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A Study of Oboe Reeds

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Abstract

Professional oboists spend more time making reeds than they do playing the oboe. Therefore, a high value is placed on reed-making in the oboe community. In this study, a controlled batch of reed cane (internodes of the grass *Arundo donax)* was selected based on microscopic inspection of cellular composition as well as macroscopic physical characteristics. For most of the participants, the cane was then processed identically to the stage known as a *blank,* after which the participants finished their reeds according to their usual methods. (The few participants who made their own blanks still used the controlled cane and also a controlled *staple*, the metal cylinder that attaches the reed to the oboe.) The sound spectra of recordings of each participant playing on his/her respective reeds were analyzed, as was a spectrum of the *crow* (sound without the oboe attached) of each reed in an anechoic chamber. These spectra were compared to one another in an attempt to discern trends.

This research protocol has been approved by the Human Research Review Committee at Grand Valley State University. File No. 465407-3 Expiration: May 11, 2014.

Introduction

Playing the oboe includes two distinct skills: actually playing the instrument and making reeds. The oboe is a member of the double-reed family, instruments—such as oboe, English horn, and bassoon—that use a double-reed to produce sound. The basic structure of these kinds of reeds is that of two pieces of curved grass, *Arundo donax*, tied together. The opening of the reed is elliptical, shaped like a flattened drinking straw with the edges of the blades in contact. When blown into, the blades of the reed vibrate against each other, producing an audible sound. The reed is inserted into the oboe where the vibrations are amplified by the body of the instrument. This method of producing vibrations contributes greatly to the oboe's characteristic sound.

There is an obvious difference between single-reeds, like those for clarinet and saxophone, and double-reeds. Single-reeds consist of a flat piece of *Arundo donax*, which must be attached to a half-circle shaped mouthpiece in order to stimulate vibrations. The structure of single-reeds is much simpler than double-reeds, thus it is effective to mass produce single-reeds in factories. The surface of a single-reed is cut at a constant angle. The surface of a double-reed, however, is much more complicated. For this reason among others, serious double-reed players make their own reeds.

In this study, we attempted to investigate how physical structure affects the harmonic structure of oboe reeds. There is not a standard way to construct an oboe reed, so the products of individual reed-makers vary substantially. The process of reed-making is a culmination of education, physiology, and personal preference; each style of cutting the reed, or an individual's *scrape*, is as unique as a fingerprint. There are characteristics that different scrapes share based upon common teachers, similar physiological features, and preferences encouraged by the professional community. However, every oboist has an individual interpretation of these commonalities, which leads to quantifiable variations between scrapes. These differences manifest in various features of the finished reed as well as in the reed-making process. Because our study focused on the physical structure of the finished reed, we controlled the reed-making process as much as possible and examined the variations in the final product.

In order to have a wide variety of finished reeds, we collected samples from professional oboists all over the world. Each player was contacted, and, if they consented to participate, was sent three identical *blanks* (half-finished reeds) to finish. We were able to uniformly control the early stages of the reed-making process: the cane selection and the thickness of the processed cane. However, because the process of reed-making and the finished reeds are so closely related, the blanks were constructed in our lab according to the participant's specifications. This caused the three blanks to vary somewhat between participants.

The Cane-Selection Process

Arundo donax is native to Mediterranean climates and much of the cane used in the musical community originates in Southern Europe and Northern Africa. The plant grows quite fast, at a rate of .3 to .7 meters per week, and will reach a height of between 2 and 8 meters. The grass is tubular and conical, with a diameter of 1 to 4 centimeters depending on the location on the cone. The wall thickness varies between 2-7 millimeters and the plant is divided into sections called internodes (Perdue, 1958). Large batches of the plant are cultivated, dried, and cut at the internode on individual cane farms. The cane is sold in bulk to suppliers, from where it will reach its eventual purpose as a reed.

Figure 1: *Arundo donax* (Xevi, 2009)

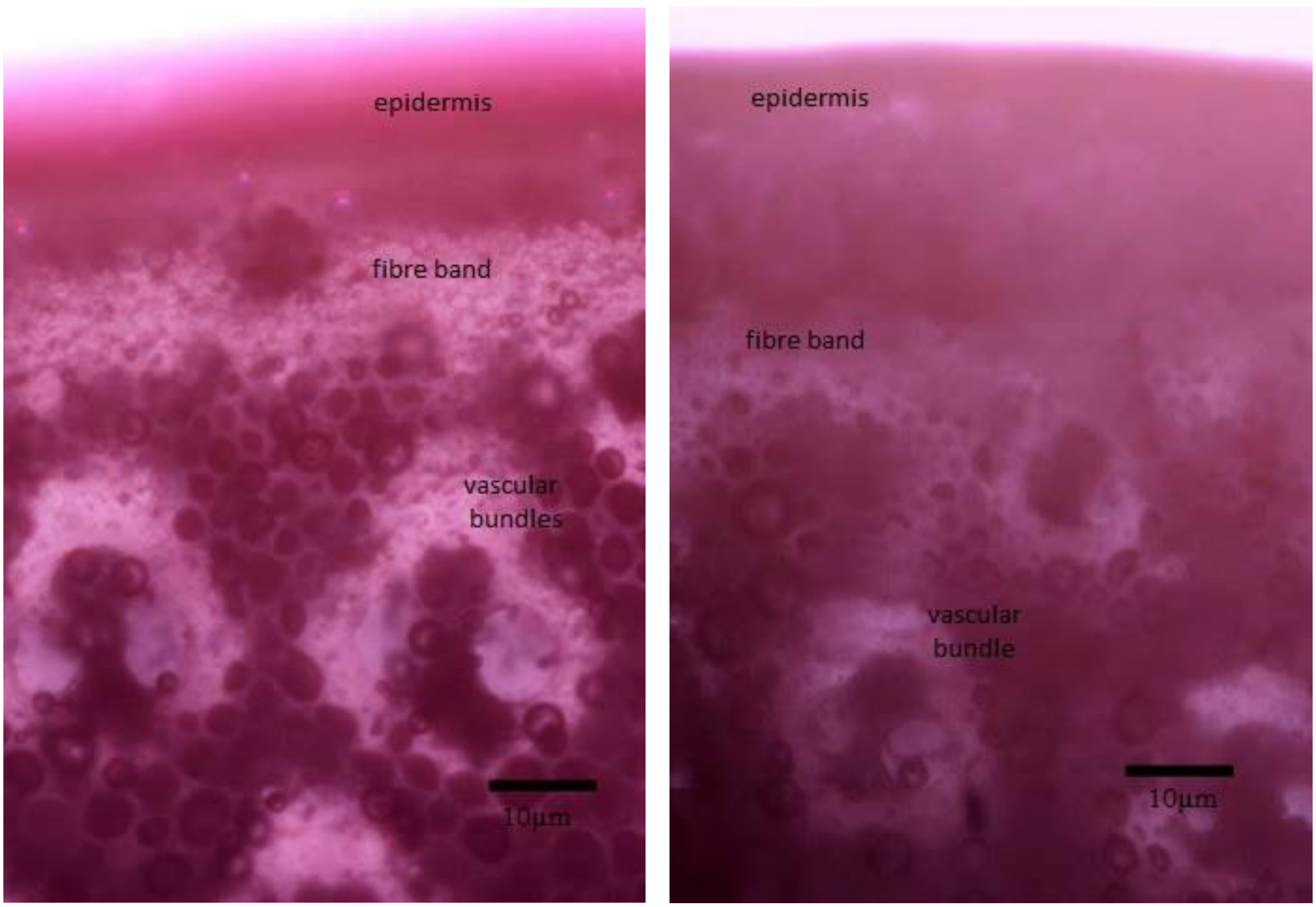
Cane is purchased in quarter-pound selections organized by cut date and farm of origin. Of this quarter-pound, only a fraction of the cane will become a finished reed. Failed reeds are often attributed to error during the reed-making process but, in many cases, the reed-maker is not at fault for the unsuccessful reed. In order for an oboist to enter the professional domain, their reed-making process must be consistent and well-practiced. A poor quality or unsuccessful reed is more often the result of an inconsistency in cane quality (Lawton, Jeronimidis, Pretlove, & Barnett, 1996).

