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# Exploring Low Brass Recording Techniques

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By

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The undersigned, appointed by the Schwob School of Music at Columbus State University, have examined the Graduate Music Project titled

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Presented by Philip Andrew Broome,

A candidate for the degree of Master of Music in Performance and hereby certify that, in their opinion, it is worthy of acceptance.

(Project Advisor)

(Project Advisor)

**Abstract**

The modern day art and science of music recording evolved through a constant process of trial and error. Although many of these techniques are well-documented and commonplace in modern recording studios, most of them are generalized recording techniques used in the popular and classical music industries. Among these techniques, there is an observable lack of recognized standards for the recording of low brass instruments. This project aims to articulate quality techniques for low brass recording through research in early recording techniques and through an experimental study comparing many popular stereophonic microphone techniques. Although testing every low brass instrument would give very specific tendencies, a more general representation was presented by recording solo euphonium.

## Contents

## Introduction

The rapid advancement of technology that began with the industrial revolution and continued through the dawn of the twentieth century saw the birth of new technology in the field of sound and music that was quite ahead of its time. Recording sound and playing it back at another time was absolutely unheard of and quite frankly, whimsical. What even Thomas Edison did not know at the time of his phonograph invention was that this fantasy would turn into an ever-growing industry and forever change the world of music and technology (Katz, 2010).

Although Edison's first recording device, invented in 1877, was initially intended for use as a dictation machine to record the human voice (Edison dubbed it "the Talking Machine") (Gelatt, 1977; Millard, 1995), recording technology quickly and naturally spread to music. It did not take long to pique the public's interest in recorded music, since it could be played back at the listener's will. The music industry was born. As with most industries, the technology developed quickly and evolved seemingly on a daily basis, largely due to competition in the new marketplace of music recordings. It was competition that drove the need for audio engineers specializing in the art of recording. Their techniques evolved through a sometimes-excruciating process of trial and error. Because recording was in its infant stages, engineers were trying to outdo one another by improving and adjusting the technology available in order to create the best sounding recordings. They were selling a product, and, ostensibly, better quality meant higher sales.

Since the inception of recording technology, techniques have been developed for specific musical instruments and sounds because of the complexity of those sounds that were being recorded. This paper will explore those techniques specific to low brass instruments. Specifically the following questions will be addressed, with the goal of giving further insight into the development of the technology over time. First, what were the first music recordings that included brass and what were the techniques used to capture the sound? Second, when magnetic recording became the norm, what techniques were changed from the previous years of phonograph and gramophone recordings? Third, with the development of the modern microphone, what techniques and/or microphones were used and became the norm throughout the development of modern recording? Fourth, what techniques are shared or different between classical and popular recordings with regards to brass? And lastly, what are the best techniques to reproduce/capture the sound of low brass instruments with today's modern technology? Although one can note that these questions are quite broad and cannot be answered definitively, the experimental studies and research conducted will provide a clearer picture of the techniques used and how common listeners perceive those techniques.

As one can note from the introduction above, the history of audio technology is an important backdrop to a paper focused on low brass instrument recording. To gain a complete picture of more than a century's worth of technological advancement, we must examine the history of audio technology since its inception. In the following section, I will provide an overview of the three audio technology eras including mechanical, magnetic, and digital.

**Mechanical Era**

The Mechanical era began presumably with the creation of the telephone, which matured over a period of time through the work of many inventors such as Alexander Graham Bell, who was granted the first telephone patent in 1876. Like many other inventions, many people were involved in the formation and development of the technology. Around the decade of the telephone's invention many engineers and inventors entertained the idea of recording and playing back sound. The first ever machine invented that could accomplish this task is said to be Thomas Edison's Phonograph in 1877 (Frayne, 1985; Gelatt, 1977; Millard, 1995).

The phonograph functions through the transmission of acoustical energy onto a stylus, which would cut vertical grooves into a wax cylinder. The same stylus could then move back over these grooves, reproducing the sound back to the listener. Although the technology was still formative, Edison saw its potential for use in business, and manufactured and distributed these new "talking machines" as dictation devices. He invested much of his time on the phonograph because of the financial return it would bring (Bodoh, 1977; Gelatt, 1977; Wile, 2002), both because of the device's magical novelty and usefulness in the business environment. Although the contraption impressed consumers, the sound quality lacked depth and realistic qualities. After the original shock wore off, they wanted better sounding recordings.

Edison eventually abandoned the process of improving the sound of the phonograph, perhaps because of his preoccupation with the development of the incandescent light bulb. Alexander Graham Bell took a deeper interest in recorded sound following Edison's apparent loss of interest. After several years of research, Bell, along with his cousin Chichester A. Bell and Charles Sumner Tainter, applied for a patent in 1885 for the "Graphophone" (Gelatt, 1977; Millard, 1995), which was similar to Edison's phonograph except Bell used lateral cutting instead of Edison's vertical cutting to make the grooves in the cylinder. Bell also used wax-coated cylinders instead of tinfoil. Another inventor around the same time period, Emile Berliner, sought to differentiate his device from the others made by Edison and Bell. His device cut grooves into a disc of heavy glass instead of a cylinder with a laterally moving stylus and photoengraved the disc in metal as the medium. Berliner called his device the "gramophone," the precursor to the modern "record."

As music recording progressed, among the first recordings were of John Philip Sousa Bands playing familiar American marches (Gelatt 1977; Millard, 1995,). There was also a plethora of opera recordings made by singers and accompanied by piano. The reason for these reduced instrumentations was the very limited frequency response of the recorders. Because of the sheer nature of the machines and the horns that picked up the sound, frequency responses were limited from about 200 Hz to about 3,000 Hz in the first phonograph recordings. From a quality standpoint, this frequency range paled in comparison to the full range of human hearing, which spans 20Hz to 20,000Hz. With regards to music, phonograph recordings only encompass around four octaves in range with the lowest audible note higher than that of the basses and tubas in an orchestra. Not even the lowest note on a piano is covered in this range. Improvements to the horns were made over time as well as to the surface noise of the cylinders.

While the general public was enthralled by the new entertainment and record companies were meeting their status quo, companies were still having trouble getting the most established music artists to record (Gelatt, 1977), despite their marketing tactic of claiming the most extensive libraries and catalogues of recorded music (Gelatt, 1977; Steane, 1993). The most popular artists shied from the recording studio because of the quality of the recordings that were being made at the time. They felt that the machines would not do their voice the justice it deserved (Gelatt, 1977). Still, Edison was marketing his machines as the best quality, using the term "high fidelity" for the first time in his advertisements (Odell, 1974). In fact, the diamond disc record that Edison produced is said to have had higher fidelity than the discs that were being used at the time. However, the units never caught on because of the incompatibility of the discs with other record players. There were too many different models and forms of the technology.

Nonetheless, the longing for the most extensive catalogues and artist rosters sparked an even larger upgrade to the technology available.

