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An Examination of Relationships Between Ear-playing Skills and Intonation Skills of High School and College-aged Wind Instrumentalists

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AN EXAMINATION OF RELATIONSHIPS BETWEEN EAR-PLAYING SKILLS AND INTONATION SKILLS OF HIGH SCHOOL AND COLLEGE-AGED WIND INSTRUMENTALISTS

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Abstract

Playing by ear and the ability to play in tune are components of musicianship that rely heavily on the ability to successfully discriminate musical pitches. Connections between ear-playing and intonation performance have rarely been addressed. The purpose of this study was to investigate relationships between intonation performance and ear-playing skills of high school and college-aged wind instrumentalists. Research questions were: 1. What is the relationship between the ability to play by ear and intonation performance? 2. How does intonation ability differ when the participants sightread notation compared to performing music that was learned by ear? 3. Do differences appear in ear-playing ability based on selected musical experiences? Sixteen high school and 18 university wind musicians ($N = 34$) submitted a background questionnaire, completed a series of musical performance tasks designed to measure ear-playing ability and intonation accuracy. Analyses indicated a moderately direct correlation between ear-playing ability and intonation accuracy for the total sample and for the university group. However, no correlation was found in the high school group. No significant difference in intonation ability appeared when comparing a melody learned by ear and one performed using notation. Analyses also revealed that musicians who had been playing 3-4 years, 5-6 years, and 6 or more years were more successful than those musicians with less experience. Implications for music teaching and learning are provided.

Chapter 1. Purpose of the Study

Introduction

Playing a wind instrument is a challenging task requiring several elements to take place synchronously to achieve a quality sound. Basic elements that are learned early in the process of playing a wind instrument include: the physical aspects needed to hold and the instrument, proper embouchure to produce a characteristic sound on the instrument, proper breathing, hand positions, and posture (Davis, 2019). Using a common curriculum containing melodic and rhythmic notation reading (Watkins, 2011), a variety of music-making activities take place, including daily in-school playing, at-home practice, or private lessons (McPherson, 2005). Through these activities, students develop higher-level qualities such as dexterity, phrasing, dynamic control, articulation, and intonation, all of which are added to the basic elements all of which become important components for higher-level musicianship (Bauer, 1993; McBeth, 1972; Sindberg, 2009).

Ensemble directors are faced with the responsibility of fostering the development of higher-level performance tasks, usually within heterogeneous instrumental settings. This challenge exists on two planes: one is that each instrument offers its own unique challenges for proper performance, and the other is that each student offers their own unique challenges for learning. While the curricula and methods available to educators do help in this situation, for greater success it is essential that the educator possess many skills and traits as a teacher, including knowledge of music theory, music instruments, ear-training, classroom management, and motivation (Chaffin, 2009; Miksza et al., 2010; Teachout, 1997).

Researchers have demonstrated that some level success can be attained by student musicians solely based on the large ensemble model (McPherson, 2005). However, students who

participate in private or small group instruction on their instrument may be more likely to reach a higher level of achievement (Cumberledge, 2016). Studying privately or in small like-instrument groups provides the students with instruction that suits both their instrumental and personal learning needs while providing extra opportunities to play their instrument beyond the school day. This allows the students to focus on the instrument-specific, specialized characteristics that their instrument requires (Yarbrough et al, 1997), in a setting that can be tailored for their learning style. Additionally, non-musical concepts like how to practice effectively can be emphasized to help educate and motivate the students to reach higher musical achievement (Woody, 2004). Whether in a large ensemble or private lesson setting, it is important for the music educator to possess the teaching skills required to help their students attain higher-level musicianship.

One facet of musicianship that is often overlooked in formal music education is ear-playing, which has been shown to be an effective and common link towards the development of other musical elements (Musco, 2010). However, the relationship between ear-playing and playing in tune (intonation performance) has not been explored. Given that listening is an important element towards intonation performance skills and ear-playing, investigating how these skills may relate to each other could have implications for how music educators structure their curriculum.

In this chapter I will describe the relevance, history, and pedagogy of intonation performance and ear-playing, along with explaining the need to explore a relationship between these two. First, the history of how intonation performance has driven music education and pedagogy will be outlined. Next, I will describe the history and culture of ear-playing and how it interacts with both formal and informal music making. Lastly, I will outline why exploring a

relationship between these two musical elements is needed and how it will contribute to the existing body of research.

Intonation

One of the many elements of instrumental music that music educators focus on is intonation, or playing in tune, which has been a topic of discussion since the early stages of the school band movement. The highly esteemed bandmaster William Revelli (1938) said "intonation represents one of the most important and difficult phases which directors of school music have to teach" (p. 227). Thirty-five years later, these sentiments persist. In his book *Effective Performance of Band Music,* Francis McBeth (1972) states:

> Good ensemble pitch is one of the most elusive and mysterious factors confronting the young band master. The usual attempt at a solution is the constant checking of individual horn lengths by ear or strobe. Certainly, correct horn length is necessary, but an entire ensemble with correct horn lengths can play miserably out of pitch. Since this is true, other factors must be involved in correct ensemble pitch. (p. 5)

These quotes reveal that proper ensemble intonation has a long tradition of both being an integral facet of ensemble teaching as well as posing a challenge for music educators. And with the recent emergent technologies to aid in intonation improvement, (Hopkins, 2014; Perez-Gil, et al., 2016; Swift, 2003) it is evident that intonation remains as an important and challenging element of music education.

Intonation Performance

Notes performed out of tune may cause discord perceived by the human ear, and musicians need to learn to account for this. There are multiple factors that can contribute to poor intonation including the audio frequency and amplitude. Poor intonation may be one of the most noticeable factors that can negatively affect a performance, even if all other aspects of the performance are done at a high level (Geringer et al., 2001). This notion is supported by many

other authors who have focused on the importance, improvement, and performance of wind instrument intonation (Ballard, 2011; Geringer et al., 2001; Karrick, 1998; Wapnick & Freeman, 1980). According to McBeth (1972), multiple steps are needed toward successful ensemble intonation, and it is the goal of the music educator to take these further steps to impart the knowledge, practices, and strategies to guide their students towards successful intonation accuracy.

Fundamental wind instrument skills such as embouchure, tone quality, and breath control, will all have a big impact on intonation (Bauer, 1993). Furthermore, awareness, experience, and personal practice methods have all shown to affect both individual and ensemble intonation. (Platt & Racine, 1985; Scherber, 2014; Yarbrough et al, 1997; Zabanal, 2020). To foster this awareness and to help develop effective practice methods, instructions from the ensemble directors and/or private instructor is key. “Findings suggest that instruction is an important influence for producing desirable wind-band intonation…A substantial component of instruction is defined by the kind and quality of activities that band directors present their students in order to improve intonation” (Wuttke, 2011, p. 93).

Driven by the pursuit of intonation improvement, many researchers focus on testing the intonation performance tendencies of wind musicians. Intonation performance is one area of study, in which both melodic and harmonic intervals performed by wind instrumentalists are analyzed to discover what tendencies may exist (Geringer,1978; Karrick, 1998). Intonation perception is a second area of study that aims to discover the perceptual intonation ability of the participants through tasks such as manipulating an electronic tone to match a second static tone. Since this does not require any level of performance of a musical instrument, there are few limitations for participants (Geringer, 1978; Yarbrough et al, 1997).

Methods for Teaching Intonation

Many music education publications include articles offering pedagogical strategies, exercises, and tips for improving ensemble intonation. Publications such as *Band World Magazine*, *The Instrumentalist*, *Music Educator's Journal*, and *Teaching Music Magazine* have often featured articles aimed at helping ensemble directors improve ensemble intonation. Ensemble directors may find articles from these periodicals to be user friendly and helpful for developing fun and effective intonation strategies for their rehearsals. However, there are several tried-and-true methods that have undergone more formal testing in the instrumental music community. One such method is centered on *beat elimination* in which musicians are trained to recognize and eliminate the sound wave interference (beats) that occur when two or more pitches are performed out of tune (Miles, 1972). Practicing intonation with a drone-pitch accompaniment has proven to be an effective and common practice, especially in the orchestral string instrument community (Zabanal, 2020). This practice can be used effectively during both solo and ensemble practice. Other effective practices for instrumental intonation include singing, using electronic tuners, and (a more recently developed method) tuner training computer programs. (Carr, 2014; Davis, 2019; Scherber, 2014; Wuttke, 2011).

Given the amount of research and attention given to the topic of intonation, it is evident that intonation is an essential element of wind musicianship. However, are the correct things being done, and are they being done enough to address the intonation problems? What other approaches to intonation improvement may be valuable, yet not explored? Exploring the role of ear-playing in relationship to intonation performance is an avenue that has not been explored but may prove to be valuable.

Ear-Playing

In music, be it singing, playing instruments, or simply listening, the development of inner hearing plays an important role for musicianship. Much like a painter or a sculptor having an eye for detail, the human ear is designed for sound, and sound is the basic material of music. Gordon (1999) states that an individual who can play *by ear* performs notes and rhythms that are informed by an inner hearing, which does not require cues from traditional music notation or other sources. The individual hears music with the mind's ear and realizes it through their musical instrument. Gordon coined the term *audiation* as a word that describes this inner hearing. Gordon (1999) relates learning to perform music to learning how to speak stating that "audiation is to music what thought is to language" (p. 42).

Ear playing skills are often developed through informal practices such as vernacular music making. Vernacular musicians (sometimes called popular or informal musicians) are defined by Adams (2017) as musicians "who learn, teach, create, and perform music primarily through aural skills and participatory methods, both alone and with others, in accordance with common social, historical, and cultural contexts." (p. 20). Vernacular musicians often utilize collaboration, improvisation, modeling, and mimicking to create emotional and expressive music as related to their immediate cultural context (Woody, 2007). These types of musicians often acquire ear-playing skills through their natural and informal music-making experiences. Ear-playing in this situation may be done organically as a tradition of the genre, and the musicians may not even consider it as a special skill. These experiences are countless and could include situations like garage bands, church bands, bluegrass and folk bands, family jam sessions, jazz combos, or even individual music making on various instruments or using technology. There are

even some situations in which musicians who first learned by formal training find themselves having to relearn an instrument to perform within the traditions of a certain vernacular style.

In vernacular music making, ear-playing has a long tradition. Even in school music education ear-playing can be traced back to Johann Pestalozzi (1746-1847) a Swiss educator who developed the sound-to-sign concept. Also, Lowell Mason (1792-1872), commonly regarded as the father of American public-school music education, was an advocate for the Pestalozzi's sound before sight (ear-playing) concept (Mark, 2008). The legitimacy of ear-playing in music education gained ground in 1994 when MENC (now NAfME) released the National Standards of Music Education, which were revised in 2014 to be more comprehensive and grade-level specific. Among these standards includes nomenclature suggesting that ear-playing is an important skill for students to develop and use as a part of a comprehensive music education. For example, the *Creating* portion of the standards under the *Imagine* category it states: "Generate musical ideas for various purposes and contexts" (NAfME, 2021).

Ear-playing is an integral skill for vernacular musicians in such genres as rock, bluegrass, folk, jazz, and hip-hop, just to name a few. Conversely, many formally trained musicians rely solely on musical notation to be able perform on their instrument, while finding ear-playing to be a challenge (Woody & Lehmann, 2010). However, research shows that formally trained musicians who participate in vernacular music making do find benefits toward their overall musicianship and self-efficacy (Green, 2008; Isbell, 2016). Though there are differences between vernacular musicians and formally trained musicians, crossing over from one type to the other is not uncommon (Isbell & Stanley, 2018). No matter what type of musician, Priest (1989) posits that all music is performed by ear on some level, even if notation is involved, furthering that an aural basis for successful musicianship is important.

Ear-playing in music education does have a storied history and the National Standards emphasize ear-playing as an important element of music education, yet it remains an element that is often neglected by music educators, partially due to their own inexperience and discomfort level with ear-playing (Musco, 2010). However, many music education scholars have advocated for the regular teaching of ear-playing skills in the music curriculum and dedicated their research to help substantiate the benefits of developing ear-playing skills. (Bernhard, 2004; Musco, 2009; Varvarigou & Green, 2015; Woody & Lehmann, 2010). These scholars have found that ear-playing can offer many benefits for musicians, regardless the age or skill level.

To foster ear-playing in beginning instrumental music, formal methods that center around ear-playing skills have been developed. On the forefront of this movement is Edwin Gordon (1927-2015) who devoted his music education career to ear-playing, audiation, and his Music Learning Theory (Gordon, 1999). Gordon developed a band method called *Jump Right In* (Azzara & Gordon, 2003) which uses ear-playing as its basis. This method follows a much different approach than the traditional notation-based methods.

Green's research (2008) on how popular musicians learn helped to bring informal music pedagogy to the school setting. Defining characteristics of informal learning in music include a student-centered structure, which allows students to choose the music they want to learn through friendship groups. Additionally, music is learned by ear through listening and copying from recordings, rather that printed notation. This model also promotes skills and knowledge acquisition based on the students need, often through cooperative peer teaching, utilizing performing, composing, improvising, and listening as the medium. In even more recent years, an increasing number of educators and scholars are putting these informal learning principles into

practice in large ensemble settings to help show effectiveness and with hope to guide the paradigm in a new direction (Norris, 2010; Sindberg, 2009; Spears, 2014; Weidner, 2020).

Other researchers have found a wide range of benefits related to ear-playing. Musical elements such as sight-reading, musicianship, tonal awareness, and improvisation have shown positive relationships with ear-playing skills. (Bernhard, 2004; Luce, 1965; McPherson, 1995; Musco, 2009; Woody & Lehmann, 2010). Additionally, there have been many extra-musical benefits found to have a relationship with ear-playing, which include self-efficacy, confidence, problem solving, enjoyment, and retention, just to name a few (Baker & Green, 2013; Hartz & Bauer, 2016; Musco, 2009; Norgaard, et al., 2019; Priest, 1989; Woody, 2007; Varvarigou & Green, 2015; Woody & Lehmann, 2010).

Need for the Study

1. Many factors contribute to musicianship and playing in tune in general.

As highlighted in this chapter, poor intonation is one of the most noticeable elements that can negatively affect a musical performance. This follows that intonation improvement is one of the main goals of many music educators, leading to the development of myriad teaching methods and technological advances to aid in this.

2. Also highlighted in this chapter, playing by ear is common among popular musicians but is not as common with school musicians.

Ear-playing skills are part of the traditions of vernacular musicians and are often learned organically through that practice. However, ear-playing instruction remains largely absent from formal music education practices, despite that it been shown to positively contribute to many musical and non-musical facets of musicians.

3. Much literature exists in these two areas—empirical research and teaching methods.

A wealth of empirical research on both the topics of intonation and on ear-playing exists to examine many different facets of these phenomena. Much of this research aims to provide insight on improving the implementation and practices of these skills, providing opportunities for the development of teaching methods.

4. Researchers have yet to examine a direct link between these two fundamental concepts.

The theory that different musical experiences of musicians relates to intonation tendencies has been addressed in previous research. However, the element of ear-playing is not a musical experience that has been investigated.

Developing ear-playing skills has been shown to offer many positive musical and extra-musical benefits for wind instrumental musicians of all ages, yet it continues to remain a skill that is not emphasized by instrumental music educators. Of all the musical benefits that ear-playing skills have been shown to offer, there has not been any research found that directly investigates the relationship between ear-playing ability and intonation performance. Given that a majority of the intonation improvement methods and strategies used by educators and musicians rely heavily on the ability to listen for pitch discrimination, it stands to reason that a relationship between ear-playing ability and intonation ability may exist.

Creating a study that will investigate the relationship between intonation performance and ear-playing ability may help to shed light on any benefits that ear-playing skills offer towards wind-instrument intonation performance. Findings may also help to bolster the myriad research that advocates for more ear-playing skills training in instrumental music education and lead to greater development and implementation of ear-playing methodologies. Educators would benefit from learning more about the relationship between playing by ear and the ability to play

in tune because educators are continuously seeking strategies and methods to help improve the intonation ability of their students.

Purpose of the Study

The purpose of this study is to investigate relationships between intonation performance and ear-playing skill of high school and college-aged wind (brass and woodwind) instrumentalists.

The following are the research questions that will guide this study:

1. What is the relationship between the ability to play by ear and intonation performance?
2. How does intonation ability differ when the participants sightread printed music notation compared to performing music that has been learned by ear?
3. Do differences appear in ear-playing ability based on:
    a. Years of experience?
    b. Private lessons?
    c. Personal practice time?
    d. Frequency of ear-playing?

In the next chapter I will outline in detail all relevant research that has informed my topic of investigating the relationship between intonation and ear-playing. This will include a wealth of research regarding intonation, the procedures for intonation performance and perception testing, intonation improvement methods, as well as the science of tuning and intonation. Additionally, the topic of ear-playing will be outlined in detail, including ear-playing in music education, ear-playing in vernacular musicians, and the musical/extra-musical benefits that ear-playing offers. This will show how the previous literature has informed my topic and led to the creation of a series of tasks to investigate the relationship between intonation and ear-playing.

Chapter 2. Review of Literature

This study investigates the relationships between ear-playing skills and intonation performance of high school and university wind instrumentalists. This literature review will begin with the scientific principles of sound and intonation, followed by the review of scholarship on multiple facets of music instrument intonation. Subsequently, literature on the history and principles of ear-playing will be covered, followed by ear-playing use in vernacular music-making as well as in music education.

Science of Sound and Intonation

In scientific terms, a pitch produced on a musical instrument is a longitudinal sound wave. According to White & White (2014), longitudinal sound waves are "those disturbances in which all parts of the medium through which the waves are traveling are vibrating, about their equilibrium positions, parallel to the waves' direction of propagation" (p. 28-29). Furthermore, the authors explain that the vibrations created by the musical instrument disturb air molecules, creating pressure waves in all directions. Pressure waves are measured as a frequency, or number of complete cycles per second, also called a period. The international unit of measurement of frequency is the *hertz* (Hz), named in honor of German physicist Heinrich R. Hertz. The higher the pitch that is played, the greater number of Hz and vice versa. This means that a 440 Hz pitch (A_4) has the period of $1/440^{th}$ of a second (White & White, 2014).

The graphic representation of a soundwave (fig. 1) reveals the parts of a soundwave, all of which combine to produce a sound that is recognized or meaningful. First, the wavelength is the distance between two successive horizontal points on the wave and represents one period. Second, the height (crest) of the wave represents the amplitude (loudness) of the sound, perceived by the ear as volume. Third, the frequency, as mentioned before, is the number of

periods per second and determines pitch. And lastly, the shape of the wave determines the harmonic motion. When a musician produces a sound on a musical instrument, the acoustic resonant nature of the instrument produces many soundwaves synchronously, known as the fundamental and the harmonics, or the harmonic series. The higher amplitude fundamental combines with the lower amplitude harmonics of the series to produce a unique, recognizable, and characteristic sound (Stainsby & Cross, 2009; White & White, 2014).

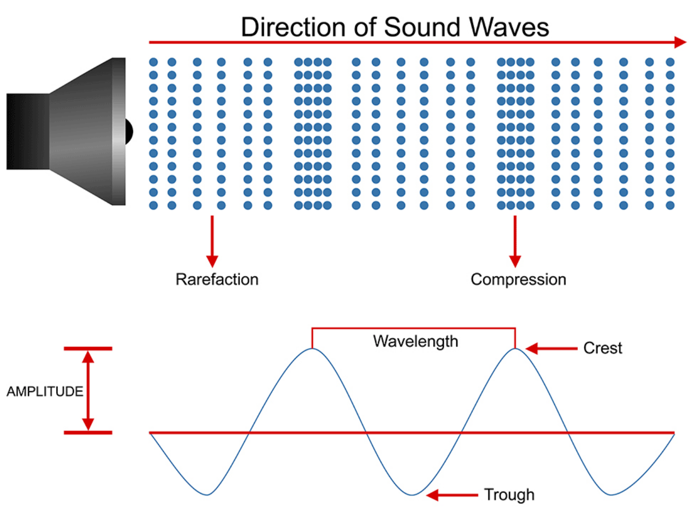

Figure 1. Visual Diagram of a Sound Wave
Source: https://www.pasco.com/products/guides/sound-waves (2023)

Most humans perceive soundwaves with a complex auditory processing system, and this process is detailed in a book by Hodges (2020). This complex hearing process begins at the outer ear which consists of the pinna (the visible part of the ear on the outside of the head), the auditory canal, and the eardrum. The process is set in motion when pressure waves traveling through the air contact the pinna, enter the ear canal, then are channeled to the ear drum. The ear drum vibrates in congruence with the frequency of a pressure wave. The ear drum is connected to three small bones in the middle ear, collectively called the ossicles, separately called the hammer, anvil, and stirrup. The synchronous vibration of the sound wave and ear drum put the

ossicles in motion, transferring and amplifying the vibrations to the oval window, a membrane that connects the middle ear to the inner ear. The movements of the oval window are transferred to the cochlea, which is a spiral-shaped body that contains tiny hair cells and a fluid substance. The fluid in the cochlea moves like waves in the water, which causes the hair cells to create neural signals. These signals are received by the auditory nerve, which moves the signals to the brain to be processed into recognizable sounds. Figure 2 shows these parts of the human hearing process.

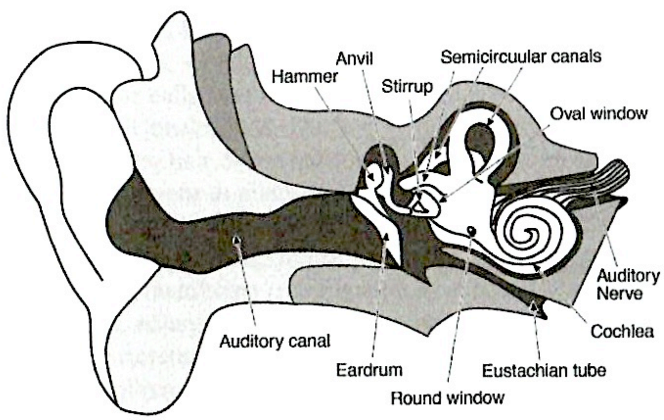

Figure 2. Diagram of the Human Hearing Mechanism *Source:* Hodges, 2020. p. 105

When multiple frequencies are produced by different sources it is possible for the human hearing process to decipher these and comprehend them separately. For purposes of this dissertation, I will discuss the act of just two different sources producing a pitch. If both pitches are the same frequency and similar amplitude, (i.e., two clarinets playing 440 Hz) they are considered to be *in phase* and are perceived by the human ear with a slightly higher intensity than a solo clarinet. However, if one of the two clarinets is a slightly different frequency (i.e. 448 Hz), the resultant combined sound would produce a sonic phenomenon known as *beats*. Beats can be described as a pulsation, and the closer in Hz the two combined frequencies are, the slower the pulsation. Figure 3 shows why this phenomenon occurs. The top soundwave (f_2) represents the clarinet playing 448 Hz whereas the middle soundwave (f_1) represents the clarinet

playing 440 Hz. When the two soundwaves are in phase - (a), (c), and (e) their amplitudes combine to create a larger amplitude. However, when the two waves are out of phase, as at (b) and (d), their amplitudes cancel each other out. The bottom soundwave in figure 3 shows result of the two different sound waves combined. Notice the higher amplitude when two top waves are in phase and the lower amplitude when they are out of phase (White & White, 2014).

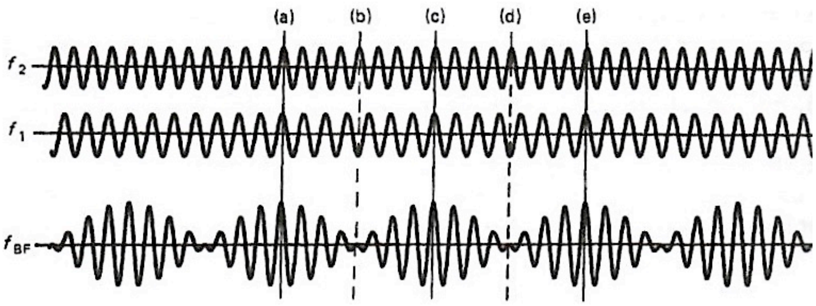

Figure 3. Visual Representation of Two Soundwaves out of Phase Causing Beats
Source: White & White, 2014. p. 58

Musicians rely on their hearing process to help with their performance success, and being able to listen, distinguish, and match pitch frequencies are important elements for this success (White & White, 2014). This process of performing correct pitch frequencies on a musical instrument is known as playing *in tune,* and can refer to matching unison pitch frequencies, or performing correct pitch frequencies within groups of two or more pitch frequencies. A term that is frequently used by musicians to describe performing in or out of tune is *intonation,* which Karrick (1994) defines as:

> A term that can be used to describe qualitatively the result of tuning, or the degree to which musicians achieve in-tuneness. When a musician or ensemble consistently performs with accurate tuning, good intonation is the result although the degree of tuning required to achieve good intonation is subjective. (p. 4)

Karrick also points out that the human perception of in-tuneness may occur in multiple capacities: (1) When two sound waves are identical; (2) When the fundamental and harmonics of one complex sound wave are identical to the fundamental and harmonics of another complex

sound wave; (3) the frequencies of two sound waves correspond to a specific tuning system (more information on this in the next section); (4) the fundamental and harmonics of two soundwaves are acceptably in tune to a listener based on cultural conditioning and/or musical background. The following section involves a close examination of the last two elements of Karrick's (1994) criteria described above: the use of a specific tuning system and the influence of cultural conditioning and the background experiences of the listener.