When cultivating *Arundo donax* for musical purposes, the plant is removed from the ground when it reaches a certain height. This is an easy indication of the plant's "readiness" even though the plant may not really be ready. Individual plants have individual growth rates, as influenced by sunlight availability, soil chemistry, and genetics. In a batch of the same height plants, the level of maturity varies immensely. This irregularity in maturity causes the inconsistency in quality experienced by oboists.

A piece of cane's maturity is most apparent at a cellular level. Oboe reeds are best constructed out of a piece of cane that has a large number of fibrous bands between the epidermis (bark) and the concave interior of the grass (Lawton et al., 1996). Fast-growing plants have a smaller number of fiber bands than plants that grow slower for a longer time period. However, the cane is harvested based upon its height, not growth time. This specific condition is responsible for the differences in quality in a single batch of cane.

Although this is an issue with reed-making in general, we used it to our advantage as means to control the study. Most reed-makers have a primitive selection process upon receiving cane; it is typically sorted by its color, bark texture, and malleability (Lawton et al., 1996). The cane is deemed 'good' if the color is consistent (the desired color varies between makers), the bark is smooth, and the cane is firm without being resistant. In order to further investigate the cane we deemed as 'good', we took samples and examined looked at them under 10x magnification. By doing so, we obtained images such as those in Figure 2. These images allowed us to look for the fibrous bands as well as group the cane into similar categories. The cane that contained a large number of fibrous bands (Figure 2a) was used in blank construction.

The presence of the fiber bands ensures rigidity once the epidermis of the cane is stripped away. As the process of scraping removes the epidermis, it is important that the remaining cane holds its shape. If the cane lacks fiber bands, then the opening of the resulting reed will collapse in on itself as there is no resistance. Additionally, the reed will not have the means to vibrate like it is necessary for professional quality sound and control. We were able to control the quality of the cane



(a) **(b)**

Figure 2: Microscopic images of *Arundo donax* cross sections at 10x magnification. Fig. 2a shows cane of good quality while Fig. 2b shows cane of poor quality.

which served to increase the chances of a well-constructed product.

The Reed-Making Process

Once cane is selected—whether it is by its microscopic or, more commonly, macroscopic, features—the reed-making process begins. An oboist receives cane as a tubular internode (Fig. 3a) of *Arundo donax*, typically between 15 and 30 centimeters in length and 10 to 12 millimeters in diameter. The cane is subsequently split into three equal pieces (Figure 3b). An ideal piece of cane has the surface curvature of a perfect circle, like that of a crescent moon. Much of the time, the tube cane is not uniformly curved so not all three pieces can be used. Cane with a sufficient curvature is trimmed into an 11 centimeter segment (Figure 3c). Because the grass is an organic material, it has a tendency to warp when internal moisture levels vary. This tendency causes irregularities in the contour of the cane.

