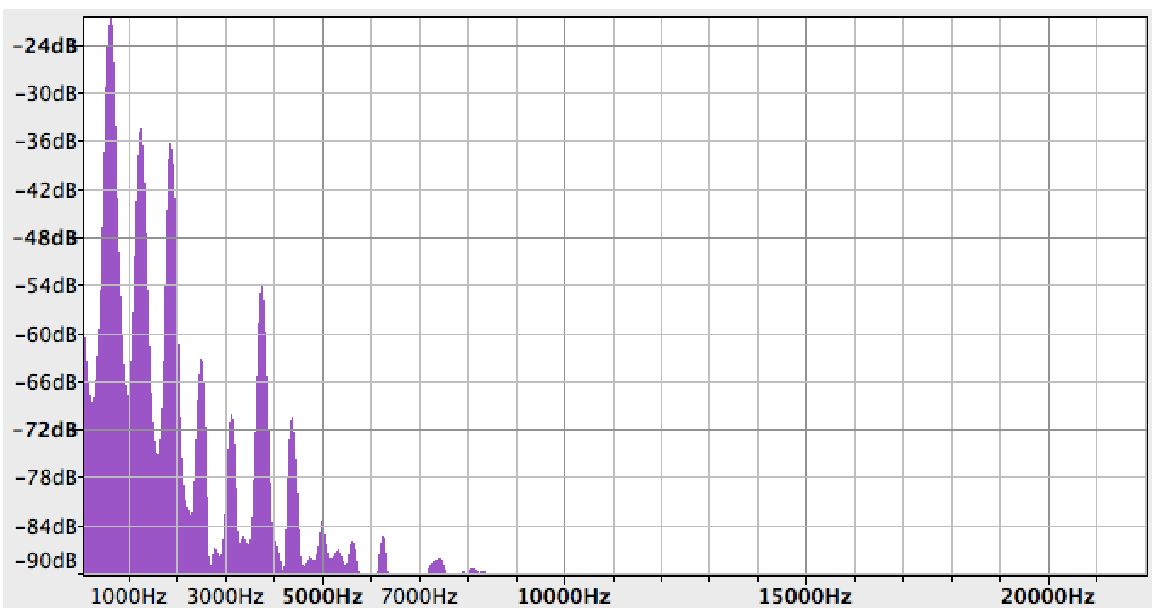

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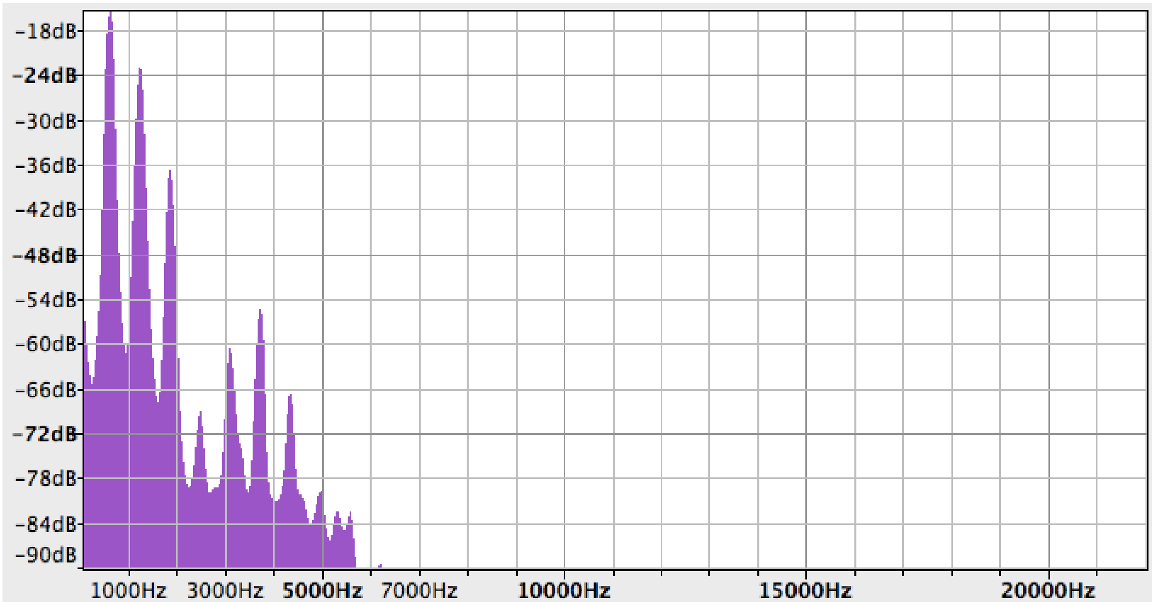

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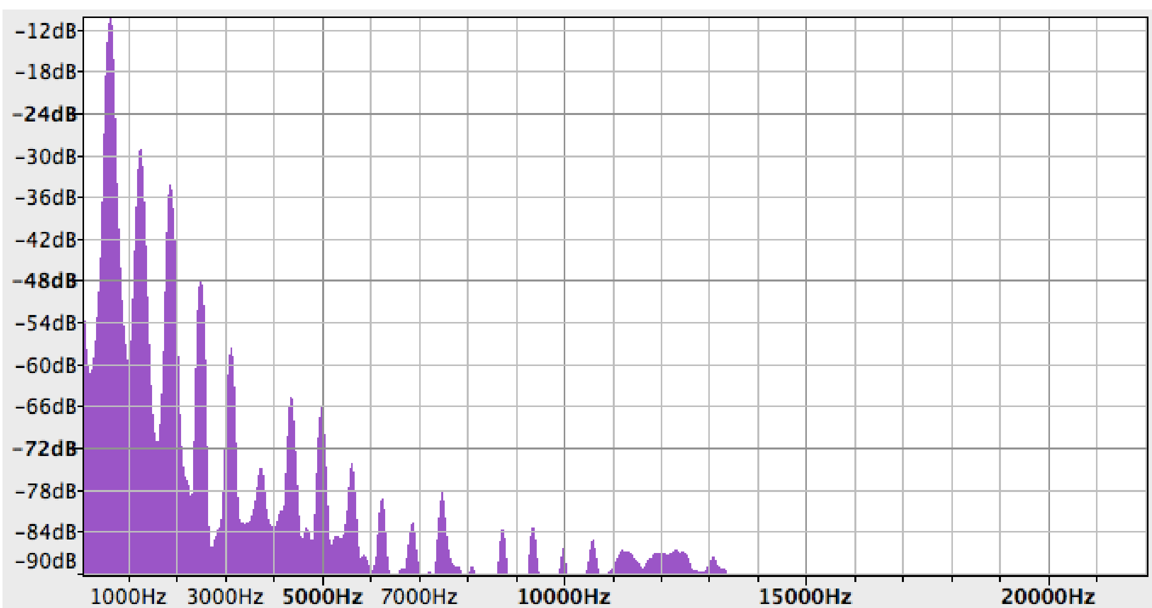

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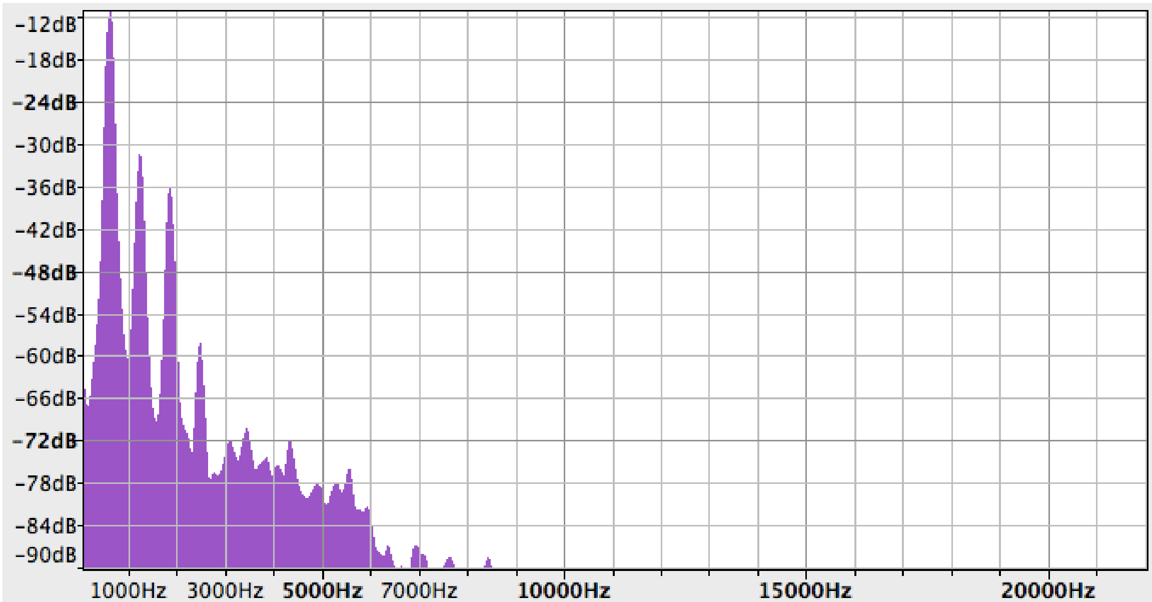

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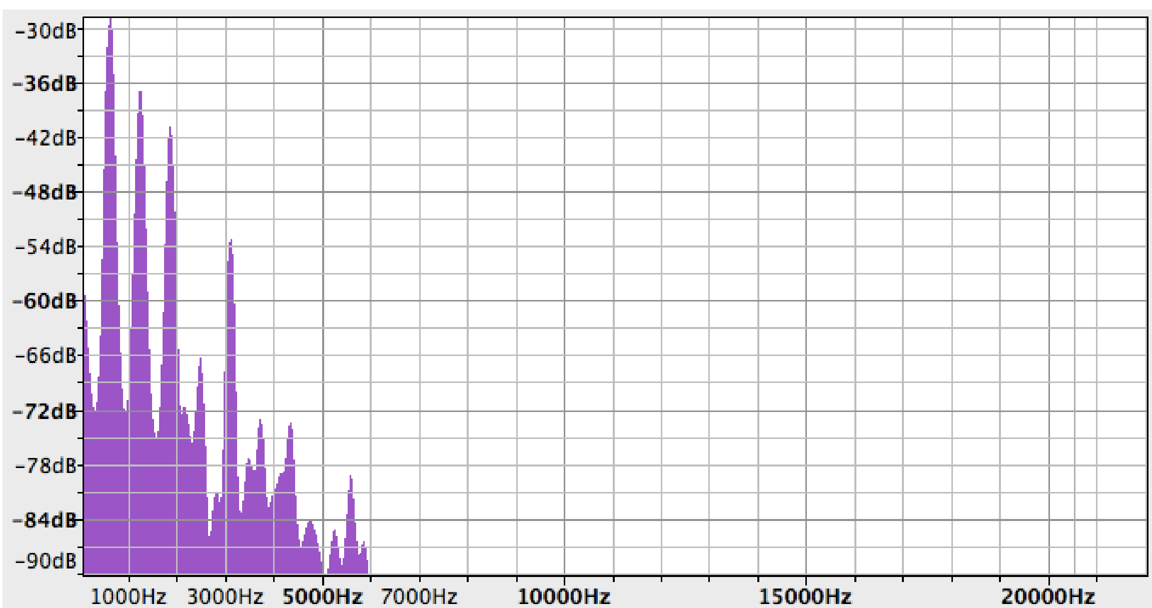

Participant Barrel

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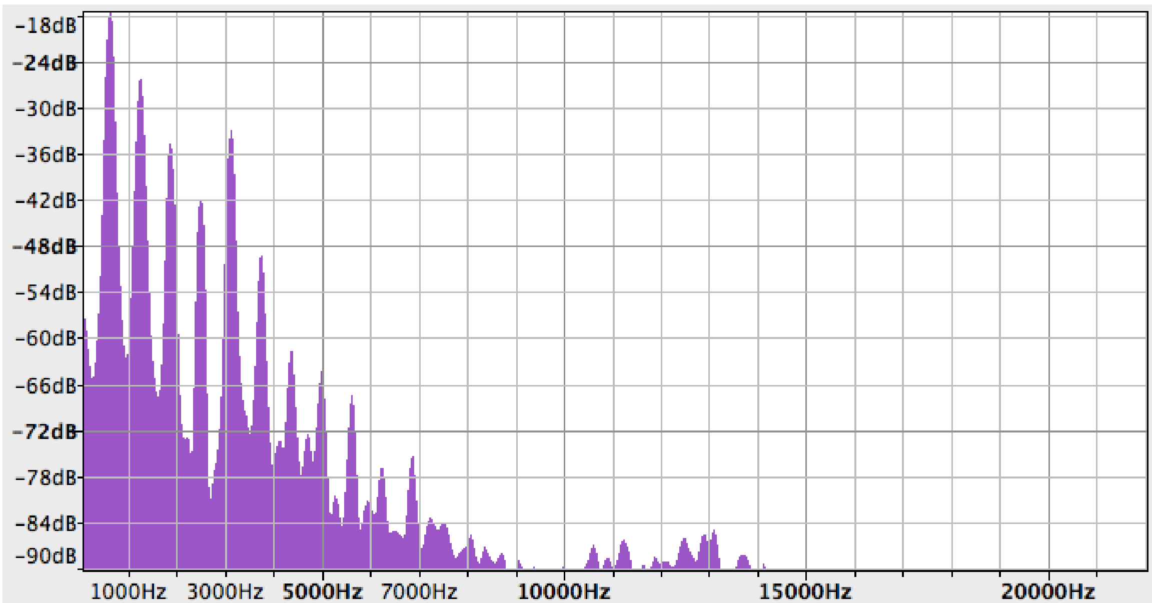