Tuning Systems

Throughout the recorded history of western music there have been numerous tuning systems to aid in music composition and performance. *Equal Temperament* is the tuning system that is currently most common in western music (Showell, 2015). Each of these systems are based on interval calculations, determined by frequency ratios. Showell states that "the harmonic overtone series not only forms the background for all western pitch systems, but also is the ultimate source of some of the vexations in each western pitch system" (p. 37). Below are the first 16 components of the overtone series, listed as intervals.

The first historical tuning system of importance that Showell details is the *Pythagorean Tuning* system, which developed beginning around 500 BC. Complications from the mathematical ratios used for developing the intervals "ultimately made this system largely unworkable for anything more complex than Gothic polyphony" (p. 38).

Next, Showell highlights *Just Intonation* which became the ideal system during the Renaissance period. The ratios used to develop Just Intonation yielded five purely in-tune chords; however, this created two sizes of whole steps and four sizes of chromatic half steps, causing limitations for practical use.

Table 1. The Overtone Series by Intervals

Tone	Intervallic Relationship
1	fundamental
2	perfect octave
3	perfect octave + perfect fifth
4	two perfect octaves
5	two perfect octaves + major third
6	two perfect octaves + perfect fifth
7	two perfect octaves + minor seventh
8	three perfect octaves
9	three perfect octaves + major second
10	three perfect octaves + major third
11	three perfect octaves + perfect fourth
12	three perfect octaves + perfect fifth
13	three perfect octaves + minor sixth
14	three perfect octaves + minor seventh
15	three perfect octaves + major seventh
16	four perfect octaves

Note. Each interval is that above the fundamental.

Next, Showell details *Quarter Comma Meantone* tuning, which is similar to Just Intonation, but alters the ratios slightly to produce uniformly tempered fifths, shifting away from perfect fifths and towards perfect octaves. Lastly, *Well Temperament* was the last major iteration of tuning and served as a transition from the Meantone system to our modern Equal Temperament system. The main characteristic of the many versions of this system was the irregular ratios between the fifths, giving each key center a distinct sound.

The aforementioned tuning systems each had an important place in music history, but all shared the same challenge. Creating cycle of 5ths (intervals) using the various ratios created something known as a *wolf interval* which refers to a severely augmented interval, often occurring at or near the final division. This created a pitch that was unusable due to its dissonance. The answer to this problem was *Equal Temperament*, which became the current standard and begun around 1800. Equal Temperament divides each octave into 12 even half steps, making all intervals and key centers consonant and usable. However, compromises were

needed for this system, making triads, for example, consonant but not purely in tune based on the harmonic series. Showell states that "one generally agreed upon consequence of the modern equal temperament system is that its intervals, though safe and eminently functional, are bland and colorless in comparison to just intonation and meantone intervals" (p. 40).

Because the Equal Temperament system has been standard in western music for so long, it has become the typical sound for the western music population. However, some researchers posit that instrumental musicians, depending on their level of experience and training on the instrument of which they perform, will tend towards favoring one tuning system over others to achieve more pure intonation in their performance. The next section of this chapter will highlight several studies in which researchers investigated the trends towards a preferred tuning system.

Intonation Perception and Performance

To investigate the intonation tendencies of experienced wind musicians, Karrick (1998) examined the harmonic intervallic tuning of advanced wind instrumentalists within three tuning systems – Equal Tempered, Just Intonation, and Pythagorean. Additionally, the possible differences in harmonic intonation playing above or below (location) a stimulus were also of interest.

Participants were two groups of wind instrumentalist: a professional group, and an advanced music major student group. Each participant was asked to play each line of an adapted two-part Bach choral, while the other line played back in headphones by a synthesizer. Target intervals were chosen prior to the experiment and used for analysis. Intervals were analyzed using the three tuning systems, resulting in three scores.

Results of this experiment showed that the intervallic tuning preference and intonation intervals during performances are likely to be inconsistent among individuals, even those

musicians of the highest caliber. Most pitches played out of tune deviated towards sharp and the participants tended to deviate least from equal temperament and most from Just Intonation. The investigator posited that the tendency for musicians to deviate least from Equal Temperament is because it the common tuning system used for fixed-pitched instruments and electronic tuning devices, making it the norm for most of the western population.

In a similar study, Ballard (2011) sought to examine the correlations between intonation perception and intonation performance in vocal and instrumental performance of college-aged musicians in relation to the same three tuning systems: Equal, Just, and Pythagorean. Additionally, the researcher explored whether participants' vocal performance correlated with their instrumental performance. The findings of this experiment clearly showed no correlation between perception and performance intonation, nor were there significant correlations found between the perceptual and performance tasks. The three tuning conditions led to mixed results, with Equal Temperament found to be better than the other two for the accompanied performing tasks, but not the unaccompanied, leading to the conclusion that participants favored Equal Temperament. The possible lack of correlation between perception and performance based on this study may have occurred because data was collected in an unnatural experimental setting, and future designs utilizing a more natural setting could provide different results.

In another study to address the trend of tuning system preferences, Loosen (1995) posited that depending on the instrument being played, different musicians tend to prefer different tuning systems, suggesting that based on the physical nature of instruments, a pianist would prefer Equal Temperament tuning and a violinist may prefer Pythagorean Tuning. A study to examine this hypothesis tested seven professional violinists, seven professional pianists, and ten musically

inexperienced individuals, requiring participants to compare accuracy level of pre-recorded scales using intervals based in the three tuning systems.

The results from this study showed a tendency of violinist preferring Pythagorean Tuning and pianists preferring Equal Temperament, however, the results were not significant enough to make a general claim. Additionally, non-musicians were generally unable to identify interval differences reliably. Moreover, tuning choices among violinists, pianist, and non-musicians differ significantly and it is most important to note a person's conception of accurate tuning is based more on prior musical experience than it is on prior views of temperament.

The studies by Ballard (2011), Karrick (1998), and Loosen (1995) help explain how Equal Temperament has become the most commonly used tuning system in western music, showing that most musicians, no matter what their caliber, favor towards this tuning system. Fixed-pitch instruments, such as pianos, electric keyboards, and mallet percussion are typically tuned using Equal Temperament. Additionally, most electronic tuning devices are calibrated to Equal Temperament. When musicians use electronic tuners or reference pitches from fixed-pitch instruments for their tuning procedures they are grounding themselves in Equal Temperament. This raises the question of whether pitch knowledge and perception are naturally occurring based on the cultural conditioning of Equal Temperament in western music, and if it is something learned and improved with musical experience. An experiment by Van Hedger, et al (2017) aimed to determine just that – whether pitch knowledge or *implicit absolute pitch* among everyday people is a prevalent phenomenon in western music cultures, using the standard of Equal Temperament.

In this experiment participants were asked to listen to a series of individual prerecorded piano and violin pitches, some which were in tune and some which were purposely adjusted out

of tune by various cents to identify if they believe a pitch was either in tune or out of tune. Additionally, participants were asked about their musical background to form two groups, a group consisting of participants that had a musical background, and a group of participants with no musical background. Results of this experiment did provide evidence that participants could determine in tune and out of tune notes when using natural instrument timbers. However, when the experiment was replicated using electronically generated triangle waves as the stimulus tones, opposite results occurred. It was also found that participants with musical backgrounds generally performed better in this experiment than those with no musical background. These results show evidence that *implicit absolute pitch* does exist to an extent for people who do not possess absolute pitch, which seems to be derived from prior experience and perhaps within certain timbre categories.

According to Van Hedger, et al. (2017), the timbre of the performed notes influences how intonation is perceived and there is a wealth of research that investigates this phenomenon. Closely related to the timbre of a musical instrument is the tone quality in which the musicians produce. The next section of this chapter will explore literature that examines the relationships between timbre, tone quality and intonation.

Timbre and Tone Quality

Wapnick & Freeman (1980) examined the effects of dark and bright timbral variations on the perception of intonation using pairs of clarinets tones listened to by undergraduate music majors. Two clarinet tones (A220 Hz and A880 Hz) were first produced by a professional clarinetist to ensure accurate tuning and ideal tone quality. These tones were then altered to create a bright sounding tone and a dark sounding tone. The bright/dark tones were also altered to be 12 cents sharp or flat, creating a total of 14 stimulus tones. For data collection, participants

listened to a random sequence of 24 pairs of stimulus tones, with timbral sequences of dark-dark, dark-bright, bright-bright, bright-dark. Additionally, the second tone was either sharp, flat, or unaltered. Participants were asked to indicate if the second tone of each pair was sharper, flatter, or the same as the first. Results of this experiment showed that a timbre is a statistically significant factor in pitch discrimination, and subjects associated darkness with flatness and brightness with sharpness.

Findings from the previous study were corroborated in a similar study by Geringer & Worthy (1999), however this study expanded the stimulus tones to three separate timbres: clarinet, trumpet, and trombone. High-quality sample recordings for each instrument were used and the stimulus tones chosen were F_4 (349.2 Hz) for clarinet and trumpet and F_3 (174.6 Hz) for trombone. All tones were then altered to produce bright and dark tones, while not altering the fundamental pitch. For this experiment the standard, bright, and dark tones were used in a series of pairs. 116 undergraduate and high school instrumentalists, 36 of whom were music majors listened to a series of pairs of tones through a loudspeaker. Participants were instructed to compare the tone quality and intonation of second tone to the first and complete two Likert-type scales, one to rate the tone quality and one for intonation. Results showed that the participants generally associated bright tones to sharper intonation and darker tones to flat. However, the changes in tone quality did not influence the judgements of the music majors a significantly as those with less musical training and experience.

A study by Vurma, Raju, & Kuuda (2011) and another by Worthy (2000) both used very similar procedures and yielded very similar results as the previous two studies, providing strong evidence that timbre does influence intonation perception, with dark tending towards flat, and bright towards sharp. Worthy, however, described the stimulus sounds as tone quality instead of

timbre. From a musical perspective the timbre of a musical instrument is essentially the tone quality of an instrument as performed by a musician. Researchers have examined how the element of instrument tone quality effects intonation perception.

Madsen & Geringer (1981) sought to investigate the discrimination of tone quality vs. intonation with 480 college aged musicians (*n* = 240) and non-musicians (*n* = 240). A professional flautist and oboist each made recordings of simple musical melodies while viewing a chromatic stroboscope for accuracy and within the parameters set by the researchers. Parameters included good tone, bad tone, sharp intonation, and in-tune performances, totaling 12 different performance conditions. Pairs of flute and oboe performance were randomly assigned to create duets containing the 12 experimental conditions. Participants listened to 24 duet performances and were instructed to respond based on the intonation and tone quality of the soloist in each duet. There were multiple elements of this study that led to inconclusive results, including the difficulties with attempting to investigate multiple variables simultaneously, and the possibility that the familiar melodies may have been rated differently than unfamiliar melodies, simply because they were familiar. However, nearly all subjects were able to correctly judge the performances that were both in tune with good tone quality. Additionally, there was a trend throughout most comparisons that subjects who indicated a preference for tone quality actually seemed to be responding to intonation variables.

Investigating the interrelationships of intonation and tone quality perception, Geringer et al. (2001), found that even among varying levels of musical training, intonation along with good tone quality were both important factors to discriminate a bad performance from a good performance. This study was a replication and extension of an earlier study by two of the same authors and utilized solo trumpet and piano accompaniment as the stimulus sounds. There were

two parts to this study; part one replicated the original study, in which the intonation of the accompaniment had 4 intonation conditions (in-tune, 25-cents flat, 25-cents sharp, and 50-cents sharp) and the tone quality of the trumpet had 2 conditions (good and bad). In part two the piano accompaniment stayed in tune to Equal Temperament while the trumpet had the intonation conditions along with the good/bad tone quality conditions. Participants were high school band members (n = 60) and undergraduate/graduate music majors (n = 60) who heard a series solo trumpet performances paired with the piano accompaniment, each having various intonation/tone quality conditions applied. One notable trend in the findings from this study is that the more musically experienced listeners discriminated intonation with greater accuracy.

The reviewed literature in this section supports an assertion that trained and/or experienced musicians may be more successful with discriminating timbre, tone, and intonation than untrained or inexperienced musicians. Several researchers (Morrison, 2000; Yarbrough et al. 1997), have examined the relationship between prior experience and intonation perception and performance. The next section of this chapter will review the literature regarding the types and amount of experience that impact intonation perception and performance.

Musical Experience

Previous researchers have established a direct correlation between musical experience and intonation perception. To examine this phenomenon, Morrison (2000) investigated the intonation accuracy of varying levels of wind players, from elementary-aged through high school. This study involved two separate experiments, both with the purpose of determining whether melodic pitch accuracy was affected by location (sounding above or below) or duration of the target pitch. Additionally, researchers investigated single pitch accuracy, error direction consistency, and intonation tendencies. The combination of the two experiments were

determined to consider whether greater musical experience favors those with less experience regarding tuning.

In the first experiment, participants ranged from one to four years of instrumental music experience in elementary through middle school. Each participant completed two performance tasks: (1) matching a single prerecorded pitch, and (2) performing a short and simple melody along with a recorded accompaniment. Four target pitches were methodically chosen, based on melodic context, which were used for comparison. The pitches from all the recorded performances were isolated and analyzed for frequency.

In the second experiment, high school band members were used, all of which had five, six, or seven years of experience. The testing method was the same as in experiment one, however, participants were randomly divided into three groups. In group one each participant was asked to tune their instrument to a prerecorded pitch, in group two each participant was allowed to tune to a pitch and was told the experiment would be measuring their intonation, and group three was a control group in which no information or instruction was given to the participants.

Results showed that a high positive correlation was found among the melodic pitch for both the more and less experienced subjects, indicating that a performer's accuracy on any one pitch was strongly related to their accuracy on any other, whereas a much lower positive correlation was found between melodic pitches and the tuning pitch. There was a slight, but significant correlation of the ability to tune to an isolated pitch and the pitch accuracy in a musical context. From a music educator's point of view, the results of this study suggest that increased pitch accuracy and intonation may not be due to experience, rather a byproduct of attrition. This means that a student struggling with these aspects of performance would be more

likely to drop music if given the opportunity and perhaps more focus on tuning and pitch matching would lead to both higher quality performances as well as higher retention rates.

Similar research by Yarbrough et al. (1997), aimed to discover the effects of musical experience on tuning performance and perception of experienced high school wind players. In their study, they sought to answer five important research questions, which are: 1) if tuning accuracy improved beyond the 4th year of instrumental instruction; 2) if more experienced player tend toward sharp intonation; 3) if knowledge of direction of mistuning was consequential to errors; 4) if taking private lessons demonstrated greater tuning accuracy; and 5) performance and perception in relation to tuning.

Data collection in the study by Yarbrough et al. (1997) involved two tasks: 1) subjects manipulate a pitch control knob to bring a pitch in tune, and 2) subjects manipulate their instrument (push in, pull out) to match a prerecorded tone. For validity, the subjects were randomly divided into three groups. Group one subjects were told that they would begin the test sharp, group two subjects were told they would begin flat, and group three subjects received no information regarding direction of mistuning. Information was also collected from each participant to gather knowledge of past musical experiences. While some minor differences did appear from the results based on years of experience, the only factor that was found to significantly affect tuning accuracy was participation in private instruction. This may indicate that time spent playing an instrument may be the key to developing tuning skills as it is likely that students taking private lessons play their instrument more than those who do not.

It is evident that musical experience does directly correlate with intonation perception and performance, with trends showing that more experience is associated with higher skill with intonation performance and perception. However, further elaboration on the types of experiences

that may positively effect intonation ability is warranted. The next section of this chapter will highlight research on the effects of specific practice methods for intonation improvement as well as pedagogical practices used by music educators to teach intonation.

Intonation Improvement and Pedagogy

One of the early formal approaches to intonation is a method called *beat elimination.* This is a method of instrumental intonation pedagogy that was developed from piano tuning practices and was first introduced as an instrumental pedagogical approach in a textbook called *Music Education in the High School* (Leeder & Hanie, 1958), and later in an article in *Music Journal* (Stegman, 1967). In essence, students are taught to recognize the beats (or sound wave interference) that are created when two or more pitches are played out of tune, and then make the necessary adjustments to eliminate the beats by bringing them into tune. Miles (1972) designed a study to investigate to what extent beginning instrumentalists could be taught to perceive and perform correct intonation using the beat elimination concept. The 118 participants first received a semester of training on their instrument before beginning six investigation sessions. There were ten steps total used for the procedures: Four demonstrations by the researcher and six pitch discrimination tasks to be performed by the subjects. Discrimination tasks increased in difficulty through the series and included the following: matching pitches on an Intonation Trainer, matching pitch of their instrument with an Intonation Trainer produced pitch, a pitch produced on an instrument by the investigator, and a pitch produced by another student, eliminating beats while playing perfect 5^{th} and major 3rds with the investigator, and eliminating beats while performing triads with two other students. All participants were able to recognize beats and were able to become successful at tuning unisons free of beats. Additionally, 95% of the subjects were able to play a perfect fifth free of beats and 88% could tune a major third. Within triads there was

about an 80% success rate at eliminating beats from the major thirds and the perfect fifths. These results indicate that this method of intonation training is effective, however, it does not indicate if it is better or more efficient than other practices.

Another intonation improvement method utilizes a drone pitch accompaniment while the musicians play. This employs the basic principles of beat elimination practices and has been proven to be an effective and common practice, especially within the orchestral string instrument community. When surveying 152 collegiate string players Zabanal (2020) found that 85% of the participants used drone accompaniment for their intonation improvement practice. Additionally, this practice can be used effectively during both solo and ensemble practice.

Vocalization is an intonation improvement practice that has become quite common within instrumental ensemble rehearsal settings. This is evident by the number of articles in publications such as *Band World Magazine*, *The Instrumentalist*, *Music Educator's Journal*, and *Teaching Music Magazine* that feature singing within the rehearsal for intonation improvement. An example of this can be found in *Canadian Winds: The Journal of the Canadian Band Association*, where Carr (2014) detailed his personally created "Ready, Aim, Fire" approach to intonation improvement, which utilized three steps for the students; listening, singing, and playing.

Vocalization may be a practice used by instrumental music educators for intonation improvement, however, evidence suggests that singing may not influence intonation performance, especially with younger students. A study conducted by Mattingly (2012) sought to investigate the variable of hearing and singing of the intonation ability of ($N = 33$) middle school flute players with between one to four years of experience playing their instrument. Participants used a control flute and were first asked to listen to and tune to a pre-recorded B-flat chord and a

single B-flat tone played by an electric piano. Secondly, they were asked to sing the B-flat before tuning the instrument. Results of this experiment showed no significant differences between tuning without or with singing.

In a similar study by Coveyduck (1998), beginning instrumentalists were used to examine the effect of singing on intonation performance. Utilizing a control/experimental group model, results initially indicated a significant difference between the two groups. However, analysis of the students' musical backgrounds revealed that students who took private voice lessons skewed the results. When these subjects removed from analysis, no significant difference was found between the control and experimental group.

Advancements in technology have provided many new opportunities for musicians to improve their intonation. Electronic tuners have progressed from bulky machinery to small handheld devices and now to free apps that can be downloaded onto a personal electronic device. In more recent years computer programs and apps have been developed to go beyond the rudimentary functions of a tuner to provide more detailed information for the user regarding their intonation performance. An experiment by Smith (2006) used researcher-created computer software that provided real-time visual feedback of intonation accuracy, printed musical examples, and recorded accompaniments to improve intonation accuracy of seventh and eighth grade saxophone and trombone students. Using both a pretest-posttest and experimental-control group design, analysis indicated that there was a significant difference in intonation ability for the experimental group compared to the control group in the pretest-posttest results.

An app developed by Pamidi (2018) takes the real-time visual feedback for intonation accuracy premise further by provide additional resources to enhance the user's experience. Not only does the app provide real-time feedback for performed intonation, but it also provides

instrument-specific fingering and tuning technique information. Since this app is relatively new, there have not been any published studies yet to determine effectiveness, however, I feel it is worth highlighting as a contribution to technology-assisted intonation improvement.

A different approach to using technology for intonation training was done in an experiment by Strickland (2013) using pitch tracking and correcting software, more commonly known as *auto-tune*. High school clarinet (n = 30) and trumpet (n = 30) players with at least three years of large ensemble experienced were the subjects and were assigned to one of three treatment groups: an aural group which used the auto-tune software, a visual group that used an electronic tuner, and a control group that was simply instructed to play in-tune as best as possible. The auto-tune software was shown to be effective towards intonation improvement, however, other variables were a factor towards these results, including time limitations and prior musical experience.

A review of literature on intonation performance, perception, and improvement supports the assertion that prior/additional musical experience and personal practice methods can affect both individual and ensemble intonation. The next section of this chapter will focus on specific practice strategies for improving intonation skill.

Music Educator's Role

Instruction from music educators, ensemble directors, and/or private lesson teachers is integral for the student's awareness of musical concepts and development of effective practice methods. "Findings suggest that instruction is an important influence for producing desirable wind-band intonation…A substantial component of instruction is defined by the kind and quality of activities that band directors present their students in order to improve intonation" (Wuttke, p. 93).

Teachout (1997) examined which skills and behaviors are important to successful music teaching. Similarly, a study by Chaffin (2009) examined the perceptions of two instrumental music teachers and their development of successful rehearsal techniques. Results from both studies showed that many of the most important traits of a successful band director had little to do with teaching musical material, skills, or concepts, but had more to do with classroom management, personality, and lesson planning. On a list of 40 skills and behaviors for effective music teaching developed by Teachout, only nine items directly relate to music, and include conducting, piano skills, instrument and singing skills, and knowledge of music theory.

Research by Teachout and Chaffin is helpful in terms of managing large rehearsals, but their studies do not extend into specific teaching strategies. To investigate rehearsal methods and techniques related directly to teaching musical elements, Bauer (1993) examined the relationship between rehearsal procedures and contest ratings for high school bands. For this study the researcher surveyed high school band directors regarding their contest preparation rehearsal methods. Emergent rehearsal methods aimed to improve aspects such as tone quality, intonation, blend, and balance. The researcher then compared the scores from the results of the contests to the survey data to determine what correlations exist. The time spent on each rehearsal method was compared to the contest score for that musical element and it was found that the amount of time spent per week on specific concepts positively correlated with the improvement of balance, intonation, and rhythm.

In a multiple case study by Davis (2019), observations and interviews were conducted with three well-respected, experienced, and successful middle school band directors to examine pedagogical techniques used to develop students' individual and ensemble intonation skill. Data revealed three main categories that the educators focused on for intonation improvement. First is

achieving quality tone production, with all participants agreeing this is held in highest priority. This includes teaching and developing fundamental skills such as embouchure and proper breathing. Second is developing aural skills, which included singing and pitch matching. Third is the importance of educating the students about the pitch tendencies of their individual instrument. As mentioned in the previous study, the combined time spent on these elements was important towards overall intonation development, even though some of the exercises were not explicitly stated to the students as intonation improvement.

The preceding research has shown that musical experience is an integral element for the development of intonation. Continued research that focuses on the role of musical experience and intonation skill would be helpful. One aspect of musical experience regarding intonation that has scarcely been addressed in research is the concept of ear-playing. The next section of this chapter will explore literature regarding how ear-playing has been shown to be an important trait for all types of musicians, offering positive effects for many facets of musicianship. Additionally, the role that ear-playing plays in music education will be discussed.

Ear-Playing

Ear-playing is a way of playing, performing, and creating music on one's instrument without the use of traditional notation or other visual cues, which may also include remembering or teaching music without the use of visual cues (Lilliestam, 1996). Additionally, Lilliestam posited that the majority of music made is played by ear, and may don the labels of folk music, improvised music, orally transmitted music, un-notated music, or popular music.