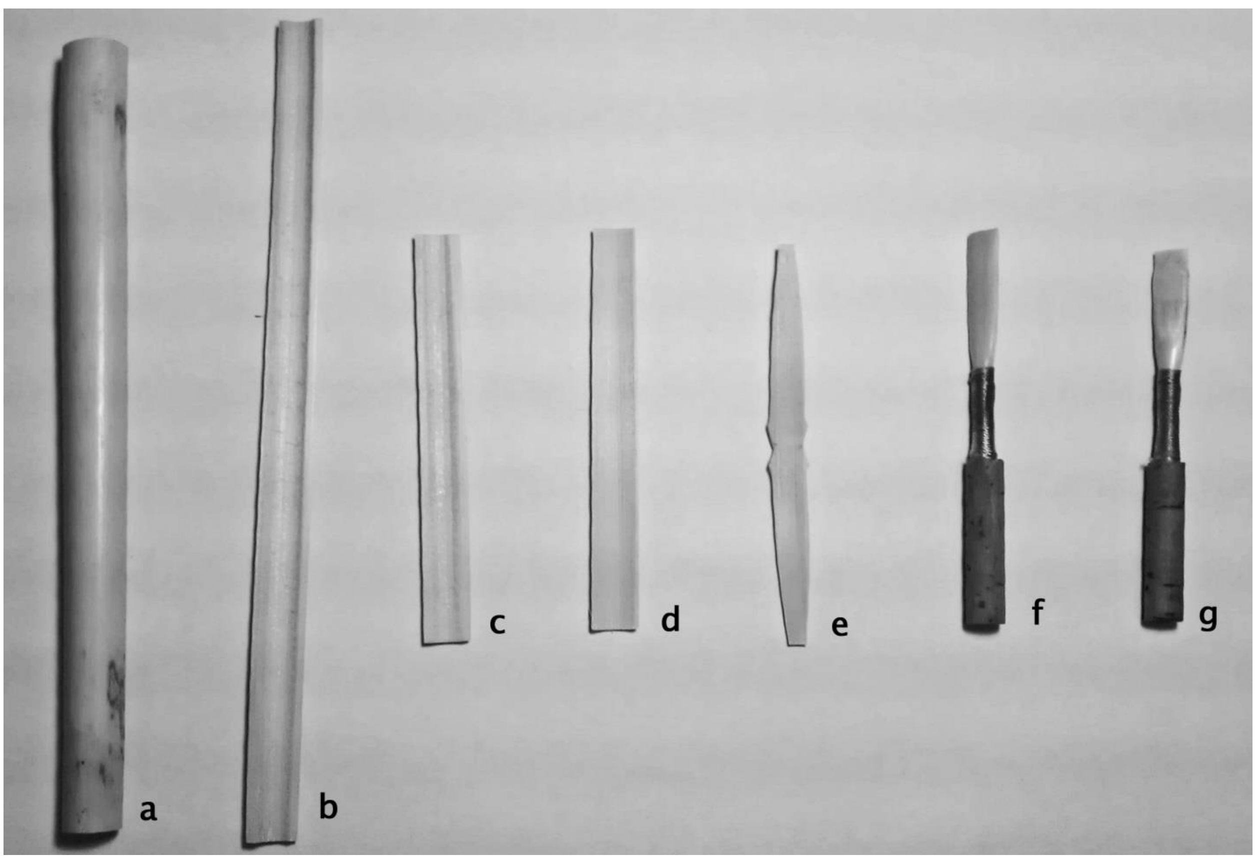


Figure 3: The reed-making process. 3a: tube cane, 3b: split cane, 3c: trimmed cane, 3d: gouged cane, 3e: shaped cane, 3f: blank, 3g: finished reed.

While the stages of the reed-making process thus far are standard across reed-makers, reed-makers begin to differ substantially from each other in the *gouging* stage, which thins a piece of cane to the dimensions necessary for creating a blank. A gouger is essentially a table-top planer: a piece of cane is inserted bark side down into a curved bed and a rounded blade is dragged horizontally across the interior surface of the cane. Material is removed until the cane reaches a thickness specified by the settings of the machine. Due to the curved nature of the blade, the middle of the cane is thicker than the edges of the cane (Figure 3d). This tendency is important in the structure of a finished reed as it forms the foundation of the reed's elliptical opening.

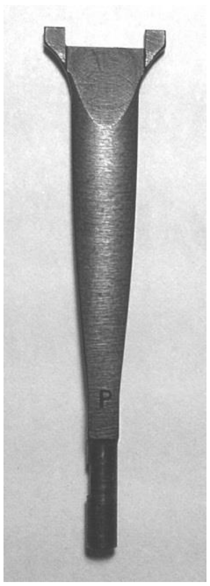


Figure 4: Shaper tip

The preferred thickness of the gouge varies from maker to maker, although it is typically between 57 and 62 micrometers. Additionally, the shape of the blade, which dictates the gradation in thickness bounded by the center and the sides, differs between makers. Many reed-makers tailor their gouge to their scrape, as the gouge controls how much material remains underneath the epidermis of the cane. Someone who has developed a more elaborate scrape may also prefer a thicker gouge, as there is more material to work with.

The next stage of the reed-making process offers even more freedom than the last. In order to prepare a piece of cane to become a reed, it has to be shaped. This entails folding a piece of cane over a roughly-triangular shaped metal form, or shaper tip (Figure 4). The shaper tip is half the length of the piece of cane and, when the cane is folded over the tip, the two blades of the double-reed are formed. The cane is clamped in place and a razor blade is used to mold the cane along the form of the shaper tip (Figure 3e). There are hundreds of variations on the basic shape of the tip and, similar to the gouge, reed-makers choose their shaper tip

Figure 5: Staple

based on their scrape. Selecting a shaper tip is like an artist selecting a canvas; the tip used determines the dimensions of the finished reed.

Once the cane is shaped, it can be made into a blank (Figure 3f). It is at this stage that the cane becomes recognizable as an oboe reed. A shaped piece of cane is folded over a conical metal tube, called a *staple* (Figure 5). The staple is inserted into the oboe, forming a connection between the reed and the instrument. The cane is tied in place such that the blades of the cane are parallel to one another and the broadest section of the shape is at the site of the fold. At this point, the cane is still in one piece, even though the blades of the double-reed are very apparent.

Blanks are also highly specific to reed-makers. Staple length and material is not standard, although most makers in America use 47 millimeter staples. A folded piece of cane is about 55 millimeters in length, but there is a significant portion of the cane covered by the tie (Figure 3f). This is to ensure that the two blades of the reed preserve their positions once they are cut apart. Depending on the shape of the cane as well as personal preference, different reed-makers tie at different lengths. Most American reed-makers tie so that the final length of the blank is between 72 and 74 millimeters, meaning that between 25 and 27 millimeters of cane is exposed on either side of the blank.