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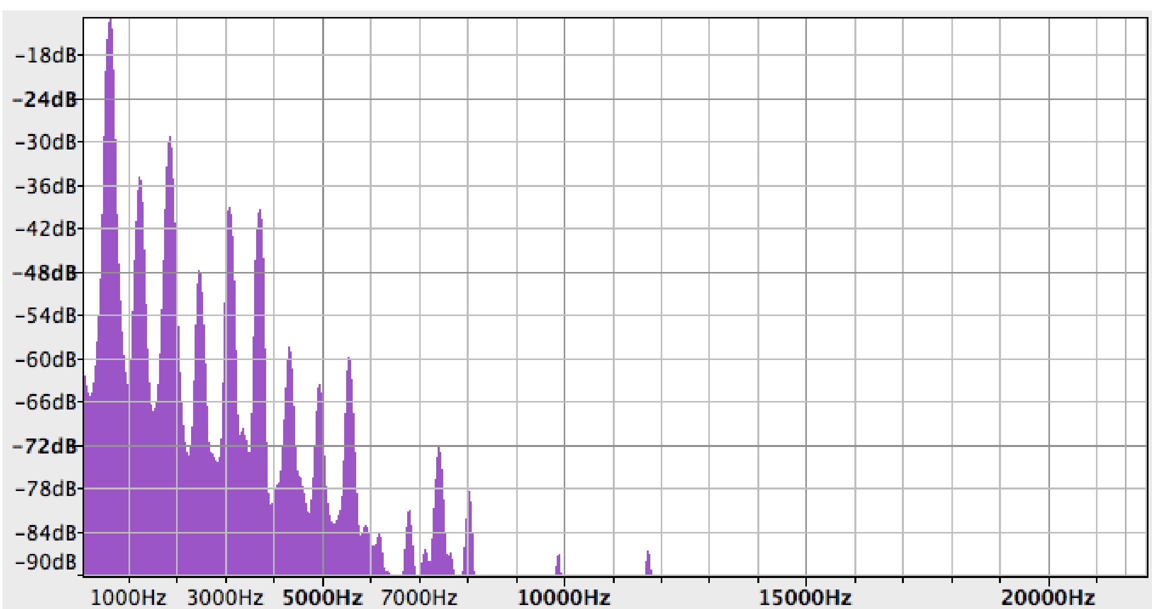

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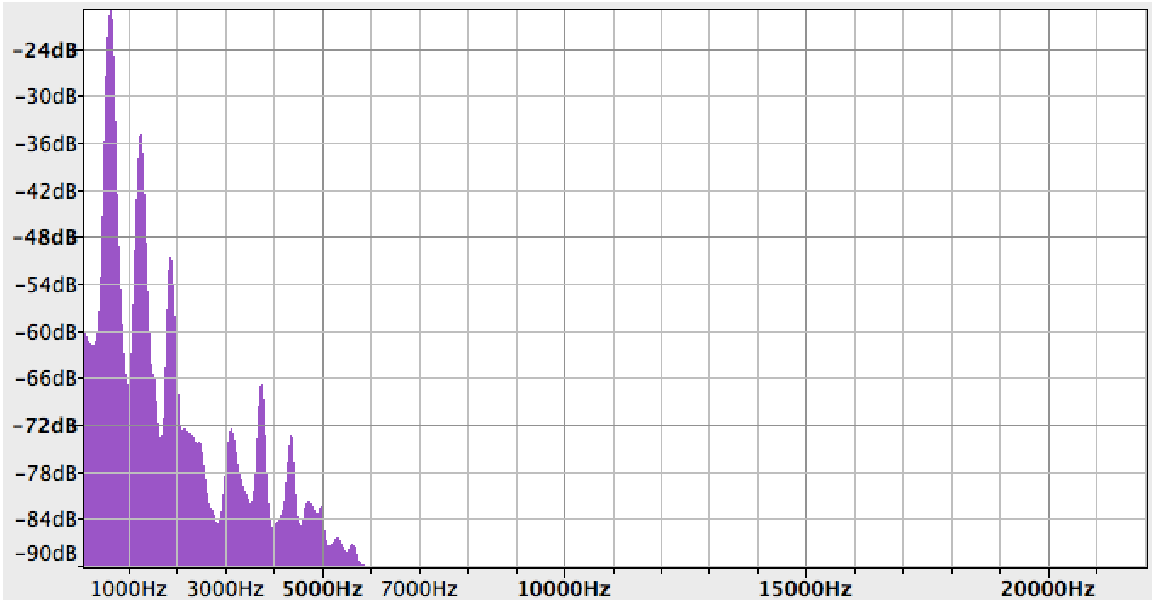

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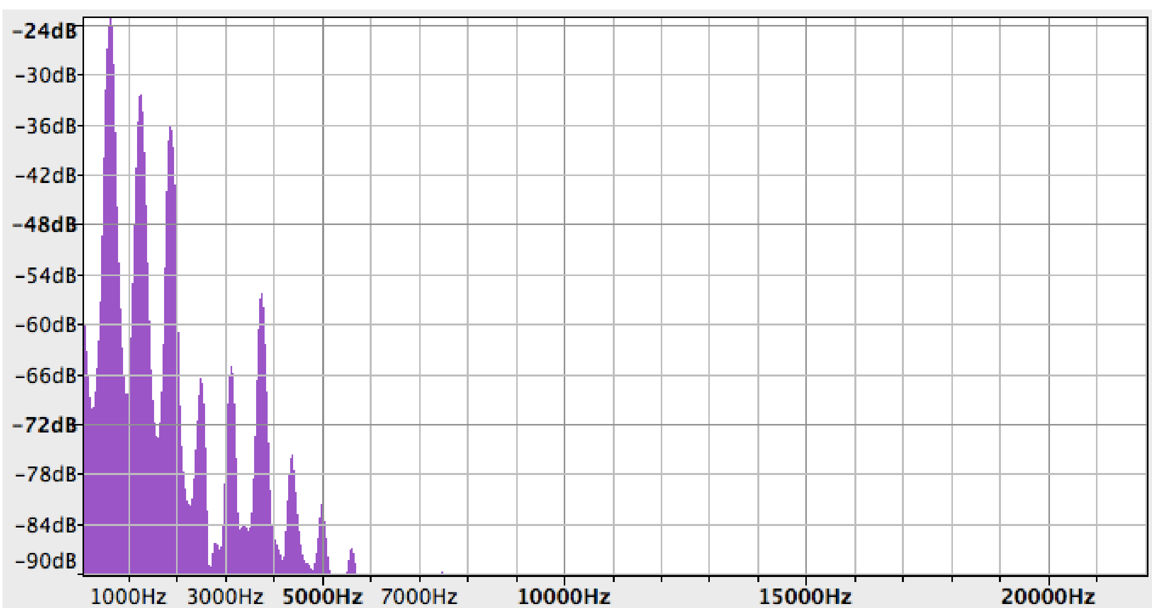

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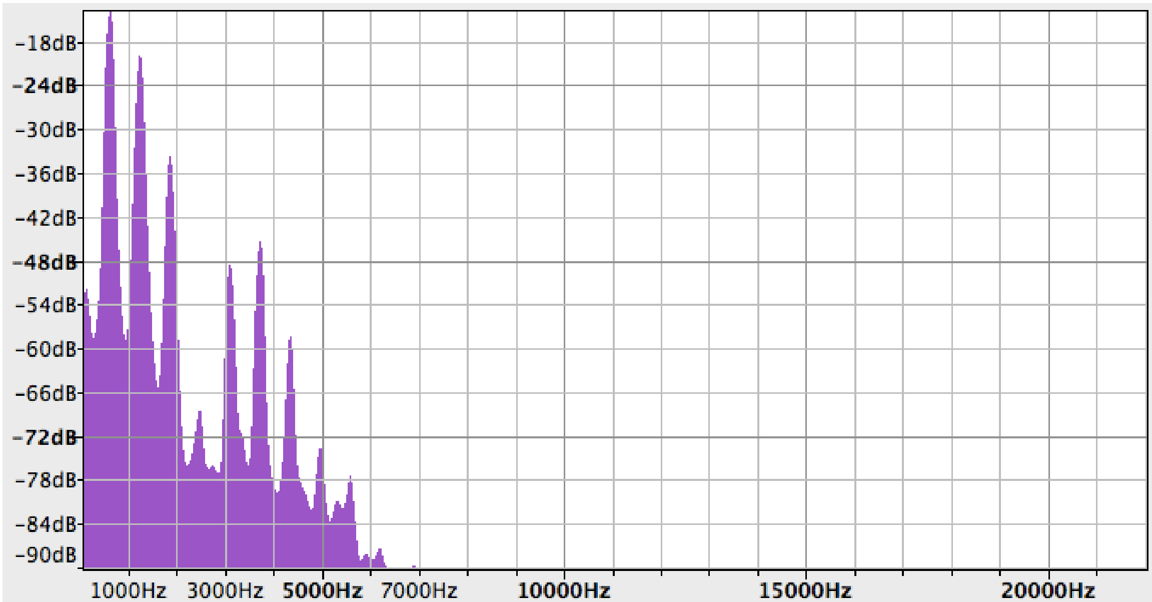

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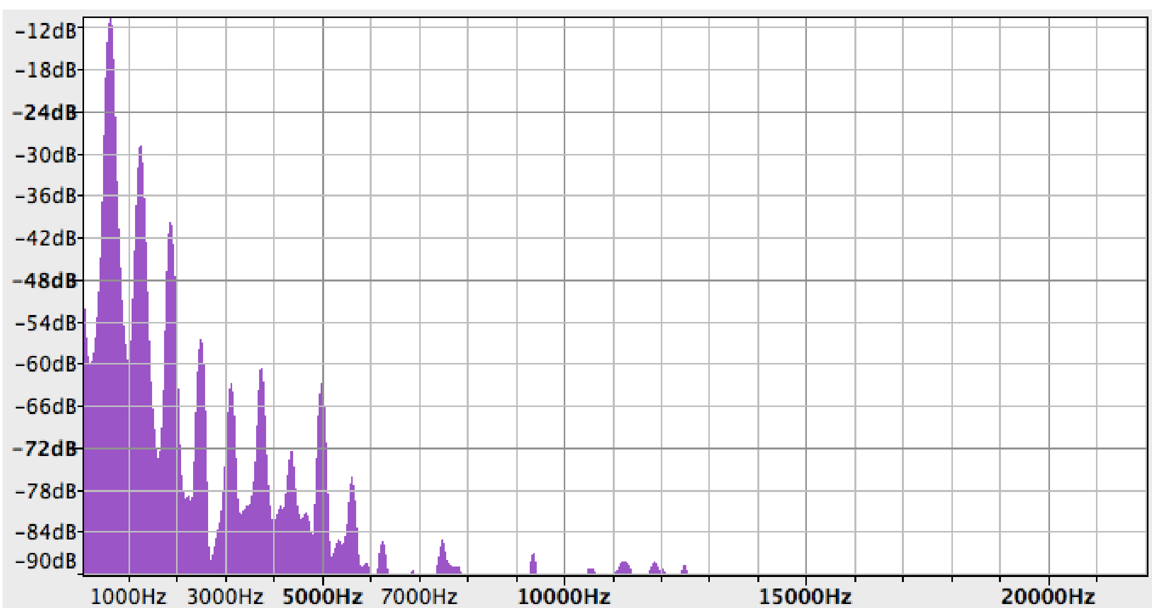

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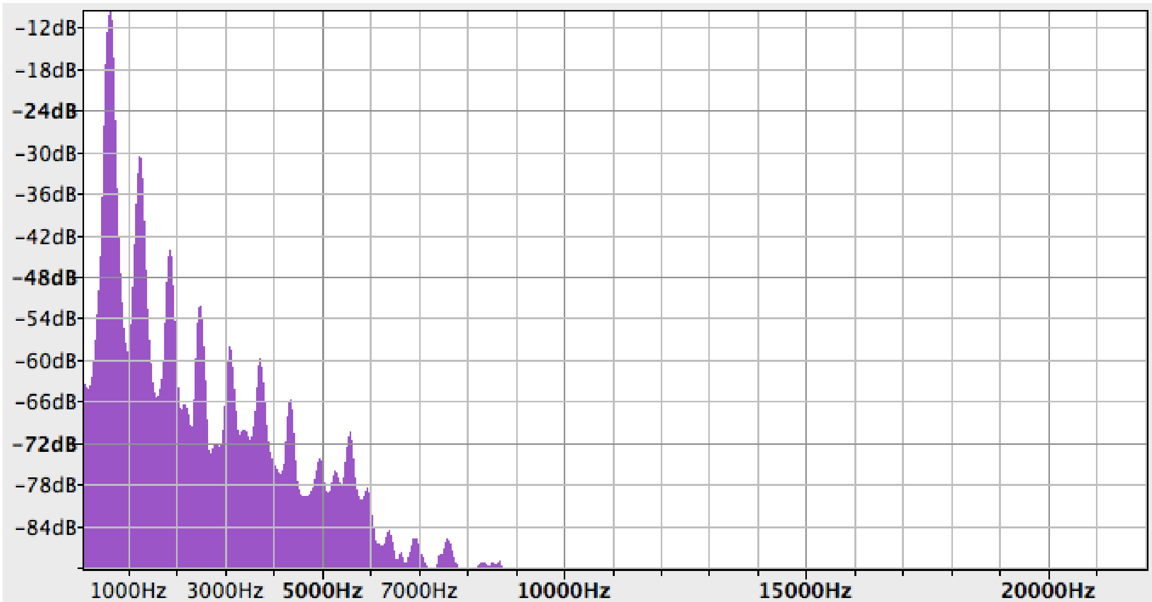