Vernacular Musicians

A term that is widely used to encompass the previously mentioned terms is *vernacular music*, which refers to the informal and ordinary music making of the common people of a region, culture, town, etc. without labeling it with a specific style or genre (O'Flynn, 2006). This way of making music is typically outside of the traditional notation-focused academic music discipline of schools and universities in Western music culture. The absence of vernacular music from education curricula reveals that the perception of what music *is* emanates from the assumption that it is something that is written in notation. Jeffery (1992) expatiates on this theory:

> Oral transmission is not a particular feature of some music at certain times, but rather a universal characteristic of almost all music at almost all times. What we call 'oral transmission' is what most human beings throughout history have known simply as 'music' – something to play or hear rather than something to write or read. We modern Westerners are the ones who do things differently, and our preference for writing is our handicap. (p. 124)

This quote reflects how notated music has become the standard in western traditions, however, the importance and traditions of vernacular music making, and ear-playing have not been ignored by scholars and have even gained greater interest since the date of this quote.

Vernacular musicians typically learn to perform music using informal approaches. Ear-playing is one approach, and may involve listening to and copying prerecorded music, listening to and copying fellow musicians, or using trial and error approaches in collaboration with other musicians to create and recreate their own music (Davis, 2005; Green, 2008). Considering this, Woody & Lehmann (2010), conducted a study to investigate if differences in ear-playing ability exist between musicians who are formally trained with no vernacular music-making experience, and musicians who have vernacular music-making experience. Twenty-four collegiate music majors —12 of which were formally musicians, and 12 of which had both formal instruction as

well as significant past experiences vernacular music making —were asked to learn and perform two different simple eight-measure melodies by ear, using a listen-then-perform approach. One melody was to be performed with voice only, while the other melody was to be performed on their instrument. The number of attempts to accurate performance were tabulated and acted as the dependent measure.

Results were explained using the concept of *musical goal image,* a theoretical model by Woody (2003), which is defined as a mental representation of a musical performance. Across both groups singing required fewer trials to reproduce the melodies than playing one's instrument. This indicates that the musical goal image is more closely connected to singing, and that the motor functions of playing an instrument may be a barrier towards reproducing one's musical goal image. Additionally, the vernacular group needed fewer trials to reproduce the melodies on their instrument, indicating that the transfer of musical goal image was more immediate for this group. Post-performance task interviews revealed that the vernacular musicians used their conceptual knowledge of music to efficiently build a goal image, whereas the formal musicians used a less efficient approach influenced by knowledge of music theory.

The results from Woody & Lehmann (2010) corroborate findings by Gordon (1985) that the concept of musical goal image is important for ear-playing skills. On the forefront of the ear-playing research movement in music education, Gordon, needed a term that described a musical imagination, and coined the word *audiation*. Audiation is to sound much like imagination is to images and is the foundation of musicianship. Gordon (1985) provides this definition: "Audiation is the hearing of music in one's mind when the sound is not physically present" (p. 34). He also compares the concept of musical goal image to audiation, noting that the word *image* relates to visual, not the aural sense, suggesting that notation is being imagined.

Conversely, audiation is associated with imagined sound, with no relationship to notation. Using audiation as a foundation, Gordon created the Music Learning Theory (MLT), a method for teaching audiation. The principles of MLT focus on tonal and rhythmic audiation and primarily utilize learning music by ear with the objectives of helping students gain a greater meaning from the music they perform, listen to, compose, and improvise.

Musical Benefits of Ear-playing

Fostering ear-playing skills along with notation-based learning may help create more well-rounded musicians and aid in improving other characteristics of musicianship. One aspect of musicianship in question regarding the effects of developing ear-playing skills is sight-reading. McPherson & Gabrielsson, (2002) found that some music educators may be concerned that fostering ear-playing skills will negatively affect a student musicians' ability to sight-read effectively. This debate has inspired several studies to help determine if there are indeed any positive or negative correlations between ear-playing and sight-reading.

One of the first researchers to study the relationship between ear-playing and sightreading was Luce (1965), who found a significant positive relationship between sight-reading and ear-playing. The high school participants in his study were first tested on sight-reading ability by playing eight 8-measure musical examples, utilizing three different key signatures. Second, their ear-playing ability was tested using a listen and play back method with six two-measure melodies. Discussing the relationship found between sight-reading and ear-playing, the author stated, "The importance of the ear in musical performance indicates that ear-playing may possibly be more important in developing musicianship than sight-reading" (p. 107).

Haston (2010) also found positive correlations between sight-reading and ear-playing abilities in a study conducted with beginning band students. Additionally, the author argued that

many countries outside of the U.S. require music students to pass proficiency exams, which include the testing of ear-playing skills, suggesting that this skill is valued and should be incorporated into a balanced curriculum.

To investigate the effects of ear-playing in selected keys on the abilities of band students to play by ear and sight read in those keys, Musco (2009) used a pretest-posttest, control-experimental group design with twenty-eight middle school band students. Over the course of four weeks the experimental group learned melodies by ear in three different keys, while the control group practiced from notation-based exercises in the same three keys. Post-test results showed that the experimental group improved their ear-playing abilities in the new keys, whereas the control group did not improve in ear-playing in any keys. Both groups improved in sight-reading in all keys that were utilized. Results of a post-treatment attitude survey showed that only the experimental group perceived improvement in performance, specifically in the new keys. These results suggest that there are potential benefits of ear-playing as preparation for sight-reading skills.

An important finding by Bernhard (2004) also addressed the sight-reading/ear-playing debate, positing that a traditional notation-based curriculum used during the beginning stages of instrumental musicianship fails to teach tonal understanding at the expense of focusing on instrumental technique. The author implemented an ear-playing-based curriculum called *tonal training*, where solfege was used to aurally learn melodies before seeing notation. Results from this study showed that this method cultivated the beginning band student's ear-playing achievement without deterring their sight-reading achievement.

Researchers have also investigated relationships between ear-playing and other musical skills. For example, McPherson (1993) examined high school clarinet and trumpet players to

identify which musical skills contribute to the function of others. Five musical skills were examined: 1. Improvising, 2. performing rehearsed music, 3. sight-reading, 4. playing from memory, and 5. playing by ear. Results showed that playing by ear was the only one skill that positively contributed to the function of the other four skills.

Similarly, Azzarra (1993) found that using an audiation-based improvisation curriculum with fifth grade band students positively contributed to multiple facets of the students' instrumental music achievement. In this experiment a control group and experimental group model at two different schools was implemented. Both groups received instruction using audiation-based methods, however, the experimental group had an added emphasis of improvisation/free-playing. Students in the experimental group showed an increased development and understanding of tonal, rhythmic, and expressive musical elements.

Through an extensive study of pedagogy and through a series of interviews with various musician, some who learned less formally with ear-playing experience and some who learned more formally without ear-playing experience, Priest (1989) posited the following regarding how ear-playing informs other aspects of musicianship: Ear-playing musicians develop a surer sense of tonality than non-ear-playing musicians, which aids in the musical skills of improvisation and transposition. Also, ear-playing musicians tend to develop a clearer aural image, creating awareness for the nuances of musical expression. He also observed some non-musical benefits in relation to ear-playing. Using the results from the research, Priest developed a pedagogical model to help create a balanced curriculum of instrumental music education for young students.

Other researchers have shown how ear-playing has a positive relationship with extra-musical elements of musicianship. Several studies have shown that having and/or learning ear-playing skills can be beneficial for self-efficacy, autonomy, confidence, problem solving,

learning strategies, efficiency, enjoyment, and retention. Next, I will review studies in which the authors have found extra-musical benefits in relation to ear-playing.

Extra-musical Benefits of Ear-playing

Varvarigou & Green (2015) developed the *Ear-playing Project (EPP)*, a project that the researchers sought to investigate the learning strategies used by student instrumentalists when learning music by ear from a recording during one-to-one instrumental lessons. The focus of this portion of the study was on learning styles and how the participants responded to the task, rather than how correct or incorrect the reproductions were. Qualitative analyses revealed four main learning strategies: 1. Impulsive style, which participants focused on rhythm rather than melody and played isolated notes with appearing to realize if they were accurate notes. 2. Practical style, which participants listened to several repetitions before attempting to copy it, then broke the music down into components. 3. Shot-in-the-dark style, which participants listened several times without playing anything, then tended to play isolated notes, not appearing to recognize accuracy. Ultimately, they were not able to reproduce the notes or rhythms, and many seemed to have a fear of the task. 4. Theoretical style, which participants asked many music-related questions before attempting to play. They were also unable to reproduce the notes or rhythms.

Interviews of the one-to-one lesson teachers revealed how learning to play by ear may positively impact the students. Knowing the learning style construct could help teachers understand their students and tailor their teaching accordingly. Also, when the teachers were asked about the benefits of the EPP, the author stated:

> The project helped them give their students more autonomy during the lessons and assess their students' needs more insightfully … the benefits for the students included an increase in students' confidence in playing diverse repertoire and in using alternative pedagogies, and enjoyment from bringing their favorite music and performing it during the lesson … (p. 717).

The author also posits that the four learning styles may be related to how students respond to reading notation, instruction, modeling, music theory, and other elements of an instrumental lesson.

Hartz and Bauer (2016) determined that ear-playing is associated with musical self-efficacy in their study of ear-playing instruction among adult amateur wind instrumentalists. Ten members of a community band volunteered to participate in an eight-week period of ear-playing instruction. Data consisted of a questionnaire, field notes of the researchers, and voluntary comments from the participants. The eight ear-playing lessons included singing solfege, listening to a melody, improvising five-note patterns, and echoing scales, thirds, and tonic-dominant patterns in three major keys. Results showed that the participants enjoyed developing a new form of musicality while expressing an increase in self-efficacy in both performing music by ear and in an ensemble setting.

Experiencing greater self-efficacy may lead to higher confidence in performing and more enjoyment in the music-making process, which may lead to a higher retention rate for student musicians. Glenn (1999) found this to be true during a school-year-long experiment incorporating rote instruction with 6th grade beginning string players. An experimental/control group design was used; the control group had traditional notation-based instruction, while the experimental group had instruction that emphasized rote learning prior to incorporating music notation. Results showed that the biggest difference between the groups was in the continuation rate. Seventy percent of students from the experimental group continued to play into the next school year, whereas only 32% from the control group continued. The researcher witnessed a higher level of motivation and enjoyment among students in the experimental group, and they appeared to encounter fewer obstacles in their playing due to the absence of notation.

Additionally, the absence of notation in the early phase of the experiment allowed for more playing since time did not have to be devoted to learning notation. When notation was introduced in the experimental class, they had an easier time reading it since they already had a certain level of physical autonomy playing the instrument. The synthesis of these elements created an overall more rewarding environment for the students, leading to their desire to continue with the instrument.

Ear-playing in Curriculum

Considering the myriad positive finding from research and pedagogy, this begs the question: Why is the reinforcement of ear playing skills widely overlooked by instrumental music educators in the United States? Reviewing existing research help demystify this phenomenon and perhaps with a better understanding, steps could be taken towards a wider implementation of fostering ear playing skills.

Musco (2010) investigated whether existing research supported expert opinion concerning the benefits of ear playing. The author determined that, while pedagogues advise ear playing and research suggests benefits, educators still have concerns. These reservations relate to these five issues: *Stereotypes and misconceptions*. This refers to the attitude and opinions note-readers vs. non-note-readers often have towards each other. The middle ground of code-switching (e.g., musicians who switch between formal and informal music making) would help alleviate this. *Worry and conflict.* This refers to the struggle that some educators feel about 'allowing' their students to play by ear, fearing the students will not be motivated to learn to read notation. Research (including examples in this review of literature) points to the contrary. *Traditions and challenges.* Focus on large ensemble instruction directed towards performances provides challenges for incorporating ear playing instruction. Devising way to add ear playing

activities to large ensemble settings may prove challenging but could be a possible solution. *Skills and knowledge.* Many educators may be or perceive themselves to be unskilled in ear playing, therefor are unconfident and reluctant to teach ear playing skills. Including training during undergraduate education may be part of a solution to this. *Pedagogy*. Educators who are able and willing to teach ear playing may find difficulties and doubt about how to teach this skill.

While it has been shown that ear-playing in curriculum faces obstacles, there are practices and methods that are being implemented that do focus on or utilize ear playing skills. These include methods for beginning instrumentalists, as well as practices that can serve as alternative or supplementary experiences to the large ensemble format in schools.

For beginning band settings, there is a curriculum called *Jump Right In* (Azzara et al., 2003) which is co-designed by Gordon. Using the principles of MLT as a foundation, this curriculum focuses on the sound-before-sight principles, stating that players become more musical if they know what sounds to expect before they play them. Students listen and learn to sing and play folk-type songs in a variety of styles and modes by ear before they see the music notation for the songs. This is done concurrently with teaching the basic executive skills needed.

In recent years there have been two distinct but similar movements in the field of music education: *Modern Band* and *Musical Futures*. The Modern Band movement in music education is a relatively recent movement and was developed from a non-profit organization (Powell, 2021). Modern Band focuses on student-centered repertoire, including songwriting and popular music choices, and utilizes music technology and/or popular musical instruments, such as guitar, ukulele, drums, keyboards, and vocals (Vasil, 2020). Pedagogical approaches for modern band stem from *Music as a Second Language (MSL)*, and share commonalities with other approaches, such as Orff Schulwerk and Dalcroze. The core principles of MSL included informal music

learning, non-sequential and holistic learning, fluent speakers as models and guides, and learning in a safe, low-anxiety spaces (Vasil, 2020).

Musical Futures is a UK based organization that began in 2003 as a research program intended to discover new approaches for music education. The research of Green (2008) to discover how popular musicians learn was the initial foundation for this program and its success led to the Musical Futures Informal Learning model with Professor Green leading the research.

The informal learning model by Green (2008) is student centered by nature, allowing students to choose the music they want to learn. Learning is done in friendship groups, and music is learned by listening and copying from recordings, rather that printed notation. This model also promotes skills and knowledge acquisition based on the students need, often through cooperative peer teaching, utilizing performing, composing, improvising, and listening as the medium.

Both Modern Band and Musical Futures are very similar in their aims to provide an alternative approach of music education, using student-centered informal practices with popular music as the curriculum foundation. Their overall mission is the same, which is to provide meaningful music learning experiences for students that promote a deeper connection and understanding to music than what a traditional music education experience may provide. The informal learning process allows for students who may not have the opportunity to be successful in a traditional music education situation thrive and succeed with music.

As alternative approaches to traditional music education, both Modern Band and Musical futures offer many resources, lessons, method books, and workshops. Music educators can use these resources to create rewarding music education settings in their schools but implementing these principles and techniques may pose a challenge for directors of traditional large ensembles.

An increasing number of educators and scholars are applying informal learning principles in large ensemble settings to help show effectiveness and with hope to guide the paradigm in a new direction (Norris, 2010; Sindberg, 2009; Spears, 2014; Weidner, 2020). This contemporary body of research is built on student-centered, democratic, popular-music as curriculum, constructivist principles, utilizing informal learning, composing, improvising, and ear-playing. The same foundation that both Modern Band and Musical Futures are built upon.

Conclusion

This review of literature examines two large concepts related to the development of this study. First the science of sound, pitch systems, and intonation was highlighted with a focus on instrumental intonation performance and perception. Second, the concept of ear-playing was introduced and how it functions within the vernacular music community, the benefits that ear-playing skill have towards other elements of musicianship, as well as current ear-playing practices within music education. However, throughout all this reviewed literature the relationship between the two main topics, intonation performance and ear-playing ability, is largely absent.

Drawing on previous literature that tested both ear-playing ability as well as intonation performance, creating a study that will address this gap in the research may help to shed light on any benefits that ear-playing skills offer towards wind-instrument intonation performance. Findings may also help to bolster the myriad research that advocates for more ear-playing skills training in instrumental music education and lead to greater development and implementation of ear-playing methodologies.

Chapter 3. Methodology

In this chapter, I will describe the methods used to investigate the relationship between intonation and ear-playing skills, as well as the relationship between select experiences and ear-playing ability of high school and university instrumentalists. Sampling and data collection procedures will be explained along with the processes used to convert the raw data for analysis. Limitations and reliability are reported at the conclusion of the chapter.

Sampling and Design Elements

Institutional Review Board (IRB)

Proper Institutional Review Board procedures were followed as well as all COVID-19 protocols that were in place by the state, city, and institution administration. IRB procedures included a security of data agreement from the researcher and advisor, parent permission forms from all minor participants, assent forms completed by all minor participants, consent forms completed for all adult participants, and consent forms from the band directors and administration from the participating high school. COVID-19 protocols included social distancing as much as possible and the wearing of face coverings for both the researcher and participant when they were not playing their instrument.

Participants Sampling

Data collection was completed using two populations of wind instrumentalists: 1. University band members ($n = 18$) both music majors and non-music majors. 2. High school band members ($n = 16$). These populations were chosen in order to address the research question of how years of experience playing an instrument may impact ear-playing ability.

The university band participants were all part of the band program at a major flagship university in the southeast region of the United States. To recruit participants, I was granted

permission by university band directors to visit two concert band rehearsals. I first described the research purpose to the band members, then told them I was looking for wind instrumentalist participants to complete a series of performance tasks on their instrument. I did mention that the tasks would involve both playing by ear and reading music, but I did not provide specific details so that the participants would not be able to prepare anything ahead of time. For additional motivation to volunteer I offered a $5.00 cash stipend to the first 25 participants upon completion of the tasks.

During this recruitment visit those who volunteered were asked to provide their name, instrument, and email address on a sign-up sheet. All volunteers were later sent an individualized personal email with further instructions on how to sign-up for a specific time slot to participate in the study (Appendix A). I used a website call SignUpGenius.com (2021) to host and organize the available time slots. This website allowed the participants to sign-up for a time slot while also providing them with auto-generated reminder emails about their appointment. Additionally, it allowed me to include other relevant information such as location and directions to the testing room.

For the high school population, I worked in conjunction with the band directors and administration at a private parochial school in the same city in which the university is located. This school was chosen because of convenience, both of location and because I already had an established relationship with the band directors. I first gained permission from the band directors to be able to come in and use individual student volunteers during their band classes. Next, I spoke directly with the principal to gain permission and access to the school, and to be sure that I followed all proper attendance and COVID-19 protocols for being on the school campus during regular school hours. This included completing a state background check.

To obtain volunteers from the high school population I first addressed each of the three concert band classes, as I did for the college bands. However, the high school participants were not offered the $5.00 stipend. Those who wished to volunteer were asked to provide their name, instrument, and which band class they were in on a sign-up sheet. Since nearly all the volunteers were minors, a permission and assent form needed to be completed before they were allowed to participate. To accommodate this, the band director sent an email to all parents whose students signed-up, describing the research and asking them to complete the online permission form. This on-line format permission form was created using the online cloud-based survey management program Qualtrics (2021). See Appendix A for these letter and forms.

Due to time conflicts, only three days of on-site testing could be used. Testing was done during the three band classes throughout the school day. The first two days had normal 50-minute-long class periods; however, the last day had an adjusted schedule, leaving only 35 minutes per class period. Because of these time constraints I knew it was not going to be possible for all 37 of the initial volunteers to participate, so to account for this, participants were selected randomly from the total pool of volunteers whose permission form was completed. Additionally, each participant completed an assent form before they began the testing procedures.

Data Collection Instruments

The first form of data collected from the participants was in the form of an online-format questionnaire. This was researcher-created, using the online cloud-based survey management program Qualtrics (2021). A link was provided to the volunteers, which they could access from either a mobile device or computer. Care was taken when creating the survey that the format was easy to read and to understand no matter which type of device from it was accessed.

Next were a series of performance tasks. For these tasks, participants listened to prerecorded melodies and were asked to replicate them on their instrument. Additionally, they were asked to play melodies in unison with the prerecorded tracks. These performance tasks were recorded for later analysis. I executed the playback and recording procedures in a consistent manner with all participants.

Playback for these tasks was executed digitally using a MacBook Pro® laptop with Swinsian® music player software. All sounds were played through a Harbinger® VARI 2310 amplified speaker, which was set on the floor using the monitor configuration, justified at a 45-degree angle, and was oriented six feet away from the participants. Similar performance-task tests used headphones for playback to prevent bleed in the recording procedure (Ballard, 2011; Byo et al., 2011; Karrick, 1998; Morrison, 2000; Yarbrough et al., 1997), but playing an instrument with headphones blocking the ear canals is not a common practice for most young musicians, and it was a goal to make this scenario as close as possible to how the participants perform most commonly.

The audio was collected using a MacBook Pro® laptop with a Blue Yeti® microphone in conjunction with a microphone isolation shield to limit the amount of bleed from the playback. These were attached to a tripod-style microphone stand with an adjustable boom arm. Additionally, a wind screen and pop shield were used on the microphone to limit any breath noise. The microphone input level and spatial arrangement was adjusted for each participant, depending on the instrument played (Ross, 2020) to maximize the instrument input and minimize bleed from the playback track. After adjusting the spatial arrangement of the microphone, the participants were asked to play a scale of their choice at a comfortable and natural volume to

check the input level. Proper physical and input level adjustments were made if needed during this sound check.

Audacity® (version 2.3.1.0) open-source audio processing software was used for recording the performances. The recording was made on a single mono channel and recorded continuously throughout the entire procedure. Upon completion, each recording was titled with the corresponding participants self-created username from their questionnaire and saved onto an external hard drive.

Playback Sounds

Previous research has revealed several different outcomes regarding the best timbres to use for testing procedure playback in both intonation and ear-playing assessments (Byo et al., 2011; Delzell et al., 1999; Hayes, 2009; Hayslett, 1990; Karrick, 1998; Morrison, 2000; Woody & Lehmann, 2010; Yarbrough et al., 1997). While elements such as lack of vibrato, attack, and familiarity were reoccurring themes, the sound of the piano was determined to be best. This is because it is a widely familiar sound and is neutral for wind players (Delzell et al., 1999). Additionally, piano was the same instrument used in two ear-playing research studies, of which I modeled my testing procedures (Delzell et al., 1999; Woody & Lehmann, 2010). Based on this information I used a synthesized piano sound for all playback elements. The tuning system used to create all playback materials was equal temperament, which has been found to be the most preferred (Ballard, 2011; Karrick, 1998; Loosen, 1995). Playback sounds were created using Finale® notation software (version 27.1.0), utilizing the Gerritan® instrument sounds of *Steinway Piano* for the melodic patterns and tuning pitch, and *Woodblocks* for the beat-keeping metronome function. Each playback track had an 8-beat count in, performed using the woodblock sound. This metronome function continued throughout the entirety of all tracks. The

playback patterns were then converted to an .MP3 file and uploaded into Swinsian® (version 2.3.6) music player software to create a playlist to use during the testing procedures. Using this music player and the playlist option allowed for the playback selections to be arranged in the proper test order. These functions aided in ease of use and the consistency between participants.

Pilot Testing

The initial design of the testing procedures was pilot tested with five undergraduate college wind instrumentalists. The pilot testing revealed that some of the procedures and/or tasks needed to be adjusted for the final testing procedures. These included:

1. Delivery of instructions – Initially all instructions were prerecorded for consistency. However, it was found that some instructions needed clarity, requiring personal interactions between the participants and the researcher. Additionally, the prerecorded instructions were lengthy and impersonal which, since the researcher was in the room for recording purposes, seemed to create an impersonal, sterile, and awkward milieu.
2. Ear-playing tasks – During pilot testing, two separate ear-playing tasks were implemented, both of which were previously used ear-playing research.
    a. The first was melodic sequence echoing (Delzell et al. 1999), which required participants to echo five sequences, each consisting of 6-12 melodic four-beat patterns, 58 patterns in total. This required a lot of time for initial explanation and to complete all the sequences. Even with detailed recorded instruction, all pilot test participants still needed additional explanation to start the test correctly.
    b. The second was a listen and play-back tasks, requiring participants to listen to an 8-measure melody, after which they were asked to replicate it on their instrument. Subsequent listen/play cycles were allowed until the participant performed the

melody with accuracy. This procedure and 8-measure melody was used by Woody & Lehmann (2010). Pilot testing consistently revealed that participants found it difficult to learn past the first four measures of the 8-measure melody. Additionally, some participants found it helpful to play along during the listen portion of the cycle, which was not part of the original instructions.

Based on the results from the pilot testing, the following adjustments were made:

1. Prerecorded instructions were eliminated and replaced with scripted instructions to be read by the researcher during the testing procedures. See Appendix B for the complete script of the instructions.
2. It was deemed unnecessary to have two different types of ear-playing tasks since they would have tested the same variable. Hence, the melodic sequence echo task was eliminated. The listen-and-playback format was chosen instead because it is based on more reputable research, it is an easier to understand and follow format, and is more time efficient.
3. The listen-and-playback task was changed from one 8-measure melody to two 4-measure melodies. This allowed for the ear-playing tasks to have two different key centers and a wider range of notes compared to the original 8-measure melody. It also helped to eliminate the challenges of the 8-measure length faced during pilot testing. The two melodies were composed by me to incorporate similar technical demands as used in the procedures by Woody & Lehmann (2010). This included range consideration, melodic and rhythmic repetition, as well as the calculated use of predictability and unpredictability.