The first microphone was introduced in 1877 by Emile Berliner, which was used in the telephone created by Bell Labs. Even though the technology had been around for some time, the idea of using an electrical transducer (like a microphone) in recordings to pick up sound electrically was not explored until around 1912 when the capacitor microphone was developed. Keep in mind the phonograph recordings transmitted sound to the cylinders acoustically, with no electricity. The only electrical components up until this point were electrically powered cranks that spun the cylinders during recording and playback.

Although the first microphones were quite primitive compared to modern microphones, it was a considerable upgrade from the mechanical age of recording. The electrical age was the bridge between mechanical and magnetic recording. A microphone was drastically more sensitive to nuances in sound and increased the frequency response top end to around 8,000Hz (Haggin, 1948; Millard 1977). In addition, because of improved recording diaphragms and microphones, musicians no longer had to crowd around a tiny horn to obtain better recordings. Large orchestras could now be recorded with all of the musicians present ("A Phonograph Album," 1977).

Shortly into the new century, the original cylindrical phonographs began fading out of existence. Edison and other companies continued making cylinders for those who still owned older technology, but the disc shaped records, made famous by Berliner, swept through the audio recording industry almost as quickly as the original phonograph. Because of the rapid change in technology, even Edison began making his own version of the record (Millard, 1977). This form of recording technology coupled with new and improved microphones as well as the development of the recording studio, stayed rather constant through two world wars until a new technology yet again transformed the recording process.

**Magnetic Era**

Although Oberlin Smith and a number of other scientists had explored the use of magnetization in the recording process around the same time as Edison's development of the Phonograph in the 1880s, the idea of using a magnetic medium to record sound was not intensely investigated until around the 1930s (Thiele, 1988). The major difference between the two time periods was the difference in the medium used. Early scientists described magnetic recording using steel wire as the medium. Engineers of the 1930s used magnetized tape for the medium, which proved to be the superior method. It is generally accepted that magnetic tape recording was discovered in Germany in the 1930s at BASF, a chemical company, and AEG, a German electricity company (Thiele, 1988). Their first magnetic tape recorder was called the "magnetophon." This research and experimentation and later patents would be solely based on research done by Fritz Pfleumer, the German engineer who first created and was given the patent for magnetic tape, which was thin paper coated with iron oxide powder (Thiele, 1988).

Magnetic recording is quite simple. Magnetic tape is fed through a recording head. The recording head is analogous to a stylus used in phonographs. An electrical signal is sent to the head, which then induces a pattern of magnetization on the tape that corresponds to the changes in signal. Although most scholars and audiophiles would agree that the advent of magnetic tape did not necessarily improve upon the recorded sound it certainly created other possibilities in the actual recording process. Tape recording gave engineers the opportunity to record something, erase it directly after, then record it over again. With the improvement of magnetic tape recorders, engineers could also record smaller sections and through a painstaking process of physically joining bits of tape together, edit them all together as one. Artists no longer had to slave over one take, striving for perfection from start to finish. They could do multiple passes and smaller sections at a time. Shortly after World War II, the allies captured a bevy of Nazi technology, including their experiments with magnetic tape, used to record and transmit propoganda during the war. John "Jack" Mullin is widely associated with discovering the magnetophons the Nazis had been hiding. After bringing them back to the United States, he began modifying them to improve performance and fidelity. This introduction of magnetic tape to the United States transformed the recording industry forever. One of the most important features of the new recorders was the length of recording they could produce, over fifteen minutes of audio, something unheard of in the recording industry at the time, especially when compared to the two-minute and four-minute cylinders in the early days of phonograph recordings.

Looking back on the evolution of the recording industry, it is easy to make the connection between the recording industry and the radio broadcast industry, as well as parallels with the film industry. Many of the innovations by either of the trades were often adopted and improved upon by the other. During this same time period, radio broadcasts began using multiple microphones when more than one DJ or character was on air at a given time. It did not take very long for recording studios to catch on to the concept and microphones began littering the studios to capture more accurate representations of the performance.

In 1955, an electronics company called Ampex developed a magnetic tape recorder that could record multiple tracks simultaneously onto the same tape. This technique would later be known as "multitrack" recording. Before this discovery, engineers could only record sounds onto a single track. Now, each individual microphone used in the studio could occupy its own track on the tape and be processed later during mixing. Although this was extremely innovative, the technique never really caught on until jazz guitarist Les Paul bought an Ampex machine and began using it to record. His methods and techniques spread throughout the engineering community, and it became the standard for recording in the 1960s. The first Ampex recorders allowed for only 8 tracks using 1-inch tape. They would expand later to as many as 32-tracks. This would open the door to endless creative possibilities and new techniques for improving recording fidelity. As was the case in the early days of phonograph recording, engineers began developing and sharing new techniques over time. One of the most useful techniques during this time was the use of "overdubbing" in which audio could be recorded on top of previously recorded material.

The introduction of multitrack recording also allowed for improvements in audio quality with the advent of stereophonic recording. Stereophonic, or two-channel recordings take advantage of the human auditory system and are capable of presenting a realistic sound field to a listener. During mixing, the engineer can place certain sounds or microphones in particular channels, exploiting the ability of the ears to distinguish between sounds from different directions. Engineers such as Alan Blumlein and others from Bell Labs pioneered this practice in the 1930s, first utilizing it for motion picture sound (Frayne, 1985; Streicher & Dooley, 1985). There are many techniques that employ this system, but the central goal remains the same: to obtain the most realistic stereo image. This can be acquired through several microphone placement techniques, most of which will be discussed at length in this paper.

## Digital Era

Although digital recording was born in the late 1970s, magnetic tape remained the dominant format in commercial recording studios for nearly two more decades. The development of digital audio progressed over a large time span, and parallels the development of the personal computer, due to the high amount of underlying technology shared between the two.

The fundamental unit of digital audio is the “sample”. Digital sampling is not to be confused with the musical device of the same name, which became popular also in the 1970s and 80s. Sampling is the process of taking snapshots of the analog signal thousands of times per second and representing them as numeric data, which correspond to amplitude values. The first digital recording machines still stored these bits on magnetic tape, but in the early 1980’s digital systems began storing audio data on computer storage devices like hard drives. Now, engineers could record audio limited only by the size of the storage medium. Shortly after, compact discs, a type of computer storage medium, began replacing cassette tapes and old records as the primary playback medium used by consumers. In addition, track limits were extended beyond the 32 tracks provided by tape recorders, offering more flexibility and allowing for more complex recording techniques.

One other development that digital audio brought about was the lowering of the cost of recording equipment. The gap between professional equipment in commercial studios and consumer-grade equipment narrowed significantly at the turn of the millennium. As a result, considerable amounts of money were no longer required to produce professional sounding recordings. In addition, digital editing reduces the amount of time and labor necessary to make complex, polished recordings, since computer systems were developed to provide non-destructive editing capability. Recordings could be captured, mixed and edited, all while retaining the possibility of reverting back to the original if necessary.