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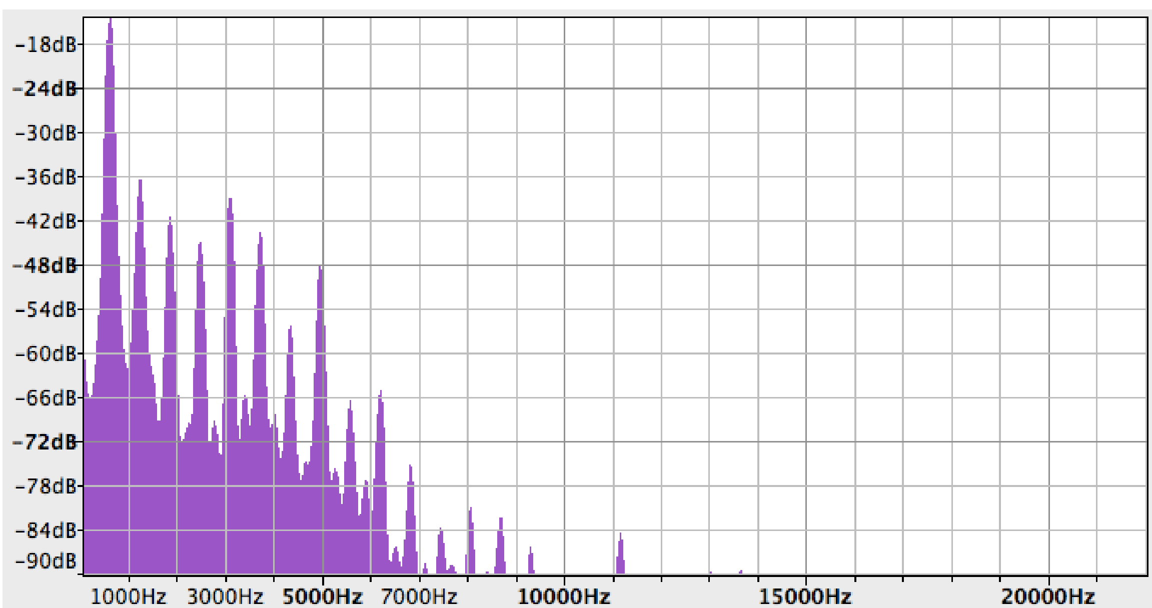

Purpleheart

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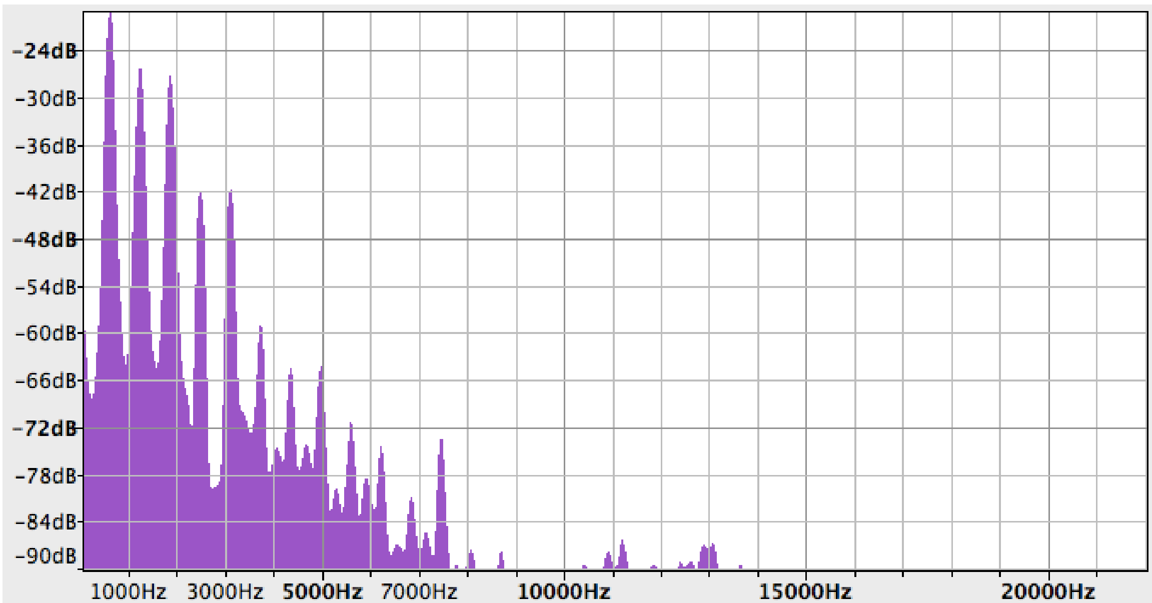

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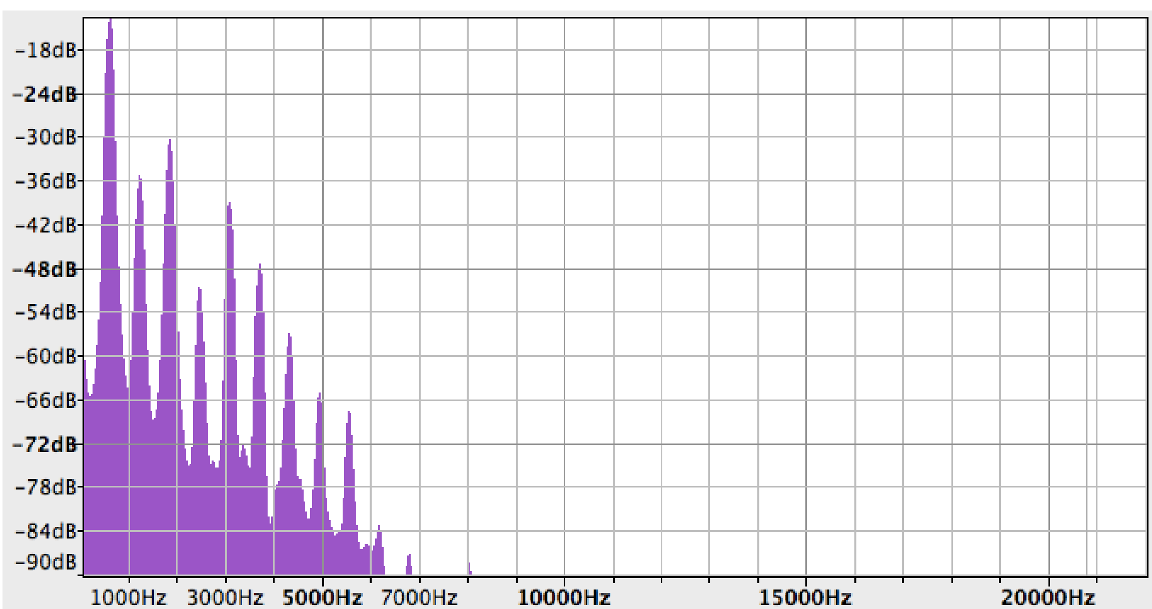

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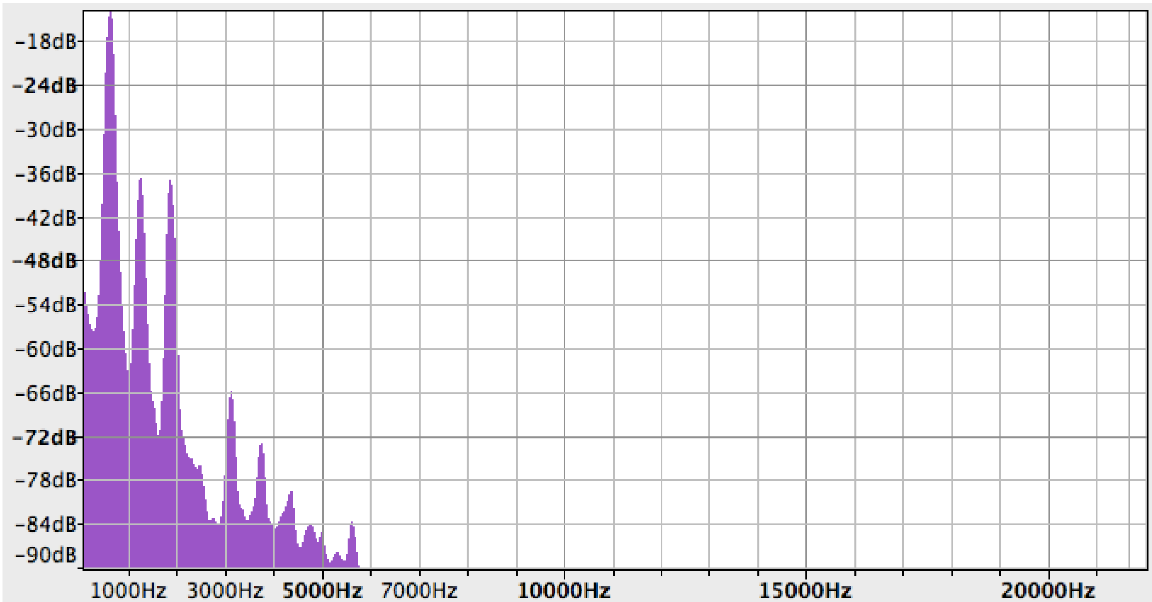

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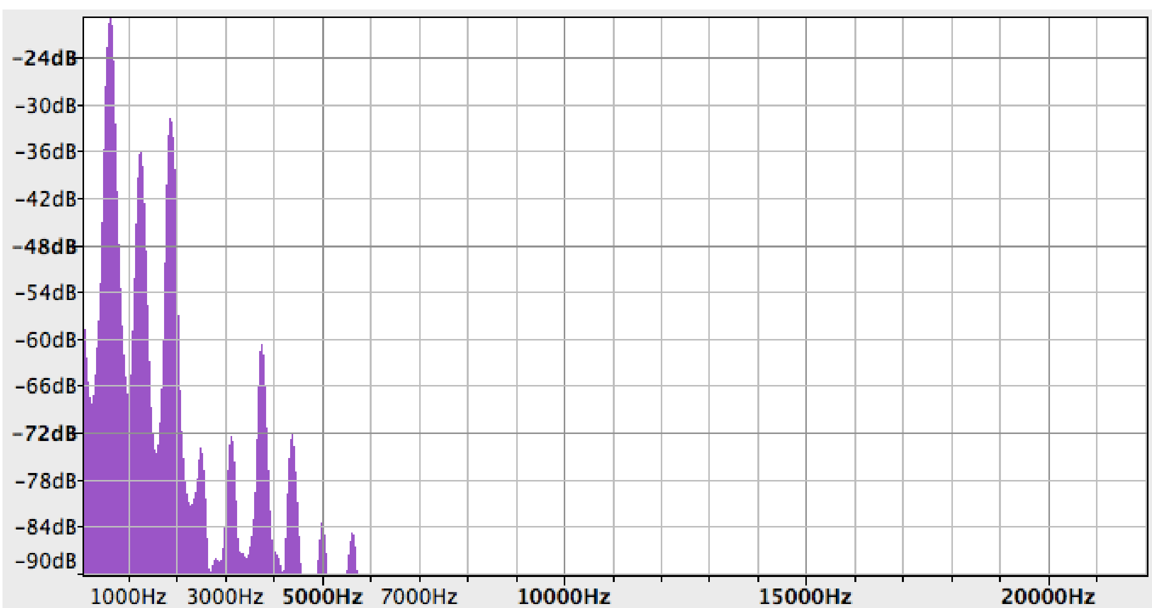

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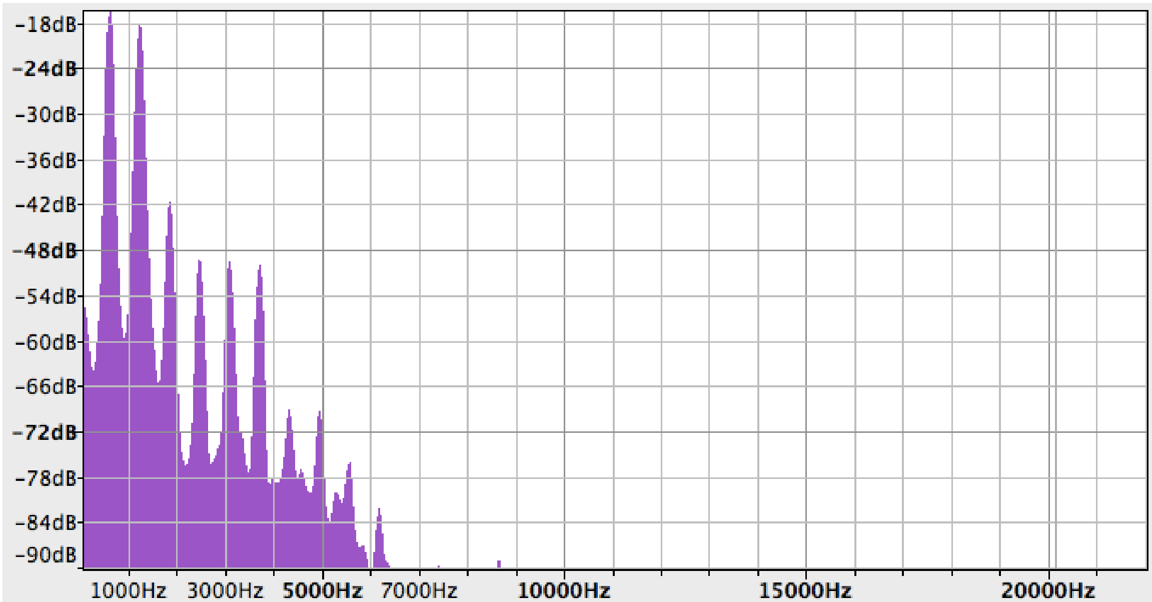