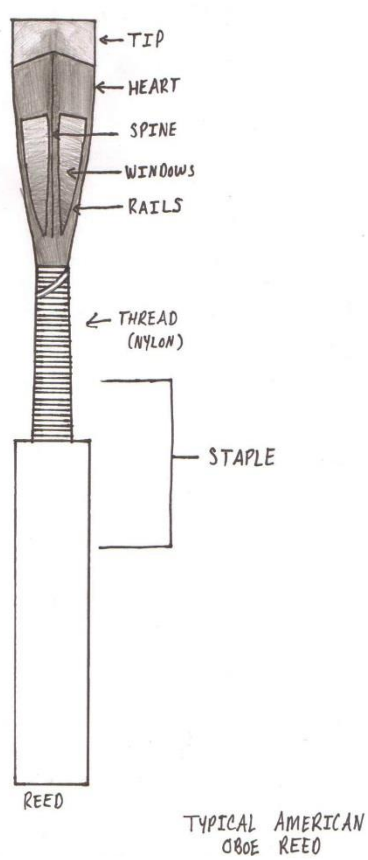


Figure 6: The basic structure of a short-scrape reed

The final stage of the reed-making process, scraping, allows for the most divergence (Figure 3g). There is a fundamental division in the reed-making community between two basic methods of scraping: the short-scrape and the long-scrape. Typically, American oboists are proponents of short-scrape while oboists elsewhere in the world prefer long-scrape. This divide is a result of cultural traditions and methods perpetuated through prominent teachers.

This preliminary study focused on short-scrape reeds. Regardless of the reed-maker, there are three main sections of the scrape: the tip, the heart, and the windows. Spanning the center of the reed is the spine while the rails outline the shape of the windows (Figure 6). The spine and the rails are the thickest components of the finished reed; much of the time, the bark is not removed. The tip is the thinnest component, reaching thicknesses of fewer than 5 micrometers at the upper corners. As shown in Figure 6, there is a gradation in thickness radiating from the bottom-center of the tip. A linear gradient occurs in the windows spanning from the bottom of the windows to the transition into the heart. The same kind of gradient occurs in the heart, except for it spans from the spine to the edges of the reed. The heart tends to be the thickest section of the reed, while the thickness of the windows shows the most variance among makers (Ledet, 2000).

Every reed-maker has a particular interpretation of the short-scrape, most evident in the length and thickness of each section. This interpretation is born out of a culmination of the player's experience. Teachers hold huge influence over their students, particularly the teacher under which reed-making is learned. As an oboist progresses, they meet more players and are exposed to more systems of reed-making. Similar to any learned skill within a community, oboists develop a unique ideology that is a composite of many other reed-making techniques.

Theory

Sound is a longitudinal pressure wave, a disturbance that travels by periodic motion of the molecules that comprise the medium (Young & Freedman, 2008). In the case of musical instruments like the oboe, sound is generated within a column of air bounded by the body of the instrument. When the air is excited (for example, by the vibrations of a reed), the column resonates in the form of a standing wave, which is created by the reflection of the wave back on itself. When a standing wave exists in the air column, all of the air particles are moving sinusoidally with the same frequency; this is called a *normal mode of vibration*. All standing waves have *nodes*, points at which the medium doesn't move at all, and *antinodes*, points of maximum displacement. Figure 7 shows the simplest mode of a standing wave in an open pipe, with a node in the center of the pipe and an antinode at each end. Higher vibrational modes will still have antinodes at the ends, but will have more structure within the tube, as shown in Figure 8 (Young & Freedman, 2008).

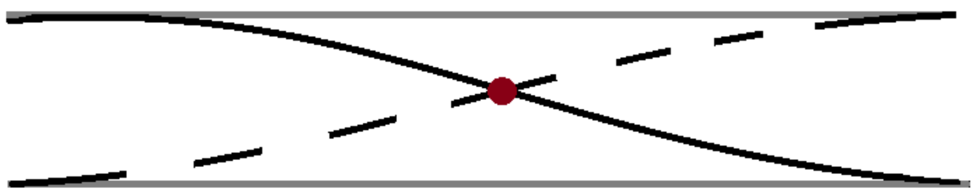


Figure 7: Displacement wave in an open pipe. The solid line represents the original wave while the dotted line represents the reflected wave.

The pitch that is heard from an instrument corresponds to the mode displayed in Figure 7 and is called the *fundamental frequency*. This is the same mode as shown in Figure 8a while Figures 8b-d show the higher vibrational modes which contribute to the *timbre*, or color, of the note. Figure 8 can be understood by realizing that due to the necessity of having an antinode at each end, only standing waves of specific frequencies can occur in the tube. The frequency of these normal modes is given by the following equation:

$$f_n = \frac{nv}{2L} \qquad (1)$$

where L is the length of the tube, v is the speed of the sound wave, f_n is the frequency, and n is an integer multiple (Young & Freedman, 2008). The most basic case, shown in Figure 7 and 8a, is when $n = 1$. Figure 8 also shows higher modes of vibration which occur for n greater than 1.

The open pipe model shown in Figures 7 and 8 is a very simplistic model of a musical instrument, but suffices to show the basic physical acoustic principles. All of these standing waves occur at the same time, but some modes have higher intensities than others. Intensity is a measure of the energy carried by a sound wave (Young & Freedman, 2008). The higher the intensity, the more energy carried, thus the more present that particular frequency will be to the human ear. The different modes contribute unequally to the perceived sound. The resulting sound that leaves the body of the instrument is a sum of all of the standing waves within the body weighted by their intensities and is also affected by the shape of the air column and the material of the instrument body (Olson, 1956/1967).