## Early Brass Recording Techniques

Although there is much more to the history of audio recording through its progression over a century, this broad overview lays a foundation for exploring recording techniques specifically for low brass instruments. Since the arrival of the first phonograph, brass instruments have played a major role in many areas of the recording industry. As previously discussed, the frequency response of early recorders was limited to a range of about 200Hz to 3,000Hz. Brass instruments, excluding only the Tuba, have their fundamental pitches fall in this range. As a result, it is no coincidence that there were many cornet solo recordings during the late 1800s. One would also find a number of photos from the same time period of brass instrumentalists crowding around a recording horn in order to get the best sound. Brass instrument design meant that the bells could project directly into the medium, which provided excellent clarity when compared to other instrument types. Because the frequency range of other instruments in the orchestra did not fall in the available limit, brass instruments were brought in to supplement sections that could not be heard. This was extremely prevalent when recording companies began to record orchestral music in the early 1900s ("A Phonograph Album," 1977; Millard, 1995).

Early brass solo recordings featured some of the most famous brass instrumentalists of the day, including trombonist Arthur Pryor and cornetist Herbert L. Clarke (Kilpatrick, 2005). Although there are many recordings of orchestras with brass sections, once the use of microphones went mainstream, the number of solo recordings was somewhat sparse because of the limited repertoire specific to those instruments. After the 1960s, this trend began to reverse with the arrival of more music written for both brass soloists and small ensembles.

**Stereophonic Recording**

When considering sound physiologically, mammals with two ears like humans are able to localize sound based off of aural cues. When a stimulus is presented such as music or sound in general, our brain perceives this sound to come from a particular location based off of the time delay that occurs when the sound enters one ear sooner than the other causing an interaural time difference, or ITD (Yost, 2007). A sound coming from the left side will enter the left ear before entering the right. Humans can also localize sound based off of interaural level difference (ILD), also called interaural intensity difference (IID), which takes its cue from the level of sound from either side. If the level of sound is much louder entering the right ear, humans can localize that sound as coming predominately from the right side. When dealing with the perception of sound, it is also worth noting the interaural phase difference (IPD). IPD is related closely to ITD in which it involves the time difference between the two signals. Because the brain measures the two signals from each ear and combines them at a higher level, the time difference can cause phase cancellation problems with certain frequencies after the brain analyzes the time difference (Hartmann & Constan, 2002). This problem should be taken into consideration when considering stereo microphone techniques. All of the techniques discussed and used in this experiment utilize these interaural differences to produce realistic images of the sound being recorded.

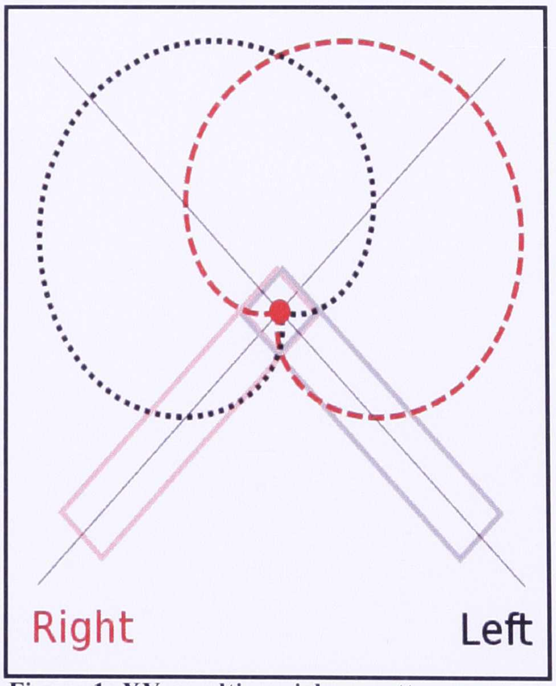


**Figure 1: XY resulting pickup pattern. (Figure by Iain Fergusson)**

**Stereophonic Microphone Techniques**

As mentioned earlier, stereophonic recordings became prevalent as well as the standard in the 1940s. For acoustic recordings, it is common practice to use stereo microphone techniques to create a realistic representation of space. Before going into detail of the techniques, one must be aware of the differences between coincident, near-coincident, and spaced techniques. Coincident techniques, also referred to as "intensity stereo" techniques, are those that derive the stereo image using directional microphones arranged very close to one another on a common axis. Examples of this type of stereo technique that were used for the present research are XY, MS, and Blumlein techniques. The effect relies on disparities in power between the two capsules because there is very little time difference between the two (Streicher & Dooley, 1985). These techniques use interaural level difference (ILD) cues to create the stereo effect. Specifically with XY, two caridioid microphones are setup on a common plane with their capsules 90° from each other. The resulting pickup pattern can be seen in Figure 1.

Similarly, Blumlein technique also generates a stereo image by the differences in power,

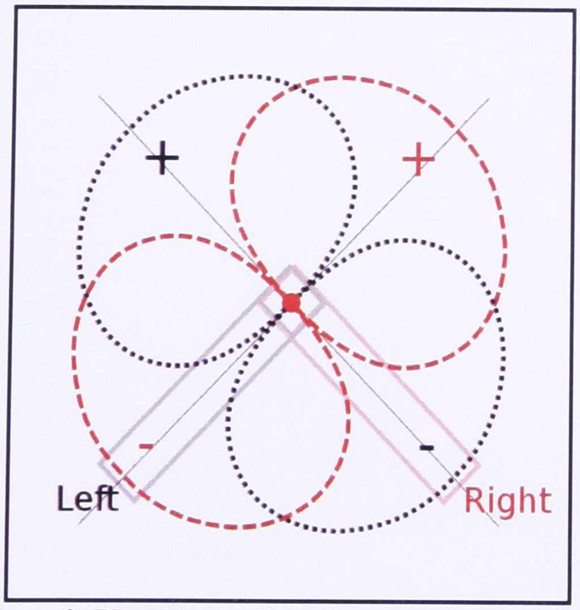


**Figure 2: Blumlein resulting pickup pattern. (Figure by Iain Fergusson)**

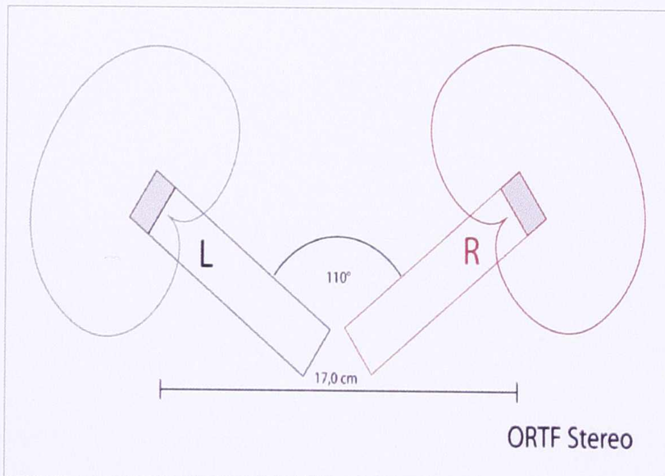


**Figure 3: O.R.T.F. resulting pickup pattern. (Figure by Iain Fergusson)**

however it utilizes two figure-8 polar pattern microphones instead. They are placed so the capsules are 90° from each other similar to XY technique with the resulting pattern seen in Figure 2.