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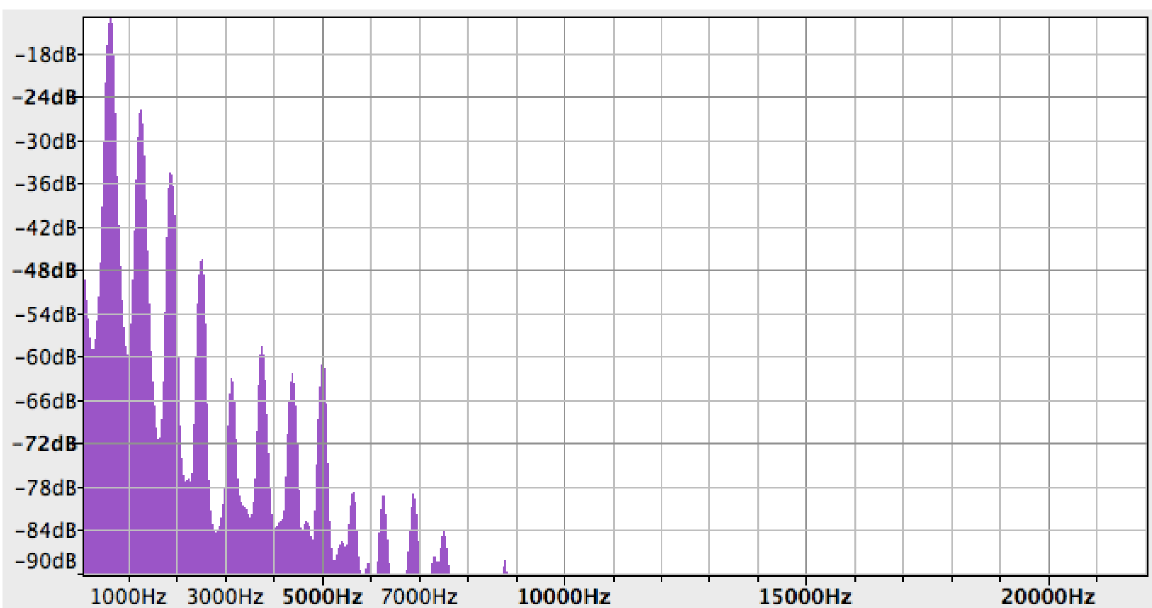

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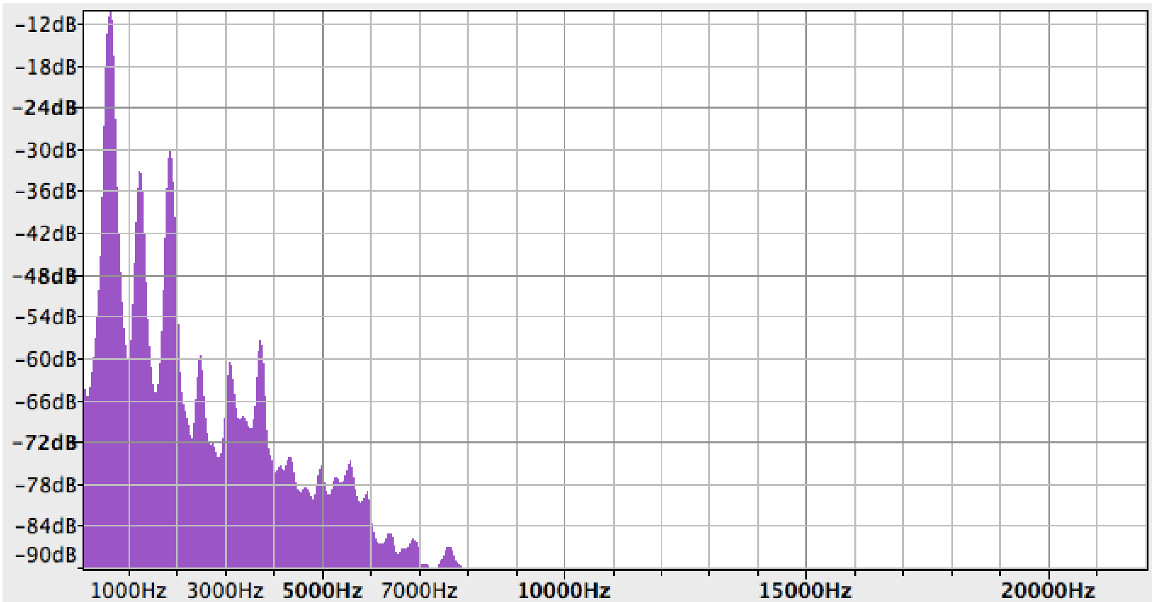

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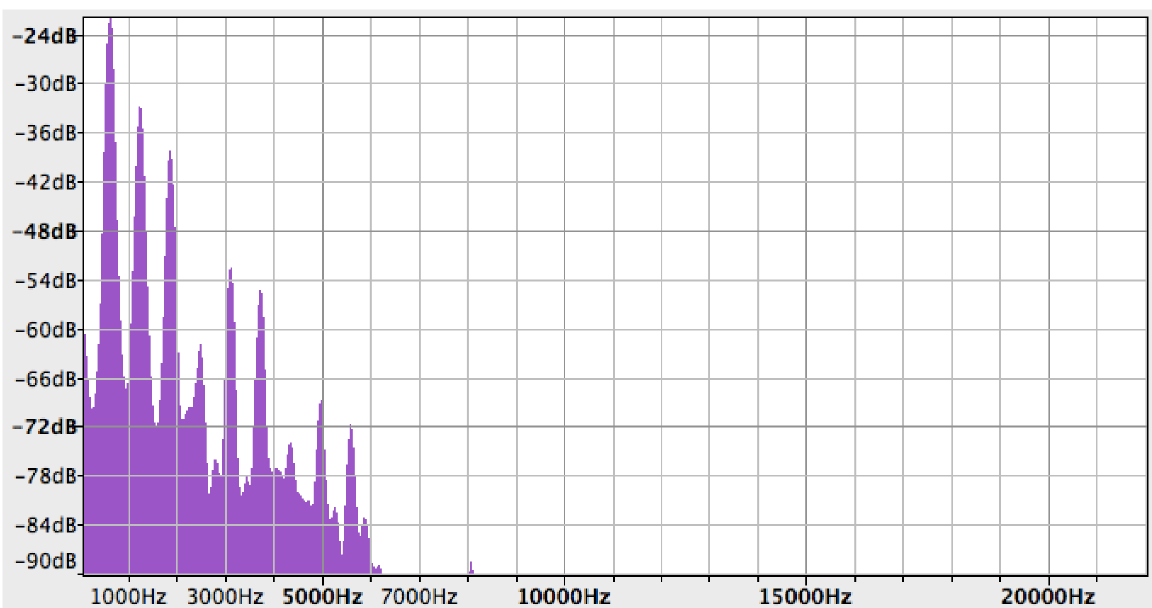

APPENDIX B

PARTICIPANT ARTICULATION PROFILE

Cocobolo

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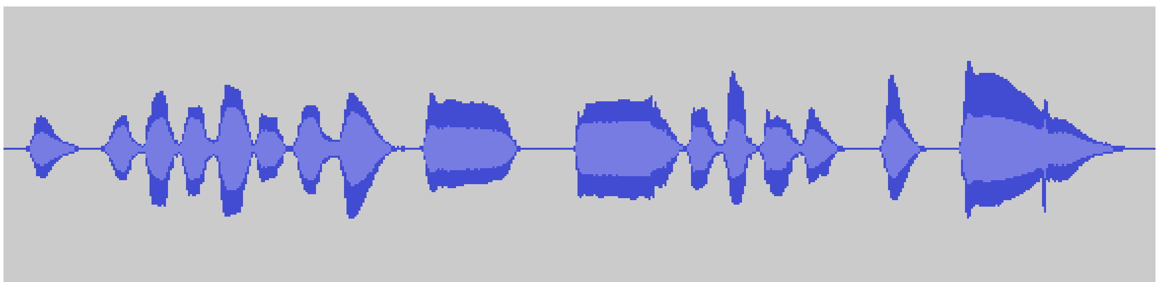

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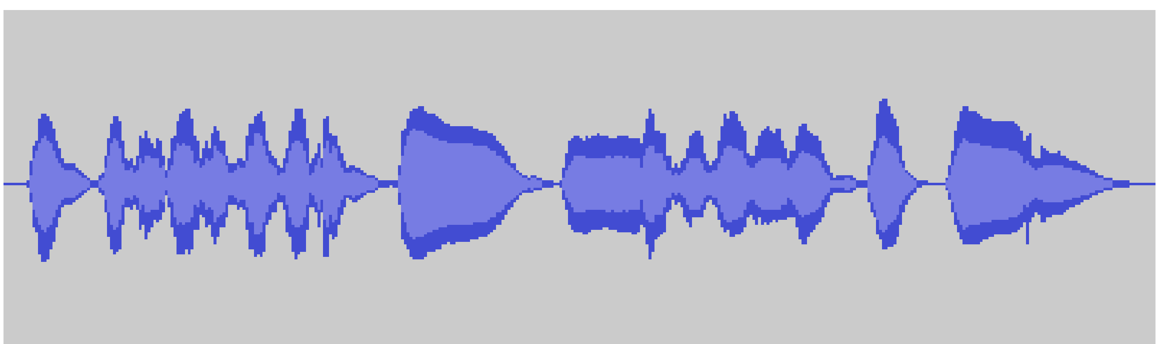

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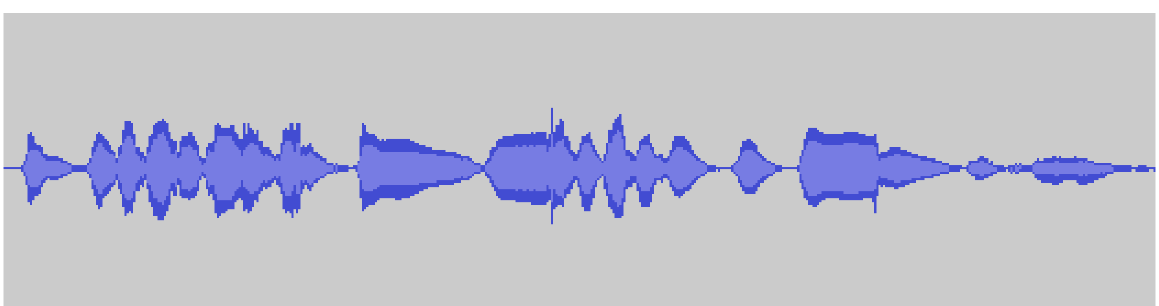

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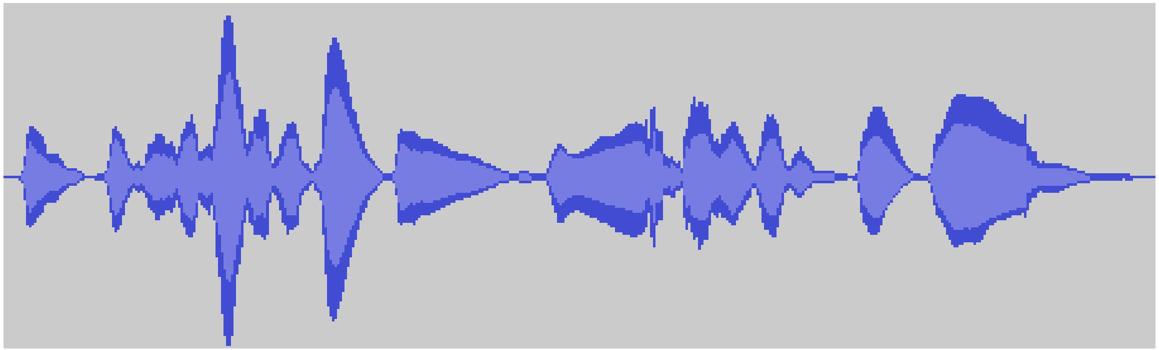

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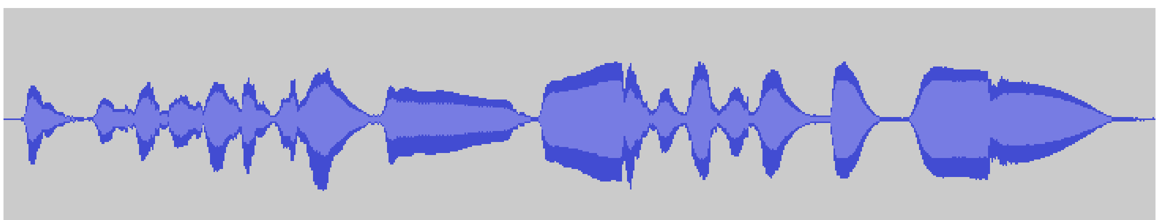