4. Instructions for the listen-and-playback tasks were modified to include language that allowed the participants to play along with the recording during the listen portion of the cycle, starting with the fourth cycle. Additionally, participants were allowed a performance opportunity at the end of each of their 30-second playback portion of each cycle.

All other elements of the pilot testing were valid and used without adjustment for the final iteration of the testing sequence. The next section of this chapter I will detail all the tasks used for the final iteration of the data collection procedures.

Testing Locations

The testing procedures for the university participants took place in the music building on the campus of the university. This room was in an isolated part of the building, away from distractions and outside noise. For each day of testing, diligence was used to ensure that the same equipment and set-up was utilized for testing consistency.

The testing procedures for the high school participants took place in an available room within the music wing of the school. This room was designated by the researcher as the best option to be most comparable to the room used at the university location, while also providing separation from distractions and outside noise. For each day of testing, care was taken to be sure the same equipment was used each time and was set-up in the same configuration.

Tasks for Data Collection

Task 1 – Questionnaire

The first task that the participants completed was a questionnaire. This provided data about the participant, including age, primary instrument, number of years playing the instrument, years of private lessons, hours of personal weekly practice time, and experience with other

musical instruments. Additionally, questions were designed to assess each participants opinion of their ear-playing ability and their intonation performance skill. Participants were also asked to create a unique and anonymous username so that their questionnaire could be linked to their performance task recordings. This on-line format survey was created using the cloud-based survey management program Qualtrics (2021). See Appendix B for the complete questionnaire.

Task 2 – Performance Assessments

The following procedures were created to assess two different skills. The first set of tasks measured the ear-playing ability of each participant. The second set of tasks measured the participant's ability to play with accurate intonation. For reliability, clear, concise, and consistent instructions were read from a script for each participant to ensure that everyone received the same instruction (Appendix B). Participants were offered permission to ask questions for clarity if needed.

Ear-playing Assessments

Findings by McPherson (1995) suggested that one important component of ear-playing is the ability to imitate previously unknown melodies immediately after hearing a live or prerecorded model. To assess this component, participants completed two different tasks with the same design. To ensure validity, this design drew on previous literature that tested ear-playing ability, with modifications made to fit the needs of this study (Delzell et al., 1999; Woody & Lehmann, 2010).

1. Listen and play back attempts

First, the participants were shown a notated starting pitch of the melody transposed for their instrument (Appendix B), followed by hearing a piano play the starting pitch, and then a triad played by the piano in the key of the melody. This triad was the only information that was

given about the key center of the melody. Melodic Pattern #1 started on the tonic, whereas Melodic Pattern #2 started on the dominant.

Next, each participant heard a 4-measure melodic pattern twice, after which they were given a 30-second practice time, followed by one chance to replicate it on their instrument (Figure 4). This melody was played in unison octaves by the piano to facilitate the various pitch ranges of the instruments that were used during testing, and so that each participant would hear the exact same recording, not one that was specified for the range of their instrument.

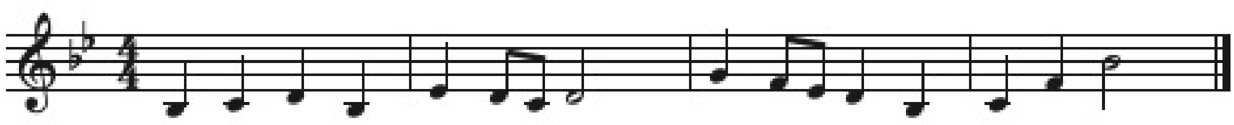

Figure 4. Listen and Playback Melodic Pattern #1
Note. This is a visual representation of the melody heard by the participants.

The goal was for each participant to achieve at least 90% success of replication, which was determined by deducting one point for every rhythmic or melodic mistake made during the replication performance. A tempo requirement for replication was not specified, however all the participants performed their replication very close to the tempo that they heard in the recording. Each of the melodies contain 16 notes and for assessment purposes, each note was worth two points—one point for pitch and one for rhythm. The maximum of a three-point deduction was allowed for the performance to be considered within the 90% success parameters.

If the participant could not replicate it with at least 90% accuracy the first time, subsequent listen/playback attempts were allowed, but with only one hearing of the reference song. This cycle continued until the participant either performed the melodic pattern with at least 90% accuracy or reached 12 attempts without success. The participants were verbally informed by the researcher when success was attained, or when it was time to move on to the next task.

The procedures for this task were based on similar tasks used in the studies by McPherson (1995), and by Woody & Lehmann (2010).

The number of times through the listen-then-perform cycle that participants require for an accurate performance was noted while reviewing the recordings. The number of trials required to accomplish an accurate performance is the dependent measure, or the score of 12 was used if success was not attained. This procedure was then repeated with an additional 4-measure melodic pattern for the second ear-playing task (Figure 5). Because the successful performance of this second melodic pattern was integral for the next task, verbal assistance was given to participants who struggled to achieve 90% success after their 12 attempts. The verbal assistance varied depending on how much help was needed, and included providing specific note names for pitches that were not being discovered correctly or helping them conceptualize the pitches by identifying interval directions and/or sizes.

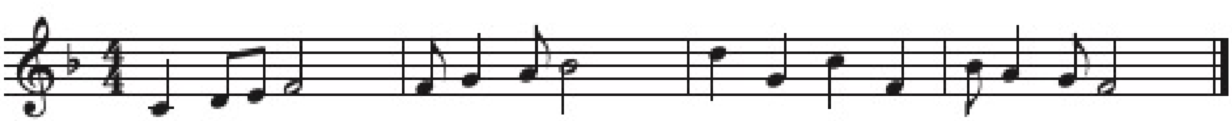

Figure 5. Listen and Playback Melodic Pattern #2
Note. This is a visual representation of what the participants heard during the task.

Intonation Assessment Tasks

This section will first describe the performance tasks that were completed by the participants for intonation assessment, followed by a detailed description of how the raw data was converted for use as variables in the statistical procedures for this study. All tasks were recorded and evaluated later to create the variables. Intonation assessments were started after each participant had played their ear-playing assessments because it provided them with sufficient time to warm-up and become acclimated to the testing environment.

1. Tune Instrument to Given Tuning Pitch

A standard tuning B-flat was produced via playback speaker to which the participants were instructed to use their own personal tuning procedures to adjust their instrument in tune to the best of their ability. After three given pitches with five seconds between each for adjustment time, participants were instructed to play the pitch one last time in unison with the piano pitch. The final performed pitch was later evaluated to determine frequency, Hertz, and cent deviation from equal temperament. Although this data was tabulated, it did not fit into the needs of the intonation variables and was not used in the statistical analyses.

2. Unison Play-along

The participants were instructed to perform the same 4-measure melody from the ear-playing assessment #2, this time playing in time with the reference recording. As discussed earlier, for those participants who did not achieve success during the listen-and-playback task, they were given verbal assistance to be able to play the melody for this task. This melody was performed twice to ensure accuracy of playing in time with the reference recording.

3. Simple Melody with Notation

Participants were given printed music notation to a simple 8-measure melody. A properly transposed version for their individual instrument was provided. Participants were given one minute to study and prepare the melody to perform it in unison with a piano play along track, without listening to it first. This piano track was also performed in octaves for the same reasons the ear-playing tracks were performed in octaves. This melody was simple enough to decrease the chances of sightreading difficulties, and the play back track had a clear tempo and introduction to facilitate playing in time.

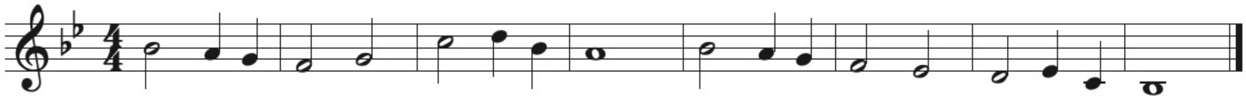

Figure 6. Notation for Intonation Task #3

The evaluation procedures were the same for both intonation assessment #2 and #3. Seven predetermined target pitches from each performance (Figure 7) were evaluated.
The seven pitches selected for each evaluation between tasks #2 and #3 were the same pitches but functioned differently within the key and context of the melodies. The target pitches were selected based on melodic context; with some pitches being approached from below, and some approached from above. These elements are based on intonation testing done in previous studies by Karrick (1998) and Morrison (2000).

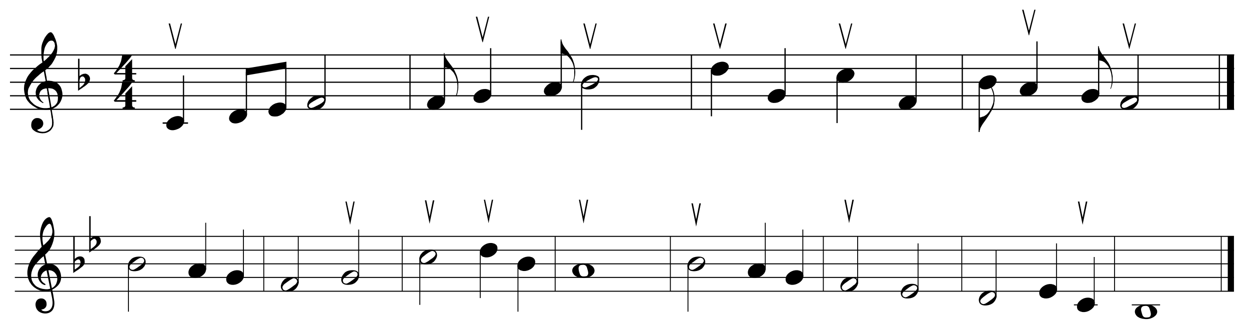

Figure 7. Notation for the Two Intonation Tasks with Target Pitches Denoted
Note. The "V" above the notes indicates a target pitch to be analyzed for intonation accuracy.

Intonation Evaluation Procedures

To convert the raw intonation assessment task data into useable variables for the statistical procedures, several steps were required. Each recorded performance was processed through Audacity®. First, the predetermined target pitches from each performance task were analyzed using the *frequency analyzer* tool, which determined the Hertz of each pitch (Morrison, 2000). This was done by first locating the graphic representation (soundwave) of the pitch to be analyzed in the Audacity® file. Next, the soundwave was selected by clicking and dragging the

cursor over the desired length (Figure 8). I selected each pitch to analyze the sustain portion only, avoiding the initial attack and the release of the performed sound. This was done consistently for all pitches and participants to prevent skewed results if the attack or release was distorted.

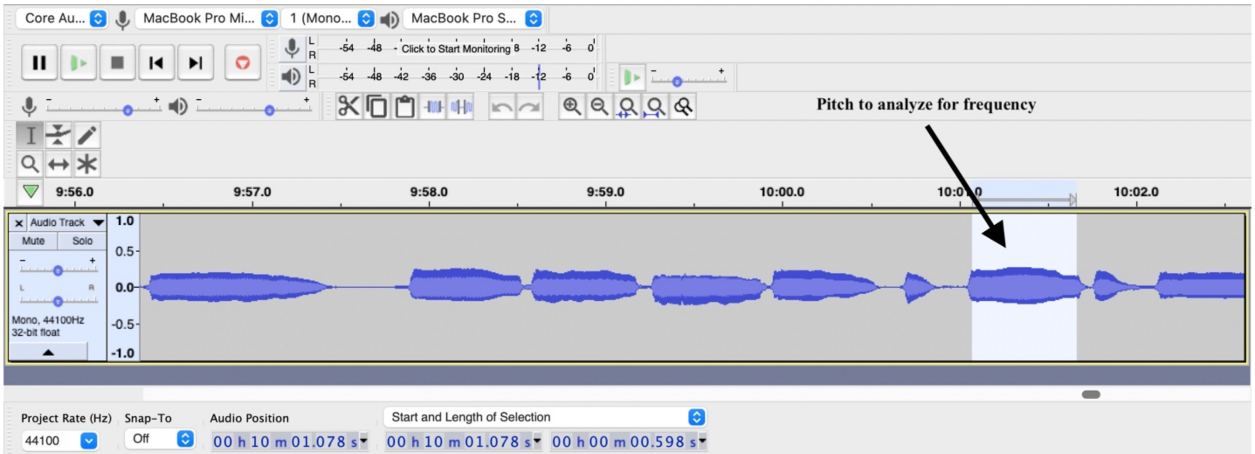

Figure 8. Audacity Screenshot #1 – Soundwave Selection
Note. Area shown with arrow is the highlighted pitch to analyze.

Next, I chose the *plot spectrum* option from the menu, which provided a frequency analysis. The highest peak decibel wave on the analysis window represented the frequency of the performed pitch. The actual frequency is provided by placing the cursor on the peak wave (Figure 9).

These frequencies were tabulated then converted to cent deviations using the online *Frequency to Musical Note Converter* found on the website *http://www.sengpielaudio.com/calculator-centsratio.htm* (Sengpiel, n.d.) to determine intonation variance from equal temperament.

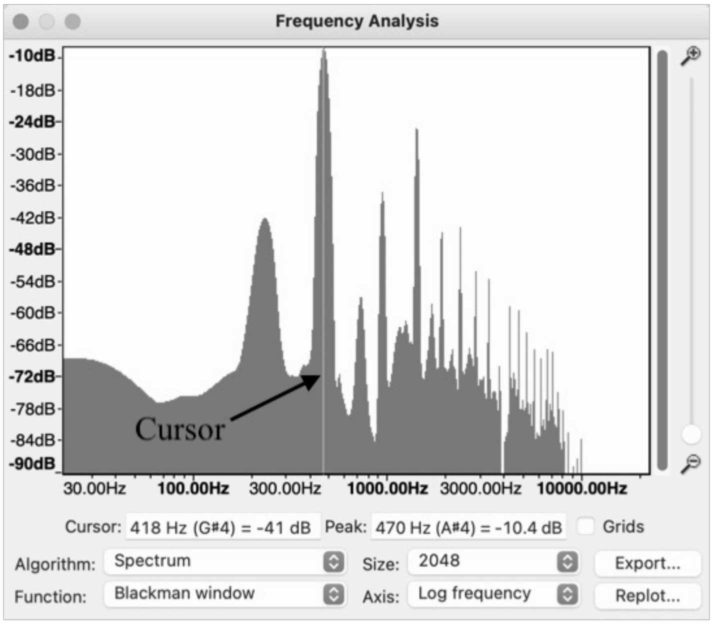

Figure 9. Audacity Screenshot #2 – Frequency Analysis
Note. This tone was analyzed at 470 Hz (Peak) as an A#4. The actual whole number equal temperament frequency for A#4 is 468 Hz. This frequency converted to cent-deviation determines that the performed pitch is 7.4 cents sharp.

Analysis Procedures

In this section, I will restate each research question, describe which statistical procedure was used for analysis, and list the variables used for those procedures. This will also be described in greater detail in the next chapter.

RQ 1. What is the Relationship Between the Ability to Play By Ear and Intonation Performance Skill?

To investigate the relationship between ear-playing and intonation, Spearman correlation analyses were conducted using the following variables:

1. The ear-playing profile score, which is the sum of the two ear-playing tasks
2. The intonation profile #1, which is the mean of the results from intonation task #1
3. The intonation profile #2, which is the mean of the results from intonation task #2

RQ 2. How Does Intonation Ability Differ When the Participants Sightread Printed Music Notation Compared to Performing Music That Has Been Learned by Ear?

To examine the differences between intonation profile #1 scores and intonation profile #2 scores, the Wilcoxon test was used. The variables for this procedure were intonation profile #1 and intonation profile #2, which are the mean results from the two intonation tasks.

RQ 3. Do Differences Appear in Ear Playing Ability Based on Selected Musical Experiences of the Participants?

To determine if significant differences in ear-playing ability exists based on selected musical experiences, a Kruskal-Wallis analysis of variants test was used. The ear-playing profile scores were used as the dependent variable, and the following were used to investigate select experiences.

1. To explore the relationship between *years of experience* and ear-playing ability, the questionnaire data of the number of years of playing the instrument (0-1 year, 1-2 years, 3-4 years, 5-6 years, 6+ years) was the independent variables.
2. To explore the relationship between *private lesson experience* and ear-playing ability, the questionnaire data of the number of years taking private lessons (none, less than 1 year, 1-2 years, 3-4 years, 5-6 years, 6+ years) was the independent variable.
3. To explore the relationship between *personal practice time* and ear-playing ability, the questionnaire data of the number weekly hours of personal practice (none, less than 1 hour, 1-2 hours, 3-4 hours, 5-6 hours, more than 6 hours) was the independent variable.
4. To explore the relationship between *ear-playing frequency* and ear-playing ability, the ear-playing frequency score (1=never, 2= rarely, 3=sometimes, 4=somewhat often, 5=often) was the independent variable. This score was determined by combining and

calculating four survey questions that asked the participants to rate how often they play by ear in different scenarios (alone, with family/friends, with prerecorded music, figure out songs by ear).

Reliability and Validity

To verify accuracy of my evaluation of the ear-playing performances a random sample of one-third of the participants final performance was listened to and evaluated by three experienced instrumental music educators. These samples only included participants who were determined by me to achieve at least 90% success during the initial testing. The evaluators were asked to grade each of their selections by deducting a point for every rhythmic or melodic mistake that they hear. Each of the two ear-playing melodies contains 16 notes and each note is considered be worth two points, one point for pitch and one for rhythm. The maximum of a three-point deduction was allowed to consider a performance within the 90% success parameters. All random samples were determined by the evaluators to be within the parameters. See Appendix B for the completed evaluator sheets.

To determine the validity of the frequency analyzer several tests were performed. First, I performed and recorded the intonation test melodies on my primary instrument using the same microphone, playback, and recording set-up, after which I used the frequency analyzer to determine my performed frequencies. Second, I recorded several pitches purposely out of tune while looking at a tuner, then used the frequency analyzer to verify that the frequencies were analyzed at the same distance out of tune as determined by the tuner. Lastly, to account for vibrato, I used the tone generator feature on Audacity® to create a one-second tone that alternated evenly between 438 Hz and 442 Hz every tenth second, similar to a musician performing vibrato.

This tone was analyzed and determined to be 440 Hz, showing that the frequency analyzer function provides the average Hz of a selected soundwave.

Conclusion

In this chapter I detailed how the design, sampling, and execution of my study was achieved, referencing the many previous studies that informed my design. Multiple previous studies were drawn upon to ensure validity and reliability, the sampling of the participants was based on both convenience of location and on previously established relationships with the band directors of the programs, and care was taken to be sure of consistency between all participants, between both testing locations, and between all days of testing.

In the next chapter, I will use the data that was created from these testing procedures in various statistical procedures to address the research question directly. I will address each research question individually, list all variables, and detail the statistical procedure used for the analysis. The results from these procedures will show if any relationships exist between ear-playing and intonation performance, as well as what previous experiences may relate to ear-playing ability.

Chapter 4. Results

In this chapter I will describe the results from the questionnaire responses as well as the data from the performance tasks completed by the participants. This will include demographic information, descriptive statistics, ear-playing task results, intonation task results, as well as the relationships that exist between this data. Each research question will be addressed separately with an explanation of how the data was used for analysis, a description of the statistical procedure used for analysis, and the results of the statistical procedure.

Data

Prior to completing any performance tasks, each participant responded to a researcher-designed questionnaire (Appendix B). This online questionnaire was administered using the cloud-based survey management program Qualtrics (2021). Data was then uploaded to SPSS statistical analysis software (Version 28.0.1.1) for analyses. Each participant then completed two ear-playing assessment tasks and two intonation performance tasks. Data from these tasks were tabulated and entered manually into SPSS software. In the next section, I will present the questionnaire results. This will be followed by a description of the performance task data.

Descriptive Statistics - Questionnaire

Thirty-four wind instrumentalists completed a questionnaire to determine musical background, experiences, and self-perception of musical abilities. The participants all play their instrument in school-organized, large ensemble settings. Below are the questions from the questionnaire along with the descriptive statistics of the responses.

Age

The age of the subjects (*N* = 34) ranged from 14 to 27 years old with a mean age of 17.94 (*SD* = 2.93). Kurtosis for age was 1.69 (*SE* = .79) indicating a slightly leptokurtic distribution. Skewness for age was .97 (*SE* = .40) indicating a moderately positive skew.

For the high school wind instrumentalists (*n* = 16) the minimum age of the participants was 14 and the maximum was 18, with a mean age of 15.63 (*SD* = 1.36), a Kurtosis of -.82 (*SE* = 1.09) indicating a slightly platykurtic distribution and Skewness of .43 (*SE* = .56) indicating a slightly positive skew.

For the university wind instrumentalists (*n* = 18) the minimum age of the participants was 18 and the maximum was 27, with a mean age of 20 (*SD* = 2.35), a Kurtosis of 4.05 (*SE* = 1.04) indicating a leptokurtic distribution and Skewness of 2.05 (*SE* = .54) indicating a positive skew.

Table 2. Age of Participants

Group	Mean	Range	SD
High School	15.63	14-18	1.36
University	20.00	18-27	2.35
Total	17.94	14-27	2.93

Instruments

All participants in the study performed on wind instruments. The most common instrument was trumpet (*n* = 8), followed by saxophone (*n* = 5), clarinet (*n* = 4), French horn (*n* = 4), and trombone (*n* = 4). The least common were bassoon (*n* = 2), and tuba (*n* = 1), See Table 3 for a complete list of instruments used by each sample.

Table 3. Instruments Used by Participants

Instrument	High School		University		Total	
	N	Percent	N	Percent	N	Percent
Piccolo	0	0.00	1	5.60	1	2.90
Flute	1	6.25	1	5.60	2	5.90
Oboe	1	6.25	2	11.10	3	8.80
Bassoon	0	0.0	2	11.10	2	5.90
Clarinet	2	12.5	2	11.10	4	11.80
Alto Sax	2	12.5	2	11.10	4	11.80
Tenor Sax	1	6.25	0	0.00	1	2.90
Trumpet	5	31.25	3	16.60	8	23.50
French Horn	0	0.00	4	22.20	4	11.80
Trombone	3	18.75	1	5.60	4	11.80
Tuba	1	6.25	0	0.00	1	2.90
Total	16	100.0	18	100.0	34	100.0

Time Playing Instruments

The number of years participants (N = 34) have played their instrument ranged from less than one year to more than six years, with a mean of 4.2 (SD = 1.05), with a skew of -1.15 (SE = .40) indicating a negative skew, and a Kurtosis of .94 (SE = .79) indicating a moderate leptokurtic distribution.

The number of years the high school sample (n = 16) played their instrument ranged from less than one year to more than six years, with a mean of 3.69 (SD = 1.14) with a skewness of -.84 (SE = .56) and a Kurtosis of .63 (SE = 1.09). The years of the university sample (n = 18) ranged from 3-4 to more than six years, with a mean of 4.56 (SD = .78) with a skewness of-1.44 (SE = .54), and a Kurtosis of .44 (SE = 1.04).

Table 4. Time Playing Instruments

Time	High School		University		Total	
	N	Percent	N	Percent	N	Percent
Less than 1 year	1	6.30	0	0.00	1	2.90
1-2 years	1	6.30	0	0.00	1	2.90
3-4 years	4	25.00	3	16.70	7	20.60
5-6 years	6	37.50	2	11.10	8	23.50
More than 6 years	4	25.00	13	72.20	17	50.00
Total	16	100.0	18	100.0	34	100.0

Over half, 58.8% ($n = 20$) of the participants reported they regularly played at least one additional musical instrument besides their primary instrument.

Private Lessons

The number of years participants reported taking private lessons on their primary instrument ranged from zero lessons to more than six years of lessons with a mean of 2.9 (SD = 1.47), a skew of .46 (SE = .40), and kurtosis of -.58 (SE = .79). The high school sample participants taking private lessons on their primary instrument ranged from zero lessons to 3-4 years of lessons with a mean of 2.38 (SD = 1.20), a skew of .21 (SE = .56), and kurtosis of -1.51 (SE = 1.09). The university sample participants taking private lessons on their primary instrument ranged from zero lessons to more than six years of lessons with a mean of 3.3 (SD = 1.57), a skew of .29 (SE = .54), and kurtosis of -.91 (SE = 1.04).

Table 5. Time Taking Private Lessons

Time	High School		University		Total	
	N	Percent	N	Percent	N	Percent
None	5	31.30	2	11.10	7	20.60
Less than 1 year	4	25.00	4	22.20	8	23.50
1-2 years	3	18.80	5	27.80	8	23.50
3-4 years	4	25.00	2	11.10	6	17.60
5-6 years	0	0.00	3	16.70	3	8.80
More than 6 years	0	0.00	2	11.10	2	5.90
Total	16	100.0	18	100.0	34	100.0

Practice Time

The amount of weekly practice time outside of school ensembles reported by the participants (*N* = 34) ranged from zero hours to more than 6 hours with a mean of 3.85 (*SD* = 1.59), skewness of .26 (*SE* = .40), and Kurtosis of -1.30 (*SE* = .79). The average hours per week the high school group ranged from less than 1 hour to more than 6 hours with a mean of 4.67 (*SD* = 1.50), skewness of -.42 (*SE* = .54), and Kurtosis of -1.63 (*SE* = 1.04). The average hours per week for the university group ranged from less than 1 hour to more than 6 hours with a mean of 4.67 (*SD* = 1.50), skewness of -.42 (*SE* = .54), and Kurtosis of -1.63 (*SE* = 1.04).

Table 6. Practice Time Per Week

Time per week	High School		University		Total	
	N	Percent	N	Percent	N	Percent
None	1	6.30	0	0.00	1	2.90
Less than 1 hour	5	31.30	1	5.60	6	17.60
1-2 hours	6	37.50	5	27.80	11	32.40
3-4 hours	3	18.80	2	11.10	5	14.70
5-6 hours	0	0.00	1	5.60	1	2.90
More than 6 hours	1	6.30	9	50.00	10	29.40
Total	16	100.0	18	100.0	34	100.0

Playing by Ear Beliefs

The next group of eight questions on the survey asked the participants to rate (from 0 = Strongly disagree – 100 = Strongly agree) how much they agree with statements regarding their ear-playing experience. Table (#) shows the descriptive results of these questions.

Table 7. Playing by Ear Beliefs

Statement	N	Mean	Std. Dev.	Skew	Kurtosis
I feel comfortable playing by ear on this instrument.	34	56.79	26.67	-.02	-.74
I feel comfortable playing by ear on other instruments.	34	36.35	28.89	.70	-.28
I am good at playing by ear.	34	46.00	27.41	.16	-.41
Playing by ear comes naturally to me.	34	42.15	32.29	.66	-.59
A music teacher helped me learn how to play by ear.	34	26.03	33.51	1.10	-.05
A family member or friend helped me learn to play be ear.	34	10.62	21.72	2.97	9.37
I prefer to play by ear, rather than reading notes.	34	23.03	31.13	1.28	.65
I am good at figuring out songs I hear and playing them on an instrument	34	44.41	32.20	.23	-1.01

Intonation Beliefs

The next group of seven questions on the survey asked the participants to rate (from 0 = Strongly disagree – 100 = Strongly agree) how much they agree with statements regarding intonation. Table (#) shows the descriptive results of these questions.

Table 8. Intonation Beliefs

Statement	N	Mean	Std. Dev.	Skew	Kurtosis
I am confident with the concept of performing with good intonation.	34	75.59	15.29	-.61	-.09
I am confident in my ability to play in tune when performing in an ensemble.	34	75.41	18.49	-.87	.06
When performing in an ensemble, I make a conscious effort to perform with good intonation.	34	93.73	9.78	-1.85	3.61
My band director (or other music. teachers) taught me strategies about how to play with good intonation.	34	82.38	22.27	-1.77	4.27
My band director (or other music teachers) taught me why good intonation is important	34	91.94	14.30	-2.24	5.13
My band director (or other music teachers) use exercises to specifically help improve ensemble intonation.	34	75.47	27.89	-1.18	.693
My band director (or other music teachers) have taught me how to improve my intonation while performing with a piano.	34	56.29	36.43	-.31	-1.32

Ear-playing and Intonation Activities

The next group of six questions on the survey asked the participants to rate (from 0 = Never – 100 = Often) how often they participated in various musical activities. Table 9 shows the descriptive results of these questions. Responses to the four statements in Table 9 with asterisks (*) were used to create an overall mean score for ear-playing frequency and an *ear-playing frequency profile* for each participant. Mean scores were then categorized into five groups; 0-20 = never (1); 21-40 = rarely (2); 41-60 = sometimes (3); 61-80 = somewhat often (4); 81-100 = often (5). The self-reported ear-playing frequency profile score was used as a variable for research question two. Table 10 displays the frequencies of the scores.

Table 9. Ear-Playing and Intonation Activities

Statement	N	Mean	Std. Dev.	Skew	Kurtosis
*I play by ear alone on this instrument or other instruments.	34	31.47	32.39	.74	-.71
Other members of my family play by ear on musical instruments.	34	15.58	28.08	1.90	3.08
*I play by ear on this, or others instruments with family/friends	34	19.11	29.57	1.66	1.86
*I play along with pre-recorded music using this or other instruments.	34	44.41	35.17	.10	-1.32
*I figure out songs I hear by ear and play them on this or other instruments.	34	37.35	33.69	.48	.78
I practice my instrument using an electronic tuner.	34	77.64	28.71	-1.30	.78

Table 10. Ear-Playing Frequency Profiles

Profile Score	High School		University		Total	
	N	Percent	N	Percent	N	Percent
1 - Never	5	31.30	6	33.30	11	32.40
2 - Rarely	4	25.00	5	27.80	9	26.50
3 - Sometimes	5	31.30	5	27.80	10	29.40
4 – Somewhat Often	0	0.00	1	5.60	1	2.90
5 – Often	2	12.50	1	5.60	3	8.80
Total	16	100.0	18	100.0	34	100.0

Descriptive Statistics – Performance Tasks

A series of performance assessments were designed to assess ear-playing ability and intonation performance ability. Ability to play by ear was assessed with two separate tasks as was the ability to play in tune. Each task is described below.

Ear-playing

Ear-playing task #1 and ear-playing task #2 were used to determine ear-playing ability, and both tests used the same exact procedure. For the two ear-playing tasks, participants listened to a four-measure melody and then attempted to play it back on their instrument within 30

seconds. The score for these tasks was the total number of listen-and-repeat cycles required to achieve 90% playback accuracy, up to 12 cycles. Therefore, the lowest possible score for each task was 1 and the maximum was 12. For this task, a lower score was interpreted as greater ear-playing skill. The scores from both tasks were then combined to create a composite ear-playing profile score.

For ear-playing task #1 the minimum score was 2 and the maximum was 12, with a mean of 5.38 (*SD* = 3.41), skewness of .99 (*SE* = .40), and kurtosis of -.33 (*SE* = .78). For ear-playing task #2 the minimum score was 2 and the maximum was 12, with a mean of 5.55 (*SD* = 3.53), skewness of .91 (*SE* = .40), and kurtosis of -.54 (*SE* = .78).

For the total sample (*N* = 34) ear-playing profile scores, the minimum score was 4 and the maximum was 24, with a mean of 10.94 (*SD = 6.44*), skewness of .82 (*SE* = .40), and kurtosis of -.64 (*SE* = .79). The high school sample (*n* = 16) minimum ear-playing profile score was 5.0 and the maximum was 24.0, with a mean of 13.62 (*SD* = 6.82), skewness of .31 (*SE* = .56), and kurtosis of -1.23 (*SE* = 1.09). For the university sample (*n* = 18), the minimum ear-playing profile score was 4.0 and the maximum was 21.0, with a mean of 8.55 (*SD* = 5.18), skewness of 1.48 (*SE* = .53), and kurtosis of 1.16 (*SE* = 1.03).

Table 11. Ear-Playing Profile Scores

Score	High School		University		Total	
	N	Percent	N	Percent	N	Percent
4.0	0	0.00	3	16.70	3	8.80
5.0	2	12.50	2	11.10	4	11.80
6.0	1	6.30	3	16.70	4	11.80
7.0	0	0.00	4	22.20	4	11.80
8.0	3	18.80	1	5.60	4	11.80
9.0	0	0.00	1	5.60	1	2.90
10.0	1	6.30	0	0.00	1	2.90
13.0	1	6.30	1	5.60	2	5.90
14.0	1	6.30	0	0.00	1	2.90
16.0	2	12.50	1	5.60	3	8.80
18.0	1	6.30	0	0.00	1	2.90
19.0	1	6.30	1	5.60	2	5.90
21.0	0	0.00	1	5.60	1	2.90
24.0	3	18.80	0	0.00	3	8.80
Total	34	100.0	18	100.0	34	100.0

Intonation Profile

To create intonation profile scores for the participants, two intonation performance tasks were completed. After tuning their instrument (task #1) intonation task #2 required participants to perform the same melody they learned during ear-playing task #2 in unison with the piano playback. For intonation task #3 the participants performed a simple melody using notation in unison with a piano playback.

Intonation profile scores were determined by first analyzing seven predetermined pitches from each task (Figure 10) to find cents out of tune (cent deviation from equal temperament) for the pitches. Second, the mean of the seven cent-deviation results were calculated to determine the intonation profile score for each task/participant. All negative cent deviations were transformed to positive to accurately determine the mean.

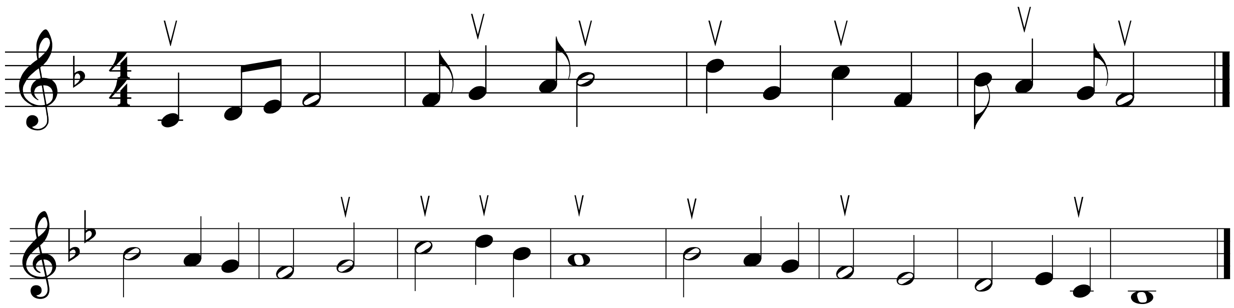

Figure 10. Notation for Intonation Tasks #2 and #3 with Target Pitches Denoted
Note. The "V" above the notes indicates a target pitch to be analyzed for intonation accuracy.

For the total sample (*N* = 34) intonation task #1 (ear-playing intonation task) the minimum cent deviation was 3.8 cents, and the maximum was 30.1 cents with a mean of 12.17 (*SD* = 6.62), skewness of 1.26 (*SE* = .40) and kurtosis of 1.33 (*SE* = .78). The minimum cent deviation for task #2 (notation intonation task) was 4.9 cents and the maximum was 31.7 cents with a mean of 11.1 (*SD* = 5.67), skewness of 1.88 (*SE* = .40), and kurtosis of 4.54 (*SE* = .78).

For the university sample (*N* = 18) intonation task #1 (ear-playing intonation task) the minimum cent deviation was 3.8 cents, and the maximum was 26.1 cents with a mean of 10.66 (*SD* = 5.90), skewness of 1.29 (*SE* = .53) and kurtosis of 1.60 (*SE* = 1.03). The minimum cent deviation for task #2 (notation intonation task) was 4.9 cents and the maximum was 17.3 cents with a mean of 9.3 (*SD* = 3.49), skewness of .70 (*SE* = .53), and kurtosis of -.11 (*SE* = 1.03).

For the high school sample (*N* = 16) intonation task #1 (ear-playing intonation task) the minimum cent deviation was 4.8 cents, and the maximum was 30.1 cents with a mean of 13.88 (*SD* = 7.15), skewness of 1.27 (*SE* = .56) and kurtosis of 1.26 (*SE* = 1.09). The minimum cent deviation for test #2 (notation intonation task) was 6.3 cents and the maximum was 31.7 cents with a mean of 13.04 (*SD* = 7.02), skewness of 1.53 (*SE* = .56), and kurtosis of 2.22 (*SE* = 1.09). See Table 12 for the complete list of the cent deviations for each participants analyzed notes as well as their intonation profile (mean) score for each task.

Table 12. Intonation Test Cent-deviations by Pitch

High School			Analyzed Note Cent Deviation							Mean
Instrument	Username	Test	A	Bb	C1	C2	D	F	G	Dev.
Trumpet	AnchorMn82	1. Ear-play	12.0	0.0	13.0	0..0	0.0	0.0	8.8	4.85
		2. Notated	11.7	11.0	0.0	3.3	-8.9	4.9	4.4	6.31
Flute	bearslol	1. Ear-play	-5.9	-3.7	26.2	6.6	5.9	-7.4	11	9.52
		2. Notated	-16	-22	9.9	-6.6	-2.9	-7.4	8.8	10.52
Alto Sax	BHC	1. Ear-play	15.8	-11	6.6	3.3	-5.9	0	0	6.1
		2. Notated	-12	-15	0	6.6	8.9	0	4.4	6.65
Tuba	CJ_Master	1. Ear-play	-16	14.7	35	-13	0	0	-18	13.78
		2. Notated	-16	14.7	35	0	0	0	17.5	10.45
Tenor Sax	CWC	1. Ear-play	0	22	26.2	26.2	11.7	19.7	26.3	18.87
		2. Notated	7.8	14.7	13.2	19.7	11.7	19.7	26.3	16.15
Clarinet	D1Clarinet	1. Ear-play	0	11.1	19.7	16.4	11.7	9.9	8.8	11.08
		2. Notated	0	11.1	6.6	19.7	8.8	4.9	13.2	9.18
Trombone	DDH	1. Ear-play	-96	0	26.2	6.6	17.6	29.4	35	30.11
		2. Notated	-48	22.1	26.2	13.2	-48	39.1	26.3	31.77
Trumpet	MarkMark	1. Ear-play	-16	-7.4	0	-17	0	-5	13.2	8.28
		2. Notated	-12	-3.7	6.6	-20	-8.9	-9.9	-8.9	9.95
Alto Sax	Remy	1. Ear-play	0	7.4	6.6	6.6	26.3	19.7	21.9	12.64
		2. Notated	0	0	6.6	6.6	8.8	19.7	13.2	7.84
Trumpet	wb194882	1. Ear-play	-12	7.4	45.6	-13	2.9	-5	13.2	14.17
		2. Notated	-12	0	32.7	-9.9	-36	-9.9	-4.4	14.91
Trumpet	Chicken	1. Ear-play	-12	3.7	-6.6	-27	-8.9	-5	-22	12.11
		2. Notated	-12	-7.4	-6.6	-23	-18	4.9	13.2	12.14
Trumpet	238488	1. Ear-play	-24	-19	19.7	-27	-30	-9.9	4.4	18.94
		2. Notated	-16	-19	13.2	-13	-21	-9.9	4.4	13.7
Trombone	Christmas	1. Ear-play	-24	22	39.2	39.2	5.9	9.9	60.7	28.65
		2. Notated	-24	22	52.1	26.2	-5.9	9.9	26.3	23.72
Trombone	Dapperparrot	1. Ear-play	-24	-7.4	13.2	0	-24	-9.9	-8.9	12.4
		2. Notated	-40	7.4	13.2	-27	-36	-9.9	-8.9	20.18
Oboe	Hap4807	1. Ear-play	7.8	11.1	0	23	23.4	5	8.8	11.3
		2. Notated	-3.9	-3.7	0	13.2	5.9	-15	4.4	6.57
Clarinet	Speedracer	1. Ear-play	0	7.4	19.7	6.6	17.6	5	8.8	9.3
		2. Notated	7.8	7.4	19.7	6.6	5.9	5	8.8	8.74

(table con’t.)

University Instrument	Username	Task	Analyzed Note Cent Deviation A	Bb	C1	C2	D	F	G	Mean Dev.
Oboe	IPlayOboe	1. Ear-play	0	3.7	-6.6	3.3	11.7	-4.9	4.4	4.94
		2. Notated	11.7	0	-6.6	3.3	14.7	4.9	0	5.88
Alto Sax	RadishSpirit	1. Ear-play	-3.9	7.4	13.1	6.6	14.7	4.9	8.8	8.48
		2. Notated	0	7.4	6.6	9.9	5.9	4.9	0	4.95
Trumpet	AddictWPen	1. Ear-play	11.7	7.4	19.7	-9.9	8.8	9.9	-22	12.77
		2. Notated	7.8	14.7	13.2	-9.9	0	9.9	11.6	9.58
Alto Sax	Bluhouse35	1. Ear-play	11.7	3.7	6.6	-6.6	0	19.7	17.6	9.41
		2. Notated	11.7	11	0	0	2.9	24.6	17.6	9.68
Fr. Horn	Whatami	1. Ear-play	-32	7.4	26.2	64.4	0	0	17.6	21.02
		2. Notated	-7.9	14.7	13.2	6.6	23.4	19.7	8.8	13.47
Trumpet	Yikesuh	1. Ear-play	7.8	11	32.7	3.3	17.6	0	13.2	12.22
		2. Notated	11.7	11	26.2	6.6	11.7	19.7	8.8	13.67
Bassoon	627	1. Ear-play	-7.9	0	13.2	0	-5.9	0	17.6	6.37
		2. Notated	-7.9	0	13.2	0	0	9.9	17.6	6.94
Flute	Flutegirl12	1. Ear-play	-3.9	1.8	9.9	9.9	17.6	-9.9	-2.2	7.88
		2. Notated	-12	-3.7	0	4.9	-1.5	-17	-2.2	5.92
Trumpet	WhoAmI	1. Ear-play	7.8	7.4	-6.6	0	5.9	0	21.9	7.08
		2. Notated	-7.9	14.7	0	0	5.9	-5	8.8	6.04
Bassoon	6282742	1. Ear-play	0	7.4	26.2	0	11.7	19.7	26.3	13.04
		2. Notated	7.8	7.4	13.2	0	11.7	19.7	26.3	12.3
Fr. Horn	CanesChckn3	1. Ear-play	-48	0	-13	-13	5.9	0	-8.9	12.71
		2. Notated	-24	-7.4	13.2	-20	-12	-9.9	8.8	13.55
Trombone	Musiclvr12	1. Ear-play	7.9	0	0	13.2	17.8	0	8.9	6.82
		2. Notated	7.9	7.4	13.2	0	5.9	19.7	17.6	10.24
Fr. Horn	Reauxtigers	1. Ear-play	-16	0	26.2	-13	11.7	9.9	0	10.97
		2. Notated	-7.8	0	-13	6.6	23.4	9.9	0	8.71
Clarinet	Tmac02	1. Ear-play	0	0	0	3.3	5.9	4.4	13.2	3.82
		2. Notated	3.9	14.7	13.2	6.6	0	4.9	17.6	8.7
Fr. Horn	User23321	1. Ear-play	-24	-15	-13	-34	-24	0	-8.9	16.84
		2. Notated	-24	-7.4	-27	-20	-30	-9.9	4.4	17.37
Clarinet	Abc...4567	1. Ear-play	-7.9	-3.7	0	0	0	-9.9	8.8	4.32
		2. Notated	-7.9	3.7	-6.6	0	-2.9	-15	0	5.14
Oboe	Mck1234	1. Ear-play	16.6	0	6.6	0	17.6	4.4	4.4	7.08
		2. Notated	15.6	3.7	0	-3.3	20.5	4.9	8.8	8.11
Piccolo	Maepy12345	1. Ear-play	23.4	24.8	36	31	21.9	29.4	16.3	26.11
		2. Notated	2.9	13.8	13.2	-5	2.2	14.8	-7.7	8.51

Research Questions

In this next section I will address each research question individually. I will describe the variables and the statistical procedures used for investigation, followed by the outcomes of these procedures.

RQ 1. What Is the Relationship Between the Ability to Play by Ear and Intonation Performance Skill?

To investigate the relationship of ear-playing ability and intonation ability the following variables were used:

a) The ear-playing profile of the total sample (N = 34, M = 10.94, SD = 6.44, skew 1.48, kurtosis 1.16).

b) The intonation profile #1 (mean cent deviations of ear-playing intonation task) of the total sample (N = 34, M = 12.17, SD = 12.17, skew 1.26, kurtosis 1.33).

c) The intonation profile #2 (mean cent deviations of the notated intonation task) of the total sample. (N = 34, M = 11.10, SD = 5.67, skew 1.88, kurtosis 4.54).

The ear-playing profile was used with the intonation profile #1 and the intonation profile #2 in separate statistical procedures to examine the correlations between ear-playing and intonation.

The data did not meet all assumptions for a Pearson's Product-Moment Correlation. A satisfactory linear relationship did not exist for either intonation task (Figures 11, 12) and Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that the variables were not normally distributed. Therefore, Spearman correlation analyses were conducted to examine the relationships between ear-playing skill and intonation performance skill. The data is monotonic and continuous, meeting all assumptions required for the Spearman test.

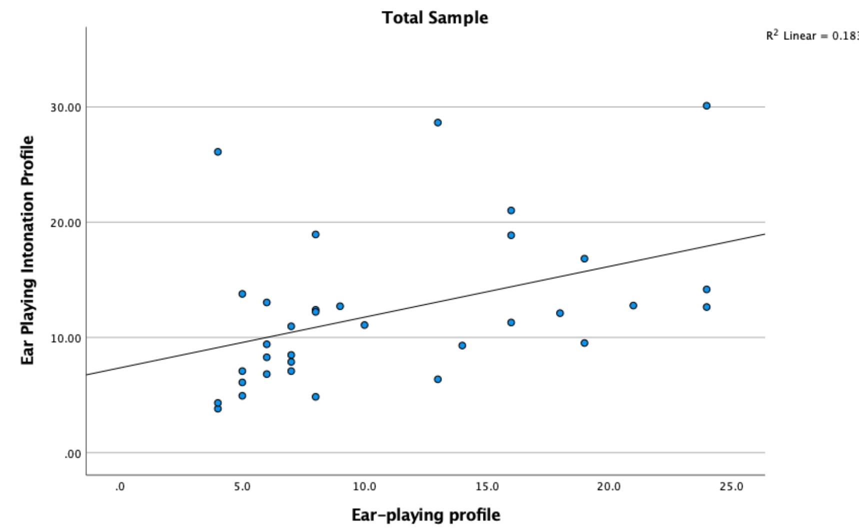

Figure 11. Scatterplot for Relationship Between the Ear-Playing Profile and Intonation Task #2

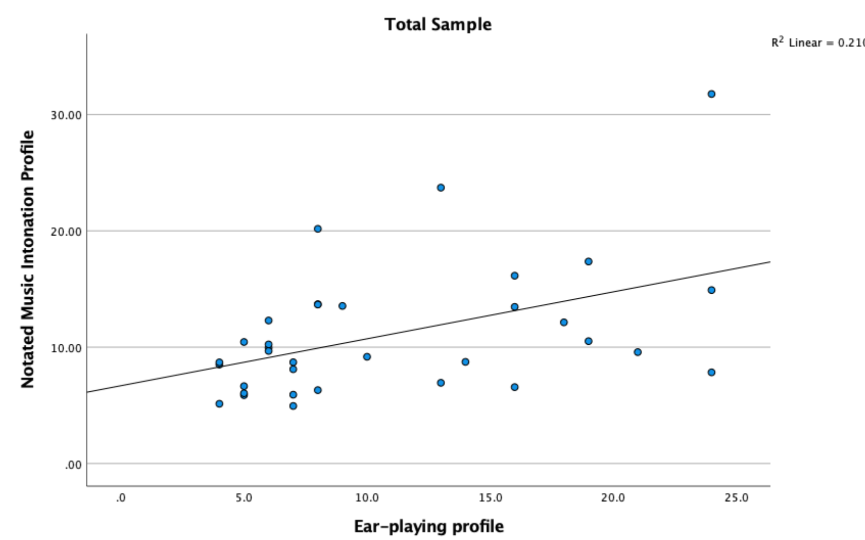

Figure 12. Scatterplot for Relationship Between the Ear-Playing Profile and Intonation Task #3

Results from the Spearman correlation test showed a statistically significant and moderately direct correlation ($\rho = .52$, $p < .01$) when comparing the ear-playing profile scores and intonation task #2. A statistically significant and moderately direct correlation ($\rho = .48$, $p < .01$) also existed when comparing the ear-playing profile scores and intonation task #3 (Table

13). The coefficient of determination was calculated for both outcomes by squaring the correlation coefficient. This resulted in about 26% of the variance for intonation task #2 and about 23% of the variance for intonation task #3 is evident with the ear-playing profile score variables. Even though there is a moderate relationship, there is still much variance (74% and 77% respectively) that is unexplained.