Near-coincident techniques are very similar to coincident in that the capsules of two directional microphones are close enough to be coincident for some frequencies yet far enough apart to introduce time delay between them. One of the near-coincident techniques used for this project was O.R.T.F, named for the French organization that devised it, the "Office de Radiodiffusion Télévisions Française." The technique uses two cardioid condenser microphones much like XY, however the capsules are spread apart instead of on top of each other about 110° apart (Streicher & Dooley, 1985). The resulting pickup pattern can be seen in Figure 3. Another coincident pair used for this experiment was M.S. or mid side pair. M.S. is very unique in that it requires electronics in order to create the stereo effect. Like the other techniques, M.S. utilizes two microphones, however one of the signals is copied and sent through an M.S. matrix to create the system. It uses one bi-directional and one cardioid or omnidirectional microphone. The figure-8 pattern microphone is placed perpendicular to the sound source while the cardioid microphone is placed above or below the figure-8 directly facing the sound source. The capsules are then perpendicular to each other. The bi-directional microphone signal is copied and phase inverted 180°. The two signals are then panned hard left and right with the cardioid signal directly in the center. A diagram of the technique and its

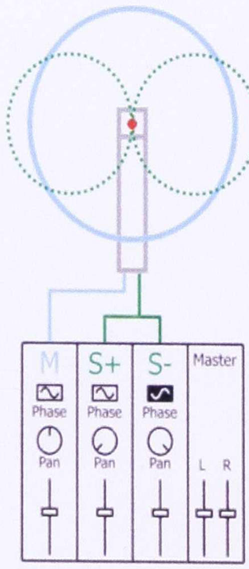


**Figure 4: MS (mid-side) resulting pickup pattern. (Figure by Iain Fergusson)**

resulting pattern can be seen in Figure 4.

The word "spaced" clearly defines the next technique, which incorporates much more space between capsules than coincident and near-coincident pairs. Perhaps the most widely used and oldest of the stereo techniques, spaced techniques integrate two or more microphones, directional or omnidirectional, spaced at varying distances generally from 2 to 10 ft. apart. The stereo effect is achieved by changes in amplitude and time of arrival (Streicher & Dooley, 1985). Like all stereo configurations, this technique relies on careful placement with regards to the sound source. Because of the greater distance between capsules, the slightest change in distance from the sound source could change the stereo information significantly causing unrealistic sound cues for the listener. An omnidirectional spaced pair was used for this experiment.

**Experimental Study**

In order to gain a better understanding of these techniques and their results, an experimental study was conducted to explore how common listeners perceive these methods. For this experiment, the author recorded himself playing the euphonium with several microphone techniques. When preparing to record sound, specifically the sound of low brass instruments, the main purpose is to capture the most realistic representation of the sound so it can be reproduced accurately. Many factors come into play that makes this task very sensitive. Not only are there options for what microphone(s) to use, but also other factors such as the size and shape of the room where the recording will take place as well as the placement of the microphones come into play among other considerations. Changing any of these variables can drastically change the quality of the recording. In order to account for the differences in room size and shape, I conducted experimental recordings at two different locations: Legacy Hall in the RiverCenter for the Performing Arts and the Loft Recording Studio, both in Columbus, Georgia. The two rooms differ greatly in size as well as the shape (see Figure 5). Legacy Hall is a large performance space primiarly used for classical music performance and has extensive reverberance, whereas the Loft Recording studio is a small commercial studio with a large room that is quite "dead" in its decay.

**Method**

The following is a detailed representation of the setup that was used at both locations. Exact measurements were taken in order to duplicate the experiment precisely. The most popular stereo microphone configurations in classical and popular recordings were employed. In addition, two extra microphones were set up in close proximity to the instrument to act as "spot" or "accent" microphones. The setup was essentially a line of stereo configurations in a row, occupying a single plane, in this order: Blumlein, XY, O.R.T.F., M.S. or mid-side, and spaced pair (see Figure 5). The author, performing on the euphonium, performed from a piano bench at the long end of the room 76 ½ inches from the Blumlein arrangement. In this case two Neumann U87 condenser microphones were used to create the configuration. I achieved this setup with a typical Blumlein bar that conveniently positions the microphones in the correct manner (see Figure 6). The bottom microphone's capsule was 62 inches off the

**Figure 5: Top- Full setup in Legacy Hall. Bottom - Full setup at the Loft Recording Studio.**

ground. Behind the Blumlein pair is an XY configuration with Neumann TLM 170R condenser microphones. The configuration was 68 inches off the ground. Behind the XY pair was an O.R.T.F. pair. The capsules are generally spaced about 17cm apart, however, for the experimental recordings, due to the equipment available, this space was increased to 12 inches. The pair was 66 inches off the ground. The microphones used for this method were Røde NT-5 condenser microphones.

Next, an M.S. pair, or mid-side configuration, was placed behind the O.R.T.F. pair. The two microphones used for this experiment were a cascades ribbon microphone for the bi-directional component and an AT 4033 Special Edition for the cardioid. The AT 4033 was on the bottom in the configuration and was placed 57 inches off the ground while the Cascade Fat Head capsule was 63 and 1/3 inches off the ground.

**Figure 6: Blumlein bar for Blumlein stereo configuration. XY pair directly behind.**

The last stereo placement was approximately 148 inches from the playing bench and was a spaced stereo pair or "A-B." The matched pair of microphones was a duo of Microtech Geffel omni directional condenser microphones. These were the highest placed microphones at 73 inches off the ground. They were both 52 inches from the center point of the setup equaling 104 inches from capsule to capsule. Lastly, I placed two accent microphones short distances from my euphonium to capture greater clarity of sound. These microphones were not placed in stereo configurations like the others; rather they were placed in strategic positions around the bell of the instrument to experiment with the different propagation patterns of the euphonium. One was placed directly above the bell roughly 62 inches off the ground and 1 foot and ½ inch from the center bell. The microphone used was a Neumann U67. The other accent mic was a Cascade Fat Head ribbon microphone placed 45 inches off the ground facing off axis at around the top of the bell 4 inches off. The placement of both mics can be seen in Figure 7. When the experiment was duplicated in Legacy Hall, the U67 spot mic was left out because of its availability at the time. Instead, it was replaced with two Neumann U87 microphones in Omni-directional polar patterns creating a spaced pair. These particular microphones are part of a default recording setup for the hall. They are always hanging and are ready for recording purposes. Additional close-up photographs of the recording setups for each location can be found in the appendix.