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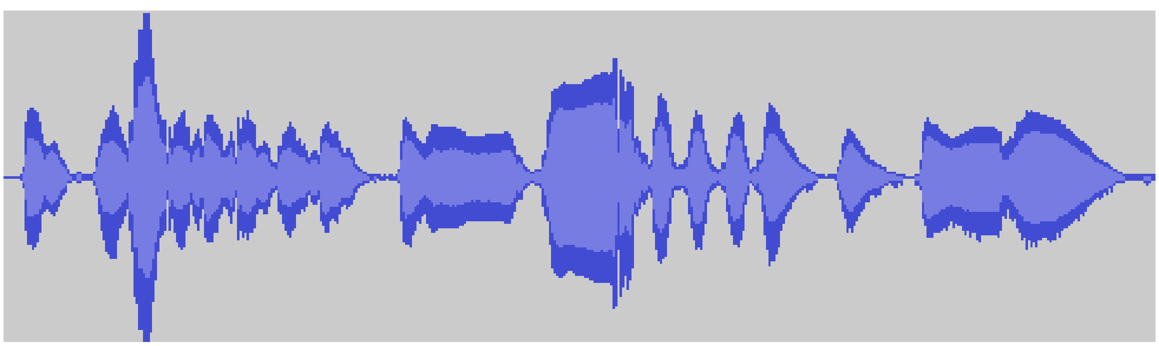

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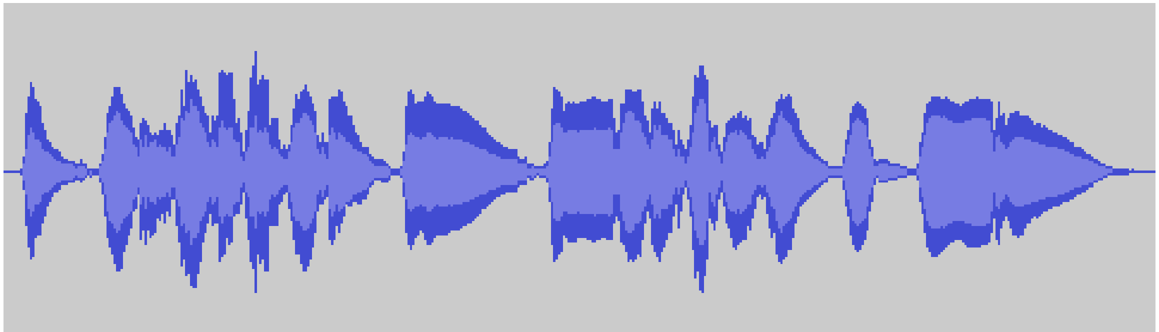

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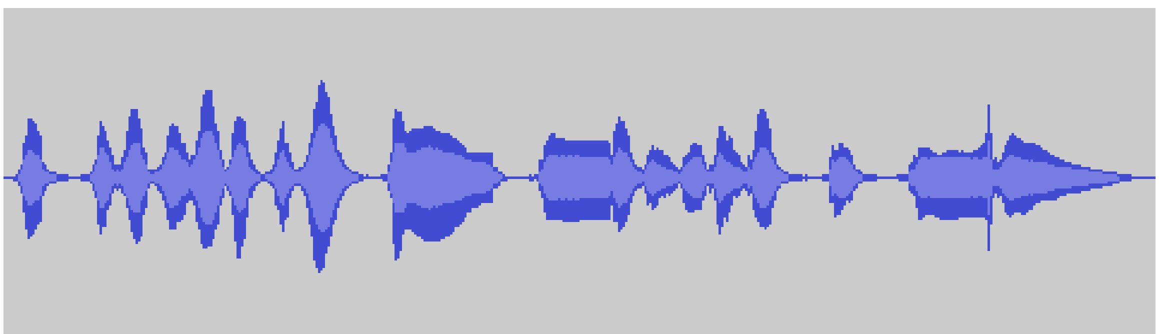
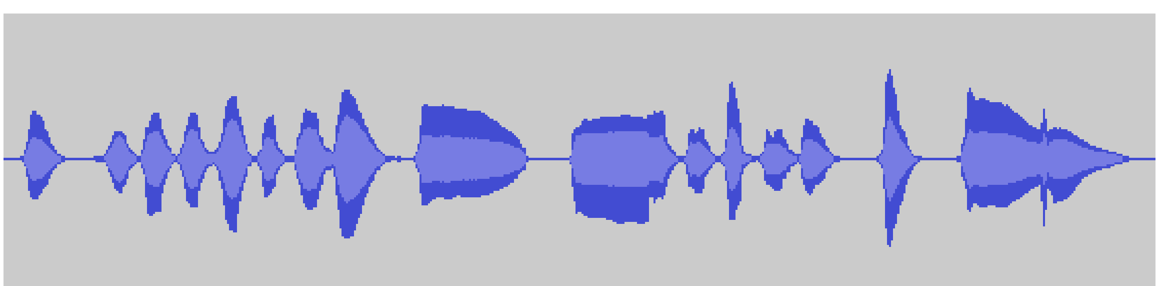


Mopane

Participant 4:



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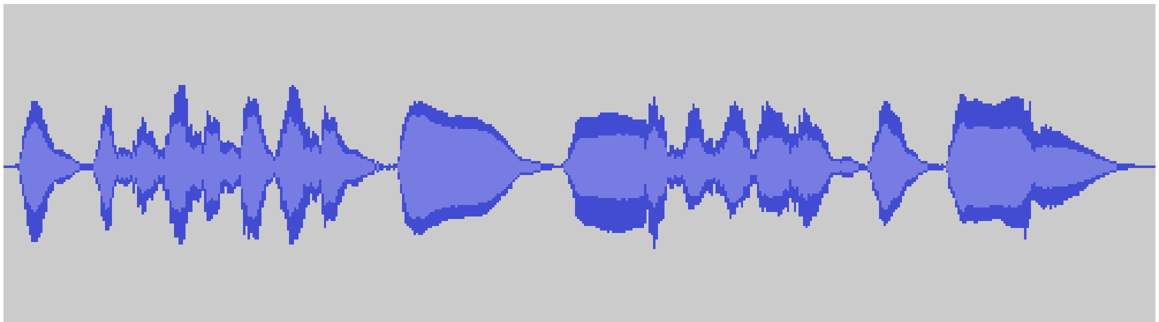

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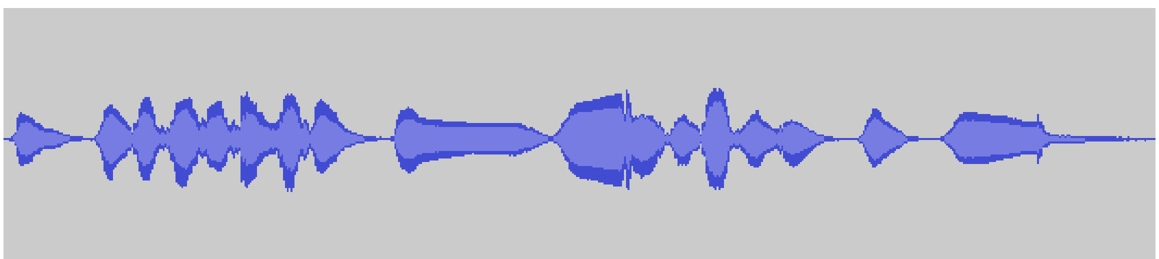

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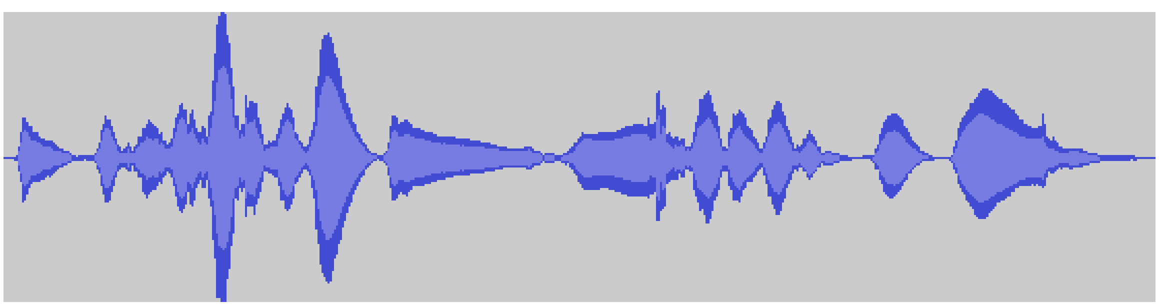

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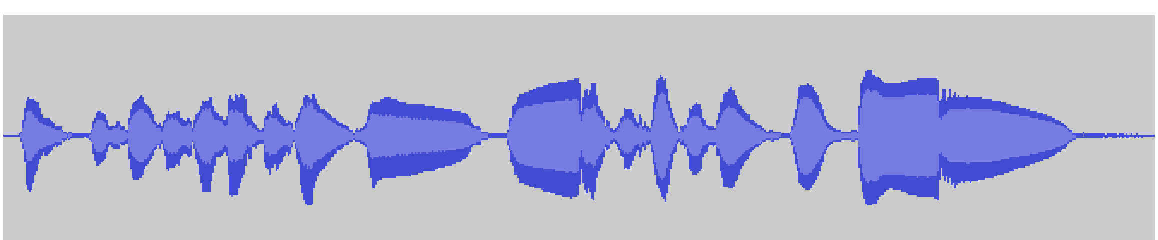

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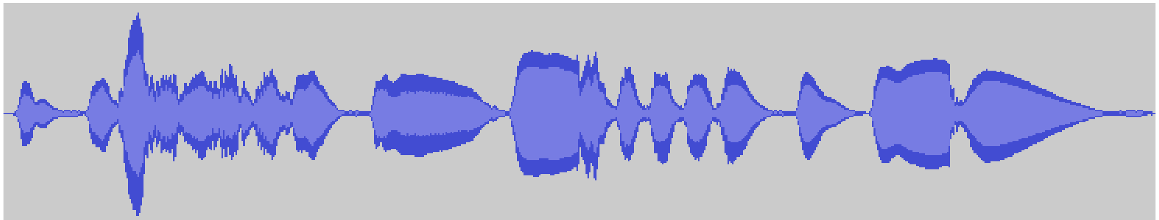

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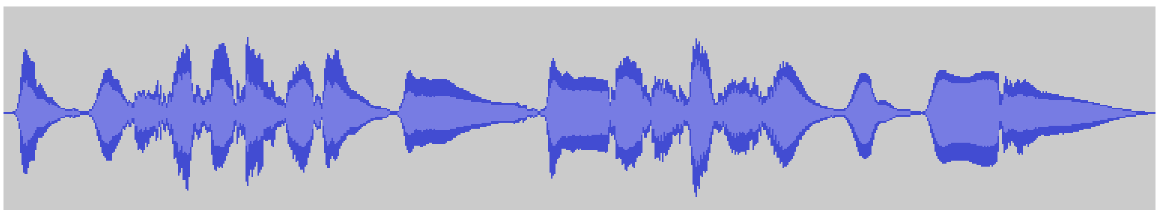

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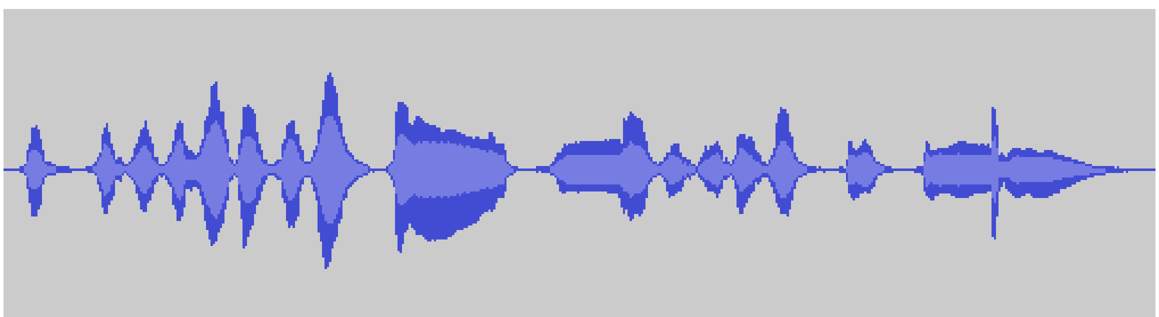
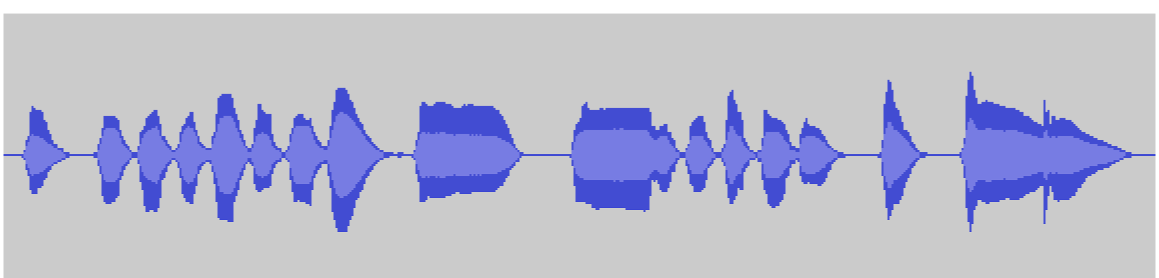


Grenadilla

Participant 4:



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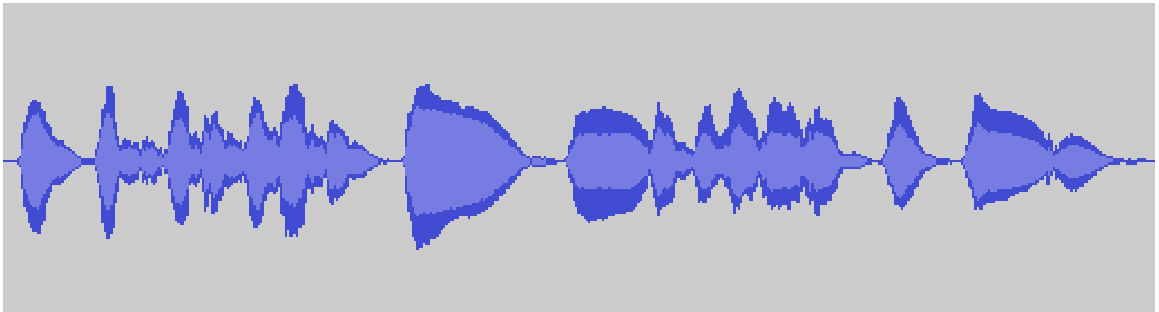

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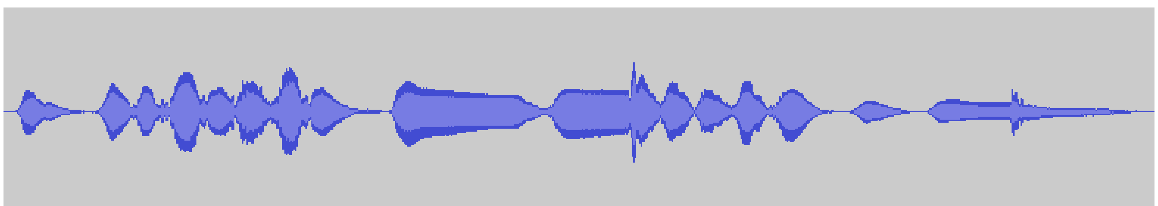

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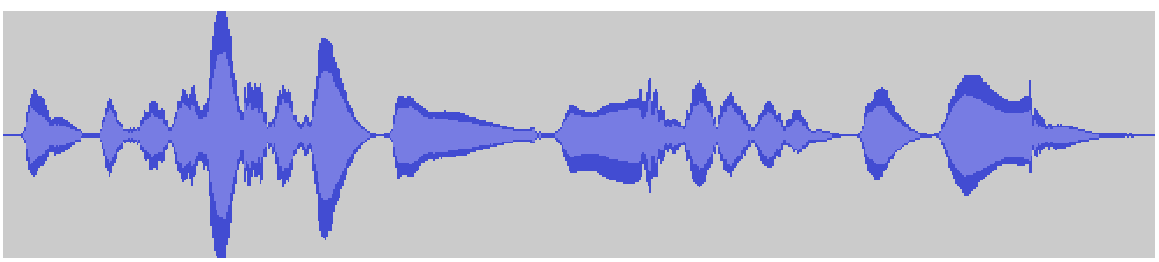

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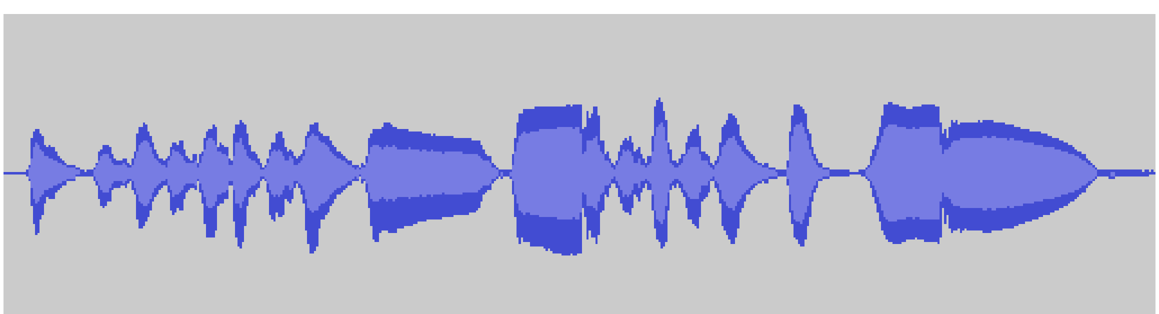

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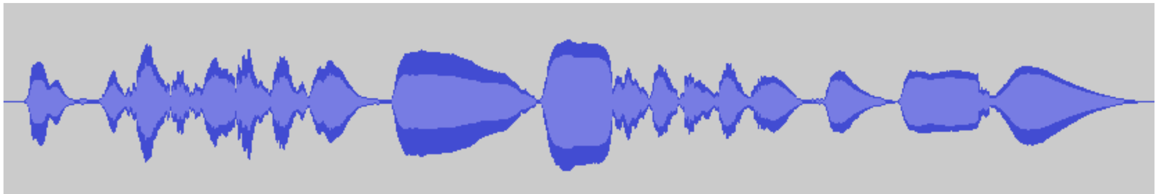

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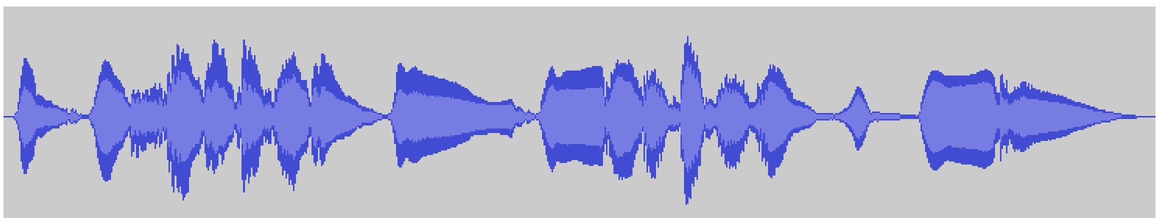

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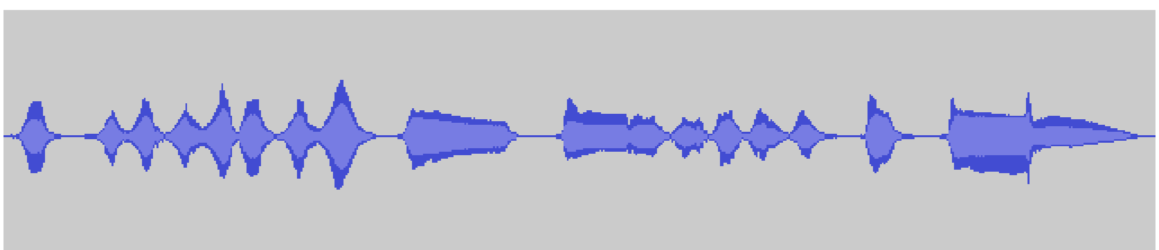
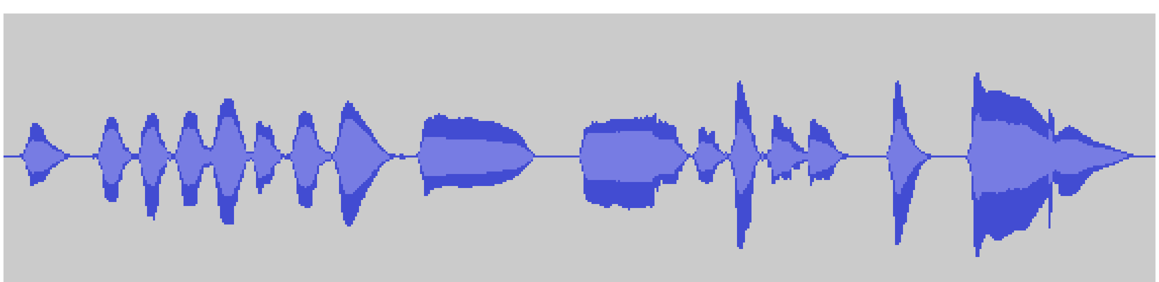


Delrin

Participant 4:



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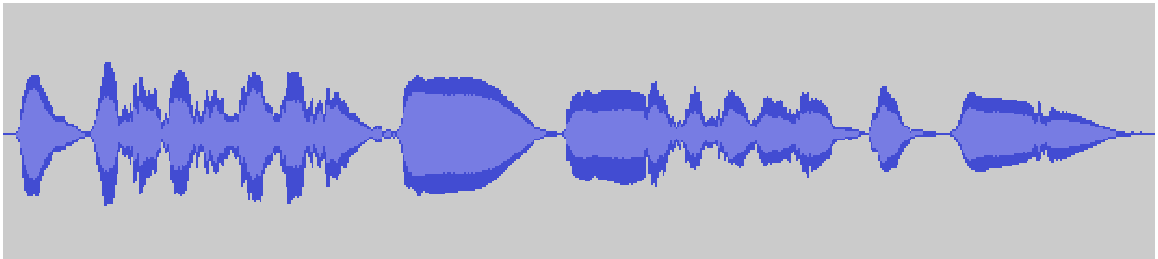

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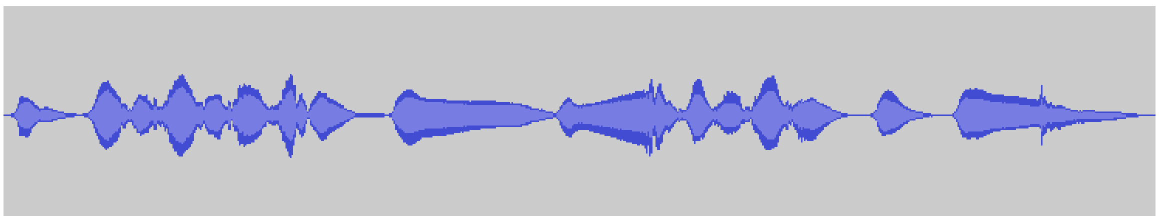

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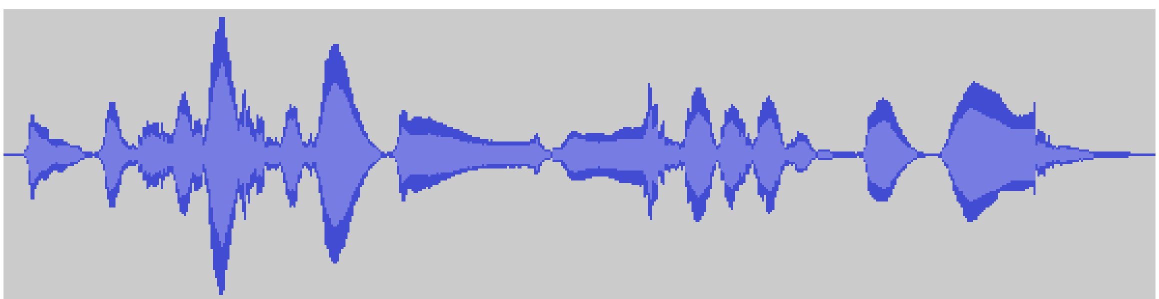
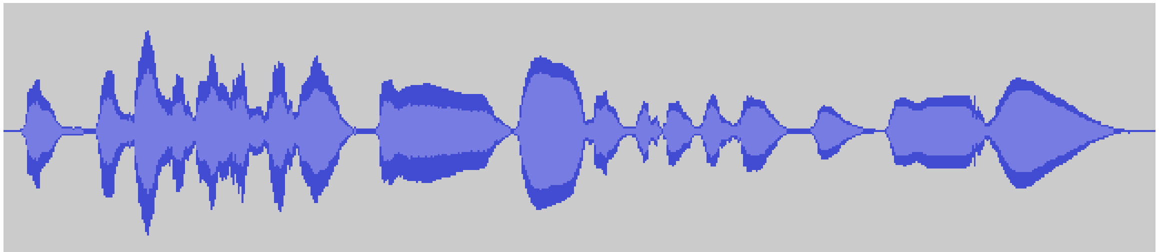


Participant 8:

Participant 9:



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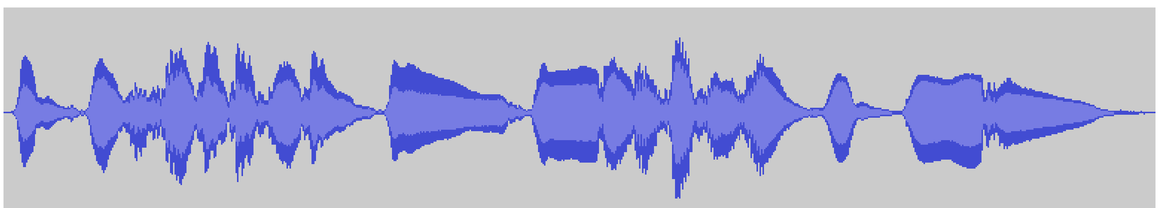