Table 13. Relationships Between Ear-Playing Ability and Intonation Skill – Total Sample

Total Sample		Ear-playing Profile	Intonation Profile #1	Intonation Profile #2
Ear-Playing Profile	Correlation Coefficient	1.000	.515**	.480**
	Sig. (2-Tailed)	.	.002	.004
	N	34	34	34
Intonation Profile #1	Correlation Coefficient	.515**	1.000	.749**
	Sig. (2-Tailed)	.002	.	<.001
	N	34	34	34
Intonation Profile #2	Correlation Coefficient	.480**	.749**	1.000
	Sig. (2-Tailed)	.004	<.001	.
	N	34	34	1634

**Correlation is significant at the 0.01 level (2-tailed).

To examine if differences existed based on the age group of the participants the same variables were used but separated by group. For both the university group and the high school group several of the assumption required for the Pearson's *r* test were not met. A satisfactory linear relationship did not exist, and Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that the variables were not normally distributed. Therefore, Spearman correlation analyses were conducted to examine the relationships between ear-playing skill and intonation performance skill. The data is monotonic and continuous, meeting all assumptions required for the Spearman test.

To investigate if differences exist based on the age group of the participants, I conducted the Spearman correlation analysis on each group separately, using the same variables.

For the high school group there was no statistically significant correlation when comparing the ear-playing profile and intonation task #1 ($\rho = .39, p < .14$), or intonation task #2 ($\rho = .28, p < .30$).

Table 14. Relationships Between Ear-Playing Ability and Intonation Skill – High School

High School Group		Ear-playing Profile	Intonation Profile #1	Intonation Profile #2
Ear-Playing Profile	Correlation Coefficient	1.000	.390	.276
	Sig. (2-Tailed)	.	.136	.302
	N	16	16	16
Intonation Profile #1	Correlation Coefficient	.390	1.000	.791**
	Sig. (2-Tailed)	.136	.	<.001
	N	16	16	16
Intonation Profile #2	Correlation Coefficient	.276	.791**	1.000
	Sig. (2-Tailed)	.302	<.001	.
	N	16	16	16

**Correlation is significant at the 0.01 level (2-tailed).

However, for the university group, a statistically significant and moderately direct correlation was found when comparing the ear-playing profile and intonation task #1 ($\rho = .47, p < .05$) and the ear-playing profile and intonation task #2 ($\rho = .49, p < .05$).

Table 15. Relationships Between Ear-Playing Ability and Intonation Skill - University

University Group		Ear-playing Profile	Intonation Profile #1	Intonation Profile #2
Ear-Playing Profile	Correlation Coefficient	1.000	.472*	.485*
	Sig. (2-Tailed)	.	.048	.042
	N	18	18	18
Intonation Profile #1	Correlation Coefficient	.472*	1.000	.616**
	Sig. (2-Tailed)	.048	.	.006
	N	18	18	18
Intonation Profile #2	Correlation Coefficient	.485**	.616**	1.000
	Sig. (2-Tailed)	.042	.006	.
	N	18	18	18

**Correlation is significant at the 0.01 level (2-tailed).

RQ 2. How Does Intonation Ability Differ When the Participants Sightread Printed Music Notation Compared to Performing Music That Has Been Learned by Ear?

To examine the differences between intonation task #2 (performing melody learned by ear) and intonation task #3 (performing a melody from printed notation) the intonation profile scores (#2 and #3) will be used as the variables.

When conducting the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality, it was determined that both intonation profile #2 and #3 scores were not normally distributed, also outliers existed in both the intonation profiles. Because the assumptions for an independent t-test were not met I used the Wilcoxon test to explore the differences between the two intonation tasks. Since the intonation profile scores are continuous and independent from any other observation, all assumptions were met for the Wilcoxon test. The Wilcoxon test revealed no statistically significant difference between intonation ability while playing a melody learned by ear and playing a melody using music notation. (Wilcoxon $Z = -1.13$, $p = .26$).

Table 16. RQ 2 Wilcoxon Test Results

Descriptive Statistics

	N	Mean	Std. Dev.	Min.	Max
Ear-playing profile	34	10.94	6.44	4.00	24.00
Ear-playing frequency	34	2.29	1.24	0.00	6.00

Ranks

		N	Mean Rank	Sum of Ranks
Intonation task #2	Negative ranks	16[a]	22.74	363.50
Intonation task #3	Positive ranks	18[b]	12.86	231.50
	Ties	0[c]		

a. Intonation test #2 < Intonation test #3
b. Intonation test #2 > Intonation test #3
c. Intonation test #2 = Intonation test #3

(table con't)

Wilcoxon Signed Ranks Test

	Int. test #2 – Int. test #3
Z	-1.13[a]
Asymp. Sig.	.26

a. Based on positive ranks.

RQ 3. Do Differences Appear in Ear Playing Ability Based on Selected Musical Experiences of the Participants?

To determine if a significant difference in ear-playing ability exists based on musical experiences, the ear-playing profile scores will be used with the following variables:

a. Years of experience

b. Private lesson experience

c. Personal weekly practice time

d. Frequency of ear-playing

Years Of Experience

To explore the relationship between ear-playing ability and the years of experience the participants have had playing the instrument, the survey data of years playing will be used in conjunction with ear-playing profile scores.

Table 17. Years Playing Test Instrument – Total Sample

Time	Frequency	Percent
Less than 1 year	1	2.90
1-2 years	1	2.90
3-4 years	7	20.60
5-6 years	8	23.50
More than 6 years	17	50.00
Total	34	100.0

The Kolmorgorov-Smirnov and Shapiro-Wilk tests of normality determined that the years playing data was not normally distributed. Additionally, when conducting the Levene test of Homogeneity of Variances with the ear-playing profile scores, it was determined that homogeneity was violated. Since the assumptions required to use a One-Way ANOVA were not met I used the nonparametric Kruskal-Wallis analysis of variants test to explore the relationship between years of experience and ear-playing. This data was ordinal, categorical, and was observed independent of any other observation, meeting all assumptions to use the Kruskal-Wallis test.

The ear-playing profile scores served as a dependent variable alongside years of experience (0-1 year, 1-2 years, 3-4 years, 5-6 years, 6+ years) as the independent variables. When conducting the Kruskal-Wallis test, significant differences in ear-playing ability were found based on the years of experience playing their instrument (H = 10.02, df = 4, p = .04).

Table 18. RQ 3 Kruskal-Wallis Test Results – Years of Experience

Descriptive Statistics

	N	Mean	Std. Dev.	Max	Min.
Ear-playing Profile	34	10.94	6.44	4.0	24.0
How long have you played this instrument	34	4.15	1.04	1.0	5.0

Ranks

	How long have you played this instrument?	N	Mean Rank
Ear-playing profile	Less than 1 year	1	28.00
	1-2 years	1	26.00
	3-4 years	7	22.00
	5-6 years	8	22.38
	More than 6 years	17	12.24
	Total	34	

(table con't)

Kruskal-Wallis Test Statistics

	Ear-playing profile
Kruskal-Wallis H	10.02
Df	5
Asymp. Sig	.04

In order to examine where actual differences existed among the five experience groups, I conducted post hoc Mann-Whitney U pairwise comparisons and found a significant difference occurred between groups 3-4 years and 6+ years ($U = 21$, $p = .014$, $r = -.50$), and between groups 5-6 years and 6+ years ($U = 34$, $p = .046$, $r = -.39$). On the basis of the effect size of these groups, I conclude that the differences between these groups are both statistically and practically significant, warranting further exploration and consideration.

Table 19. RQ3 Years of Experience Post Hoc Mann-Whitney U Test Results

Mann-Whitney Test Ranks

	How long have you played this instrument	N	Mean Rank	Sum of Ranks
Ear-playing profile	3-4 years	7	18.00	126.00
	More than 6 years	17	10.24	174.00
	Total	24		

Mann-Whitney Test Statistics – 3-4 years; More than 6 years

	Ear-playing profile
Mann-Whitney U	21.00
Wilcoxon W	174.00
Z	-2.46
Asymp. Sig. (2-tailed)	.014
Exact Sig. (1-tailed sig.)	.013

(table con't)

Mann-Whitney Test Ranks

	How long have you played this instrument	N	Mean Rank	Sum of Ranks
Ear-playing profile	5-6 years	8	17.25	138.00
	More than 6 years	17	11.00	187.00
	Total	25		

Mann-Whitney Test Statistics – 5-6 years; More than 6 years

	Ear-playing profile
Mann-Whitney U	34.00
Wilcoxon W	187.00
Z	-1.99
Asymp. Sig. (2-tailed)	.046
Exact Sig. (1-tailed sig.)	.049

Private Lessons

To explore the relationship of ear-playing ability and the years of private lessons the participants have had, the survey data of years of private lessons will be used in conjunction with the ear-playing profile scores. As previously shown, the ear-playing profile scores are not equally distributed. Additionally, a Kolmorgorov-Smirnov and a Shapiro-Wilk tests of normality determined that the years of private lessons data was also not normally distributed.

Since the data was not normally distributed, all the assumptions required to us a One-Way ANOVA were not met. Because of this, I used the Kruskal-Wallis test to explore the relationship between years of private lessons and ear-playing ability. This data was ordinal, categorical, and was observed independent of any other observation, meeting all assumptions to use the Kruskal-Wallis test.

To determine if a significant difference exists between ear-playing ability and years the participants have taken private lessons, the ear-playing profile scores served as a dependent variable alongside years of private lessons (none, less than 1 year, 1-2 years, 3-4 years, 5-6 years,

6+ years) as the independent variables. When conducting the Kruskal-Wallis test, no significant differences in ear-playing ability were found based on years of private lessons ($H = 3.84$, $df = 5$, $p = .57$).

Table 20. RQ 3 Kruskal-Wallis Test Results – Years of Private Lessons

Descriptive Statistics

	N	Mean	Std. Dev.	Min.	Max
Ear-playing profile	34	10.94	6.44	4.00	24.00
Years of private lessons	34	2.88	1.47	1.00	6.00

Ranks

	Years of Private Lessons	N	Mean Rank
Ear-playing profile	None	7	17.36
	Less than 1 year	8	20.88
	1-2 years	8	19.31
	3-4 years	6	16.67
	5-6 years	3	9.67
	More than 6 years	2	11.50

Kruskal-Wallis Test Statistics – years of private lessons on test instrument

	Ear-playing profile
Kruskal-Wallis H	3.84
df	5
Asymp. Sig.	.57

Personal Weekly Practice Time

To explore the relationship between ear-playing ability and the hours of weekly personal practice time, the total sample survey data of years of hours per week of personal practice will be used in conjunction with the ear-playing profile scores.

A Kolmorgorov-Smirnov and a Shapiro-Wilk tests of normality determined that the hours per week of personal practice data was not normally distributed. Additionally, it has been previously shown that the ear-playing profile scores are also not normally distributed.

Table 21. Personal Weekly Practice Time

Time per week	High School		University		Total	
	N	Percent	N	Percent	N	Percent
None	1	6.30	0	0.00	1	2.90
Less than 1 hour	5	31.30	1	5.600	6	17.60
1-2 hours	6	37.50	5	27.8	11	32.40
3-4 hours	3	18.80	2	11.10	5	14.70
5-6 hours	0	0.00	1	5.60	1	2.90
More than 6 hours	1	6.30	9	50.00	10	29.40
Total	16	100.0	18	100.0	34	100.0

Since the data was not normally distributed, all the assumptions required to us a One-Way ANOVA were not met. Because of this, I used the Kruskal-Wallis test to explore the relationship between personal practice time and ear-playing ability. This data was ordinal, categorical, and was observed independent of any other observation, meeting all assumptions to use the Kruskal-Wallis test.

To determine if a significant difference exists between ear-playing ability and hours per week of personal practice, the Kruskal-Wallis analysis of variants test was performed. The questionnaire data of the number weekly hours of personal practice by each participant created six subject groups: none, less than 1 hour, 1-2 hours, 3-4 hours, 5-6 hours, more than 6 hours. For the Kruskal-Wallis test, these six groups were used along with the ear-playing profile scores and was determined that no significant differences in ear-playing ability were found based on the amount of personal practice time. ($H = 3.81$, $df = 5$, $p = .58$).

Table 22. RQ 3 Kruskal-Wallis Test Results – Personal Weekly Practice Time

Descriptive Statistics

	N	Mean	Std. Dev.	Min.	Max
Ear-playing profile	34	10.94	6.44	4.00	24.00
Hours of personal practice per week	34	3.85	1.59	1.00	6.00

Ranks

	Personal Weekly Practice	N	Mean Rank
Ear-playing profile	None	1	5.50
	Less than 1 hour	6	18.83
	1-2 hours	11	20.18
	3-4 hours	5	19.10
	5-6 hours	1	9.50
	More than 6 hours	10	14.95

Kruskal-Wallis Test Statistics – personal weekly practice time

	Ear-playing profile
Kruskal-Wallis H	3.81
df	5
Asymp. Sig.	.57

Ear-playing Frequency

To explore the relationship between ear-playing ability and the frequency that participants play by ear, the total sample ear-playing frequency score will be used in conjunction with the ear-playing profile scores. To create an ear-playing frequency score for each participant, four survey questions asking the participants to rate how often they play by ear in different scenarios (alone, with family/friends, with prerecorded music, figure out songs by ear) were combined and calculated to create the data.

Table 23. Ear-playing frequency profiles

Profile Score	High School		University		Total	
	N	Percent	N	Percent	N	Percent
1 - Never	5	31.30	6	33.30	11	32.40
2 - Rarely	4	25.00	5	27.80	9	26.50
3 - Sometimes	5	31.30	5	27.80	10	29.40
4 – Somewhat Often	0	0.00	1	5.60	1	2.90
5 – Often	2	12.40	1	5.60	3	8.80
Total	16	100.0	18	100.0	34	100.0

A Kolmorgorov-Smirnov and a Shapiro-Wilk tests of normality determined that the ear-playing frequency scores were not normally distributed. Additionally, it has been previously shown that the ear-playing profile scores are also not normally distributed.

Since the data was not normally distributed, all the assumptions required to us a One-Way ANOVA were not met. Because of this, I used the Kruskal-Wallis test to explore the relationship between ear-playing frequency and ear-playing ability. This data was ordinal, categorical, and was observed independent of any other observation, meeting all assumptions to use the Kruskal-Wallis test.

To determine if a significant difference exists between ear-playing ability and ear-playing frequency, the Kruskal-Wallis analysis of variants test was performed. The five ear-playing frequency groups were used along with the ear-playing profile scores, determining that no significant differences in ear-playing ability were found based on the ear-playing frequency of the participants. ($H = 4.08$, $df = 3$, $p = .25$).

Table 24. RQ 3 Kruskal-Wallis Test Results – Ear-Playing Frequency

Kruskal-Wallis Test Descriptive Statistics

	N	Mean	Std. Dev.	Min.	Max
Ear-playing profile	34	10.94	6.44	4.00	24.00
Ear-playing frequency	34	2.29	1.24	0.00	6.00

Ranks

	Ear-playing frequency	N	Mean Rank
Ear-playing profile	Never	10	19.60
	Rarely	7	17.29
	Sometimes	13	17.19
	Somewhat often	0	0.00
	Often	3	6.83

Kruskal-Wallis Test Statistics – ear-playing frequency

	Ear-playing profile
Kruskal-Wallis H	4.08
df	3
Asymp. Sig.	.25

Summary

The ear-playing profile scores were used along with multiple other variables to investigate relationships between ear-playing ability and these variables, including intonation, years of experience, practice time, private lessons, and ear-playing frequency.

The following is a synthesis of the findings and the information presented in the figures and tables.

Summary of Results for the Relationship Between Ear-Playing and Intonation Skills.

When comparing ear-playing profile scores with the two intonation profiles:

1. For the total sample, a moderately direct correlation was found between ear-playing and intonation skill when the intonation melody was learned then performed by ear (Intonation profile #2).

2. For the total sample, a moderately direct correlation was found between ear-playing and intonation skill when the intonation melody was performed using notated music (Intonation profile #3).
3. For the high school group, no correlation was found between ear-playing or either of the intonation profiles
4. For the university group, a moderately direct correlation was found between ear-playing and both intonation profile #2 and intonation profile #3.

Summary of Results for the Relationship Between Intonation Ability When Learning a Melody by Ear Compared to Playing A Melody Using Notated Music.

When comparing Intonation profile #2 with Intonation profile #3:

1. No significant difference occurred between intonation ability while playing a melody learned by ear and playing a melody using notated music.

Summary of Results for the Relationship Between Ear-playing and Other Selected Musical Experiences.

When comparing the ear-playing profile scores with the following musical experience variables:

1. Years of experience – Significant differences in ear-playing ability were found based on years of experience. Significant differences occurred between groups 3-4 years, 5-6 years and 6+ years.
2. Private lessons – No significant differences in ear-playing ability were found based on the number of years of private lessons.
3. Personal practice time – No significant differences in ear-playing ability were found based on the amount of weekly personal practice time.

4. Ear-playing frequency – No significant differences in ear-playing ability were found based on the amount of ear-playing that is done by the participant.

In the next chapter I will discuss what these results mean and how they connect with prior research from the literature review. I will also discuss how the findings from this research has provided important implications for music educators for the skills of both ear-playing and intonation. Lastly, I will provide recommendations for further research.

Chapter 5. Discussion

Introduction

The purpose of this study was to investigate the relationship between ear-playing skills and intonation performance of high school and university wind (brass and woodwind) instrumentalists. Ear-playing was defined as performing on one's instrument without the aid of notation or other visual cues. Intonation performance was defined as a pitch performed on a wind instrument at the time and the same frequency as a given pitch. Differences in ear-playing skills were also examined based on the participants demographic variables of years of experience playing their instrument, years of private lessons on their instrument, their amount of weekly personal practice time, and their frequency of ear-playing.

Participants ($N = 34$) were wind instrumentalists from two separate band programs, a high school group ($n = 16$) and a university group ($n = 18$). Each participant completed an on-line questionnaire to provide relevant information about their musical background and experiences. Next, each participant was recorded performing four tasks.

Two tasks were used to measure ear-playing ability. The first task required participants to listen to a 4-measure melody, then attempt to reproduce that same melody without using notation. The total number of attempts to recreate the melody at 90% accuracy was recorded. The second task was the same as the first, however, a different 4-measure melody was used. The total number of listen-then-repeat cycles needed to achieve 90% performance accuracy for each task was used to create an ear-playing profile score.

Next, two tasks were used to measure intonation performance ability. In the first task, the participant performed the melody that was previously learned by ear during the second ear-playing task in unison with a piano recording. In the second intonation task the participant

performed a simple 8-measure melody in unison with a piano recording using notated sheet music. For each task, seven target pitches from each melody were evaluated using the Audacity® frequency analyzer, then converted to cent deviations from equal temperament. The mean of the cent deviations from the seven target pitches was used as the intonation profile score, providing two intonation profile scores for each participant.

Spearman correlation analysis indicated a moderate direct relationship between ear-playing and intonation performance within the total sample. However, when both groups were analyzed independently, significances only existed in the university group. Additionally, the two intonation tasks were used as variables to examine the differences in intonation when a melody was learned by ear and when a melody was learned with support of notation. A Wilcoxon test revealed no significant differences between the two.

Survey data was used to investigate the relationship between selected musical experiences and ear-playing ability. To examine this relationship, a Kruskal-Wallis test was performed using the ear-playing profile scores with the following musical experiences as variables: years of experience, private lesson experience, personal practice time, and frequency of ear-playing. The only variable that was related to ear-playing was the years of experience the participants had playing their instrument, with significance between those who have played 3-4 years, 4-5 years, and 6 or more years.

In this chapter, I will restate each research question and the findings from the analysis, discuss in terms of how these findings connect to/align with existing research, and discuss implications for music teaching and learning and music teacher preparation. Next, I will review limitations and discuss suggestions for future research. I will conclude with practical applications by providing a few suggestions of how ear-playing can be implemented into a curriculum.

Research Question 1.

What is the Relationship Between the Ability to Play by Ear and Intonation Performance Skill?

Analysis indicated a moderate direct relationship between ear-playing and intonation performance when learning a melody by ear within the total sample. However, when both groups were analyzed independently, significances only existed in the university group.

Analyses revealed that those people who are skilled at playing by ear are also likely to be skilled at playing in tune. When people play by ear, they are focusing very closely on the pitch to be able to replicate it on their instrument. Finding the correct pitch may be the first step or prerequisite to the finer skill of adjusting the pitch of a note to be in tune. Those with greater ear-playing skills can hear and match pitches quickly and efficiently; this pitch-matching efficiency could be attributed to how the musician listens to and hears the pitches. Those with greater ear-playing skills may have an approach to listening that gives them an understanding of how to match pitches on their instrument, and this understanding could transfer from pitch matching to pitch adjusting.

These findings coincide with what Davis (2019) found when investigating the pedagogical techniques used by highly effective band directors for intonation improvement with their students. Among the three main themes that emerged, developing aural skills, including pitch matching, was one of the most common among all the directors. These band directors use pitch matching with their students during the first phase of their learning, often beginning with singing to help develop the young students' musical goal image. They capitalize on the findings of Gordon (1985), Priest (1989), and Woody & Lehmann (2010) that the mental representation

of music is an important element in developing pitch matching skills, and what Woody (2003) found in that singing is closely related to one's mental representation of music.

The band directors then transitioned from singing to ear-playing on their instruments to continue to their development process. These strategies are often done prior to the introduction of sheet music, following the sound-before-sight approach to music learning that is "grounded in the work of pedagogues such as Zoltan Kodaly, Shinichi Suzuki, Edwin Gordon…" (Davis, 2019 p. 129). This allows the students to focus their development on musical goal image and executive skills without the added element and distraction of deciphering notation.

Both the ear-playing tasks and the intonation tasks in this study required participants to match pitches, either after a melody was heard (ear-playing tasks) or in unison with a piano recording (intonation tasks). The results from this study and the findings by Davis (2019) provide evidence that ear-playing is a valuable skill towards the improvement of intonation performance. This finding is not surprising given that many researchers, including Gordon (1985), Priest (1989) Woody (2003), and Woody & Lehmann (2010) support similar findings. The pedagogical technique used by highly effective band directors of developing pitch matching skills for intonation improvement further supports the relationship between ear-playing and intonation performance.

Differences existed based on the school level of the participants. The high school group showed no significant relationship between ear-playing skill and intonation performance. However, a significant moderately direct relationship was found with the university group for both intonation task #2 and #3, indicating that more years of experience may contribute to the relationship between ear-playing and intonation. These findings were in line with Yarbrough et al. (1997) who found that experience relates to intonation accuracy, positing that those

participants who played their instrument more frequently were more successful with intonation accuracy.

Research has shown that ear-playing instruction is largely absent from ensemble rehearsals (Musco, 2010), and the survey data from this study is consistent with those findings. When asked to rate how much they agree (0 = never through 100 = often) to the statement "A music teacher taught me how to play by ear" the mean of these responses was 26.03 (SD = 33.2), which provides further evidence that students are not receiving much, if any formal ear-playing instruction in school music classes. With ear-playing instruction being largely absent from school instruction, the participants who show greater ear-playing ability likely learned and honed these skills outside of ensemble rehearsals. Subsequently, it can be argued that musicians with greater ear-playing ability may spend more time playing their instrument outside the school ensemble.

Implications

The relationship between ear-playing and intonation performance in this study aligns with the work of other researchers in these areas (Davis, 2019; Yarbrough et. al., 1997). Music educators would benefit from incorporating ear-playing into their curriculum towards intonation improvement. The research of Hatson (2003) and Priest (1989) support this notion of including ear-playing within a balanced instrumental music curriculum. With listening and hearing being a main element of intonation performance, creating opportunities for students to develop and improve their listening skills through ear-playing activities could be a big step toward overall intonation improvement.

Playing by ear requires effective listening skills and giving students more opportunities to play by ear could help them not just improve their listening skills, but also develop a greater

understanding of how and what to listen for as it relates to their specific instrument. The development of these listening skills will lead to more effective and efficient pitch matching, ultimately transferring to greater intonation accuracy. This aligns with many researchers and pedagogues that have stressed how good intonation is essential for a successful performance (Ballard, 2011; Geringer et al., 2001; Karrick, 1998; McBeth, 1972; Ravelli, 1938; Wapnick & Freeman, 1980).

Research Question 2.

How Does Intonation Ability Differ When the Participants Sightread Printed Music Notation Compared to Performing Music That Has Been Learned by Ear?

I used the Wilcoxon test to explore the differences between intonation task #2 (melody learned and performed by ear) and intonation tasks #3 (melody performed using notation). The Wilcoxon test revealed that no significant differences existed between the two tasks, indicating that intonation is not positively or negatively affected by the method of which the melody was learned and performed.

This is a surprising result, as there have been several researchers (Azzarra, 1993; Baker & Green, 2013; Gordon, 1985; Liperote, 2006; Woody & Lehmann, 2010) who posit that the idea of a *goal image*, or *tonal image* is an important element for overall musical performance, and ear-playing positively contributes to this. It was expected that the melody that was learned by ear would have provided the participants with a better goal/tonal image in preparation of their intonation task, causing higher intonation accuracy than the melody that was performed using notation.

Performing a melody learned by ear versus performing a melody using notation did not elicit any differences in intonation performance in this study. One factor that could have

contributed to this result is that the simplicity of the notated melody may have provided an advantage for successful intonation performance. The melody was built from one of the most common young band scales (B-flat), with most notes changing stepwise, and using rhythmic values no shorter than quarter notes. Based on these elements and the previous experience of the participants, it could be argued that it was easy for the participants to build a tonal image of this melody just from viewing it. Further exploration of this is warranted to gain a better understanding of how tonal image affects intonation performance and how ear-playing skills may contribute. Expanding the current test design to include notated melodies with higher complexity could provide a clearer picture of notated intonation performance to compare with ear-playing intonation performance.

Implications

Results from this study imply that a goal or tonal image is an important concept towards successful intonation performance. Providing ways for students to understand, develop, and improve their concept of goal/tonal image could be an additional tool for music educators to use towards intonation improvement. Ear-playing exercises that utilize various intervallic patterns along with various tonal centers may build a greater understanding of goal and tonal images for students on their instrument, leading to a greater understanding of intonation performance. Additionally, building an understanding of goal images through ear-playing practices may lead to greater effectiveness of other musical skill, such as sight-reading and expressivity. As Luce (1965) stated “the importance of the ear in musical performance indicates that ear-playing may possibly be more important in developing musicianship than sight-reading” (p. 107).

Research Question 3.

Do Differences Appear in Ear Playing Ability Based on Selected Musical Experiences of the Participants?

When examining the relationship between ear-playing skills and, 1. the selected musical experiences of years of experience playing the instrument, 2. years of private lesson experience, 3. hours of weekly personal practice time, and 4. frequency of ear-playing activities significant differences in ear-playing ability were only found with the years of experience. This provides further evidence that gaining years of experience could be one key element towards developing ear-playing skills.

Results from this study suggest that ear-playing skills do improve with years of experience. One possible explanation for this phenomenon is that the musicians gain a mental understanding and muscle memory of their instrument over time while playing/practicing their everyday repertoire. The ear-playing examples used in this study were designed to be similar to the types of melodies instrumental music students typically learn in their first and second year of formal instruction. As the student progresses beyond simple melodies and into more complex compositions and arrangements, they may still experience pattern-based passages in their repertoire. It is possible that experiencing this pattern-based repertoire repeatedly in daily rehearsal during their most formative stages of development contribute to their mental understanding and muscle memory, consequently developing the basics of their ear-playing ability, even if ear-playing was not a focus of their instruction, practice, or performance (Gerber, 1992; McPherson, 2005).

However, this may only be a small piece of a more complex issue. It is known that there are many successful musicians who read notation at a high level but do not play or cannot play

by ear successfully or comfortably (Hartz & Bower, 2016; Isbell, 2016; Woody, 2012). As found by Gerber (1992) playing from notation at a high level may contribute to the development of rudimentary ear-playing skills, but if ear-playing is absent from practice, the skill may not develop past a basic skill. Findings by Woody & Lehmann (2010) support the notion that vernacular musicians (musicians who make music using informal approaches, including ear-playing), have greater ear-playing skills than non-vernacular musicians. Another important related finding from this study is that vernacular musicians used their conceptual knowledge of music to build a goal image, whereas the non-vernacular were influenced by their knowledge of music theory.

The results from the Woody & Lehmann (2010) study that show that musicians with greater ear-playing experience play by ear with more success than those with less ear-playing experience. This is not surprising, as those who regularly participate in an activity tend to be more familiar with it. However, results from this study show no statistically significant relationship between ear-playing frequency and ear-playing ability, which is surprising and unforeseen.

It was expected that the frequency of ear-playing by the participants would directly reflect their ear-playing ability, but this was not the case. The participants in my study had a range of previous experience with ear-playing, with a majority reporting they had little to no experience. Nearly 59% of the participants fell into the lowest categories of “never” or “rarely” play by ear, whereas only 11.7% fell into the highest categories of “somewhat often” or “often” play by ear. The remaining 29.4% were in the middle category of “sometimes” play by ear. The ones who reported playing by ear most frequently had high ear-playing skills, but the number of participants in this category was very low—only four participants (11.7%). Those four

participants unsurprisingly scored among the best on both ear-playing tasks, with their mean score being 5.25 (out of 24). Conversely, there were 11 participants (32.4%) in the lowest category of "never" play by ear, with their mean score being 12 (out of 24), which were among the lowest scores on the ear-playing tasks. Based on this, there does appear to be a relationship between ear-playing frequency and ear-playing ability. However, an interesting and surprising phenomenon occurred in the form of outliers and may explain why a statistically significant relationship does not appear in my results.

The outliers were three participants who scored among the best in ear-playing ability but who were in the lowest categories of ear-playing frequency. Perhaps there are other unexplored demographic variables such as an influence of a musical family, number of concerts attended, types and frequency of music that is listened to, or myriad other possibilities that may account for this.

Other possible explanations for the lack of a significant relationship could be due to a small *N* or because of data collection methods for creating the ear-playing profile scores and/or the ear playing frequency scores. The ear-playing profile scores were created by tabulating how many listen-then-repeat cycles it took for a participant to achieve at least a 90% replication on the ear-playing tasks, up to a maximum of 12 attempts. This, however, was a judgment call by me in the moment, which may have negatively impacted internal validity. Additionally, the ear-playing frequency scores were created using survey data that reflected only the current practices of the participants on their primary instrument; however, the survey did not have questions that would have provided information regarding their past experiences with ear-playing activities or other possible influences.

Implications

Results from this study show a relationship between ear-playing and years of experience. Similar results from research by Morrison (2000) and Yarbrough et al. (1997) also revealed a positive relationship with years of experience; however, intonation ability was the dependent variable, not ear-playing skill. Other studies involving ear-playing as a variable (Bernhard, 2004; Haston 2010; Luce 1965; McPherson & Gabrielsson, 2002; and Musco, 2009), revealed that ear-playing experience contributed to other elements of musical performance, such as sight-reading, expressiveness, improvisation, and playing from memory. Together, these findings show that musical experience does factor into musical growth, and ear-playing can be an important element. However, participants in this study do not provide evidence of a relationship between ear-playing skill and ear-playing frequency, with most of them having low ear-playing frequency. Perhaps the participants from my study do not play by ear more often because they do not possess the strategies needed to begin. Additionally, there may be a stigma around ear-playing by teachers or peers, discouraging them from participating in such activities, much like what was found by McPherson & Gabrielsson (2002), and Musco (2010). The idea that ear-playing may discourage or distract from learning how to read notation or inhibit sigh-reading skills, the attitudes that note-readers versus non-note-readers often have towards each other, and the focus on large ensemble traditions are some stigmas and challenges that may be experienced. Combatting these stigmas/challenges and creating more opportunities for students to develop their ear-playing skills within their curriculum would add to their variety of experiences and contribute to their musical growth. Results from a study by Musco (2009) align with this theory, showing that middle school band students improved on sight-reading skills in certain keys after practicing ear-playing in those keys.

Another element to consider is the level of awareness that ear-playing is a recognized form of music making. It may be possible that some young music students are not aware that playing by ear is a natural and recognized form of music making. They may need to be reminded that playing from notation is not the only way to be musical, and that many musicians around the globe and across time have made music this way. Introducing this practice at a young age may encourage students to explore their instruments away from notation and develop their ear-playing skills, consequently developing their musicianship. This may also provide extra-musical benefits for students such as higher enjoyment levels in music making, higher retention with music, and greater confidence and autonomy as a performer. (Bauer & Hartz, 2016; Glenn 1999; and Varvarigou & Green 2015).

Limitations

The following limitations may have influenced data collection, analysis, and subsequent interpretation of findings.

Piano Playback Melodies

The melodies that were performed by the piano for the participants to either listen to or play along with were played in octaves to facilitate for the various instrument ranges. However, hearing octaves may have affected the interpretation or conceptualization of the melody by the participants, potentially causing a barrier to learning the melodies by ear. The choice to have the melodies performed in octaves was not supported by research and posed a threat to validity.

Ear-playing Tasks

The method of measuring ear-playing skill was ultimately subjective in that it relied upon a judgment call regarding the level of accuracy. This judgement was based on the goal of 90% accuracy (three errors or less) and was a similar method utilized in a study by Woody &

Lehmann (2010). Even though a random sample of the final performances that were considered successful were evaluated by three music educators to help strengthen construct validity, it is possible that the margin for error with this approach was larger than the use of other methods, such as a computer.

Frustration and defeat were obvious for some of the participants who struggled to learn the melodies by ear, and this emotional state may have affected other portions of the testing procedures. Additionally, since the first intonation tasks required that the participants play a learned-by-ear melody, those participants who could not learn it accurately by ear on their own after the allotted number of tries were given verbal assistance by the researcher for them to be able to successfully perform the melody as needed for the intonation task. This may have affected the data for the intonation task.

Intonation Tasks

The intonation testing and analysis procedures for this study had potential limitations. For the task procedures, the main limitation existed with the playback sound that the participants performed in unison with. Piano was chosen based on research showing that it is the most familiar and neutral sound for wind players (Delzell et al., 1999). Using high-quality recordings of like instrument for the intonation tasks may have provided different results. Playing in unison with a like instrument is much more likely to occur in ensemble settings and it is possible that musicians would be more comfortable matching pitch with the same instrument.

A limitation with the frequency analyzer is that it only provides whole numbers with no tenths position, rounding to the nearest whole number. When converting the frequencies to cent deviations, there could be an inaccuracy by up to 5 cents in the lower-frequency instruments. However, the higher the frequency is, the less of a difference that the tenths position affects the

conversion to cent deviation. Middle range notes may be off by only 1-2 cents, and higher range notes may have a difference of less than one cent. The notes that would be most affected by this are the notes in the lower tuba range for the intonation tests. Since only one tuba participated in this study, there is no threat to validity based on this limitation. Software that provides greater details in frequency analysis or software that analyzes and provides cent conversion could help provide greater accuracy, especially in the lower frequency instruments.

Second, when determining the frequency of each note, the entire duration of the note was analyzed. This was to account for vibrato as well as intonation adjustments. The limitations exist because not all notes were the same length. The note lengths varied from one beat, two beats, or four beats.

Third, this study did not discriminate or account for tone quality in the intonation tasks. Tone quality is an important element for successful musicianship, and the lack of discrimination may have provided unreliable results. Future research would benefit by taking this into account, either by eliminating the recordings with unacceptable tone quality, or by including the tone quality as a variable.

Lastly, these intonation tasks only analyzed playing in unison with a piano sound, i.e., pitch matching. While pitch matching is important towards successful intonation performance, it is only a small part of the overall intonation process required by wind instrumentalists. Results would likely be very different if the complex elements of harmonies, chords, and melodic intervals were explored.

Further Research

The results from this study show that ear-playing skills are related to intonation performance. However, further investigation is warranted to explore if selected experiences (e.g.,

years of experience, private lessons, practice time) along with ear-playing ability show a relationship to intonation performance skill. Discovering if the combined elements reveal a positive relationship could provide for a stronger argument for more ear-playing instruction in music education and a curriculum design that targets the elements that contribute the greatest.

It appears that ear-playing skills improve with years of experience and further investigation is needed to discover in what ways ear-playing skills are acquired. It may be especially valuable to learn what has influenced people that have high ear-playing skill but low ear-playing frequency. Exploring the musical experiences of successful ear-players in greater detail, including their past activities and family influence, could reveal what has influenced their ear-playing ability and how it has developed over time. This could include a qualitative portion to help achieve a richer story of their early musical development, family history, and personal musical influences throughout their lifetime. Results could inform curriculum design and practice strategies toward the development of ear-playing.

While witnessing the participants complete the ear-playing tasks, it was interesting to see the various approaches they used to try and learn the melodies. It was obvious that some participants had a clear and successful strategy, while others struggled. Varvarigou & Green, (2015) created categories for ear-playing strategies and my participants could have been sorted similarly. What is not clear from previous research is why participants choose the strategy they used or how they acquired those strategies. Is it something that was taught to them? Is it something that is innate? Further exploration of which strategies provide greater success towards ear-playing ability and how participants learn these successful strategies could be a step towards developing a curriculum for ear-playing, with a focus on usability for teachers and students with little to no previous ear-playing experience.

Another surprising outcome of the data collection procedure came from the short conversations with the participants after they completed all the tasks. One topic that arose from these conversations was that even though many of them rarely play by ear, they enjoyed the ear-playing portion, see a value of ear-playing towards overall musicianship, and intend to do it more often during their own practice time. This aligns with finding from studies by Hartz and Bauer (2016), Glenn (1999), and Varvarigou & Green (2015), who all reported that ear-playing offered both musical and extra-musical benefits, similar to how the participants reacted during the informal post-task conversations. A longitudinal experimental/control study that consistently incorporates ear-playing into a curriculum from beginning through high school level may reveal what musical or extra-musical benefits ear-playing offers to instrumental students.

Practical Applications

Given the amount of evidence this document has shown regarding the musical and extra-musical benefits of ear-playing, it is important to provide information for music educators to help incorporate ear-playing into their curriculum. The following suggestions are just a few ways that ear-playing could be used with various grade levels of instrumentalists. These suggestions are not meant to be a comprehensive list or a replacement for a curriculum, rather, activities to sprinkle into an existing curriculum, to serve as a jumping off point, as well as a spark for creativity. After implementing these suggestions, the next step would be to continue the process by developing or seeking out more creative ideas to foster ear-playing within a balanced curriculum. Consistency in implementing ear-playing activities is essential for improvement.

Pitch Matching

This is a simple activity that could be used in any instrumental setting and with any age group. Using an instrument of choice, a single pitch is sounded and held for 4 seconds. The

students are then asked to sing the pitch on a neutral syllable, followed by matching it on their instrument only using their ears, without any visual cues. They should be encouraged to make adjustments until they find the correct pitch. This process can be repeated until success is obtained by all students. When used with younger students, pitches used should be limited only to the notes that are known by them.

Rote Songs

This is a process where the student learns a melody only by hearing it played by another instrument (either a recording or live) without any visual cues. The complexity of the melody should be appropriate in length and technical ability based on the performance level of the student. Below are some examples of how this process could be used in different class settings.

Beginning Band/Orchestra

An appropriate ability-level melody should be chosen. If a method book is being used as curriculum, choosing all or a portion of a melody from a song that is a few pages beyond what they have practiced yet will provide them an extra connection to reading the notation to a melody they already learned by ear. Daily listening to a recording of this melody before, after, and during class as well as at home should be done for familiarity. Students should be encouraged to learn and demonstrate this melody by ear only.

High School Band/Orchestra

All or a portion of a melodic theme is selected from the current repertoire being practiced in class. This melodic theme is performed either live or from a recording. The goal is for all students to learn to play the theme by ear only without visual cues. To account for the fact that many students will have the theme notated in their sheet music, the theme could be transposed and demonstrated in a different key so that all students are able to learn the melody by ear only.

Talking Instruments

For this exercise a list of short, well-known quotes or sentences is created and given to the students. The purpose of this exercise is to choose and perform a sentence from the list using a musical instrument. The chosen sentence should be read aloud first to help establish a sense of rhythm, melodic contour, and mood. Depending on the experience-level of the students, limitations of using only known notes could be implemented. After students practice their sentences, they could then perform it for the class, partner, or teacher with the goal of having others be able to recognize which sentence was being performed. Below are a few examples of short sentences that could be used. Longer sentences or quotes could be included as the students gain more experience.

1. Practice makes perfect!
2. Home is where the heart is.
3. True friends are friends for life.
4. Music makes the world go around.
5. Dance like there is nobody watching.

Call and Response Echo

Variation 1

The director, on an instrument of choice, chooses and plays (at random) from a page of created melodic passages. The students then try to play back what they heard. The director can choose to or not to tell the students which pitch the melody starts on. It is suggested that if the director-chosen instrument is one that is played by any students in the room that the director's hands be concealed as to not visually "give away" the answers to those students.

Variation 2

Students volunteer to choose and play a passage for other students to echo. Only the student who volunteers and is playing at the time may have his/her passages available to look at.

These exercises can progress from the limited range of beginning band into more complexity as the students gain more experience. Melodic passages can be grouped by starting pitch to aid in organization. Figure 13 is an example excerpt score for a beginning band class.

Figure 13. Call/Response Excerpt for a Beginning Band Class – Concert B-flat Starting Pitch

Melody and Bass

Recordings of a high/medium range instrument performing a melody and a low range instrument playing a bass line together are provided to students. The goal of the exercise is for the student to listen to and learn to play both the melody and the bass line on their instrument by ear only, then perform them in duets or ensembles.

A variation of this could be to provide recordings of three different bass lines of the same length, one of which fits well with a selected melody from their known curriculum. They perform the selected melody along with the provided bass line recordings to choose which bass line sounds the best with the melody. After choosing a bass line, the student then learns the bass line by ear to perform as a duet or in an ensemble with the melody. The complexity of the bass lines and selected melodies should be appropriate to the experience level of the students.

Question and Answer

This exercise is similar to the call and response echo exercise, however, instead of the students echoing the short melodic example, the goal is to perform a musical "answer" completely made up by ear to a short melodic "question" phrase. Guidance of using only the notes from a certain scale or only the known notes (if a young student) could be used if desired. This can be done in conjunction with teaching musical concepts of themes and phrasing.

Finale

As shown by the myriad research presented in this document, ear-playing skills can have many musical and extra musical benefits for musicians. The goal of all music educators should be to provide students with a well-rounded and enriching musical experience, to which the training of ear playing skills will contribute greatly. The suggested exercises above may serve as a starting point for incorporating ear-playing into a balanced curriculum and to ultimately

contribute to a positive impact in the overall success of instrumental of music education. It is my hope that through this research and the research by the many other scholars on the topic of ear-playing, music educators of all grades, ages, and settings will discover the benefits that ear-playing has to offer and actualize this valuable aspect of musicianship into their curriculum.

Appendix A. IRB and Subject Sampling

IRB Approval

TO:	Daniel Scott Isbell LSUAM | Col of MDA | Music
FROM:	Alex Cohen Chairman, Institutional Review Board
DATE:	14-Oct-2021
RE:	IRBAM-21-1056
TITLE:	An examination of relationships between ear-playing skills and intonation skills of high school and college-aged wind instrumentalists
SUBMISSION TYPE:	Initial Application
Review Type:	Exempt
Risk Factor:	Minimal
Review Date:	13-Oct-2021
Status:	Approved
Approval Date:	13-Oct-2021
Approval Expiration Date:	12-Oct-2024
Exempt Category:	2b
Requesting Waiver of Informed Consent:	No
Re-review frequency:	Three Years
Number of subjects approved:	40
LSU Proposal Number:	
By:	Alex Cohen, Chairman

Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.

5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc. Approvals will automatically be closed by the IRB on the expiration date unless the PI requests a continuation.**

** All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/research*

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Consent Script Form – University Sample

Study Title: An examination of relationships between ear-playing skills and intonation skills of high school and college-aged wind instrumentalists

Principal Investigator: Ben Herrick

Advisor: Daniel Isbell

1. Purpose: The purpose of this study is to examine relationships between ear-playing skills and intonation skills of secondary-level and college-level wind instrumentalists. Wind instrumentalist (brass and woodwind) students from any of the Louisiana State University instrumental music programs are invited to participate because they are part of a college-level instrumental music program. 40 participants (across two school sites) will be recruited for this study. Participation will require approximately fifteen minutes for each subject to complete the procedures.

2. Procedures: Students who volunteer to participate in this study will each participate in a 15-minute individual performance session where they will be asked to play a pre-determined set of melodies on their primary instrument. During this session, the audio-only portion of their performance will be recorded (no video) for later analysis. They will also be asked to complete a short questionnaire to help determine musical background, experience, and basic demographic information.

3. Performance Site: For the college-level participants, procedures will take place in the LSU Music and Dramatic Arts building, room 255.

4. Risks: There are no known risks to participating in this study.

5. Benefits: Participation in this study may not directly benefit the student. The study may identify a link between ear-playing ability and intonation performance which could lead to developing new successful strategies for improving both ear-playing skills and intonation performance, creating a more rewarding experience for wind instrumentalists.

6. Inclusion Criteria: Any wind instrumentalist (e.g., brass or woodwind instruments) currently participating in any LSU instrumental music programs

7. Exclusion Criteria: Students who do not meet enrolment requirement or do not play wind instruments (e.g., percussion or string instruments) will be excluded.

8. Voluntary Participation and Withdrawal: Participation is voluntary, and a participant will become part of the study only if they agree to participation. At any time, the subject may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

9. Confidentiality: We will keep all the student records private to the extent allowed by law. Ben Herrick and Dan Isbell have access to the information participants provide. The audio recordings will be stored on a designated hard drive which will remain locked in the researcher's home office. The questionnaire data will be stored in password protected cloud-based storage provide by LSU. Participants' names will not be used on any of the data. Instead, the participants will create a unique username so that the questionnaire and audio recordings can be linked together. Students will not be identified personally.

10. Financial Information: There is no cost for participation in the study. To compensate for their time, all college-level participants will receive a gift card in the amount of $5.00 at the completion of their participation.

11. Contact Persons: Contact Ben Herrick at bherr15@lsu.edu or Dan Isbell at disbell1@lsu.edu if you have questions, concerns, or complaints about this study.

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subject's rights or other concerns, I can contact Alex Cohen, Chairman, LSU Institutional Review Board, (225) 578-8692, irb@lsu.edu, or www.lsu.edu/research. I agree to participate in the study described above and acknowledge the researcher's obligation to provide me with a copy of this consent form if signed by me.

Subject Signature____ Date _______________

School Administrator Permission Form – High School Sample

Study Title: An examination of relationships between ear-playing skills and intonation skills of high school and college-aged wind instrumentalists

Principal Investigator: Ben Herrick **Advisor:** Daniel Isbell

1. Purpose: The purpose of this study is to examine relationships between ear-playing skills and intonation skills of secondary-level and college-level wind instrumentalists. Wind instrumentalist (brass and woodwind) students from the Catholic High School band are invited to participate because they are part of a secondary-level instrumental music program. 40 participants (across two school sites) will be recruited for this study. Participation will require approximately fifteen minutes for each subject to complete the procedures.

2. Procedures: Students who volunteer to participate in this study will each participate in a 15-minute individual performance session where they will be asked to play a pre-determined set of melodies on their primary instrument. During this session, the audio-only portion of their performance will be recorded (no video) for later analysis. They will also be asked to complete a short questionnaire to help determine musical background, experience, and basic demographic information.

3. Performance Site: For the secondary-level participants, procedures will take place in the music wing of Catholic High School, Baton Rouge.

4. Risks: There are no known risks to participating in this study.

5. Benefits: Participation in this study may not directly benefit the student. The study may identify a link between ear-playing ability and intonation performance which could lead to developing new successful strategies for improving both ear-playing skills and intonation performance, creating a more rewarding experience for wind instrumentalists.

6. Inclusion Criteria: Any wind instrumentalist (e.g., brass or woodwind instruments) in grades 9-12 is eligible for participation

7. Exclusion Criteria: Students who do not meet grade-level requirement or play wind instruments (e.g., percussion or string instruments) will be excluded.

8. Voluntary Participation and Withdrawal: Participation is voluntary, and a student will become part of the study only if both student and parent agree to the student's participation. At any time, either the subject may withdraw from the study or the subject's parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

9. Confidentiality: We will keep all the student records private to the extent allowed by law. Ben Herrick and Dan Isbell have access to the information participants provide. The audio recordings will be stored on a designated hard drive which will remain locked in the researcher's home office. The questionnaire data will be stored in password protected cloud-based storage provide by LSU. Participants' names will not be used on any of the data. Instead, the participants will create a unique username so that the questionnaire and audio recordings can be linked together. Students will not be identified personally.

10. Financial Information: There is no cost for participation in the study, nor is there any compensation to the secondary-level subjects for participation

11. Contact Persons: Contact Ben Herrick at bherr15@lsu.edu or Dan Isbell at disbell1@lsu.edu if you have questions, concerns, or complaints about this study.

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subject's rights or other concerns, I can contact Alex Cohen, Chairman, LSU Institutional Review Board, (225) 578-8692, irb@lsu.edu, or www.lsu.edu/research. I agree to participate in the study described above and acknowledge the researcher's obligation to provide me with a copy of this consent form if signed by me.

School Administrator Signature_____________________________________ Date __________

Parent Permission Form – High School Sample

Study Title: An examination of relationships between ear-playing skills and intonation skills of high school and college-aged wind instrumentalists

Principal Investigator: Ben Herrick

Advisor: Daniel Isbell

1. Purpose: Your child invited to participate in a research study. The purpose of this study is to examine relationships between ear-playing skills and intonation skills of secondary-level and college-level wind instrumentalists. Your child is invited to participate because they are part of a secondary-level instrumental music program. 40 participants (across two school sites) will be recruited for this study. Participation will require approximately fifteen minutes of your child's time.

2. Procedures: If you and your child decide to participate, your child will be invited to participate in a 15-minute individual performance session where they will be asked to play a pre-determined set of melodies on their primary instrument. During this session, the audio-only portion of their playing will be recorded (no video) for later analysis. They will also be asked to complete a short questionnaire to help determine musical background, experience, and basic demographic information.

3. Performance Site: For the secondary-level participants, procedures will take place in the music wing of Catholic High School, Baton Rouge.

4. Risks: There are no known risks to participating in this study.

5. Benefits: Participation in this study may not directly benefit your child. The study may identify a link between ear-playing ability and intonation performance which could lead to developing new successful strategies for improving both ear-playing skills and intonation performance, creating a more rewarding experience for wind instrumentalists

6. Inclusion Criteria: Any wind instrumentalist (e.g., brass or woodwind instruments) in grades 9-12 is eligible for participation

7. Exclusion Criteria: Students who do not meet grade-level requirement or play wind instruments (e.g., percussion or string instruments) will be excluded.

8. Voluntary Participation and Withdrawal: Participation is voluntary, and a child will become part of the study only if both child and parent agree to the child's participation. At any time, either the subject may withdraw from the study or the subject's parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

9. Confidentiality: We will keep your child's records private to the extent allowed by law. Ben Herrick and Dan Isbell have access to the information participants provide. The audio recordings will be stored on a designated hard drive which will remain locked in the researcher's home office. The questionnaire data will be stored in password protected cloud-based storage provide by LSU. Participants' names will not be used on any of the data. Instead, the participants will

create a unique username so that the questionnaire and audio recordings can be linked together. Your child will not be identified personally.

10. Financial Information: There is no cost for participation in the study, nor is there any compensation to the secondary-level subjects for participation

11. Contact Persons: Contact Ben Herrick at bherr15@lsu.edu or Dan Isbell at disbell1@lsu.edu if you have questions, concerns, or complaints about this study.

12. Copy of Consent Form to Subject: We will give you a copy of this consent form to keep.

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subject's rights or other concerns, I can contact Alex Cohen, Chairman, LSU Institutional Review Board, (225) 578-8692, irb@lsu.edu, or www.lsu.edu/research. I agree to participate in the study described above and acknowledge the researcher's obligation to provide me with a copy of this consent form if signed by me.

Parent Signature____ Date _____________

Parent Printed ____ Date _____________

Researcher ____ Date _____________

LSU

Principal Investigator - Ben Herrick
Advisor – Dr. Daniel Isbell

Institutional Review Board
Dr. Alex Cohen, Chair 1
30 David Boyd Hall
Baton Rouge, LA 70803
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Child Assent Form – High School Sample

I,____________________________________, agree to participate in a study that will help examine the relationship between ear-playing and playing in tune. I will participate in a 15-minute-long individual recording session, during which I will be audio-only recorded (no video) performing a few simple melodies using my primary musical instrument. I will also complete a questionnaire that asks about my background and experience with music. My participation will take place at school in the music wing. I can decide to stop being in the study at any time without any problems.

Child's Signature: ____________________________ Age: ______ Date: _____________

Witness* _________________________________ Date: _________________
* (N.B. Witness must be present for the assent process, not just the signature by the minor.)

Principal Investigator - Ben Herrick
Advisor – Dr. Daniel Isbell

Institutional Review Board
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High School Participant Sign-up Sheet

Name (first and last)	**Instrument**	**Band Name**

University Participant Sign-up Sheet

Name (first and last)	**Instrument**	**Email Address**

University Volunteer Email

Dear (Volunteer name)

Thank you so much for your interest in helping me out with my research (and earning 5 bucks)! I appreciate it beyond words!

The activity will take place in the Music building on the second floor in room 255 and will only take about 15 minutes to complete.

Please visit the following link to sign-up for a participation time (starting next week)

https://www.signupgenius.com/go/10C0C4DA4A92AA4F8C5-instrumental

All that you will need is your instrument - there is nothing to prepare for. I will just have you play a few simple melodies. It'll be fun!

If you have any questions, please let me know.

Thank you, I'm looking forward to this!

Ben Herrick
Ph.D. Candidate
Louisiana State University

High School Parent Information Email

Dear (…) High School Band Parent,

A Music Education Ph.D. candidate from LSU feels that (…) HS band students would be excellent participants for his important dissertation research. He visited the band classes last week to tell about it, and your student has signed up to volunteer for participation.

Please visit the following link for complete details and to grant permission for your child to participate. You student will not be allowed to participate without completing this form.

http://lsu.qualtrics.com/jfe/form/SV_72gcSGdIkTtJqSi

Thank you,

(Name)
Assistant Band Director
(…) High School

Appendix B. Task Elements

Survey Questions

Default Question Block

Please create a unique username that does NOT contain any part of your real name.
You may use letters and numbers.
This will only be used to link this questionnaire to your playing portion of this study.
All of your information will remain anonymous.
(remember this username for later)

Do you give your consent to participate in this study? (This includes answering basic questions about your music background as well as making an audio recording on your instrument.)

Yes, I agree

No, I do not agree

How old are you?

What instrument are you playing for participation in this study?

How long have you played this instrument?

Less than 1 year

1-2 Years

3-4 Years

5-6 Years

More than 6 years

How many years of private lesson have you had on the instrument played for this study?

None

Less than a year

1-2 Years

3-4 Years

5-6 Years

More than 6 years

Please list any other instruments you play regularly.

How many years have you taken private lesson on OTHER musical instruments?

None

Less than a year

1-2 Years

3-4 Years

5-6 Years

More than 6 years

How many hours a week (on average) do you practice the instrument used for this study outside of school ensembles?

None

Less than 1

1-2

3-4

5-6

More than 6

Block 1

Use the slider to rate how much you agree with the following statements about playing by ear.

	Strongly disagree		Somewhat disagree		Neither agree nor disagree		Somewhat agree		Strongly agree		
	0	10	20	30	40	50	60	70	80	90	100
I feel comfortable playing by ear on this instrument											
I feel comfortable playing by ear on other instruments											
I am good at playing by ear											
Playing by ear comes naturally to me											
A music teacher helped me learn how											

to play by ear.

A family member or friend helped me learn how to play by ear.

I prefer to play by ear, rather than reading notes

I am good at figuring out songs I hear and playing them on an instrument

Use the slider to rate how much you agree with the following statements about intonation (playing in tune).

	Strongly Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

0 10 20 30 40 50 60 70 80 90 100

I am confident with the concept of performing with good intonation

I am confident in my ability to play with good intonation (in tune).

When performing in an ensemble, I make a conscious effort to perform with good intonation.

My band director(s) (or other music teachers) have taught me strategies about how to play with good intonation

My band director(s) (or other music teachers) have taught me why good intonation is important
My band director(s) (or other music teachers) use exercises to specifically help improve ensemble intonation
My band director(s) (or other music teachers) have taught me how to improve my intonation while performing with a piano

Rate the following statements based on <u>how often</u> you participate.

		Never		Rarely		Sometimes		Somewhat often		Often	
	0	10	20	30	40	50	60	70	80	90	100
I play by ear alone on this instrument or other instruments											
Other members of my family play by ear on musical instruments											
I play by ear using this or other instruments together with family or friends											

I play along with pre-recorded music using this or other instrument

I figure out songs I hear and play them this or other instruments

I practice my instrument using an electronic tuner

Powered by Qualtrics

Task Script

Ear-Playing/Intonation Study – Task Script

Introduction

Hello and thank you for participating in this study. I know your time is valuable and I appreciate your willingness to participate.

Please sit in a comfortable playing position so that the microphone may be adjusted to suite you. After the mic is adjust feel free to play the B-flat scale or other notes of your choice to acclimate yourself to the room and the set-up. Please do your best to play in the same position into the microphone for the entire event today.

Okay, let's begin.

Task #1 (Ear-playing)

For this first task you will hear a 4-measure melody two times in a row.
After you hear the melody the second time, you will have 30 seconds to do your best to play it back with the correct rhythms and notes on your instrument. If you don't quite get it, it's ok. You can listen again and have another 30 second trial period as many times as it takes until you are successful.

To begin you will first hear a single piano note, a chord, and the piano note again. The single piano note will act as the starting pitch for the melody. The starting pitch printed on the sheet in front of you, labeled "Melody 1"

Here is the starting pitch and chord.

(Play recording of Melody Session starting pitch) (A)

Now, please find and play the pitch printed on the sheet in front of you labeled "Melody 1."

Please listen to the melody two times, then make your best attempt to play it on your instrument.

(Play recording of the melody twice)

After 30 seconds, ask if they want to hear it again (if they don't ask first)
(Repeat until they are able to play the whole melody successfully or until they give in)

<u>Task #2</u> (Intonation)

For this task you will use your personal tuning procedures to tune your instrument to a Concert B-flat played by a piano.

The piano B-flat will play three times. Each pitch will sound for 5 seconds, with a 5 second pause in between. During this time, please tune your instrument accordingly.
Tuning will begin now.

(Play "Tuning" recording)

Now that your instrument is tuned, please play the concert B-flat one last time along with the piano recording. You will be prompted to begin playing.

(Play Bb Intonation" recording)

<u>Task #3</u> (Ear-playing)

For this task, you will follow the same procedures as your first task, but the melody will be different.

Here is the starting pitch and chord.

(Play recording of Melody Session starting pitch) (A)

Now, please find and play the pitch printed on the sheet in front of you labeled "Melody 2."

Please listen to the melody two times, then make your best attempt to play it on your instrument.

(Play recording of the melody twice)

After 30 seconds, ask if they want to hear it again (if they don't ask first)
(Repeat until they are able to play the whole melody successfully or until they give in)

<u>Task #4</u> (Intonation)

For this task, you will play "Melody #2" that you just learned by ear, but you will perform it in unison along with the piano recording. You will have two tries to complete this task with your best possible accuracy.

There will be a clear tempo and count-in for you to begin.

Here is your first attempt

(Play recording)

Here is your second try.

(Play recording)

<u>Task #5</u> (Intonation)

For this task you will perform a notated melody using sheet music in unison with a piano recording. You will have two tries to complete this task with your best possible accuracy.

You have 1 minute to study the provided sheet music before the task begins. Please observe the key signature. You may play your instrument during the 1-minute study time.

There will be a clear tempo and count-in for you to begin.

Here is your first attempt

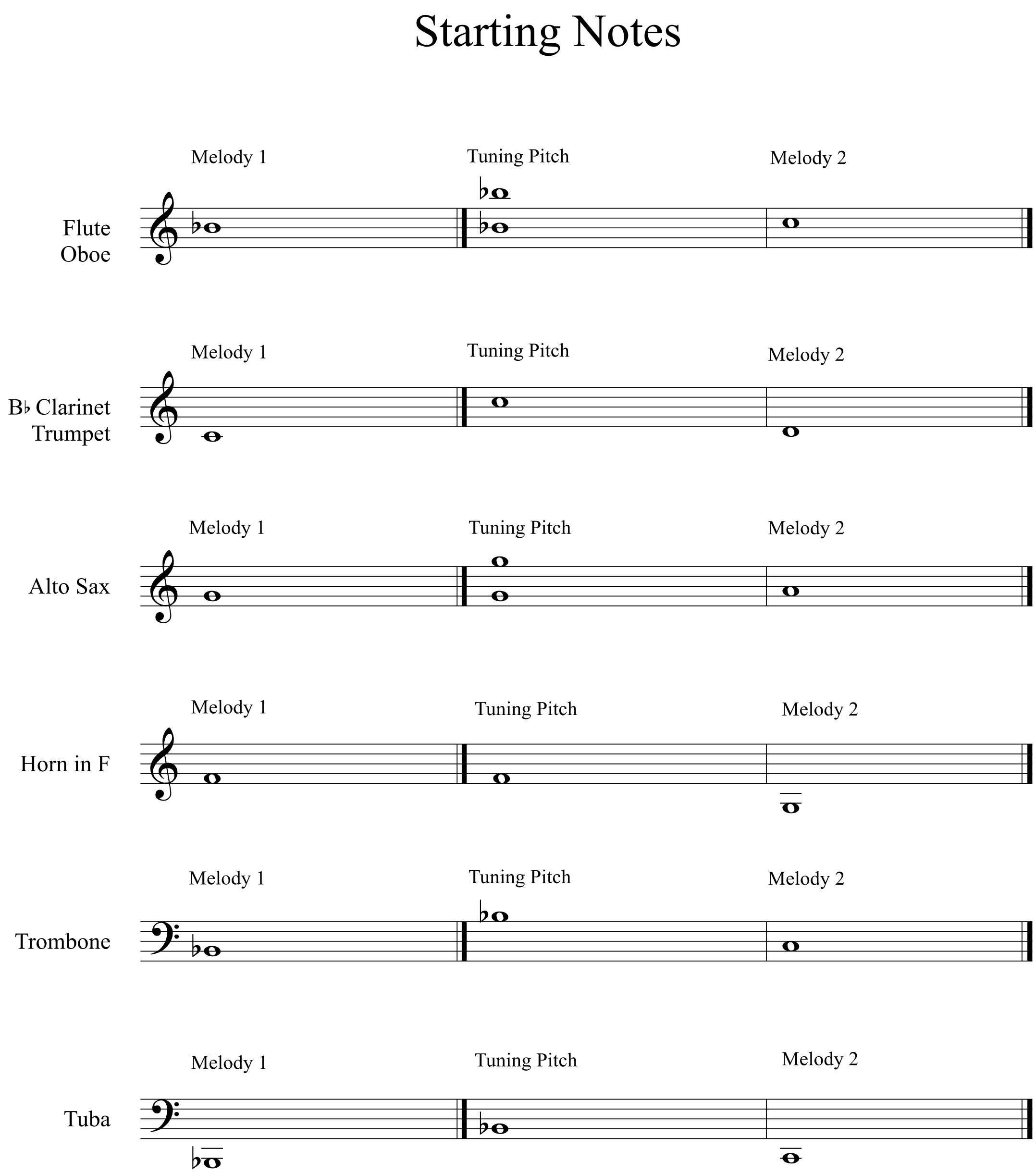
(Play recording)

Here is your second try.

(Play recording)

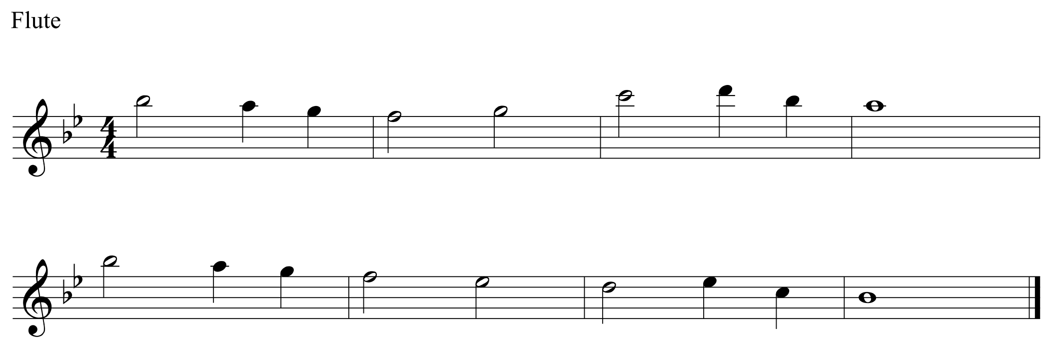
Thank you very much for participating today. This research will contribute to the important body of research on the topic of playing by ear and intonation.

Starting Notes and Tuning Pitch Notation



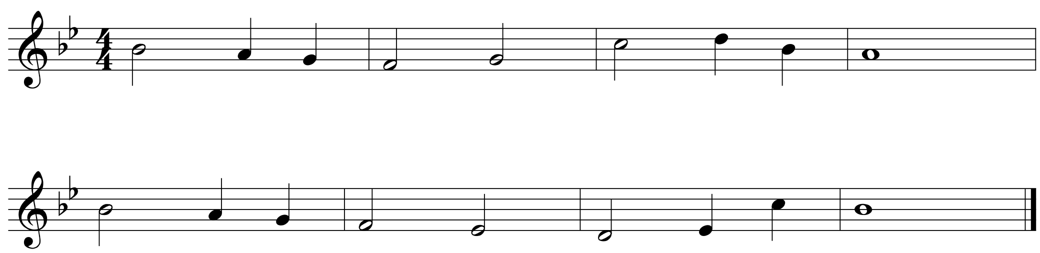
Notated Intonation Task Notation

Notated Melody - Task #5



Notated Melody - Task #5

Oboe

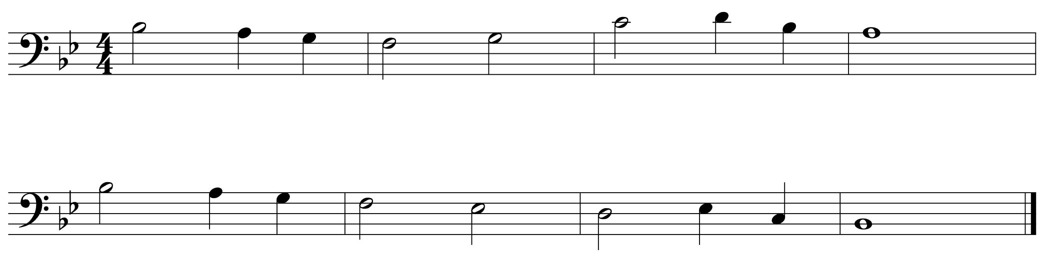


Notated Melody - Task #5

Clarinet
Trumpet

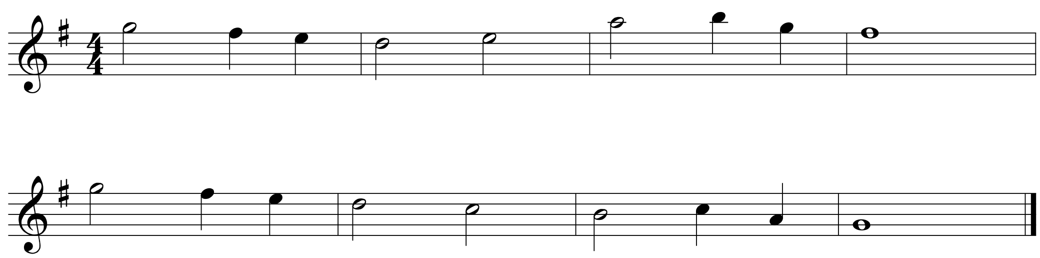
Notated Melody - Task #5

Basssoon
Trombone



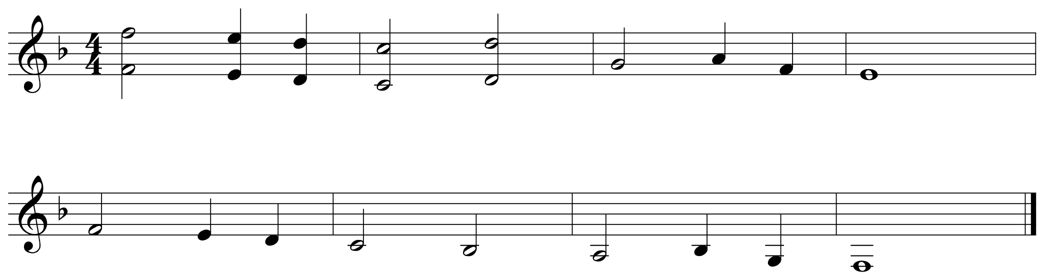
Notated Melody - Task #5

Alto Sax



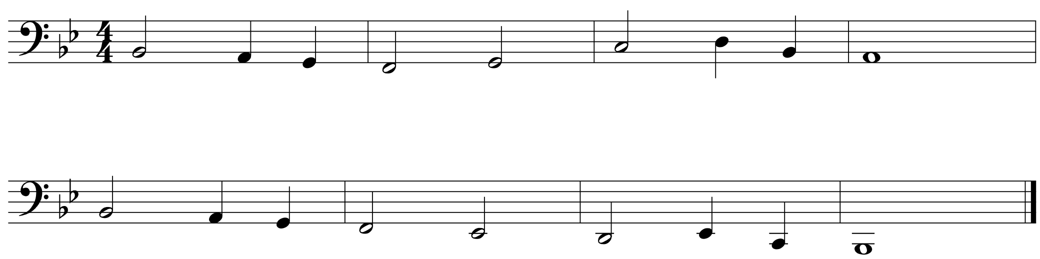
Notated Melody - Task #5

Horn in F
Choose high or low option



Notated Melody - Task #5

Tuba



Evaluator Sheets

A[redacted]S[redacted] - Evaluator #1

Sample #	Incorrect notes	Incorrect rhythms	Total
5	0.5		99.5
7	0.5		99.5
8			100
10			100
13	1		99
15			100
23			100
25	1		99
27	0.5		99.5
31			100
32			100
33			100
34			100
35			100
41		0.5	99.5
44			100
48	1	2	97 *
53	0.5		99.5
54	0.5		99.5
57	0.5		99.5

Instructions for Grading:
1 point for completely incorrect note
1/2 point for almost incorrect note (initially played wrong but adjusted very quickly to be correct incorrect octave)
1 point for completely incorrect rhythmic error
1/2 for slight rhythmic error/incorrect timing

Use your best judgement on this to determine if you believe each performance was within 90% accuracy of the original melody - 3 points total deduction = 90% accuracy.

[redacted] S [redacted] - Evaluator #2

Sample #	Incorrect notes	Incorrect rhythms	Total
2	0	0	0
3	0	0	0
4	0	0	0
6	0	0	0
9	2	0	2
10	0	0	0
11	0	0	0
15	0	0	0
17	0	0	0
18	0	0	0
24	0.50	0	0.5
29	0	0	0
30	0	0	0
31	0	0	0
35	0	0	0
37	0	0	0
40	1	1	2
48	1	1	2
55	0	0	0
56	0	0	0

Instructions for Grading:
1 point for completely incorrect note
1/2 point for almost incorrect note (initially played wrong but adjusted very quickly to be correct incorrect octave)
1 point for completely incorrect rhythmic error
1/2 for slight rhythmic error/incorrect timing

Use your best judgement on this to determine if you believe each performance was within 90% accuracy of the original melody - 3 points total deduction = 90% accuracy.

[redacted] - Evaluator #3

Sample #	Incorrect notes	Incorrect rhythms	Total
3	0	0	0
4	0	0	0
7	0.5	0	0.5
11	0	0	0
19	1	0.5	1.5
21	0.5	0.5	1
23	0	0	0
25	1	0	1
28	0	0	0
29	0	0	0
37	0	0	0
40	1	1	2
45	0	0	0
46	0	0	0
47	0	0	0
50	0	0	0
52	0	0.5	0.5
53	0.5	0.5	1
54	0.5	0	0.5
56	0	0	0

Instructions for Grading:	
1 point for completely incorrect note	
1/2 point for almost incorrect note (initially played wrong but adjusted very quickly to be correct	
1 point for completely incorrect rhythmic error	incorrect octave)
1/2 for slight rhythmic error/incorrect timing	

Use your best judgement on this to determine if you believe each performance was within 90% accuracy of the original melody - 3 points total deduction = 90% accuracy.

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Vita

Ben Michael Herrick, born in Swanton, Ohio, worked as a high school and middle school band director for several years after receiving his bachelor's degree from the University of Toledo and after completion of basic military training for the Ohio Air National Guard. After his military service obligations and after nearly ten years as a public-school teacher, he enrolled in the University of Cincinnati College-Conservatory of Music to pursue a master's degree in music education. After his master's program, Ben was the band director for two separate colleges in Ohio until he enrolled in Louisiana State University to pursue a Ph.D. in music education, with his graduation anticipated for May 2023. He has also remained an active semi-professional trombone performer throughout his career as a student and educator, mainly in the style of New Orleans jazz.