The recorded material was an etude out of the Kopprasch book of etudes, played by the author lasting approximately 2 minutes and 45 seconds. The reason for using the Kopprasch was to give listeners a short example to evaluate with substantive content to display characteristic qualities of the instrument. For the survey portion of the study, four volunteer participants were brought in to listen to the recordings from each location and complete a survey on what they heard. The location where they listened was the main recording studio at Columbus State University. The speakers they listened on were Yamaha HS80 Reference Monitors. Each

**Figure 7: Left – Spot mic setup in Legacy Hall.**
**Right – Spot mic setup in the Loft Recording Studio**

participant was placed directly in the center between the two speakers so as to be in the center of the sound field that is created. These variables were held constant throughout the experiment. The listening space can be seen in Figure 8. Each participant was also given the exact same instructions at the start of the listening session. In all, there were seven different microphone techniques used in the experiment for each location. The Loft location was labeled "Location #1," in an effort to keep the study as blind as possible and was thus played first in the session. The participants listened to #1 first, which corresponded to the Blumlein pair. Approximately 10 seconds later, the recording was switched in real time to technique #2 and then to #3 ten seconds later, and so on. A list of the techniques and their specific placement can be seen in the Appendix. Because the recordings were multitracked in pro tools, I was able to play the participants the exact same performance of the etude and switch in and out of techniques on the fly. While listening, the participants were asked to reflect on certain elements including clarity, warmth, depth, sense of space, communicates expressivity of the performance, precision, and at the end, their favorite technique.

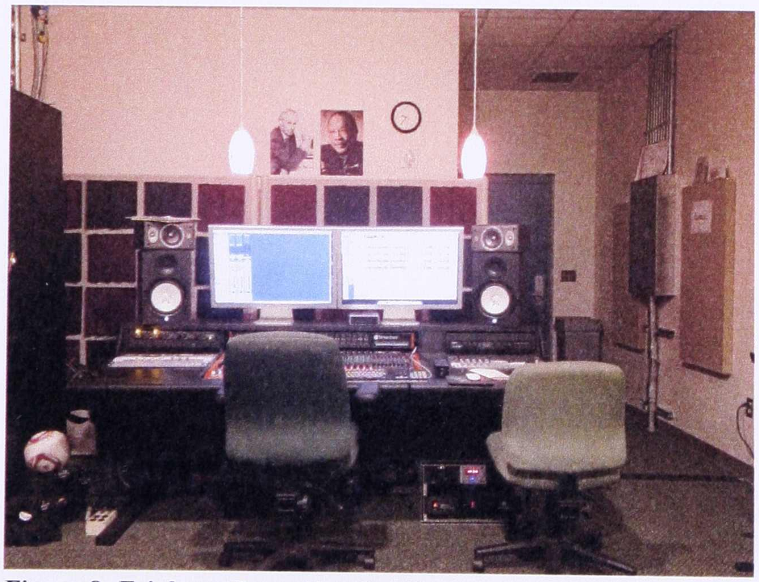

**Figure 8: Feighner Recording Studio at Columbus State University (Listening space).**

When considering clarity, participants were asked specifically to judge the clearness of articulation and tone. Warmth was somewhat self-explanatory to the participants but it generally encompasses the presence of low and low-mid frequencies, which is important when considering the recordings of low brass instruments. They were asked to consider whether or not those colors were prevalent in the recorded sample. Depth specifically pertains to the sense of vertical space in the recording, similar to the vertical depth in paintings. Does the recording accurately depict the location's sense of depth? Sense of space refers to the stereophonic space of the recording. Does the technique portray a realistic or desirable stereo image? Whether or not the recording communicates the expressivity of the performance can be quite ambiguous however, careful listening to recordings can show discrepancies in the expression of the performance due to a number of factors including among others mic placement and choice of microphone. As a result, the participants were asked to consider this element when evaluating.

**Survey Instrument**

Evaluation was done using a ranking system on a spreadsheet (see Appendix for a copy of the survey instrument). The system remained constant for each location. The participants were asked to rank each of the seven techniques for each category listed above with 1 being the best and 7 being the worst. While listening through the etude for the first time and cycling through the techniques, the participants were asked to consider the first element of clarity when evaluating. They were also given the option of taking notes while listening on paper provided, as one goal of the experiment was to capture the participant's initial response to hearing each successive technique. After listening through two or three times, still cycling through each technique, most participants were able to complete the evaluation of the other elements without having to listen for those elements specifically. It appears that the sonic quality of recordings is imprinted in memory very quickly, especially during critical listening. In some cases, the participants would ask for specific numbered techniques to compare and contrast after listening through several times. After completing the first six elements of evaluation, the participants were then asked to rank the techniques on the same scale based off of their favorite. Most participants achieved this by comparing which techniques had the most “1s” during evaluation. Interestingly, the ranking of “1s” did not necessarily contribute to the selection of the participant’s favorite.

After completing the initial evaluation sheet, the participants were asked to make combinations of techniques to form their most desirable blend of methods. Most participants started out by making combinations of their top choices from the initial evaluation sheet, and then began choosing other options to refine their choice. What they found was that some techniques provided superior performance in some categories but not in others. As a result, the participants often chose up to three or even four techniques to combine in order to create the best balance of sound with regards to the elements listed on the evaluation sheet. This supports the practice of using multiple microphones and placement techniques.

**Results**

As expected, the results from the experiment and listening sessions were extremely varied from one participant to the next. Starting with location #1, each participant gave a different “1” ranking for each element being considered except for the “communicates expressivity of performance” category and the “precision” category. This observation points to the variability of opinions related to recorded sound. A spreadsheet with the complete data can be found in the appendix.

**Participant #1.** Participant #1 is a professional musician, playing tuba in a professional symphony orchestra for 8 years. He also teaches tuba and euphonium in college and has been in that profession for 14 years. With regards to Location #1, his rankings were spread out quite evenly among the 7 techniques. Every participant gave a different "1" ranking for clarity in Location #1. Participant #1 gave Technique #7 a "1" for clarity in Location #1. Because this technique was so close to the top of the bell, it tends to pick up very clear articulations, however, it also introduces unwanted airiness in the sound as well as a very bright sound because of the sound waves propagating through the metal of the horn. For warmth, he chose Technique #6 for both locations, the ribbon spot microphone that was placed close to the bell but off axis to the top of the bell. For depth and sense of space, he chose the O.R.T.F pair (technique #3) consistently for both locations. This supports that the O.R.T.F. technique provides the most realistic stereo image because it emulates the human hearing system by having the capsules distances apart similar to human ear lobes. In the "Communicates Expressivity of Performance" category, Participant #1 gave a "7" to the O.R.T.F. pair for Location #1 but a "1" for Location #2. This also supports the theory that O.R.T.F. pairs benefit from larger recording spaces in general. For precision, he chose Technique #2, the XY pair, for Location #1 and Technique #5, the spaced pair, for Location #2. The XY pair was also given a "2" for precision in Location #2. This is very interesting considering the XY pair only received one other "1" ranking in his survey which was for the "communicates expressivity" category for Location #1. In other words, Participant #1 felt the XY technique provided the most realistic representation of the euphonium. On the other hand, the XY configuration performed rather poorly in the "sense of space" and "depth" categories hinting Participant #1 cared less about stereophonic imaging when considering the accuracy of the technique with regards to the euphonium. In addition, Participant #1 chose technique #5, the spaced pair, for precision in Location #2.