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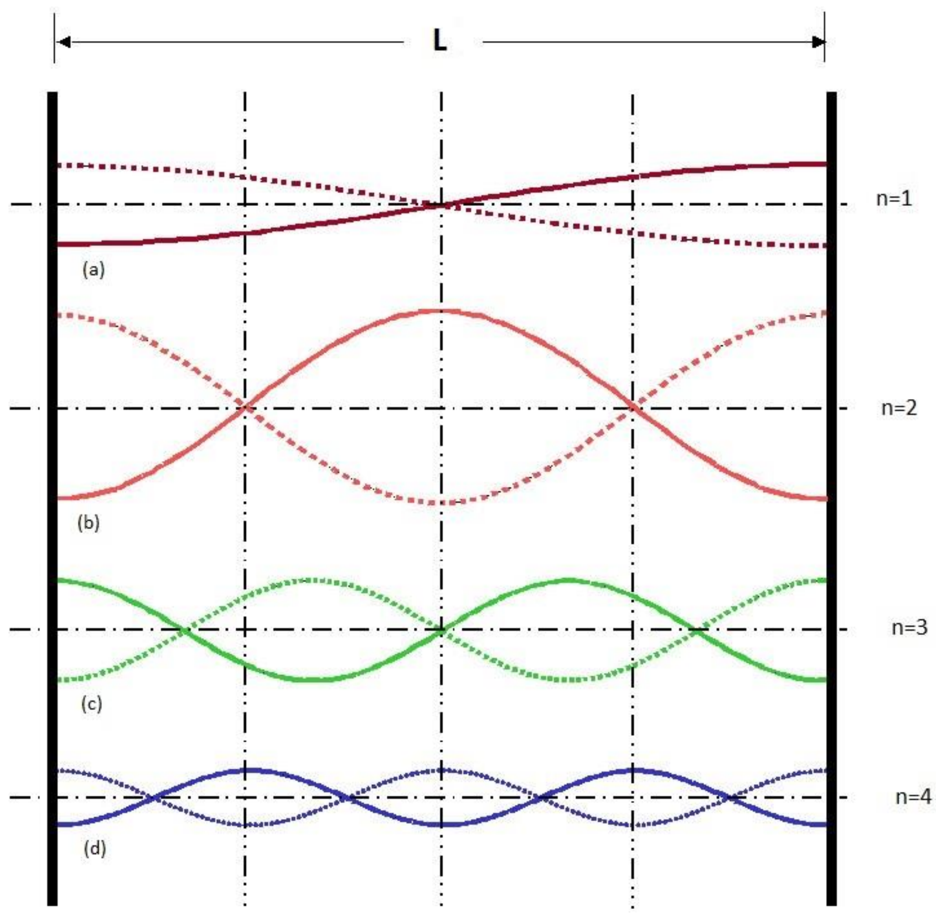

Figure 8: The first four modes of vibration in an open pipe (Buesching, 2000). 8a is the first mode, 8b is the second, 8c is the third, and 8d is the fourth

There is a discrepancy in physics and music between the terms predominately used to describe the modes of vibrations shown in Figures 7 and 8. Physics uses the word *harmonics* to describe the modes while music uses *overtones*. The first mode of vibration is called the "first harmonic" in physics but the "fundamental frequency" in music. Subsequent frequencies in physics are called the second harmonic, third harmonic and so on, whereas in music, the second mode is called the first overtone, etc. The names of the harmonics and the overtones, although referring to the same frequencies, are off by one number. We will refer to harmonics for the remainder of the paper. The collection of all of the harmonics is known as the sound spectrum.

Experimental Set-up

This study was broken into three distinct phases: contacting participants, creating samples, and collecting data. Participants were selected based upon their prominence in the field, their accessibility, and their ability to meet the timeline of the project. All participants were contacted through official university, orchestral, or self-provided channels. From each participant, we requested three finished reeds, a recording of the participant playing on each reed, and a completed questionnaire about his or her reed-making background. The questionnaire included information about the participant's education, experience, and preferences for reed-making (Appendix 1).

The reed samples were constructed as a joint effort between our lab and the participants. While we understood and respected the connection between a finished reed and the reed-making process, it was necessary to have measures of control in the study. Thus, we controlled the cane used in sample construction as well as the specific measurements of its gouge. The participants were given the choice out of three shaper tips—narrow, wide, and in between—to be used in constructing their blanks for them. They were also asked to specify their preferred staple length and their tie length. From this information, we constructed three blanks as close to identical as possible.

The blanks were sent to the participants to finish and then sent back to our lab after being scraped by the participants according to their usual methods.

Along with the reeds, the participants sent a recording of themselves playing a two-octave D-major scale on each reed to be used our the analysis. The sound of a particular oboist is not influenced by any one factor; it is a result of the instrument, the reed, and the morphology of the player (Caplan, 2009). In order to achieve an accurate representation of a reed's sound, we had to consider that a reed is crafted for a particular player and instrument. To have one player in our lab play on all of the received reeds would yield inaccurate sound spectra as the reed is only a part of an individual's sound spectrum.

Once the finished reeds were received in the lab, the data was collected. Using the program iZotope by Insight, a plug-in for Avid Pro-Tools, sound spectra were analyzed for individual pitches from the recordings. The *crow* of the reed, or sound a reed makes without an oboe, was recorded using a Shure microphone in an anechoic chamber and interfaced through an Avid MBox into Pro-Tools. With that same set-up, individual oboists were recorded playing on all of the sample reeds. Sound spectra, using iZotope, were collected for those recordings as well.

Data

When analyzing each recording, we documented the intensity level for the nineteen harmonics in the case of a crow and twenty-one in the case of a pitch. This allowed us to isolate each peak in Figure 9. From these data, we normalized each set in order to compare them against each other. We could then look for trends in the intensity levels across different samples (Figures 10-13).

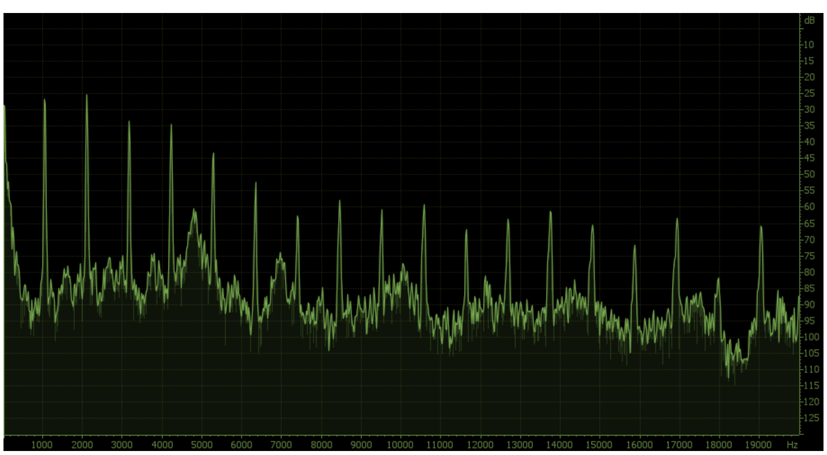

Figure 9: Example sound spectrum

This gave much qualitative insight into the relationships among the sample reeds. In addition to the harmonic structure of each reed, we recorded the physical composition. By measuring the lengths of each section of the reed, we were able to build a model of the reed.

Results and Discussion

Figures 10 – 13 are examples of the normalized results, where the horizontal axis on each graph is the harmonic number (*n* in Equation 1). For clarity the vertical bars are plotted side-by-side, but note that there is one bar of each color (red, green, blue) that corresponds to the same harmonic number. Since these graphs are taken directly from the sound spectra, we will use the term *power spectra* to refer to them. Note that the intensity scale is negative so longer the bars on these graphs correspond to lower sound intensities. Zero on all graphs—except Figures 12b and 13—indicates the intensity of the first harmonic (Figures 12b and 13 were normalized differently than the rest of the graphs for reasons discussed below).

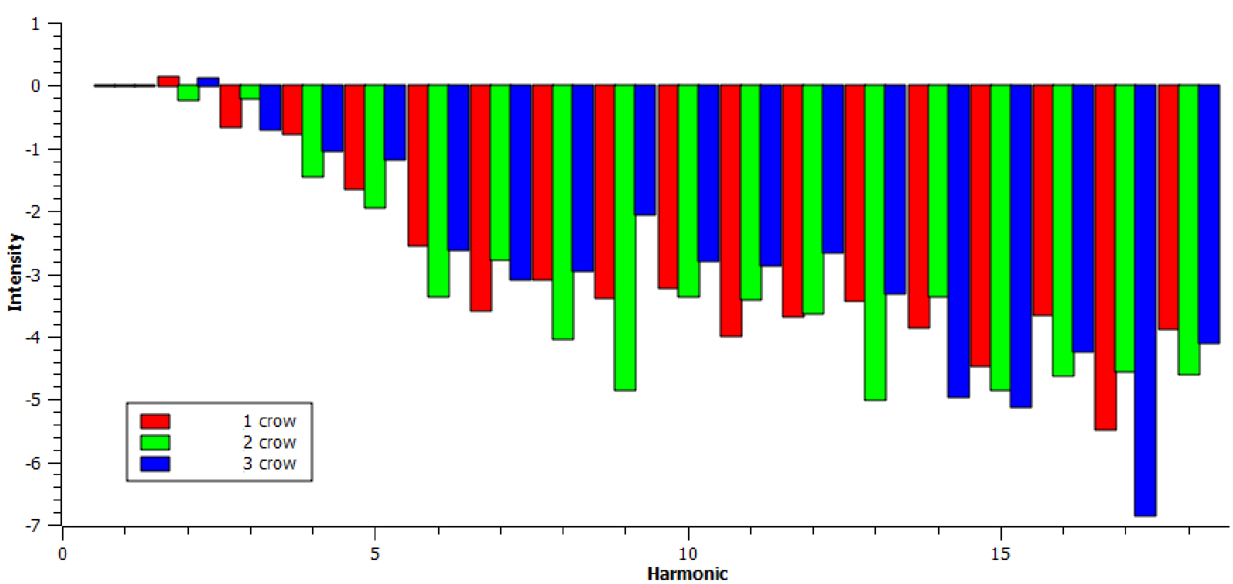

Figure 10: Power spectra of the crows of three reeds from one reed-maker.

Figure 10 compares three reeds constructed by the same oboist. The intensity levels do not rise and fall at the same harmonics, indicating that the three crows have fundamentally different timbres. For instance, the reed represented by the red bars and the reed represented by the blue bars reed appear to be similar until sixth harmonic.

Figure 11 shows a sample of the crow of a single reed along with a note (D4) played by both the maker and another oboist on that same reed. This analysis was performed for all of the samples. We failed to see any obvious trends between the crow and the pitches.

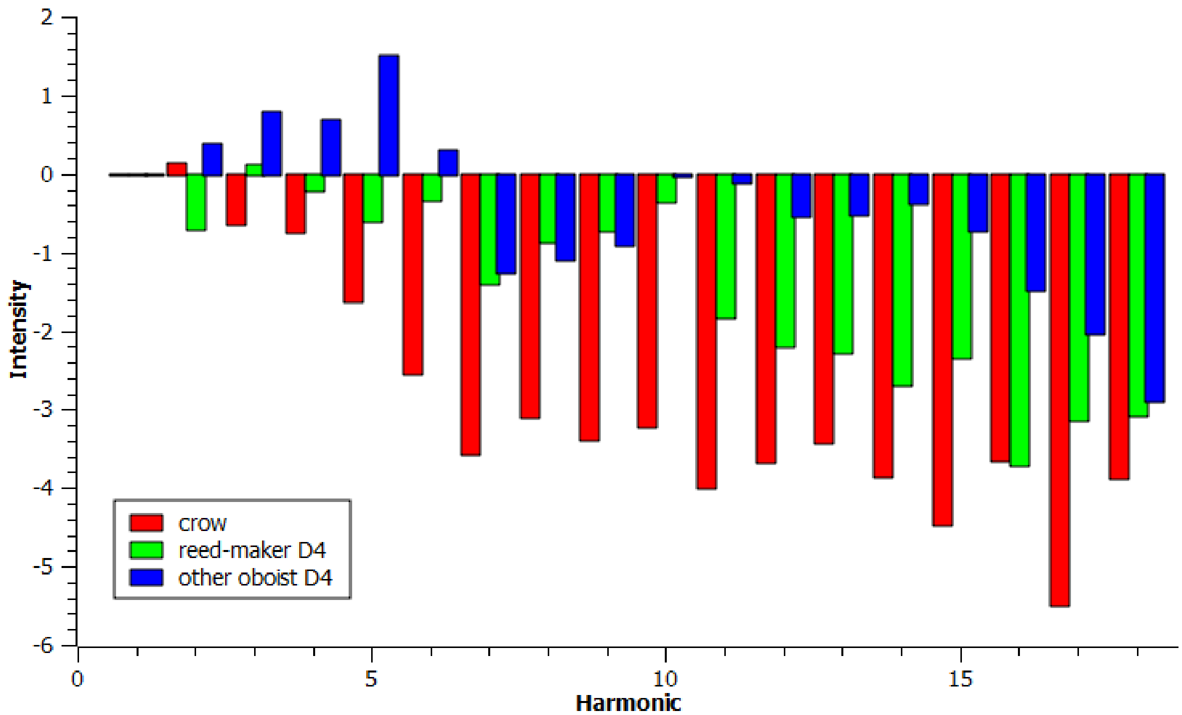

Figure 11: Example of the power spectra of a single reed under various playing conditions. The red bars show the crow of the reed, the green bars show the spectrum of the reed when played by its maker, and the blue bars show the spectrum of the reed when played by another oboist.

From these spectra, it is also obvious just how different the harmonic structure can be between two oboists. When looking at the green and blue bars, one can see a remarkable difference in the sound spectra even though the same pitch on the same reed is being played. An experienced musician can readily hear this difference in the timbre of the pitch; many oboists can even identify the nationality or past teachers of another oboist just by hearing a recording. Because reeds are tied so closely with education and experience, it is commonly thought that the reed has a profound influence on the sound. However, our results indicate that this may not be the case and suggest that the oboist may contribute more to the timbre than the reed itself.

To test this hypothesis, we examined the power spectra of a single oboist playing on three different reeds (Figure 12). We saw clear trends within the spectra; there seems to be a definitive shape to the harmonic structure.

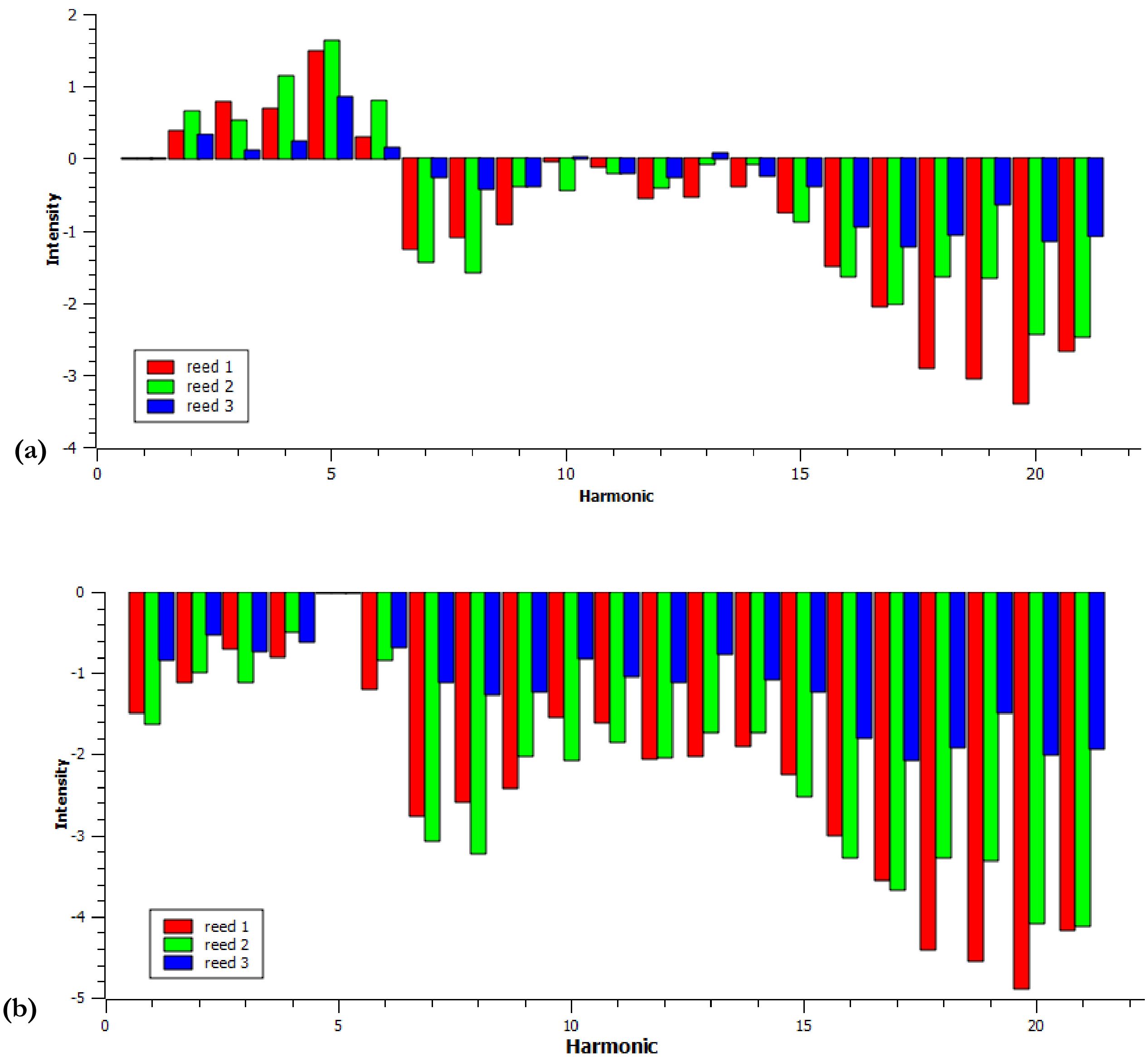

Figure 12: Normalized intensity of one oboist playing the same pitch on three different reeds. The graphs are identical, but 12a is normalized to the fundamental while 12b is normalized to the most present harmonic.

In all three spectra, the most present frequency is that of the fifth harmonic. The first four have a general slope upward to meet the fifth harmonic and then fall almost immediately after. The middle of the spectra comes up toward the level of the first six, but then falls once more toward the end. Figure 13 shows the same data, but plotted on separate graphs to readily see the pattern.

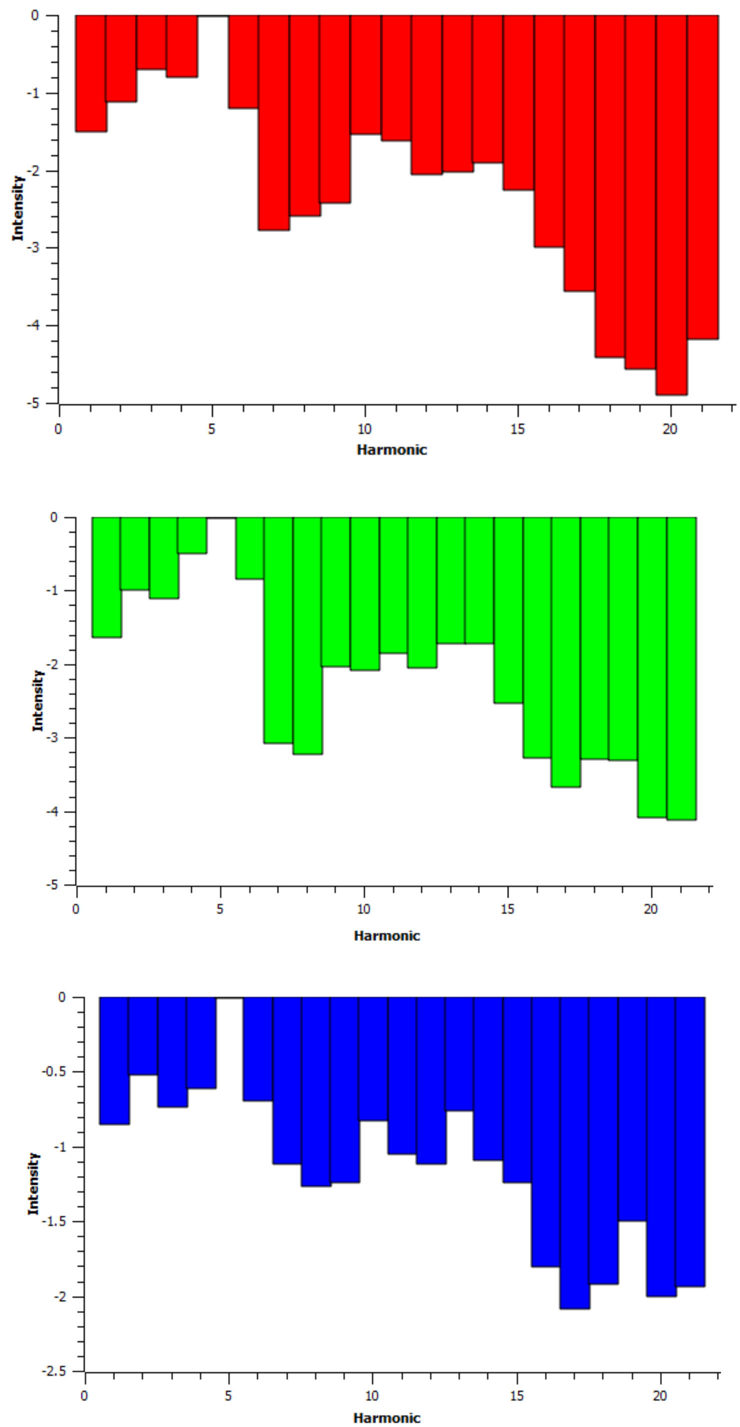

Figure 13: Individual sound spectra. Each spectrum is extracted from Figure 12: 13a is reed 1, 13b is reed 2, and 13c is reed 3.

Much importance is placed on reed-making in the oboe community; however, when comparing the power spectra of three crows played on reeds made by one maker (Figure 10), there doesn't seem to be an apparent trend within the spectra. When comparing the power spectrum of the crow to the spectrum of a pitch (Figure 11), there again doesn't seem to be an apparent trend. This analysis suggests that the reed may not influence the sound as much as originally thought.

However, we were able to see that the way the oboist plays greatly contributes to the timbre of the pitch. Three different reeds were used in Figures 12 and 13, yet the power spectra were quite similar in shape. This suggests that the player—not the reed—is in control of the quality of sound, and that an oboist can impress their individual sound upon any reed, provided that the reed is functional. Additionally, from a qualitative perspective, reeds made by the same player seem to be quite different from one another. This suggests that oboists compensate for these discrepancies by adjusting the way in which they configure their *embouchure* (the way in which the mouth and the throat are shaped) while playing.

Conclusions and Future Work

From a qualitative perspective, this study suggests that while there are definitely differences between reeds, they do not seem to contribute as much to the overall sound as the player does. We would like to investigate this observation more thoroughly by having multiple oboists play on various reeds as well as doing a more a quantitative analysis of the data. Comparison of the spectra of reeds to their physical measurements may also lend insights to whether our main conclusion is robust. In this study, all of the reeds were made from similar quality cane of the same age, as well as tied by the same reed-maker. Eventually, we would like to investigate different aspects of the reed-making process, such as the age of cane and the influence of different tying methods on the finished product.

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The participants include:

Robert Botti, New York Philharmonic/Manhattan School of Music; Tracy Carr, Eastern New Mexico University; Sandro Caldini, Conservatory of Music in Milan and Cagliari, Italy; John Dee, University of Illinois at Urbana-Champaign; Dušan Foltýn, University of Ostrava, Czech Republic; Sara Fraker, Tucson Symphony Orchestra/University of Arizona; Jared Hauser, Blair School of Music at Vanderbilt University; Ann Lemke, private studio Troy, Michigan; Nora Lewis, Kansas State University; Jurij Likin, Janáček Academy of Musical Arts, Czech Republic; Andrea Ridilla, Miami University of Ohio; Robert Sorton, Ohio State University; Austin Smith, Innoledy Music Suppliers; Daniel Stolper, Interlochen Center for the Arts; Marlen Vavříková, Grand Valley State University; Allan Vogel, Los Angeles Chamber Orchestra; David Walter, Paris Conservatory, France; Jiří Žídek, Janáček Conservatory in Ostrava, Czech Republic.

A Study of Oboe Reeds
Questionnaire for participants

This questionnaire is completely voluntary, but filling it out will help the researchers understand the thought process and methods behind your finished reeds. Any information you disclose on this form will supplement the theoretical framework behind this project and may be used as such in dissemination of this work. Your name would only be tied to your responses if you so indicated by your initials on the relevant clause of the consent form. Thank you for your time and your skills!

Who were your primary teachers?

How have these teachers influenced your reeds and reed-making?

What measurements, if any, do you adhere to when scraping blanks?

What do you listen for in your reeds?

What qualities do you aim for within your tone, and how do your reeds reflect this goal?

How do you describe reed-making to a novice reed-maker?

If there is additional information you would like to share about your reeds or about reed-making, please do so on the back of this page.

If you have any questions about this study you may contact the researchers as follows:

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If you have any questions about your rights as a research participant, please contact the Research Protections Office at Grand Valley State University, Grand Rapids, MI
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This research protocol has been approved by the Human Research Review Committee at Grand Valley State University. File No. 465407-3 Expiration: May 11, 2014.