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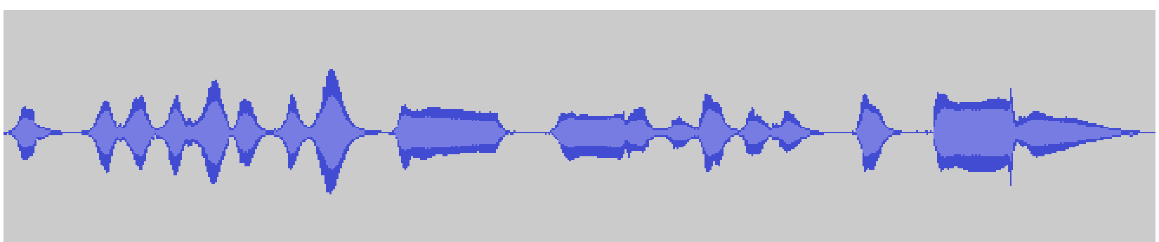
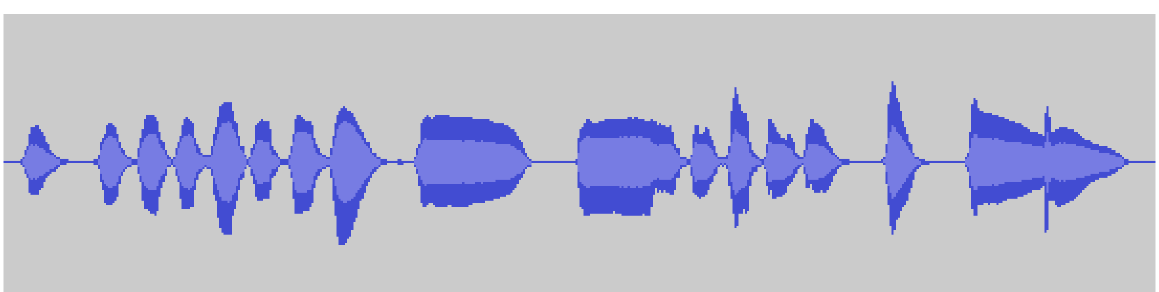


Personal Barrel

Participant 4:



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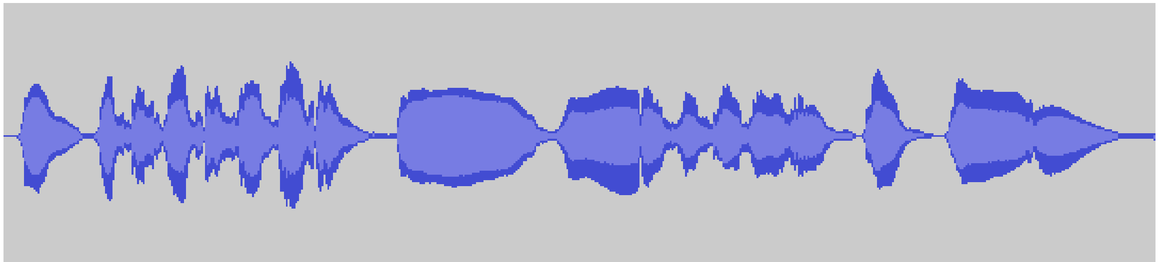

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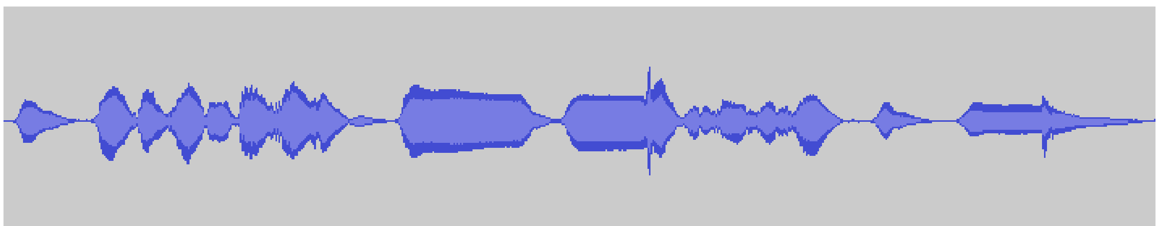

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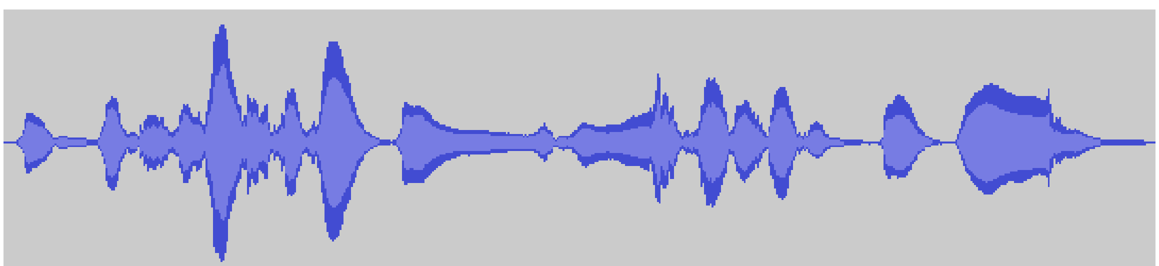

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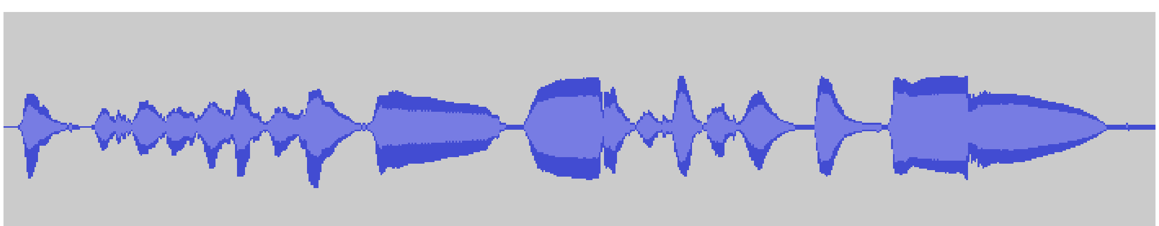

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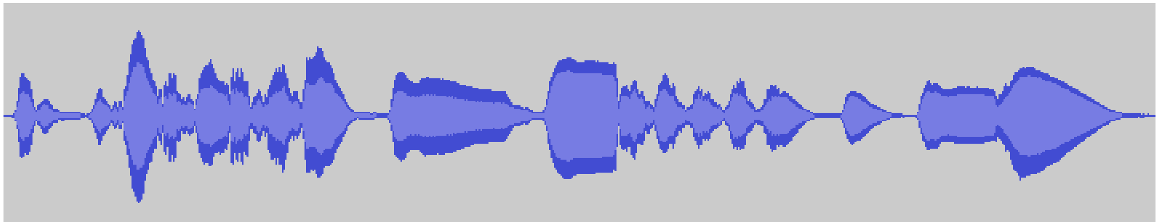

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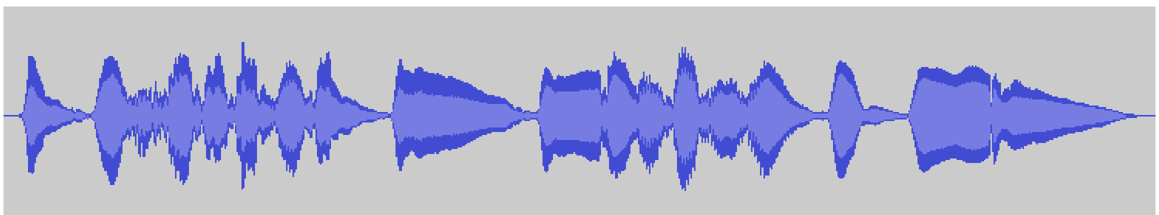

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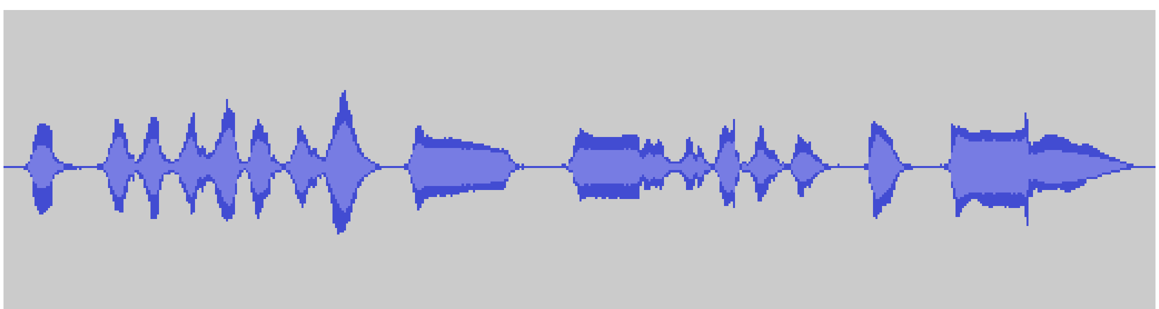
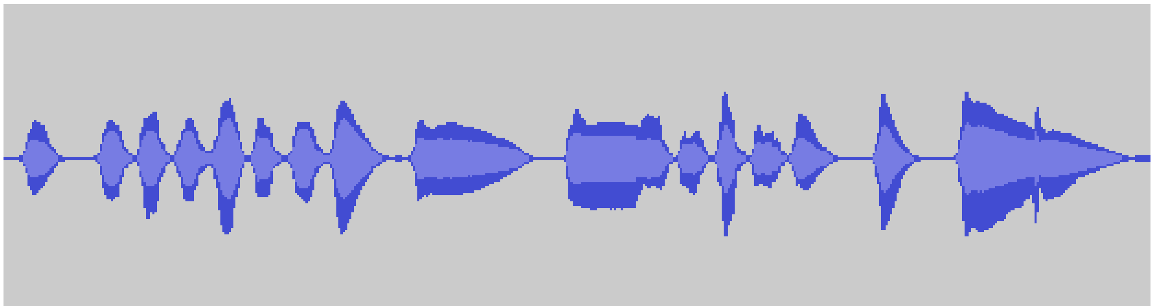


Purple Heart

Participant 4:



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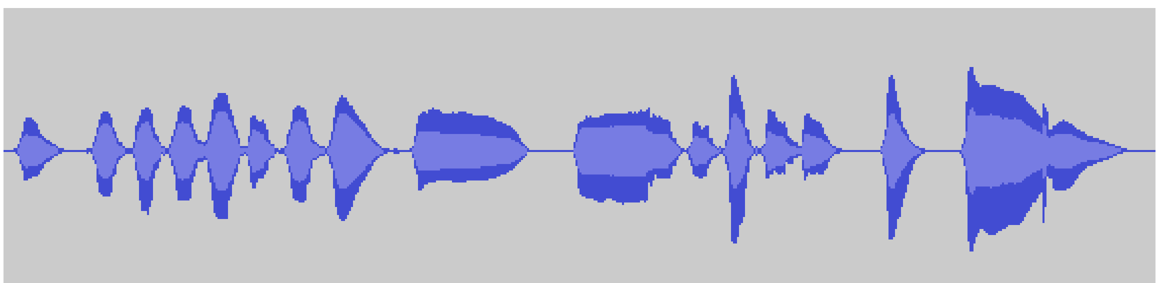

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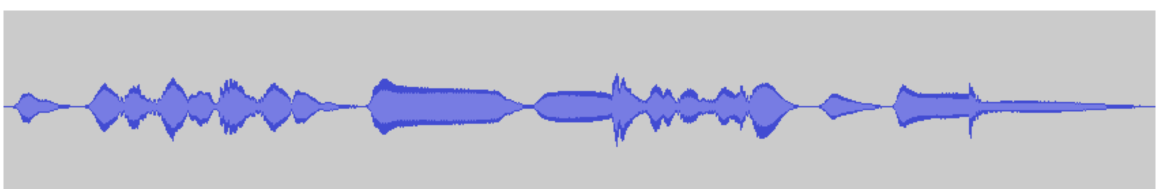

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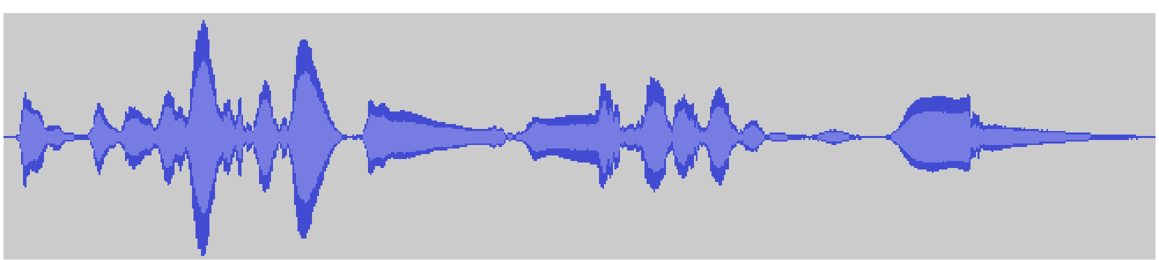

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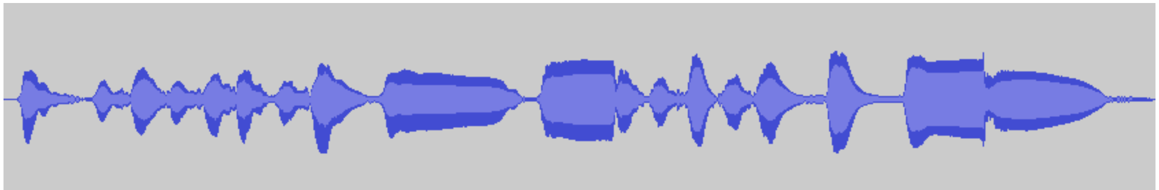

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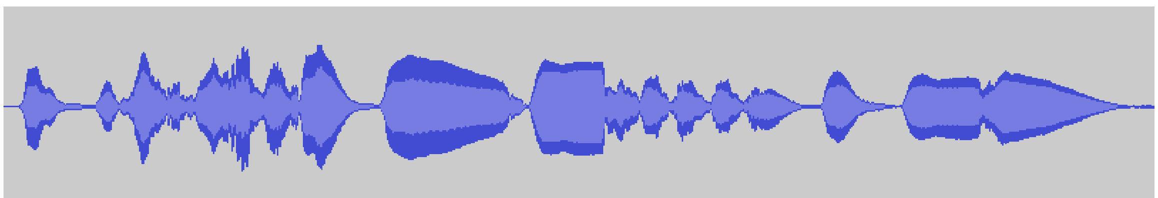

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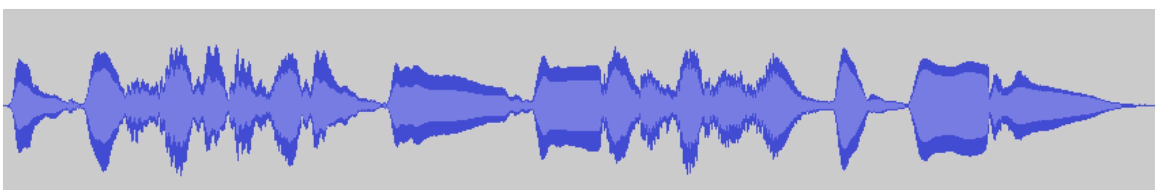

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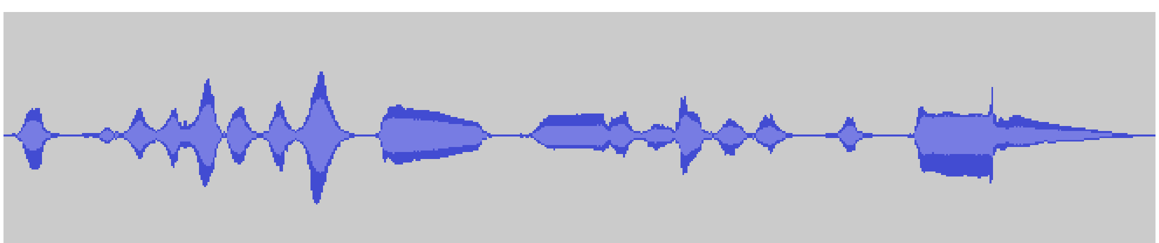

APPENDIX C

CLARINET BARREL MATERIAL PREFERENCE SURVEY

School of Music, Theatre, and Dance
The University of North Carolina at Greensboro
100 McIver St.
Greensboro, NC 27412

Dear Participant:

I am a doctoral student at The University of North Carolina at Greensboro. As part of my dissertation, I am investigating the effects of materials on the acoustic properties of clarinet barrels. The purpose of this survey is to compare player perception versus acoustic reality. Your participation in this study is strictly voluntary and you may withdraw at any time without penalty. The survey should take less than 30 minutes to complete. Your survey answers will be confidential as no personal identifiers are used on the survey. The surveys will be retained in a locked file for five years, after which I will destroy the forms and data.

You were selected as an outstanding member of the clarinet community across the United States to participate in this study. You will be asked to perform brief excerpts on barrels made from five different materials, which will be recorded for analysis only. You will also be asked to answer questions about your impression of the tone quality, response, and ability to produce varying dynamics.

I appreciate your help with this project. Should you have any questions, suggestions for further research, of if you would like a copy of the survey results, please feel free to email me at mjcramer@uncg.edu or call me at (616) 889-4314.

Sincerely,

Mark J. Cramer

CLARINET BARREL MATERIAL PREFERENCE SURVEY

Instructions

1. Carefully read the cover letter.

2. Take out the survey and complete Part I, which collects individual information, such as gender, age, and ethnicity; and, professional information, such as teaching experience, major instrument, and undergraduate institution. All information will be kept confidential and will only be used for reference by the researcher in this study.

3. Parts II and III of the survey are designed to capture tone quality preferences, observations of response, and the ability to produce dynamics. You will be asked to play sustained tones and a short musical excerpt. The final task requires you to make a decision based on your preference of material. The researcher will handle your mouthpiece, reed, and ligature configuration very carefully. The researcher will proctor the procedures; all you need to do is perform the tasks.

4. Results from the survey are available by contacting Mark Cramer, Graduate Assistant at The University of North Carolina at Greensboro, 100 McIver St., Greensboro, NC 27412.

5. Thank You.

CLARINET BARREL MATERIAL PREFERENCE SURVEY

Part I

This part of the survey provides information about you, your education, and your teaching experience. Please take a moment to provide this important information. All information will be kept confidential and will only be used for reference by the researcher in this study.

1. Circle the job description(s) that best describes what you do (circle all that apply):

Private Clarinet Teacher	College Clarinet Teacher

Orchestral/Symphony Clarinet Player

2. Equipment of choice:

- Mouthpiece: ____________
- Ligature: ____________
- Reed Brand and Strength: ____________
- Barrel: ____________
- Clarinet Brand/Type: ____________

3. Years of playing experience: _______

4. Years of teaching experience: _______

5. Highest education level attained (Please circle one):

Bachelor's Degree	Master's Degree

Doctoral Degree

Other: ________________

6. Undergraduate institution:____

Major(s): ________________________

7. Graduate institution(s): ____

Major(s): ______________________

8. Gender (please circle): Female Male

9. Age: ___________

10. Ethnicity (please circle):

African American

Asian

Hispanic – Other origin

Mexican American

Mixed

White/Caucasian

END OF PART I

CLARINET BARREL MATERIAL PREFERENCE SURVEY

Part II

The researcher will handle your mouthpiece, reed, and ligature configuration in addition to your instrument while changing materials in order to keep this part of the experiment blind. Please rank all responses on a scale of 1-5.

1= Very Difficult 5= Very Easy

1. **Barrel #1**

    a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

    b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

    c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

2. **Barrel #2**

a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

3. **Barrel #3**

a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

4. Barrel #4

a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

5. Barrel #5

a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

6. Barrel #6

a. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for one second. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of reaching 91 dB:

1 2 3 4 5

On a scale of 1 to 5, rate the barrel relative to ease of achieving characteristic clarinet tone quality:

1 2 3 4 5

b. Play a clarion register F-natural at 91 dB into the SPL meter and sustain the tone for three seconds. After performing the task, record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of sustaining 91 dB:

1 2 3 4 5

c. Play the short excerpt from Gounod's "Faust – Ballet Music" and record your feedback.

On a scale of 1 to 5, rate the barrel relative to ease of response to articulation:

1 2 3 4 5

END OF PART II

CLARINET BARREL MATERIAL PREFERENCE SURVEY

Part III

This portion of the survey determines your preference of material. The researcher will handle your mouthpiece, reed, and ligature configuration in addition to your instrument while changing materials in order to keep this part of the experiment blind. Please play a short passage of your choosing (e.g. a solo passage or personal technical composition) in order to narrow down the preferred material.

Barrel chosen: ______________________

END OF PART III

APPENDIX D

PHONE RECRUITMENT SCRIPT

Dear Participant:

I am a doctoral student at The University of North Carolina at Greensboro. The title of my dissertation is: "Effects of Materials on the Acoustic Properties of Clarinet Barrels." The purpose of this study is to compare player perception versus acoustic reality.

You were selected as an outstanding member of the clarinet community across the United States to participate in this study. You will be asked to perform brief excerpts on barrels made from five different materials. Sessions will be audio recorded for analysis only. You will be asked questions regarding your impressions of tone quality, response, and ability to produce varying dynamics of each barrel. Participation will take place in a place of convenience (your studio or music building) and will take 30 minutes to complete. There is no compensation for participating in this study.

Would you be interested in participating? I appreciate your help with this project. Should you have any questions, suggestions for further research, or if you would like a copy of the survey results when they are completed, please feel free to email me at mjcramer@uncg.edu (616) 889-4314 or Dr. Kelly Burke at kjburke@uncg.edu.

Sincerely,

Mark J. Cramer

Approved IRB
10/3/14

APPENDIX E

EMAIL RECRUITMENT SCRIPT

Dear Participant:

I am a doctoral student at The University of North Carolina at Greensboro. The title of my dissertation is: "Effects of Materials on the Acoustic Properties of Clarinet Barrels." The purpose of this study is to compare player perception versus acoustic reality.

You were selected as an outstanding member of the clarinet community across the United States to participate in this study. You will be asked to perform brief excerpts on barrels made from five different materials. Sessions will be audio recorded for analysis only. You will be asked questions regarding your impressions of tone quality, response, and ability to produce varying dynamics of each barrel. Participation will take place in a place of convenience (your studio or music building) and will take 30 minutes to complete. There is no compensation for participating in this study.

Please email back if you have an interest in participating. I would appreciate your help with this project. Should you have any questions, suggestions for further research, or if you would like a copy of the survey results when they are completed, please feel free to email me at mjcramer@uncg.edu (616) 889-4314 or Dr. Kelly Burke at kjburke@uncg.edu.

Sincerely,

Mark J. Cramer

Approved IRB
10/3/14

APPENDIX F

IRB CONSENT FORM

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

CONSENT TO ACT AS A HUMAN PARTICIPANT

Project Title: EFFECTS OF MATERIALS ON THE ACOUSTIC PROPERTIES OF CLARINET BARRELS

Principal Investigator and Faculty Advisor (if applicable): Mark Cramer and Dr. Kelly Burke

Participant's Name: ___________________

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in the study is voluntary. You may choose not to join, or you may withdraw your consent to be in the study, for any reason, without penalty.

Research studies are designed to obtain new knowledge. This new information may help people in the future. There may not be any direct benefit to you for being in the research study. There also may be risks to being in research studies. If you choose not to be in the study or leave the study before it is done, it will not affect your relationship with the researcher or the University of North Carolina at Greensboro. Details about this study are discussed in this consent form. It is important that you understand this information so that you can make an informed choice about being in this research study.

You will be given a copy of this consent form. If you have any questions about this study at any time, you should ask the researchers named in this consent form. Their contact information is below.

What is the study about?
This is a research project. Your participation is voluntary. The general purpose of the study is to identify the sound qualities of different materials (i.e. exotic hardwoods and plastics) used to make the clarinet barrel in order to properly serve the musical and technical demands of the professional or amateur musician. Specifically, the purpose of this study is to examine the effects of materials on acoustic properties of clarinet barrels.

Why are you asking me?
You are a professional clarinetist who represents the pinnacle of clarinet performing. Your reputation as having a high standard of performance is what is required in order to participate in this type of research.

What will you ask me to do if I agree to be in the study?
After completing a short demographic survey, participants will perform brief excerpts in order for the researcher to take measurements of the acoustical properties of the various types of wood. Audio will be recorded for later spectrographic and sound envelope comparison by the

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researcher. Each subject will perform the test on multiple barrels made of different materials as well as on his or her personal barrel. This test will be performed blind, with a cone blocking the participant's view of the material. This is done in order to eliminate participant bias based on prior experience involving materials being used in this study. Throughout the test, the subject will perform the excerpts on his or her personal mouthpiece, reed, and ligature combination. Following each task, the researcher will ask the participant a brief question rating their response to the material they just played. The test will take 30 minutes.

Is there any audio/video recording?
Yes, audio will be recorded for later spectrographic and sound envelope comparison by the researcher.

What are the risks to me?
The Institutional Review Board at the University of North Carolina at Greensboro has determined that participation in this study poses minimal risk to participants. At no time will these recordings be used for any purpose other than stated in this consent form.

If you have questions, want more information or have suggestions, please contact Mark Cramer, who can be reached at (616) 889-4314 or mark.j.cramer@gmail.com or Kelly Burke at kjburke@uncg.edu.

If you have any concerns about your rights, how you are being treated, concerns or complaints about this project or benefits or risks associated with being in this study, please contact the Office of Research Integrity at UNCG toll-free at (855)-251-2351.

Are there any benefits to society as a result of me taking part in this research?
With the depletion of industry standard materials (i.e. Grenadilla Wood), woodwind manufacturers are working diligently to find alternative materials that harness the qualities of the traditional materials used for generations. The M'pingo wood commonly used for clarinets is in increasingly short supply as are other exotic rainforest hardwoods. This study may provide empirical evidence that other materials are acoustically equivalent.

Are there any benefits to *me* for taking part in this research study?
There are no direct benefits to participants in this study.

Will I get paid for being in the study? Will it cost me anything?
There are no costs to you or payments made for participating in this study.

How will you keep my information confidential?
All data collected related to this study will be kept in a locked file in the Music Research Institute office for the required duration, as well as a password protected computer at the home of the student investigator. No data will be sensitive. All information obtained in this study is strictly confidential unless disclosure is required by law.

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What if I want to leave the study?
You have the right to refuse to participate or to withdraw at any time, without penalty. If you do withdraw, it will not affect you in any way. If you choose to withdraw, you may request that any of your data which has been collected be destroyed unless it is in a de-identifiable state. The investigators also have the right to stop your participation at any time. This could be because you have had an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

What about new information/changes in the study?
If significant new information relating to the study becomes available which may relate to your willingness to continue to participate, this information will be provided to you.

Voluntary Consent by Participant:
By signing this consent form, you are agreeing that you read, or it has been read to you, and you fully understand the contents of this document and are openly willing consent to take part in this study. All of your questions concerning this study have been answered. By signing this form, you are agreeing that you are 18 years of age or older and are agreeing to participate, or have the individual specified above as a participant participate, in this study described to you by

_______________.

Signature: ________________________ Date: ________________

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