When asked to make combinations of techniques to form their favorite blend for the second portion of the survey, Participant #1 began making combinations based off of the results he generated. He began by comparing the techniques that garnered the most "1s." For Location #1, he chose the combination of techniques 2, 3, and 6. He also added Technique #7, the U67 spot mic, could also be employed but at a much smaller level than the others for additional clarity. For Location #2, he also chose the techniques that acquired the best rankings throughout the survey. This included techniques 5 and 6. In addition, he also added Technique #3 but that he could "take it or leave it," in the mix.

**Participant #2.** Participant #2's results were vastly different than Participant #1 in many categories but similar in others. He is a director of bands at a university and has been in the music business for 15 years. He also plays the trombone as his primary instrument. Beginning with clarity, he chose Technique #4, the MS pair, for Location #1 and Technique #3, the O.R.T.F. pair, for Location #2 as the most clear. It is interesting to note he was the only participant to choose the O.R.T.F. pair as the most clear. Also, he gave technique #6 consistent "7s" for both locations in stark contrast to Participant #1's rankings. He even wrote down it was "clear but hollow." Perhaps his judgment was clouded by the fact that it was so different sounding than the other techniques and did not contain the same amount of depth or frequency information. For warmth, he gave a "1" to Technique #1 for Location #1 and a "2" to that technique for Location #2. It is worth noting he was the only participant to give this particular ranking. For Location #2 he gave a "1" to Technique #3 for warmth. For "depth," he chose technique #1 and #4 for Location #1 and #2 respectively. With regards to "sense of space" and "depth," Participant #2 chose somewhat similar techniques compared to the other participants. He preferred Technique #1 for depth for Location #1 and Technique #4 for Location #2. For "sense of space," he chose the O.R.T.F. pair, consistent with 3 of the 4 participants for Location #1. He favored Technique #7 in Location #2 for sense of space, which was the spaced pair of U87s hanging in the hall. This is consistent with the fact that this pair captures a large amount of ambience and reverberation because of the placement in the hall. For the "communicates expressivity" category, he chose Technique #2 and #3 for both locations respectively. These are the exact same results for Participants #1 and #3. Participant #4 also picked technique #3 for Location #2 for "communicates expressivity," however, he picked the same technique for Location #1. It is interesting to note it was documented that Participant #2 placed emphasis on the accuracy and expressivity of the performance when considering his favorite techniques. This is evident in the results. His "favorite" techniques correspond to the techniques that received "1s" for the categories "communicates expressivity" and "precision," for both locations, Techniques #2 and 3 respectively.

For the second phase of the experiment, Participant #2 chose the same combination for both locations: Techniques 1, 2, 3, and 6. He was the only participant to choose four techniques for the combination segment.

**Participant #3.** Participant #3 is also a college professor who teaches trumpet and has been doing so for 27 years. Much like all of the results in this experiment, his rankings were also quite different from the other participants in some categories but strikingly similar in others. Starting again with "clarity," he chose Technique #2 and #5 for both locations respectively, contrasting with the choices of the other participants. The results also differed for "warmth" in that he was the only one to choose Technique #5 for Location #1. However, he did choose technique #3, the O.R.T.F. pair, for Location #2, similar to the choices of the others. His preference of technique for "depth" and "sense of space" was also rather similar to the other participants. He chose Technique #1 and #3 for "depth" for the two locations respectively and #2 and #3 for "sense of space" for both locations respectively. In addition, he picked somewhat similar techniques for "communicates expressivity" but not for "precision." He picked Techniques #2 and 3 for the two locations respectively for the former. As for "precision," he preferred Technique #5 for both locations, the spaced pair. Interestingly, Participant #3 also chose Techniques #2 and 3 for the two locations respectively as his favorite configurations, the exact same choice as Participant #3. It should also be noted Participant #3 took considerably less time than the other participants when making his decisions with the ranking system. He also marked his favorites first before attempting to fill in the rankings for the other categories. He noted that arriving at the rankings and favorites for Location #2 was much easier.

For the combination section, he auditioned several combinations before arriving on techniques #2, 5, and 6 for Location #1 and Techniques #3 and 6 for Location #2. The other techniques he tried were 3 and 1, 3 and 3, and 3 and 2 clearly highlighting Technique #3 as his favorite technique overall.

**Participant #4.** Participant #4, like the other participants, is also a college teacher who teaches trombone in a university and has been for 12 years. He also has an extensive background in audio technology, the only participant with those credentials. With regards to the overall results, his rankings were strikingly similar to Participant #1. However, this generalization is still far fetched, as there are still many differences between his results and the others. Pertaining to "clarity," he actually preferred Technique #1 for Location #1. Similar to Participant #1, he chose Technique #6 for Location #2. This particular similarity is quite interesting considering both Participant #1 and 4 are low brass players and teachers while the others have different backgrounds. They both tended to give high marks for clarity and warmth to Technique #6 while the other participants tended to dismiss it based on its characteristic of being so dissimilar when played by itself. When considering "depth" and "sense of space," Participant #4 chose similar to Participant #1 by choosing Techniques #3 and 7 for both locations and categories respectively. His selections for the category "communicates expressivity" were also similar to all the other participants as he chose Technique #3 for both locations. For "precision," he chose the same as Participants 1 and 2 by choosing Technique #2 for Location #1. However, for Location #2, he was the only participant to pick Technique #6 as his most preferred for "precision." When asked to determine his favorite technique, he actually labeled Technique #6 as one of his least favorite for both locations. He chose Technique #3 as his favorite for both locations much like the other participants.

During the combination phase, Participant #4 chose Techniques #3 and 7 as well as #6 mixed in 10 dB less than the others. It should be noted, Participant #4 with his background in audio recording was the only one who chose to audition techniques at different levels in an attempt to "mix" different ones.

**Interpretation.** After sifting through the results of all the participants, many interpretations could be formulated as an outcome. As a whole, the results varied from one participant to the next. However, there were also many similarities. If one only looks at the favorite choices of each participant, which were only given by Participants 2, 3, and 4, one could conclude Techniques #2 and 3 were quite consistent as the leaders. Both techniques, the XY pair and O.R.T.F. pair respectively, are coincident pairs with the latter being a near-coincident pair. All participants had somewhat different choices for "clarity" and "warmth." Those choices did not necessarily reflect their choices when considering favorite techniques as a whole. In fact, one could also conclude the participants overall "favorite" choices were mostly consistent and even influenced by their rankings for "communicates expressivity" and "precision" more than any other categories. As noted earlier, Participant #2 even documented he considers "communicates expressivity" as the greatest determining factor in his opinion. This can clearly be seen while looking at the results specifically for Technique #3. It performed well in both categories but not necessarily as well in other earlier categories that pertained specifically to sonic qualities of the recordings, such as "clarity" and "warmth." Nonetheless, Technique #3 consistently performed well as the participants' favorite. In addition, all participants seemed to agree there was enormous value in combining techniques to create the desired blend of sound. There was not one technique that seemed to be able to stand alone as the best technique. When combined with other techniques that displayed the characteristics missing in others, participants were able to find ideal permutations. This clearly supports the opinion that multiple microphones provide for the most realistic representation of low brass instruments.

When considering my own opinion about the recordings in this experiment, there were many disparities between the participants and mine, however, like the results in general, there were also many similarities. With regards to the techniques played by themselves, the Blumlein pair provided the most realistic and warm response indicative of the euphonium. The O.R.T.F. pair, however, provides the most spaced stereo image highly desirable for this type of recording. Although the Cascade spot microphone is lacking space, depth, and high frequency content, mixed in with other realistic stereo configurations, the technique adds much needed clarity and warm tone to the overall balance. The most ideal combination, in my opinion, would be techniques 1, 3, and 6, with some of Technique #5 mixed in for light ambience to taste.

## Conclusion and Implications

Since the dawn of the recording industry, the need for engineers specifically trained in the art has created a plethora of techniques exploiting the limitations and benefits of specific microphones as well as the human hearing system. A review of literature has highlighted the haphazard nature of obtaining and developing recording techniques. Over time, these techniques were improved upon and made standard through scientific research and development. In order to gain a better understanding of these techniques and their strengths and weaknesses specifically for low brass instruments, an experimental study was conducted using many of the popular stereo and accent microphone configurations. The recordings were played for four participants whom completed a survey asking their opinions on specific elements of the recordings. They were asked to complete the evaluation using their initial responses to the sound they were hearing and for those specific elements they were asked to discern.

Although most of the popular stereo microphone techniques were employed for this experiment, one should note that the sonic qualities of these configurations vary greatly on the brand and make of microphone used. While I used an array of widely popular condenser and ribbon microphones, both small and large diaphragm, it is possible the results that were obtained could be quite different if other microphones were used. As expected, the results and interpretation thereafter varied greatly from one participant to the next. Additionally, the participant pool was kept to four in order to remain close to the data, as well as to pilot the research area.

Many findings within this study were consistent with documented tendencies of certain techniques. For instance, some participants leaned towards the spaced Omni pair for Location #

2, which aligns with this technique performing well in larger recording spaces with greater levels of reverberation. In addition, with spaced Omni pairs, there is generally a better low frequency response, an element that low brass instruments benefit from greatly.

The results of this experiment also prove that perception of recorded sound relies on an exhaustive list of variables, including demographics, background in recording or instrumental playing, and to a certain extent, the speakers or other medium the listener is using to hear the sound. The discussion of this phenomenon is outside the scope of this particular research project, however the concept is worth noting. Each participant came from similar backgrounds in the music field, yet had very different views on recorded sound and their desired product in the end. This echoes the conundrum of the audio engineer. Although techniques have become standard and even the sounds themselves, it is very difficult to pinpoint a specific technique or method that obtains the "best" recording of low brass instruments. The word "best" even implies opinion in this case, which highlights the irony of this experiment. Although it was the mission of this paper to answer the above question, it was highly improbable that one specific technique or combinations thereof would reign superior over all others.

If one answer could be obtained from this experiment, it would be the use of multiple microphones is not necessarily needed but desirable because of the pros and cons of each configuration. Each participant noted each microphone configuration contained multiple pros and cons and not one of the methods completely obtained the sought-after sound by itself. It was not until they were given the option of combining techniques that they were able to find the sonic quality that created the most realistic and clear reproduction of the euphonium.

Although the results of the experiment can be interpreted a number of ways because of the variability of the rankings, this analysis should stand as a potential guide to recording and accurately reproducing the sonic qualities of low brass instruments. There are many possibilities that stem from this particular topic that would guide recording engineers in the future on techniques that have either not been explored or simply not tested. Additionally, this study only contained recordings of the euphonium as an example of low brass instruments. Other low brass and even high brass instruments would certainly benefit from a similar experimental study. Even further, only seven different stereo and accent microphone techniques were utilized for the experiment. There are many other techniques and measured placements that were not explored during this testing. Further analysis of these techniques and placements could yield larger and possibly more favorable results. In addition, research with different brands of microphones would also produce clearer outcomes. In most cases, the type and brand of microphone contributes as much to the sound quality of the recorded material as the placement. The two tend to work hand and hand. Also, it is worth noting that although advances in technology have improved the ability to create quality recordings quickly using documented successful techniques, the use of trial and error is still very much in place in audio recording. Thus the need for studies on documented trial and error experiments. One might also explore the effects the actual hall has on the recorded sound. There is much research on these effects but little has been tested with low brass instruments. Furthermore, this experiment was also only conducted with solo euphonium, without accompaniment. The variables change significantly when other instruments and timbres are added to the euphonium sound. Perhaps a much greater problem arises when trying to mix and maintain the integrity of the euphonium sound with, for instance, a piano accompaniment. The precise use of stereophonic techniques changes somewhat because of the wash of mid-range sound between the piano and euphonium. Isolated recordings of instruments are certainly much easier to control when it comes to the frequency response. A study on this would undoubtedly complement the research in this project.

Although there is no clear answer to the question of recording low brass instruments effectively, there are several methods and concepts that seem to shed light on the situation at hand. The most prevalent is the use of some sort of ambient microphone placement mixed with spot, or accent microphone placement. Even though this is a very vague concept, it seems to rule supreme and yields the best recordings when this very basic rule is followed. Ambient microphone placement captures the frequency response of the room while the accent microphones capture much more clarity of sound and articulation. Mixed together, the two produce a very realistic representation of the sound. As noted earlier, this has always been and continues to be the most important model in music recording.

A more specific conclusion can also be obtained from analyzing this study involving overall microphone placement with regards to accent microphones. While simply looking at the structure of the instrument, it is easy to conclude the best possible accent microphone placement would be directly above the bell. However, after careful research and analysis of this study, this conclusion would be premature. When considering the sound source of the euphonium, the listener is certainly not listening directly in front of the bell merely because that would be impossible unless the player were to point the bell in the audiences direction. In contrast, the sound leaves the bell, propagates through the room after hitting the medium directly above, and then reaches the audience. The resulting sound is far from the resonance one would hear directly above the bell. Instead, the audience hears the warm, mid-range qualities of the horn compared to the more metallic, harsh articulations resounding candidly above the bell. In order to accurately capture the more desirable sound the audience is accustomed to hearing, the accent microphone should be placed more in front of the musician, off-axis of the bell in order to eliminate metallic sounds resonating from the bell itself. This can be heard with Technique #6, which utilized a ribbon microphone for this particular experiment. The latter technique of placement directly above the bell was implemented in Technique #7 in Location #1. The results of the experiment echo the opinions of the author in this argument. Almost every participant chose Technique #6 over #7 for their accent microphone choice when paired with other stereophonic techniques. In all, this study provides an in-depth look at a select few techniques and their perceived results while recording low brass instruments.

References


A Phonograph Album (1977). *Music Educators Journal, 64*(4), 52.

Bodoh, A. G. (1977). The Jukebox, the Radio, and the Record. *Journal of the Audio Engineering Society, 25*(10), 836-842.

Frayne, J. G. (1985). History of Disk Recording. *Journal of the Audio Engineering Society, 33*(4), 263-270.

Gelatt, R. (1977). *The Fabulous Phonograph 1877-1977*. New York City: Macmillan Publishing.

Hartmann, W. M., & Constan, Z. A. (2002). Interaural level differences and the level-meter model. *Journal of the Accoustical Society of America, 112*(3), 1037-1045.

Katz, M. (2010). *Capturing Sound: How Technology Has Changed Music*. Los Angeles, California: University of California Press.

Kilpatrick (2005). Overview: Brass. *American Record Guide, 68*(5), 57-61.

Millard, A. (1995). *America on Record*. New York, NY: Cambridge University Press.

Odell, B. (1974). The Edison Diamond Disc phonograph--perfect fidelity, sixty years ago! *Association for Recorded Sound Collections Journal, 6*(1), 3.

Steane, J. B. (1993). *The Grand Tradition*: Amadeus Press.

Streicher, R., & Dooley, W. (1985). Basic Stereo Microphone Perspectives--A Review. *Journal of the Audio Engineering Society, 33*(7/8), 548-556.

Thiele, H. H. K. (1988). Magnetic Sound Recording in Europe up to 1945. *Journal of the Audio Engineering Society, 36*(5), 396-408.

Wile, R. (2002). The Automatic Phonograph Exhibition Company and the Beginnings of the Nickel-in-the-Slot Phonograph. *Association for Recorded Sound Collections Journal, 33*, 20.

Yost, W. A. (2007). *Fundamentals of Hearing: An Introduction. Waltham, Massachusetts*: Academic Press.

Appendix A: Survey Instrument

| Participant #1<br>Techniques | Clarity | | Warmth | | Depth | | Sense of Space | | Communicates Expressivity of Performance | | Precision | | Favorite | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3 | 6 | 5 | 3 | 3 | 3 | 4 | 6 | 5 | 5 | 5 | N/A | N/A |
| 2 | 7 | 2 | 5 | 3 | 2 | 4 | 4 | 5 | 1 | 2 | 1 | 2 | N/A | N/A |
| 3 | 6 | 6 | 7 | 6 | 1 | 5 | 1 | 1 | 7 | 1 | 2 | 3 | N/A | N/A |
| 4 | 4 | 5 | 3 | 4 | 5 | 2 | 5 | 3 | 4 | 4 | 3 | 4 | N/A | N/A |
| 5 | 5 | 4 | 2 | 2 | 4 | 6 | 2 | 2 | 3 | 3 | 4 | 1 | N/A | N/A |
| 6 | 2 | 1 | 1 | 1 | 7 | 7 | 6 | 7 | 2 | 6 | 6 | 6 | N/A | N/A |
| 7 | 1 | 7 | 4 | 7 | 6 | 1 | 7 | 6 | 5 | 7 | 7 | 7 | N/A | N/A |
| Participant #2 | Clarity | | Warmth | | Depth | | Sense of Space | | Communicates Expressivity of Performance | | Precision | | Favorite | |
| 1 | 4 | 3 | 1 | 2 | 1 | 3 | 2 | 5 | 2 | 3 | 2 | 2 | 2 | 3 |
| 2 | 3 | 2 | 4 | 5 | 3 | 4 | 5 | 6 | 1 | 2 | 1 | 3 | 1 | 2 |
| 3 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 3 | 3 | 1 | 5 | 1 | 3 | 1 |
| 4 | 1 | 4 | 5 | 4 | 5 | 1 | 3 | 4 | 6 | 4 | 4 | 4 | 6 | 4 |
| 5 | 6 | 5 | 3 | 3 | 4 | 5 | 4 | 2 | 4 | 6 | 6 | 5 | 4 | 6 |
| 6 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 7 | 5 | 7 | 6 | 2 | 6 | 6 | 6 | 1 | 5 | 5 | 3 | 6 | 5 | 5 |
| Participant #3 | Clarity | | Warmth | | Depth | | Sense of Space | | Communicates Expressivity of Performance | | Precision | | Favorite | |
| 1 | 3 | 4 | 3 | 3 | 1 | 3 | 2 | 3 | 3 | 3 | 4 | 4 | 2 | 3 |
| 2 | 1 | 3 | 2 | 4 | 3 | 4 | 1 | 4 | 1 | 4 | 2 | 3 | 1 | 4 |
| 3 | 4 | 2 | 4 | 1 | 4 | 1 | 5 | 1 | 4 | 1 | 3 | 2 | 4 | 1 |
| 4 | 5 | 5 | 6 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 5 | 2 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 3 | 2 |
| 6 | 7 | 7 | 5 | 7 | 6 | 7 | 7 | 7 | 6 | 7 | 6 | 7 | 6 | 7 |
| 7 | 6 | 6 | 7 | 6 | 7 | 6 | 6 | 6 | 7 | 6 | 7 | 6 | 7 | 6 |
| Participant #4 | Clarity | | Warmth | | Depth | | Sense of Space | | Communicates Expressivity of Performance | | Precision | | Favorite | |
| 1 | 1 | 2 | 3 | 5 | 2 | 5 | 2 | 6 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | 3 | 4 | 2 | 4 | 3 | 5 | 3 | 6 | 3 | 5 | 1 | 3 | 3 | 5 |
| 3 | 2 | 3 | 5 | 2 | 1 | 3 | 1 | 3 | 1 | 1 | 3 | 5 | 1 | 1 |
| 4 | 4 | 5 | 7 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 7 | 4 | 4 | 3 |
| 5 | 7 | 6 | 4 | 3 | 4 | 2 | 4 | 2 | 5 | 4 | 6 | 6 | 5 | 4 |
| 6 | 6 | 1 | 1 | 1 | 6 | 7 | 6 | 7 | 6 | 7 | 5 | 1 | 6 | 7 |
| 7 | 5 | 7 | 6 | 7 | 7 | 1 | 7 | 1 | 7 | 6 | 4 | 7 | 7 | 6 |

| Technique # | Configuration | Microphones used | Distance from playing bench | Distance off ground | Additional info |
|---|---|---|---|---|---|
| 1 | Blumlein | Two Neumann U87s | 76 ½ inches | 62 inches | |
| 2 | XY | Two Neumann TLM 103s | 82 inches | 68 inches | Center of capsules were 2 ½ inches apart. |
| 3 | O.R.T.F | Two Rode NT5s | 87 inches | 66 inches | |
| 4 | M.S. | AT 4033 (mid) Cascade Fat Head (side) | 8 ft. | 57 inches (mid) 63 1/3 inches (side) | |
| 5 | Spaced | Two Geffel Omni condensers | 12 Ft. 4 inches | 73 inches | 8 ft. 8 inches spaced apart |
| 6 | Close Spot | Cascade Fat Head | N/A | 45 inches | 4 inches from the top of the bell. |
| 7 | Close Spot<br>Spaced ambient | U67<br>Two U87s | N/A | | |

Appendix C: Participant Evaluation Sheet

## LOCATION # 2

| MICROPHONE CONFIGURATION | CLARITY | WARMTH | DEPTH | SENSE OF SPACE | COMMUNICATES EXPRESSIVITY OF PERFORMANCE | PRECISION | FAVORITE |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |