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Effects of Different Instrumental Accompaniment on the Intonation of High School and Collegiate Violinists, Violists, and Cellists

John Rine Anacito Zabanal

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EFFECTS OF DIFFERENT INSTRUMENTAL ACCOMPANIMENT
ON THE INTONATION OF HIGH SCHOOL AND COLLEGIATE VIOLINISTS, VIOLISTS, AND CELLISTS

By

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A Dissertation submitted to the College of Music in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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To my family who have supported me in my endeavors.
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ABSTRACT

The purpose of this study was to examine the effects of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. The following questions guided this research: (1) Are there differences in tuning accuracy of melodic content between accompanied and unaccompanied conditions among string musicians? (2) Are there differences in tuning accuracy of melodic content between accompaniment octaves? (3) Are there differences in intonation accuracy between string, oboe, and piano accompaniments? (4) Are there differences between the number of flat, sharp, and in-tune responses of participants? (5) Are there differences in string musician preferences between accompaniment types? (6) Are string musicians’ self-perceptions of tuning accuracy associated with performed pitch accuracy? (7) Are there differences between age and experience of participants in intonation accuracy with various accompaniment types?

Performances of Frère Jacques were recorded by a cellist, oboist, pianist, and a violinist to serve as accompaniment stimuli for the study. Additionally, a questionnaire was created to measure preferences for accompaniment, perceptions of tuning accuracy, and collect background information of participants. The participants (N = 103) were high school (n = 60) and collegiate (n = 43) violinists (n = 55), violists (n = 22), and cellists (n = 26). Participants performed an excerpt of Frère Jacques in Eb major in five conditions: with a cello accompaniment, oboe accompaniment, piano accompaniment, violin accompaniment, and as a solo. Absolute cent deviation from the tonic, mediant, subdominant, and dominant scale degrees were collected from each participant for analysis.

A significant main effect of intonation was found for accompaniment conditions. Participants performed more in tune with the cello, oboe, and violin accompaniments than with the solo. Additionally, they performed more in tune with the oboe accompaniment than with the piano accompaniment. The octave of accompaniment and instrument performed also did not appear to affect intonation. A significant main effect was found between high school and college participants. High school participants performed with less pitch acuity than college participants. An additional significant main effect was found between the deviations of analyzed notes. The Ab (subdominant) had significantly higher mean cent deviation than the Eb (tonic) and Bb
(dominant). No differences were found between instruments performed and no interactions between variables were found.

Participants demonstrated a propensity to perform with sharp intonation. Sharp responses occurred more frequently than in-tune (defined as ±6 cents) and flat responses with high school participants. Additionally, performances with the oboe accompaniment produced more in-tune responses than other conditions. In-tune responses occurred more frequently with collegiate participants; however, sharp responses occurred more frequently than flat responses. Performances with the oboe accompaniment also produced the most frequent flat responses as well as the lowest number of sharp responses.

Questionnaire responses indicated that participants preferred to perform with the string accompaniments more than the non-string accompaniments. Participants least preferred to perform with the oboe accompaniment compared to the other accompaniments. A significant main effect was found in participants’ rating of their perceived intonation accuracy between conditions. Although participants rated their intonation as highest with the cello, their performances did not reflect this perception. A significant main effect was also found between the levels of participants. High school participants rated their intonation lower than college participants. No significant main effect was found between instrumental groups and no significant interactions were found.

A moderate positive correlation was found between participants’ perception of their intonation and their actual performance of intonation with the violin accompaniment. Additionally, a weak positive correlation was found for the cello accompaniment and the solo condition. Participants’ rating of their perceived intonation correlated positively to the actual pitch accuracy for the string accompaniments and solo condition while no associations were found for non-string accompaniments.
CHAPTER ONE
INTRODUCTION

Carl Seashore stated that, “Music is not one talent, but hierarchy of talents” (Seashore, 1967). He also proposed such a hierarchy in a conceptual model consisting of hearing, feeling, understanding, and expressing music. It is important to note that at the beginning of the list was hearing. As musicians, we must be able to perceive accurately whether or not a particular note is in tune. We must be able to use that skill to discriminate whether or not the pitches we perform are tuned accurately. Additionally, music teachers must be able to train music students to accurately perform this task and how to independently develop their skill.

Two words should be differentiated that have similar meaning, tuning and intonation. According to McBeth (1972), tuning is the mechanical process of adjusting the instrument to allow the user to perform in tune, whereas, intonation is the physical process that requires the user to perform the instrument so that its pitch can match the pitch of others. Additionally, intonation is described as “the degree to which pitch is accurately produced in performance, especially among the players in an ensemble” (Apel, 2003). The ability to hear subtle differences in pitch is defined as pitch discrimination (Seashore, 1967). Although there are a number of other important aspects in music such as rhythm, tone quality, note accuracy, technique, and musicality, accurate intonation has been found to be one of the most important elements that distinguishes a good musical performance (Geringer & Madsen, 1981, 1989, 1998; Johnson & Geringer, 2007).

In the canon of Western classical music, there are four major tuning systems that provide a basis for accurate intonation: equal temperament, just intonation, meantone temperament, and Pythagorean tuning (Barbour, 1951; Ostling, 1974; Radocy & Boyle, 2012). Even though these four tuning systems are considered as a reference, it appears that instrumental musicians do not necessarily conform to any one specific system. Wind instrumentalists appear to deviate less from equal temperament compared to other tuning systems (Karrick, 1998; Kopiez, 2003; Mason, 1960). Although pianists do not really have a choice in which temperament they wish to perform, when given the opportunity, they adjusted scales that conformed to equal temperament (Loosen, 1994) in addition to preferring equal tempered scales compared to scales tuned to other temperaments (Loosen, 1995). String musicians have demonstrated a preference towards
Pythagorean tuning (Loosen, 1994, 1995). Analyses of string musicians’ performance found that they demonstrated a tendency that approximates Pythagorean tuning especially in major tonalities; however, little evidence has been provided to show that they consistently perform in a particular temperament (Geringer, 2018; Geringer, Macleod, & Ellis, 2013; Greene, 1937; Loosen, 1993; Nickerson, 1949a, 1949b).

Pedagogues and teachers have offered a variety of techniques that are intended to enhance pitch discrimination and improve intonation. These techniques include using a piano to teach beginning students intonation (Green, 2010), having studio teachers perform with their students as duets (Kohut, 1973), creating individual pitch tendency charts (Rush, 2006), and using drone accompaniments with electronic sound sources (Curry, 2011; Hopkins, 2012), adjacent open strings (Curry, 2011; Hamann & Gillespie, 2013; Hopkins, 2012; Reel, 2005; Watkins, 2004), and other string instruments (Hopkins, 2012). Researchers have attempted to verify a number such of techniques proposed by pedagogues. This includes contingent verbal feedback (Salzberg, 1980; Sogin, 1997), programmed drill training courses (Tromblee, 1972), computer training programs (Dalby, 1992; Hopkins, 2014; Meyer, 1993), vocalization (Schlacks, 1981; Silvey, Nápoles, & Springer, 2019; Smith, 1995), piano accompaniments (English, 1985), and drone accompaniments (Laux, 2015).

Ongoing research concerning the effects of accompaniment on overall music performance has produced mixed outcomes. Solo performances were rated higher when performed with an accompaniment (Brittin, 2002; Brittin, Sheldon, & Lee, 2002; Springer & Silvey, 2018), though type of accompaniment was found to be a factor for musical preference (Brittin, 2000; Moore, Staum, & Brotons, 1992). Recorded practice accompaniments meant to help students improve musical performance did not enhance the intonation and music skill for kindergarteners and first graders (Atterbury & Silcox, 1993; Guilbault, 2004) and beginning clarinetists (Anderson, 1981). Additionally, beginning string musicians who were less exposed to piano accompaniment were more accurate with intonation and rhythm compared to those who had more exposure (English, 1985). However, beginning brass students showed improvement with rhythm discrimination, pitch matching, and a reduction of pitch errors when using an audiotaped accompaniment (Zurcher, 1975).

Although the use of accompaniment to improve performance is inconclusive, accompaniment does appear to positively affect pitch acuity (Brittin, 1993; Geringer, 1978;
Kantorski, 1986). Specifically with string musicians, Garman (1992) found that string instrumentalists performed with more pitch acuity when accompanied with an electric piano in unison, harmonized by a single voice, and harmonized by diatonic triads or seventh chords compared to performing unaccompanied.

**Statement of the Problem**

As violinist and a music teacher, I have performed and taught in a variety of settings: large orchestras, small orchestras, chamber ensembles, duets, with strings alone, with woodwinds and brass instrumentalists, and with choirs. When I worked in a smaller setting with strings and woodwinds, I have informally observed myself adjusting my own pitch differently with wind instrumentalists compared to other string instrumentalists. After talking with other string players, I found that many of them experience the same type of phenomenon. The present study was an attempt to systematically explore these observations in a melodic context.

Several studies that looked at musicians’ perception of intonation and timbre utilized a single-pitch stimulus rather than an accompaniment in a melodic context. Additionally, studies that focus on accompaniment used harmonized accompaniments rather than melodic accompaniments performed in unison and octaves. These studies also typically involved wind instrumentalists as participants performing with various stimulus conditions. There is relatively little research with participants whose primary instrument is from the string family, especially studies that utilized melodic accompaniments as stimuli. There is a need to explore intonation accuracy of string instrumentalists when performing with accompaniments of different instrument types in a melodic context.

**Purpose Statement**

The purpose of this study was to examine the effects of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. The research questions were as follows:

1. Are there differences in tuning accuracy of melodic content between accompanied and unaccompanied conditions among string musicians?
2. Are there differences in tuning accuracy of melodic content between accompaniment octaves?
3. Are there differences in intonation accuracy between string, oboe, and piano accompaniments?
4. Are there differences between the number of flat, sharp, and in-tune responses of participants?
5. Are there differences in string musician preferences between accompaniment types?
6. Are string musicians’ self-perceptions of tuning accuracy associated with performed pitch accuracy?
7. Are there differences between age and experience of participants in intonation accuracy with various accompaniment types?

**Delimitations**

The present study examined the effects of different instrument accompaniments on the intonation of high school and collegiate violinists, violists, and cellists in a melodic context. However, there are a few limitations that must be taken into consideration when examining the results. While attempts were made to recruit an equal number of violinists, violists, and cellists, there were more than twice as many violinists than violists and cellists. There were more high school participants than college participants. Although there was roughly an equal number of ninth, tenth, eleventh, and twelfth graders among high school participants, there was a greater number of undergraduate students compared to graduate students among collegiate participants.

Another factor to take into consideration is time of day participants participated in the study. Due to scheduling constraints, collegiate participants performed in the late morning through late afternoon. High school participants only performed in the early to late morning, some as early as 7:30 a.m. There is mounting research that provides evidence that adolescents may not be completely alert in the early morning due to changes in their circadian rhythm that controls sleep patterns (Adolescent Sleep Working Group, 2014; Carskadon, Acebo, & Jenni, 2004; Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). As such, high school participants in the present study may have been less alert, therefore more inaccurate in their performance, compared to their older counterparts at the collegiate level.

Intonation accuracy in the present study was measured as cent deviation relative to equal temperament. A majority of intonation-based studies used equal temperament as the accepted
measurement standard as it is the closest to performances of Western music (Karrick, 1998; Rakowski, 1990). Although string musicians have demonstrated a tendency to perform in a temperament that approximates Pythagorean, they are generally inconsistent to performing to a specific tuning system (Geringer, 2018; Geringer et al., 2013; Greene, 1937; Loosen, 1993; Nickerson, 1949a, 1949b). It should be noted that the present study does not attempt to compare tuning systems.

Given these limitations, generalization of results to all high school and collegiate string musicians should therefore be done with due caution.
CHAPTER TWO
REVIEW OF LITERATURE

Intonation and Temperaments

Musicians strive to perform with accurate intonation; however, it is a task that requires years of music training. The Harvard Dictionary of Music described intonation as “the degree to which pitch is accurately produced in performance, especially among the players in an ensemble” (Apel, 2003). Salzberg (1980) described intonation accuracy as the ability of a musician to perceive pitch deviations and to adjust appropriately during her own performance. Morrison and Fyk (2002) further described intonation as the manipulation of pitches and intervals within a real musical context. It is described as an idea that has two levels: pitch discrimination, which is described as the ability to distinguish differences between two successive pitches or two dissimilar examples of a single pitch; and pitch matching, the ability of a musician to exactly reproduce a given pitch (Morrison & Fyk, 2002).

Tuning systems

Intonation is bound to culture and is relative to norms and criteria of a given music tradition (Morrison & Fyk, 2002). In the Western classical music tradition of music, intonation has been defined by one of four major tuning systems: equal temperament, just intonation, meantone temperament, and Pythagorean tuning (Barbour, 1951; Ostling, 1974; Radocy & Boyle, 2012). The following definitions were presented by Barbour (1951, pp. x-xi):

Equal Temperament: The division of the octave into an equal number of parts, specifically into 12 semitones, each of which has the ratio of \( \frac{\sqrt[12]{2}}{1} \), or 1.0546.

Just Intonation: A system of tuning based on the octave (2:1), the pure fifth (3:2), and the pure major third (5:4).

Meantone Temperament: Systems of tuning with flattened fifths (\( \sqrt[5]{5}:1 \)) and pure major thirds (5:4).

Pythagorean tuning: A system of tuning based on the octave (2:1) and the pure fifth (3:2).

Tuning system preference

While intonation is bound to the culture of a given music tradition, there are preferences among musicians of those traditions. Loosen (1994) measured tuning preferences of pianists,
violinists, and non-musicians by having them complete a tuning task. Participants listened to ascending and descending diatonic scales and adjusted the pitches as necessary. Results indicated that pianists tuned scales that conformed to equal temperament while violinists tuned scales that fit closest to Pythagorean tuning, meanwhile, non-musicians had no preferences. A follow-up study was performed with only discrimination tasks of pianists, violinists, and non-musicians (Loosen, 1995). Participants listened to a series of ascending and descending paired scales tuned to equal temperament, just intonation, or Pythagorean tuning and were asked to identify which scale of the pair was most accurately tuned. Similar to the previous study, results indicated that pianists preferred scales tuned to equal temperament over Pythagorean tuning while violinists preferred Pythagorean tuning over equal temperament. Pianists and violinists judged scales tuned to just intonation as less accurate than the other two temperaments while non-musicians indicated no preference to any temperament.

Intonation preferences for equal temperament, just intonation, meantone tuning, and Pythagorean tuning was also investigated among collegiate music majors \( (n = 161) \) and non-music majors \( (n = 198) \) (Bisel, 1987). Participants listened to 16 melodic and 16 harmonic musical examples that were tuned to one of the four temperaments and rated each example on a Likert-type scale with in-tune (1) and out of tune (5) as anchors. For melodic examples, music majors’ preference for tuning systems were significantly different in the following order: (1) Pythagorean tuning, (2) equal temperament, (3) meantone tuning, and (4) just intonation. For harmonic examples, music majors preferred (1) meantone tuning, (2) equal temperament, (3) Pythagorean tuning, and (4) just intonation. All differences were significant except between Pythagorean tuning and just intonation. Preference scores of non-music majors for melodic examples were significant between equal temperament and Pythagorean tuning, with preference towards equal temperament. For harmonic examples, non-music majors significantly preferred equal temperament over just intonation, no other significance was found. It appears that music majors were able to perceive the subtle differences between temperaments more accurately than non-music majors.

**Music temperaments with wind musicians**

While the above researchers found that instrumental musicians preferred one tuning system over another, investigations of performance tendencies for various tuning systems have different outcomes. For example, Mason (1960) examined solo and ensemble performances of
student and faculty woodwind quartets and found no conformity to perform in Pythagorean tuning, just intonation, or equal temperament. However, the professional wind musicians performed with less cent deviation from equal temperament while student musicians deviated less from Pythagorean tuning. Karrick (1998) examined the intonation tendencies of wind instrumentalists who were advanced university students and professional musicians who performed on flute, oboe, bassoon, soprano clarinet, alto saxophone, trumpet, horn, trombone, or tuba. Results indicated that wind instrumentalists did not completely conform to one temperament and that absolute deviation was least from equal temperament and greatest from just intonation. Subsequently, Kopiez (2003) investigated the ability of two trumpet musicians to adapt to just intonation and equal temperament. The trumpeters performed the upper voice while listening to a stimulus recording consisting of three lower voices through headphones. Two recordings were created as stimuli; one recording was tuned to equal temperament and the other tuned to just intonation. Musicians were also given an aural perceptual skills test where they listened to three excerpts of cadences and were asked to identify which excerpts were tuned to Pythagorean tuning, equal temperament, and just intonation. While not significant, the results indicated that the musicians deviated less from equal temperament than just intonation. Although wind instrumentalists do not completely conform to any specific tuning systems, they do appear to deviate less from equal temperament (Karrick, 1998; Kopiez, 2003; Mason, 1960).

Music temperaments with string musicians

Unlike wind instrumentalists, string musicians appear to have a tendency to prefer Pythagorean tuning (Loosen, 1994, 1995). However, like wind instrumentalists, string musicians’ tendency to perform in one tuning system over another are inconsistent (Carman, 1936; Geringer, 2018; Geringer et al., 2013; Greene, 1937; Nickerson, 1949a, 1949b; Ostling, 1974).

One of the earliest studies of music temperament performance was an examination of phonograph records of two violinists performing an unaccompanied piece, Sonata No. 1 in G minor by J. S. Bach (Carman, 1936). He found that both musicians performed notes and intervals that generally adhered to just intonation. Greene (1937) studied six violinists who performed three standard unaccompanied pieces and found that violinists typically performed in neither just intonation nor equal temperament, but an approximation of Pythagorean tuning. Nickerson (1949a, 1949b) examined 24 violinists’ performances of a melodic passage in a solo and
ensemble and found that while performances did not completely conform to any of the main tuning systems, melodic content approximated patterns of Pythagorean tuning.

There is evidence that temperament may be influenced by the context of the performance. Loosen (1993) examined the intonation of eight professional violinists who performed a three octave ascending and descending C major scale. When the entirety of the scale was examined, he found that the performances fit Pythagorean tuning and equal temperament more precisely than just intonation. When the size of intervals between notes were analyzed, he found that the interval size was halfway between the interval sizes in Pythagorean tuning and equal temperament.

Geringer et al. (2013) studied the intonation of performances on four editions of the album *Suzuki Violin School Volume I*. They examined one excerpt of the same piece performed by four different professional violinists, one each from years: 1979, 1986, 1999 and 2003. The excerpt was the first eight measures of *Minuet I in G Major* by J. S. Bach. The range of pitch deviations of the performers ranged from -13 to +26; however, most deviations were smaller. Three of four performers tended to perform intonation closer to Pythagorean tuning while one performer was closer to equal temperament. However, similar to previous research, no performer consistently conformed to either equal temperament or Pythagorean tuning. This particular study was unique compared to other investigations examining the degree of conformity to a particular tuning system (Greene, 1937; Loosen, 1993; Nickerson, 1949a, 1949b), it included recordings of a performance with a piano accompaniment while previous studies included solo performance without accompaniment. Geringer suggested that the piano accompaniment, which was tuned to equal temperament, could have affected the performers’ intonation tendencies.

The most recent descriptive analysis of violin intonation included eight artist-level violinists performing two unaccompanied pieces by Bach: the *Allemande from Partita No. 2 in D minor, BWV 1004*; and the *Minuet I from Partita No. 3 in E major, BWV 1006* (Geringer, 2018). By examining each occurrence of the first, third, fourth, fifth, and sixth scale degrees of each excerpt, he looked for patterns of the performance that would approximate just intonation, Pythagorean tuning, or equal temperament. While none of the artist conformed to any specific tuning system, they each had their own individual tuning tendencies. Further examination found that the third and sixth scale degrees in the major key displayed a propensity towards Pythagorean tuning.
**Intonation and Performance**

Investigations of intonation are prevalent in music research literature. Numerous researchers have investigated the effects of variables such as age, experience, training in music performance, and tuning stimulus on intonation preference and performance. Findings from these studies indicated intonation trends among musicians such as a preference for sharp intonation or more accurate discrimination of flat intonation. While most researchers found that instrumentalists have a propensity to perform with sharp intonation, a few researchers found tendencies to perform flat as well. The following is a systematic review of intonation research.

**Listener preference for sharp intonation**

Musicians have a tendency to prefer sharp intonation. Madsen, Edmonson, and Madsen (1969) tested the auditory discrimination of a modulated frequency (F# at 369.99 Hz) of two hundred subjects representing second graders, fifth graders, eighth grades, eleventh graders, college non-music majors, music majors, graduate music students, and music faculty. While younger participants did not accurately rate pitches, older participants demonstrated better pitch acuity demonstrating a proclivity towards identifying flatness errors, demonstrating a preference for sharp intonation. In an examination of tuning preferences of undergraduate and graduate music students, participants listened to ten excerpts from orchestra pieces and were asked to modulate a variable speed tape recorder to adjust the excerpt to their preferred pitch level (Geringer, 1976). Participants had a tendency to modulate recordings of excerpts to the sharp direction relative to the recorded pitch level. Madsen and Geringer (1976) asked undergraduate and graduate music students to rank eight sets of trumpet performances according to tone quality and intonation of the performance. Each performance was performed with an accompaniment adjusted 25 cents flat, 50 cents sharp, and in-tune. Participants preferred sharp and in-tune accompaniments significantly more than flat accompaniments. These findings were further corroborated in a subsequent replication study which found that listeners preferred excerpts that were in-tune, then sharp 25 cents, and finally flat 25 cents when rating accompaniments (Geringer, Madsen, & Dunnigan, 2001). Listeners also rated trumpet performances and indicated preference to performances that were 15 cents sharp and in-tune. Madsen and Geringer (1981) asked music and non-music graduate and undergraduate students to select good and bad tone quality and intonation classifications after listening to each of twenty-four oboe and flute duet performances. Each duet was unaccompanied and performed with good or bad tone quality.
Additionally, each duet was tuned close to equal temperament or one part was adjusted 50 cents sharp to the other, no performance was adjusted to be flat. Thirty-eight percent of the participants indicated that the excerpts were sharp while 62% indicated they were flat which further demonstrated a preference towards sharp intonation. Perception of intonation among music majors was investigated with accompanied performances of solo trumpet, violin, and soprano voice (Geringer, MacLeod, & Sasanfar, 2015). The pitch of each recording was adjusted with cent deviation of 0, 10, 20, or 30 in either the sharp or flat direction relative to the accompaniment. Participants rated voice performances as most in-tune compared to the violin and trumpet for phrases that were adjusted 10, 20, and 30 cents sharp. Listeners were more tolerant of the vocalist performance, especially in the sharp direction.

**Tendency to perform with sharp intonation**

Researchers previously found that listeners have a proclivity for sharp intonation and other studies indicated that instrumentalists have a tendency to perform sharp. The propensity towards sharpness was typically found while researchers were investigating other areas of interest. While investigating musicians’ tendency towards one temperament over another, Mason (1960) found that the performers had a general tendency to play sharper than the established pitch. Vocal performance of scales by elementary students, high school students, and undergraduate student vocalists, pianists, and violinists tended to be sharp after a short term practice session (Madsen, 1974). After comparing performances of woodwind instrumentalists’ intonation to three tuning systems, Karrick (1998) also found a propensity towards sharp intonation when investigating intonation patterns of wind instrumentalists. While examining intonation patterns of melodic and harmonic intervals among junior high school, high school, and college undergraduate wind musicians, Duke (1985) found that junior high school students had a propensity to perform with sharp intonation. Brittin (1993) investigated performances of trombone players who were accompanied with a pre-recorded piano part that was purposely mistuned. Participants were put into two groups, the first group included high school students and second group included college and professional musicians. Although no significant difference was found between the two groups, high school trombonists consistently performed more sharp than the college and professional musicians. Morrison (2000) completed two investigations: the first included band students with up to four years of formal music training, the second included high school band students who had five to seven years of experience. Results
indicated that participants had tendency to perform sharp even when performing with a pre-
recorded melody. The more experienced high school musicians had a stronger propensity
towards sharp tuning errors compared to other age groups.

Wind instrumentalists have been found to have a tendency to tune their instruments sharp
to a reference pitch. Yarbrough, Karrick, and Morrison (1995) asked first, second, third, and
fourth year wind instrumentalists to tune their instrument to a reference pitch. Participants were
separated in three groups: group one was told that their instrument was mistuned sharp, group
two was told their instruments were mistuned flat, and group three was given no direction on
mistuning. Students with more years of experience had a greater number of sharp responses. Byo
and Schlegel (2016) investigated the effects of stimulus octave and timbre on the tuning accuracy
on collegiate musicians and found no significant difference between in-tune, sharp, and flat
responses. Even though no significance was found, the number of sharp responses was more than
double the number of flat responses.

String musicians have also demonstrated a tendency to perform with sharp intonation.
Geringer (1978) investigated the performance and perception of intonation for ascending scales
of 96 undergraduate and graduate musicians who were string or wind instrumentalists, pianists,
or vocalists, and found that all musicians had a tendency to perform sharp. Salzberg (1980)
examined the effect of visual stimulus and instruction on the accuracy of intonation of 50 string
musicians. String musicians were placed in one of five instructional groups: contingent verbal
feedback, tape-recorder playback, model performance, free practice, and no instruction.
Participants were also asked to perform a scale, an arpeggio, double stops, and a melody.
Although results indicated that the contingent verbal feedback group performed with the most
accurate intonation and was more in-tune than the model performance and tape-recorder groups,
a propensity towards sharp intonation was also found. Kantorski (1986) also examined string
intonation using scalar passages. String musicians ($N = 48$) performed whole-tone tetrachords
with four different accompaniments in upper and lower registers. Upper register performances
with accompaniment below were sharper than lower register performances with accompaniment
relative to equal temperament; however, both performances were consistently sharp. Descending
tetrachords were also significantly sharper than ascending tetrachords. Yarbrough and Ballard
(1990) examined the effects of accidentals, leading tones, direction of scalar patterns, and the
performers’ opinions of their intonation on the performance with undergraduate ($n = 22$) and
graduate (n = 17) string musicians and found that the musicians performed sharp regardless of the direction of the scale. Two investigations reviewed earlier also found a tendency of string musicians to perform with sharp intonation. The first examined the intonation of recorded excerpts from four different albums of *Suzuki Violin School Volume I*, two of the four professional musicians consistently performed sharp relative to equal temperament and Pythagorean tuning, and pitch deviations ranged higher on the sharp side (+26 cents) than the flat side (-17 cents) (Geringer et al., 2013). The second examined recorded performance of eight professional violin artists (Geringer, 2018). Certain notes were found to be sharper relative to equal temperament – the major third was sharp relative to ET for all eight solo artists, the major sixth was sharp relative to ET for seven of the eight solo artists. However, there was no consistent propensity towards sharp intonation for all of the notes studied (first, third, fourth, fifth, and sixth scale degrees)

A propensity towards sharpness of string musicians was not limited to performances of music, scales, and basic patterns, it was also found in the tuning of open strings. Geringer and Witt (1985) investigated tuning performance and perception of string musicians when tuning an open A-string. High school students and college students/professionals were asked to tune their A-string to a provided reference pitch (oboe tuning tones tuned to 440Hz, 25 cents sharp to 440Hz, and 15 cents flat to 440Hz) in six trials; however, they were notified that the reference pitch could be incorrect so they should tune to a pitch they perceive as accurate. After each tuning task, they were asked to indicate whether they thought the reference pitch was in-tune, flat, or sharp. Collegiate and professional musicians tuned their A-string sharper than high school participants for both the sharp and flat reference pitches. Both groups judged pitches as “flat” more frequently than “sharp” or “in-tune,” which could indicate a preference for sharp intonation.

**Tendency to flat intonation**

Although a large number of studies indicated that musicians have a tendency to prefer sharp intonation, there are some inconsistent results. In an investigation of the effect of a pre-recorded soprano melody on a corresponding vocalized harmony part, Small (1977) found that undergraduate music majors (twenty vocalist and twenty instrumentalists performing a vocal alto, tenor, or bass part) sang a harmony part accompanied by melody with a propensity towards flat intonation. Duke (1985) found that junior high, high school, and collegiate undergraduate
wind musicians who performed ascending intervals tended to be flat, specifically, he found that collegiate musicians in general demonstrated a propensity towards flat intonation. When investigating the effects of timbre on college woodwind players, Ely (1992) found that woodwind musicians had consistently flat intonation while performing with a unison prerecorded melody. Although Brittin (1993) found that high school trombonists consistently performed more sharp than collegiate/professional performers, both groups tended to perform on the flat side of the pitch when they played excerpts below the accompaniment and started flat. Yarbrough et al., (1995) found that when tuning their instrument to a reference pitch, students in their first year of music instruction had a greater number of flat responses than students with more experience. When tuning to a reference pitch produced by a flute, oboe, clarinet, and tuba, high school wind players performed with no significant difference across sharp, flat, and in-tune categories (Byo, Schlegel, & Clark, 2011).

String musicians have also been found to have a propensity towards flat intonation. In an attempt to test the reliability of the Tuning Perception Test (TPT), a recently developed computer software application, Hopkins (2014) measured the tuning accuracy of fifth-, seventh-, ninth-, and eleventh-grade string students and university music majors. Participants demonstrated a tendency to tune presented tones flat compared to a reference pitch. In a subsequent study, Hopkins (2015) used the TPT to explore the relationship between the pitch perception and instrument tuning skill of eighth grade violinists. Similar to his previous study, results indicated the eighth graders had a tendency to tune tones flat compared to the reference pitch. They also had a tendency to tune their instruments flat compared to the reference pitch. These findings corroborated an earlier study that explored perceived and actual tuning ability (Hamann, Lauver, & Asher, 2006). Middle school string students were asked to tune their instruments to a reference pitch, one group tuned to a viola tuned to A440hz, the other group tuned to A440Hz provided by a Korg tuner. Students in both groups had a tendency to tune their strings flat. In an investigation of the effect of a tonic drone accompaniment on pitch accuracy of scales performed by beginning violin and viola students, students tended to perform pitches flat more often than sharp; however, there was no significant differences between sharp and flat pitches (Laux, 2015).

**Age and experience**

Age, experience, and training have been found to be a major factor in pitch perception and performance tasks. Geringer (1983) explored the relationship between pitch-matching and
pitch-discrimination abilities of preschool and fourth-grade students. A significant difference in pitch-matching abilities between preschool and fourth-grade students was found; fourth-grade students had lower deviation scores than preschool students. Overall results of a Spearman Rank Correlation between pitch-discrimination and pitch-matching scores were low and not significant for all groups, with the exception of high-ability fourth graders where a significant positive moderate correlation was found. In an earlier study, a significant difference was found on the pitch acuity of a singing task between precollege groups (elementary and high school students) and collegiate groups (undergraduate students whose primary instrument were vocal, piano, or violin), with collegiate groups performing with greater pitch accuracy (Madsen, 1966). After investigating auditory discrimination of age populations from elementary to professional level musicians, Madsen et al. (1969) found that correct responses increased with age and musical training. They also found that older participants perceived flat intonation more often while younger participants selected sharp intonation more frequently. In an exploration of the intonation of a scalar solo vocal performance by elementary school students, high school students, and collegiate music students whose primary instruments was either piano, violin, or voice, Madsen (1974) found that elementary and high school students’ vocal performances tend to be flat compared to college music majors.

Age and experience have been found to be a factor in intonation accuracy among wind instrumentalists. Duke (1985) found that younger and less-experienced wind instrumentalists had a slight tendency to sharp intonation while collegiate musicians had a tendency to perform flat intonation. Brittin (1993) found that high school trombonists tended to perform with sharper intonation compared to college and professional players; however, she noted that the result was not significantly different. Yarbrough et al. (1995) found that students with more experience performed with a greater number of sharp responses compared to students in their first year of instruction, who performed with greater flat responses. Morrison (2000) reported that performance accuracy of elementary and middle school band students improved with experience. Private instruction was found to be the only significant factor to have an effect on tuning accuracy after examining the effect of experience, private instruction, and knowledge of directional mistunings with high school band students (Yarbrough, Morrison, & Karrick, 1997).

Researchers also observed age and experience to affect intonation accuracy among string instrumentalists. Geringer and Witt (1985) found that collegiate and professional string
musicians tune their A-string sharper than high school string musicians. While examining vibrato of violin and cello students, Geringer and Allen (2004) found that university musicians tend to move sharper for both vibrated and non-vibrated tones compared to high school musicians. After pilot-testing computer software designed to measure tuning accuracy, Hopkins (2014) found that pitch-matching and perfect fifth interval tuning accuracy of middle and high school string instrumentalists improved consistently as school level increased.

**Training programs**

The effectiveness of training programs designed to improve intonation has been tested in various studies. Tromblee (1972) examined the effect of a programmed drill training course on pitch discrimination skills of high school and college band students. All participants were asked to complete the pitch, timbre, and tonal memory sections of the *Seashore Measures of Musical Talents* tests to provide a basis for selection of an experimental and a control group. Participants in the experimental group received the programmed drill training. Post-test results of an Intonation Discrimination test indicated that participants in the experimental group had more accurate intonation discrimination scores compared to the control group. Fyk (1987) found that inexperienced music students who went through short term tuning training had more accurate pitch-matching scores than experienced music students who completed 3.5 years of traditional ear training courses with piano and voice only. Dalby (1992) created the Harmonic Intonation Training Program (HITP) and tested it to see if it improved students’ ability to make judgments on harmonic intonation. Undergraduate students underwent a 9-week training period with the HITP which consisted of drill-and-practice exercises with interval, triads, and three- and four-part musical passages. Results indicated that participants who were trained with the HITP scored higher than those who did not. Schlacks (1981) investigated the effect of vocalization through an interval training program on the pitch accuracy of high school band students. Four schools were separated into three experimental groups (training with instrumental performance of intervals, vocalization of intervals, and a combination of vocalization and instrumental performance of intervals) and one control group without treatment. Results indicated that the school with both vocalization and instrumental performance of intervals demonstrated greater improvement than the control school.

There is also extant literature on training programs to improve intonation with string musicians. Meyer (1993) developed a computer system which was designed to provide violinists
an aural and visual feedback to intonation while practicing. This program was tested with an advanced violinist who was faster in correcting pitches and demonstrated an eagerness to improve his score. Smith (1995) examined the effects of an aural-oral pitch-matching training program on string students’ ability to accurately discriminate pitches. Beginning string students were assigned to an experimental group, two 20-minute weekly training sessions with the Pitch Master Machine (PMM), or a control group, performing the same exercises as the experimental group without singing. Results indicated that students who were trained with the PMM demonstrated greater gains in pitch discrimination and performance accuracy compared to students who received training without the PMM.

Although a training program was not developed, Nuñez (2002) investigated two instructional methodologies used to improve intonation accuracy of seventh grade violinists and violists: aural and aural-visual. Participants from two middle schools were randomly assigned to two groups of intact classes. The first was assigned an aural methodology where the teacher modeled a series of pitches and the students imitated the model. The second group was assigned an aural/visual methodology and had color coded dots attached to their fingerboards to indicate finger placement for each pitch. Results revealed no significant difference between the two methodologies. In Laux's (2015) investigation of a tonic drone accompaniment on pitch accuracy, beginning students were place in three groups: pitch matching, tonic drone accompaniment, or pitch matching with tonic drone accompaniment. Students received training on scales through daily classroom instruction for five to ten minutes each day for a period of seven school days. Students in the experimental groups were exposed to tonic drone accompaniment during these training sessions. Analysis of pre- and post-test data revealed no significant differences between groups.

**Timbre**

The effect of timbre on preference and performance of intonation has been extensively studied by researchers. The timbres used in experimental and descriptive investigations have included both acoustic and synthesized stimuli. There are four types of basic synthesized sounds that are represented as a cyclical waveform: sine wave, sawtooth wave, square wave, and triangle wave.
Several studies in music have utilized one or more of these electronic waveforms: sine waves (Parker, 1983; Rakowski & Miśkiewicz, 1985; Sergeant, 1973; Spiegel & Watson, 1984), square waves (Cassidy, 1989; Hayslett, 1990; Laux, 2015; Rakowski & Miśkiewicz, 1985; Spiegel & Watson, 1984), sawtooth waves (Cassidy, 1989; Hopkins, 2014, 2015; Platt & Racine, 1985), and triangle waves (Rakowski & Miśkiewicz, 1985). Other studies have utilized an electronically generated pitch; however, the authors did not specify which type of wave the stimulus pitch approximated (Alexander, 2011; Byo & Schlegel, 2016; Hamann et al., 2006; Kantorski, 1986).

**Electronic stimuli**

Rakowski and Miśkiewicz (1985) used square wave, triangle wave, and sine wave stimuli to determine how they would affect listeners’ tuning accuracy of a pure-tone frequency oscillator. The participants performed two tasks: the first task was to adjust the oscillator without a musical context and the second was to adjust the oscillator in a musical context. Results indicated that small intervals tuned without a musical context were tuned smaller while large intervals were larger than their equally-tempered values. Findings also indicated that tuning was more accurate in a musical context. Platt and Racine (1985) examined the effect of frequency, timbre, experience, and feedback on the tuning accuracy of musicians who had experience tuning string instruments and musicians who did not have experience tuning string instruments. Results indicated that participants with string instrument tuning experience demonstrated more accurate pitch matching skills than participants who did not have experience. Tuning and pitch discrimination was also found to be more accurate when the reference and comparison tones were both complex tones of the same timbre. Spiegel and Watson (1984) utilized sine waves and square waves to examine frequency-discrimination tasks of musicians and non-musicians. Results indicated that both groups discriminated square wave tones more accurately than sine wave tones. A study that examined both acoustic and electronic sources on the tuning accuracy of collegiate band members found that participants tuned more accurately to acoustic sources (oboe and tuba) compared to an electronically generated square wave (Hayslett, 1990).

**Acoustic stimuli**

Acoustic instruments have also been used to examine the effect of timbre on the perception and performance of intonation. While investigating the discrimination of tone quality and intonation in unaccompanied flute and oboe duets with undergraduate music majors,
graduate music majors, and non-majors, Madsen and Geringer (1981) found that participants appeared to confuse differences in tone quality and intonation. Participants were asked to discriminate between good and bad tone quality while listening for intonation errors. Findings indicated that participants perceived more intonation errors than tone quality errors. Continuing this line of study, Geringer and Madsen (1981) found that participants preferred sharpness or in-tune intonation to flatness when listening to oboe-flute duet pairs. Like the previous study, participants responded more to sharp and in-tune intonation over tone quality. While examining the effects of timbre on collegiate musicians who performed the saxophone, clarinet, and flute, Ely (1992) found that timbre had a significant effect on participants’ abilities to detect intonation deviations but not on their abilities to play in-tune. Trumpet and voice tones were judged as sharper than viola tones of the same pitch even though each tone shared the exact same fundamental frequency (Vurma & Ross, 2006). In a more recent study, a trumpet soloist was judged most out of tune, even though the trumpet player objectively performed with more accurate intonation than the violinist and vocalist (Geringer et al., 2015). Findings also indicated that the vocalist was rated most in-tune even though actual measures indicated the vocalist had the highest cent deviation.

**Preference for timbre of tuning stimulus**

Researchers have investigated musicians’ preference and performance of a tuning stimulus when tuning an instrument. Collegiate wind musicians were more accurate tuning to an oboe or tuba compared to tuning with an electronic source (Hayslett, 1990). In a similar study, Byo et al. (2011) found that more high school wind musicians perceived a pitch provided by tuba as the easiest to match compared to oboe, clarinet, and flute. However, an analysis of actual tuning responses revealed that participants tuned to the oboe, clarinet, and flute more accurately compared to the tuba. A follow up study found that collegiate wind musicians also perceived a pitch provided by a tuba as easiest to match compared to an oboe, clarinet, and electronic stimulus; however, no significant difference was found in tuning accuracy scores between reference pitches provided by the oboe, clarinet, electronic tuner, and tuba (Byo & Schlegel, 2016).

Investigations of tuning stimuli with string musicians appear in the literature as well. A survey of high school and middle school string students found that students who felt most confident tuning their own instrument most often indicated that a student instrument was used for
tuning (Hamann, Frost, & Wieters, 2002). However, when perceived and actual tuning ability were measured with middle school string students, no significant difference in tuning accuracy scores was found between those who tuned with a viola or an electronically generated pitch (Hamann et al., 2006). Additionally, a study of high school string students found no significant difference in A-string tuning accuracy between those who tuned with an electronically generated pure tone stimulus and a complex tone stimulus (Alexander, 2011).

**Tone quality and intonation**

Multiple researchers investigating timbre and intonation have found that timbre influences the perception and performance of intonation. Specifically, investigators found that “bright” sounding stimuli were perceived as sharp while “dark” sounding stimuli were perceived as flat. Undergraduate music majors listened to pairs of clarinet tones and were asked to indicate whether or not the second tone was sharp, flat, or same as the first pitch (Wapnick & Freeman, 1980). Clarinet tones were adjusted to have a bright or dark timbre relative to the original recorded level and adjusted to either ±12 cents or left unaltered. Results indicated that participants associated dark tones with flat intonation and bright tones with sharp intonation. This was corroborated in a study by Geringer and Worthy (1999) who investigated high school students’, undergraduate music majors’, and non-music majors’ perceptions of tone quality in various pairs of tones consisting of clarinet, trumpet, and trombone timbres. Participants who were inexperienced judged “bright” tones with sharper intonation and “darker” tones with flat intonation. Extending the previous investigation, Worthy (2000) assessed the effects of change in tone quality on the perception of pitch and examined how tone quality conditions affects the performance of pitch. High school and university wind instrumentalists judged “bright” tones as sharper in pitch and “dark” tones as flat. Participants also performed sharp with matching “bright” stimuli and performed flat when matching “dark” stimuli. Using stimuli produced by a viola, trumpet, and a tenor voice, Vurma, Raju, and Kuuda (2011) also determined that “brighter” sounds were perceived as higher in pitch while “darker” sound were perceived as lower.

**Accompaniment**

The effects of accompaniment and accompaniment type have been thoroughly investigated. Using the Headturn Preference Procedure (Kemler-Nelson et al., 1995), infants
were shown to prefer singing that was unaccompanied over singing that was accompanied (Ilari & Sundara, 2009). Type of accompaniment was found to affect elementary school students’ preference toward a melody even though the melody was the same with each accompaniment (Brittin, 2000). These students preferred accompaniment styles that were R&B and rock-based over samba, hully gully, funk 2, bluegrass, march, and polka accompaniment styles. Middle and high school instrumentalists gave solo performances higher preferences scores when accompanied with band method book recordings over performances that were unaccompanied or accompanied with a piano (Brittin, 2002; Brittin et al., 2002). Accompaniments with chords that were performed live or recorded were preferred over a recorded melodic line or synthesized accompaniments among people aged 65 years or more (Moore et al., 1992). More recently, Springer and Silvey (2018) found that ratings of solo trumpet performances were higher when accompanied with good and no piano accompaniments than with a bad accompaniment.

**Accompaniment on performance**

The effect of accompaniment on student performances has also been investigated. Anderson (1981) found no significance difference of performance skill between 6th grade clarinetists who practiced with an audiotaped accompaniment and those who did not. Tonal achievement in kindergarten and first grade did not improve between those who had instruction with a root melody accompaniment and those who did not (Guilbault, 2004). A year-long study found no significant difference in singing ability between two groups of kindergartners, those who had instruction with accompaniment and those who had instruction without accompaniment (Atterbury & Silcox, 1993). Although audiotaped accompaniments had no effect on performance ability in the previously listed studies, Zurcher (1975) found that brass beginners showed improvement in rhythm discrimination, pitch matching, and a reduction of pitch errors when using audiotaped accompaniment.

The use of accompaniment to improve intonation has been recommended by several pedagogues. Green (2010, p. 58) suggested that intonation should be taught to beginning string students using a piano during the first year of study; however, she also warned that the piano should not be used as a crutch. Kohut (1973, p. 200) recommended that studio teachers should use duets as a means for teaching intonation to students. He suggested that students learn to listen to their teacher’s pitch and adjust to it. Hamann and Gillespie (2013) advised string teachers to teach students to match a fingered pitch using double stops with open strings for
intermediate students (p. 106) and to use selected chords to accompany scales and melodies to improve aural skills for advanced students (p. 143). String pedagogues have also recommended the use of drone accompaniments to improve intonation of string musicians (Curry, 2011; Hopkins, 2012; Watkins, 2004).

English (1985) investigated the effect of piano accompaniment on a beginning string orchestra classes. Forty-two junior high beginning string students were assigned to one of three treatment groups: 100% piano accompaniment, 50% piano accompaniment, and no piano accompaniment. Students who were not exposed to piano accompaniment scored higher than students who were exposed to piano accompaniment in areas of intonation and rhythmic accuracy. Furthermore, students who were exposed to limited piano accompaniment were more accurate than students who had 100% piano accompaniment. This outcome may suggest that beginning string students may advance more efficiently without accompaniment.

Sheldon, Reese, and Grashel (1999) investigated the effects of digital accompaniment and live piano accompaniment on solo performance ratings. Undergraduate music education students in a secondary instrumental methods class were used as participants. The students were arranged into three conditions of solo preparation: no accompaniment, live accompaniment, intelligent digital accompaniment. Students who were assigned the live accompaniment condition were provided a pianist who was also a music education student. Each student practiced their secondary instrument 1.5 hours each week for six weeks in their assigned condition. At the end of the treatment period, all groups recorded twice: once without accompaniment and then in the designated accompaniment mode. Recordings were judged by a panel of five judges who used a rubric to rate performances. Results indicated no significant difference in rating scores between the three groups. The highest scores for all groups were achieved in rhythm, technique, and articulation while the lowest ratings were intonation, tone quality, and interpretation.

**Accompaniment and intonation**

The presence of accompaniment was found to affect listeners’ preference for intonation. Using the Continuous Response Digital Interface (CRDI), Madsen, Geringer, and Heller (1991) found that music majors rated accompanied excerpts of “good” and “bad” intonation significantly higher than unaccompanied excerpts. This study was replicated and participants were asked to focus on tone quality (Madsen, Geringer, & Heller, 1993). Although participants
were able to distinguish between “good” and “bad” tone quality, no significant differences were found between accompanied and unaccompanied conditions.

Accompaniment has been shown to affect the intonation of the solo performer. Accompanied scales were perceived and performed with greater pitch accuracy than unaccompanied scales (Geringer, 1978). Brittin (1993) found that high school and collegiate/professional trombonists were significantly more accurate when they began a duet with a pre-recorded piano accompaniment that was flat rather than sharp, regardless of register. An examination of string players found that they were significantly sharper performing in the upper register with a low-register computer-generated accompaniment compared to low register performances with a high-register accompaniment (Kantorski, 1986).

Closely related to the present study, a dissertation by Garman (1992) investigated the effect of accompaniment texture and contextual pitch distance on the intonation of string musicians. String musicians (N = 42) whose primary instruments were either the violin, viola, cello, or double bass, performed in four conditions of accompaniment (unaccompanied, accompanied in unison or at the octave, harmonized by a single voice, and harmonized by diatonic triads or seventh chords) and two conditions of register (proximate register, in which the pitch range of performance tones overlapped with or was within the range of the accompaniment tones, and distant register, where the performed tones were an octave distant from the accompaniment). For the distant register condition, violinists and violists performed an octave above while cellists and double bassists performed an octave below. String musicians performed an excerpt from Handel’s Flute Sonata No. IV in C major, third movement, Larghetto. An electronic piano with an acoustic piano tone was used for the accompaniment conditions. Performances were recorded and analyzed with absolute cent deviation compared to equal temperament. Results indicated that accompanied performances in the three accompanied conditions were significantly more in-tune than unaccompanied performances. A significant difference was found between the four instrument groups with double bassists performing with greater deviation than the other instruments. Performances by violinists, cellists, and double bassists had greater cent deviation in the distant register condition while violists deviated more in the proximate register condition.
Summary

Musicians must consider several variables when performing or teaching accurate intonation. Musicians should be aware of tuning temperaments and the context in which each temperament may be used. Adjusting to equal temperament might be considered when performing with a piano, while Pythagorean tuning may be more relevant when performing with a string instrumentalist. When practicing intonation, it would be helpful for musicians to be aware that as a group they may have a tendency to perform sharp, and possibly can train themselves to tune lower when self-assessing their pitch. Researchers have generally found that training programs designed to help musicians improve intonation can do so. Music teachers can implement various methods to train students to listen more carefully to their pitch and improve their intonation. Music teachers should also know that the stimuli of a reference pitch may be a variable when perceiving and performing accurate pitch. Researchers have found that musicians generally match pitch more accurately to acoustic pitches more than electronically generated pitches. Understanding that performing in different accompanied conditions can affect pitch accuracy is also important for musicians, especially if accompaniments are used in a training situation. As musicians work to improve their own intonation, music teachers must also work to help music students to adjust their intonation independently. Future research is warranted to explore how all musicians perceive and perform intonation in various contexts.
CHAPTER THREE
METHOD

The purpose of the present study was to examine the effects of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. Specifically, this study explored intonation accuracy between accompanied and unaccompanied performances, the effects of octave, string accompaniments and non-string accompaniments, musicians’ perception of their intonation performing with different accompaniments, the relationship between musicians’ perception of their intonation and their actual intonation, and effects of age and experience. Prior to the start of the study, approval was obtained from the FSU Human Subjects Committee at the Office of the Vice President for Research at Florida State University (see Appendix A), as well as from the Leon County Schools Office of Testing, Research and Evaluation (see Appendix B).

Participants
Participants were volunteers from two orchestral ensembles at the Florida State University College of Music, one orchestra class from a neighboring high school, and two orchestra classes from a second neighboring high school. The first high school had a student population of 2094 with 1047 (50%) self-identified as female and the other 1047 (50%) self-identified as male. The demographic breakdown of this school was 1041 Caucasian (50%), 745 African American (36%), 117 Hispanic/Latino (6%), 86 Asian (4%), 12 American Indian or Alaskan Native (1%), or Multi-Racial 91 (4%). The orchestra director at this high school program identified as female. She had been teaching orchestra for 11 years and taught at this high school for three years. The program at this high school was relatively new and had been in place for five years. She taught two orchestra classes: a beginning level orchestra (n = 8) and the regular orchestra class (n = 19). Participants were recruited from the regular orchestra class (n = 16). The second high school had a student population of 2077 with 1023 (49%) self-identified as female and 1054 (51%) as male. The demographic breakdown of this school was 1581 Caucasian (76%), 184 African American (9%), 107 Hispanic/Latino (5%), 139 Asian (7%), and 58 Multi-Racial (3%). The orchestra director at this high school program identified as male, had been teaching orchestra for 22 years, and taught at this high school for 17 years. The orchestra
program had been established for 17 years and currently offers three levels of string orchestra: a freshman class \((n = 21)\), a regular ensemble \((n = 28)\), and an advanced ensemble \((n = 27)\). Participants were recruited from the regular and advanced ensemble \((n = 46)\).

During recruiting efforts at Florida State University, I presented the research study to undergraduate and graduate string musicians. I made appointments with participants by having them sign up for a day and time of their choice and asking them to provide a best email address to contact them. A day before their appointed time, I contacted participants sending them a reminder of our appointment. Additionally, I attached a PDF of the Participant Consent Form (see Appendix C) so they could review it on their own time. Recruiting efforts at the high schools involved a short 5 to 10-minute presentation during class. I passed out the Parent Consent (see Appendix D) and Student Assent (see Appendix E) forms to all students in the class and discussed purpose and procedures of the study. Prior to participation, I obtained consent forms from university participants and student assent and parent consent forms from high school participants. After participation of the study, data from one high school participant was eliminated from data analysis procedures due to the performance of wrong notes. The total sample of participants used for data analysis consisted of 103 string musicians.

There were 43 participants recruited from the Florida State University College of Music. The participants were undergraduate \((n = 31)\) and graduate \((n = 12)\) music majors whose primary instrument was the violin \((n = 20)\), viola \((n = 11)\), or cello \((n = 12)\). Their mean age was 22.63 years \((SD = 4.15)\) and their reported years of performing experience on their primary instrument ranged from 5 to 32 years \((M = 13.59; SD = 5.42)\). Further breakdown by course of study consisted of music performance majors \((n = 25)\), music education majors \((n = 11)\), and other \((n = 7)\). Participants who selected the other category indicated music therapy, musicology, commercial music, and music composition as their field of study.

There were 60 participants recruited from one of two high schools in close proximity to Florida State University. The participants were ninth graders \((n = 10)\), tenth graders \((n = 14)\), 11th graders \((n = 21)\), and 12th graders \((n = 15)\) whose primary instrument was the violin \((n = 35)\), viola \((n = 11)\), and cello \((n = 14)\). Their mean age was 16.20 years \((SD = 1.15)\) their reported years of performing experience on their primary instrument ranged from 2 to 13 years \((M = 6.63; SD = 2.36)\).
Testing with collegiate students occurred during a two-week period towards the end of January and the beginning of February. Their scheduled appointments were made from late morning to late afternoon. Testing of students from the first high school occurred for five days at the beginning of February during the fourth period class from 10:23 a.m. to 11:14 a.m. High school students at the second school were tested for five days at the end of February, right after Music Performance Assessment, during the first period (7:30 a.m. - 8:20 a.m.) and third period (9:25 a.m. - 10:15 a.m.) classes.

**Accompaniment Stimuli**

Solo oboe, violin, cello, and piano performances of a simple melody were recorded as the accompaniment stimuli for this study. The melody chosen comes a traditional French song, *Frère Jacques* (see Figure 3.1). The melody for *Frère Jacques* was first printed in the 1811 edition of *La Clè due Caveau, à l’usage de tous les Chansonniers français* and the first known printing of the French lyrics with the melody is seen in *Recueil de Rondes avec Jeux et de Petites hansons* by Charles Lebouc (Fuld, 1985). This piece was chosen because of its simplicity and familiarity to most musicians and it was used in previous studies in music (Lindström, 2006; Mills, 1995; Portowitz, Peppler, & Downton, 2014). This melody is mostly stepwise with very few jumps, it contains a perfect fifth between the tonic and the upper dominant towards the end of the tune, which is the largest leap in the excerpt. It is notated with half, quarter, and eighth notes, which provided participants’ ample time to listen to their pitches so they could match their performed pitch with the accompaniment at 76 beats per minute. All excerpts were performed in E♭ major. This key was chosen because it necessitated string performers to use fingers for each pitch and eliminated the use open strings. The violin and oboe’s first pitch started on E♭₄, the bottom line on the treble clef. The cello and piano’s first pitch was an E♭₃, the third space from the bottom of the bass clef. This pitch was chosen because it was within the normal range of the cello. Stimulus recordings were made using a Blue Spark Condenser Microphone attached to a Pyle 2 channel mixer (PAD10MXU) with an XLR cable, the mixer was then connected to a MacBook Pro via USB cable. Ableton Live 9, a digital audio workstation, was used to save recordings with a sampling rate of 44.1 kHz at 24-bit resolution as a WAV file. Recording equipment was operated by a recording specialist.
All stimulus recordings were performed by graduate music students working on a terminal degree on their primary instruments. Solo performances by the oboist, violinist, and cellist were recorded in a sound-treated room designed for audio recordings. The solo performance of the pianist was recorded in a piano lab on a Yamaha U1 Upright Acoustic Piano. Accompaniment performers were brought into the room individually and were provided time to warm up and get acclimated to their surroundings. The task was explained and sheet music for Frère Jacques was provided for reference. Performers were asked to perform each excerpt and demonstrate accurate intonation without using vibrato. Each performer warmed-up on his or her instrument, played through the excerpt a few times as needed, and a sound check was completed. The first note for the oboe and violin part was an E♭\textsubscript{4}. As such, prior to each recording, the oboist and the violinist were given a reference pitch of E♭\textsubscript{4} at 311.1 Hz with a triangle wave timbre using the application Cleartune Version 2.2 on an iPhone 8. The first note for the cello part was an E♭\textsubscript{3} and the cellist was given the option to use an E♭\textsubscript{3} at 155.6 Hz as a reference pitch;
however, he preferred to use an E♭₄. The pianist was not provided a reference pitch. After the reference pitch was produced, the performers were given four clicks of a metronome at 76 beats per minute before starting the excerpt. The metronome click was provided using the application Pro Metronome Version 3.13.2 on an iPhone 8. The metronome clicks were included in the recording to help participants anticipate the tempo of the stimulus. Multiple recordings of each performance was made for each instrument until the performer, researcher, and recording specialist were satisfied with recording, specifically regarding intonation and tone quality. The top two recordings on each instrument were selected for analysis (Oboe A, Oboe B, Violin A, Violin B, Cello A, Cello B, Piano A, Piano B).

Directional cent deviation from equal temperament was measured for each pitch of the accompaniment excerpts using pitch analysis software, Tony (v. 2.0) (Cannam, Mauch, Fazekas, Salamon, & Bittner, 2018) which were then converted to absolute cent deviation. A dependent t-test was calculated to determine if there was a significant difference of overall mean absolute cent deviation between each stimuli pairing. Results indicated a significant difference between Oboe A ($M = 5.72, SD = 4.20$) and Oboe B ($M = 7.06, SD = 4.31$), $t (31) = -4.48, p < .001$. No significant difference was found between other pairings. For the remaining pairs, the stimulus recording with the lowest absolute cent deviation mean was ultimately chosen for the study: violin, $M = 4.69, SD = 3.51$; cello, $M = 6.28, SD = 4.92$; and piano, $M = 3.81, SD = 2.78$. The final stimuli were edited using the VariAudio function in Cubase (v. 9.5) and the manual pitch correction effect in Adobe Audition CC (v. 10.1) in order to produce versions of the files that contained all pitches deviating no more than ±6 cents from equal temperament. The process of editing sound files to reduce the magnitude of pitch deviation in the reference stimuli have been used in previous studies (Geringer, MacLeod, & Allen, 2010; Geringer, Macleod, & Sasanfar, 2012; Geringer et al., 2015) and ±6 cents was considered the threshold of deviation in a previous study (Karrick, 1998). An independent one-way ANOVA was calculated to determine if there was a significant difference of absolute cent deviation between each stimulus recording, no significant difference was found, $F (3, 124) = 2.58, p > .05$. These pitch versions of the stimuli were used as the master files for all accompanied conditions.

**Presentation order of accompaniment and final audio files**

Five audio files each containing a different presentation order of accompanied and unaccompanied conditions were created using Audacity (v. 2.1.2). The order of conditions was
Table 3.1

*Presentation Order of Accompaniment Conditions*

<table>
<thead>
<tr>
<th>Order</th>
<th>Cello</th>
<th>Oboe</th>
<th>Piano</th>
<th>Solo</th>
<th>Violin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order A</td>
<td>Cello</td>
<td>Oboe</td>
<td>Piano</td>
<td>Solo</td>
<td>Violin</td>
</tr>
<tr>
<td>Order B</td>
<td>Oboe</td>
<td>Piano</td>
<td>Violin</td>
<td>Cello</td>
<td>Solo</td>
</tr>
<tr>
<td>Order C</td>
<td>Piano</td>
<td>Solo</td>
<td>Oboe</td>
<td>Violin</td>
<td>Cello</td>
</tr>
<tr>
<td>Order D</td>
<td>Solo</td>
<td>Violin</td>
<td>Cello</td>
<td>Piano</td>
<td>Oboe</td>
</tr>
<tr>
<td>Order E</td>
<td>Violin</td>
<td>Cello</td>
<td>Solo</td>
<td>Oboe</td>
<td>Piano</td>
</tr>
</tbody>
</table>

determined by a counterbalanced design using Latin squares (see Table 3.1), this was applied so that experimental treatments were presented in randomized order (Campbell & Stanley, 1963). Audacity project files contained pre-recorded instructions that occurred at the beginning of each file and between accompaniment conditions in an appropriate order to guide the participants. Also included in the project was a 15-second excerpt of *Am Scheideweg, Op. 28. No 1* by A. Schoenberg. In previous studies, researchers played pieces between treatments which was intended to block tonal memory (Geringer, 1978; Kantorski, 1986; Madsen, 1966; Madsen & Geringer, 1976). This piece was chosen because it is polytonal and contains no single pitch center. Additionally, it is a choral a capella piece which contains a different timbre than any of the accompaniment stimuli or string instruments. At the end of each project file were concluding statements that reminded participants to complete the written questionnaire and thank them for their participation. Project files were exported as 24-bit WAV files and were used as master files for the remaining procedures.

**Questionnaire**

I developed the Intonation Study Questionnaire (ISQ) to measure participants’ preferences for accompaniment and perceptions of their tuning accuracy (see Appendix F). The participants were asked to numerically rank the instrumental accompaniment they preferred from *most preferred* (1) to *least preferred* (4). Additionally, participants were asked to rate their perceived tuning accuracy to each condition (accompanied or unaccompanied) on an 11-point rating scale with the anchors *not accurate* (0) and *very accurate* (10). The items listed were based on questions from previous studies where researchers asked participants which accompaniment condition they believed to be the easiest and most difficult to tune with (Byo & Schlegel, 2016; Byo et al., 2011). The following demographic information was also collected.
with the questionnaire: age, years of study, where the participant started (school, private lessons, other), level of study (high school, undergraduate, graduate masters, graduate doctoral), and if relevant, the specified major (performance, music education, other).

**Pilot test**

A pilot study was completed the previous school year using string music education majors \((N = 19)\) as participants who played the violin \((n = 14)\) and viola \((n = 5)\). The stimulus recordings were made by an oboist, flutist, violinist, and cellist who performed *Twinkle Twinkle Little Star* in E\(^{b}\) major. The stimulus recordings were made using different equipment than the present study: a USB microphone (CAD U37 Studio Condenser Recorder Microphone) attached to a MacBook Pro; and audio editing software, Audacity (v. 2.2.1), was used to save recordings. No other changes in the procedure of recording stimuli were made. The decision to remove the flute and add the piano stimuli was made to control for the effect of octave, the flute stimulus in the pilot study started on E\(^{b5}\) while the piano stimulus started on E\(^{b3}\). In the pilot study, the cello stimulus was an octave below participant performances which started on E\(^{b3}\) while the flute stimulus was performed an octave above the participants starting at E\(^{b5}\). The piano in the present study controlled for octave as it was a second instrument in the same octave as the cello. This control for octave also permitted the inclusion of cellists as participants in the study. The decision to replace *Twinkle* in the pilot study with *Frère Jacques* in the present study was made to provide more rhythmic variety in the excerpt. The pilot test did not include a questionnaire for participants.

**Room set up**

Testing procedures for collegiate level participants took place on campus at Florida State University in a room designed for music recording. High school participants were tested at the high school in an available quiet room near the orchestra room. Considering the rooms were not acoustically equivalent, every attempt was made to replicate the set-up of equipment between each facility (see Figure 3.2). A table was placed towards the center of the back wall of the room. A portable external speaker (Soundfreaq Sound Platform 2) was placed on the center of the table with a MacBook Pro placed next to it. The researcher was on the side of the table to avoid direct eye contact between the participant and the researcher. This was done in an attempt to reduce music performance anxiety of participants. In front of the table was a music stand, which held sheet music of the excerpt that was parallel to the table approximately four feet away. Also
placed on the table was an area to store the attachable microphone (HEIMU Clip On Instrument Condenser Microphone) and the Pyle 5 Channel Audio Mixer which were connected to a MacBook Pro and used to record the performance. A smaller table and a chair was placed outside the room designated for recording. This was the designated location for participants to complete the questionnaire described earlier (see Appendix F).

Procedure

Collegiate level participants received an e-mail the day before their scheduled appointment that included a reminder of testing time and location. High school participants who had completed parent consent and student assent forms were dismissed by their teacher to the area designated for recording.

I greeted each participant as they entered the room individually and I verified that the appropriate consent and/or assent forms were signed and submitted. Once confirmation occurred,
I instructed them to prepare their instrument to perform. I assigned each participant with a subject number and logged it in the appropriate order (see Appendix G). This allowed me to keep track of which order group (see Table 3.1) each participant was assigned in an attempt to prevent order effects. During this time, all participants were given the opportunity to ask questions prior to the start of the study and were informed that they could stop at any time.

Once the participant prepared his or her instrument, I instructed them to tune it accurately to a tuner calibrated to $A_4 = 440\text{Hz}$. If the participant was unable to do so, the researcher offered to tune the instrument. After the instrument was tuned, the researcher asked the participants if a pickup microphone could be attached to the instrument (HEIMU Clip On Instrument Condenser Microphone). If the participant did not provide permission to attach the microphone, the testing procedures were concluded and the participant did not continue. The microphone was placed near the f-holes to capture the acoustic pitches produced by the instrument without interference produced from accompaniment stimuli. The pickup microphone was connected to a Pyle 5 Channel Audio Mixer which was connected to a MacBook Pro via USB. Audio software, Audacity, was used to record the performances. After the microphone was attached, each participant was asked to stand or sit in front of the music stand. Once the participant was properly placed, they were instructed to perform a one-octave C major scale to serve as a sound check to ensure that the recording equipment was working properly. It also allowed the participants to acclimate themselves to the room and recording equipment, and served as a brief warm-up before the performance task.

Instructions

Once the participants were comfortable and properly positioned, they were presented with a pre-recorded instructional track:

On the music stand in front of you is an excerpt of Frère Jacques in E-flat major. This is the tune that you will be performing today. You will be given an opportunity to practice this for two minutes. You do not have to utilize all two minutes. Once the two minutes are over, we will proceed. You may begin practicing.

I momentarily paused the instructions and the participant was given two-minutes to practice the excerpt. If the participant indicated readiness to proceed before the two-minute practice window was over, I continued the procedure and resumed the instructions:
Before you begin performing the excerpt, you will hear four metronome clicks. These clicks will help you begin the performance of the excerpt with the accompaniment accurately. Your primary focus is to perform with the excerpt demonstrating accurate intonation. Please note that in between models, you will hear choral a capella music to help you clear your ear. Do you have any questions?

During this time, I paused the instructions to provide time for the participant to ask a question. Once the participant indicated she was ready to continue, the instructions continued:

Please begin after the metronome clicks.

These steps were repeated for the other accompaniment versions. Each condition was introduced by a prompt indicating the instrument of accompaniment (cello, oboe, piano, and violin) and succeeded by the metronome clicks and the audio. Prior to the solo condition, a different set of instructions were provided:

For this performance, you will now perform the excerpt as a solo. You will hear four metronome clicks, but no accompaniment. As before, focus on your intonation. Please begin after the metronome clicks.

If the participant was assigned the presentation order where the solo condition was first, the instructional track began with a modified set of instructions:

You will first perform as a solo. Before you begin performing the excerpt, you will hear four metronome clicks. These clicks will provide a starting tempo. Your primary focus is to perform the excerpt demonstrating accurate intonation. Please note that in between performances, you will hear choral a capella music to help you “clear” your ear. Do you have any questions?

After the solo condition was completed, the next dialogue instructed the participants of the remaining performances:

For all remaining performances, you will perform with an accompaniment. You will still hear four metronome clicks. As before, focus on your intonation. Please begin after the metronome clicks.

During the solo condition, the instructional track allotted the proper amount of time of silence to allow the participant to perform the excerpt as a solo. After each solo, the Schoenberg excerpt, the next condition, or the next set of instructions was produced. At the conclusion of the five performance tasks, the participants heard the following remarks:
This concludes the performance portion of the study. Please hand your instrument to the researcher to remove the microphone, put your instrument away, and remember to complete the written questionnaire. Thank you again for your participation in the study.

The participants gave their instrument to me and I then removed the microphone from the instrument. Once the participants put away their instrument, I handed them the Intonation Study Questionnaire to complete. The participants completed the ISQ in a quiet location outside the testing area and submitted the forms in a box. One this task was completed, collegiate participants were free to go and high school participants were dismissed back to their orchestra rehearsal.

While participants were completing the questionnaire, I exported all audio recordings as a WAV file at 24-bit resolution and saved each file with the participant’s number. I thanked the participants again for their time and talents. I also asked them to keep the details of the study confidential until all data collection procedures were completed. The whole protocol took an average of 12 minutes to complete.

Analysis of Performances

WAV audio recordings of participant performances were analyzed using the software Tony (v. 2.0) (Cannam et al., 2018) (see Figure 3.3). Tony is a software program used for scientific pitch and note transcription by allowing the user to easily visualize, edit, and export pitch analysis. Tony allows the user to visualize pitch tracks and notes from audio files. It allows the user to correct analysis errors such as alternative pitch track selection, octave shift, and easy note split, merge, and deletion. It can also allow the user to export pitch and note track data into a comma-separated values format. The program automatically selected pitches and calculated the average frequency in Hertz and cent deviation for a selected pitch. I entered the directional cent deviation for all 32 notes of Frère Jacques that were calculated from Tony into a Microsoft Excel spreadsheet. Additionally, I edited each analysis on Tony as needed (e. g., extend a note selection, split a note, combine notes, correct the octave, double check a cent deviation calculation).

Directional cents deviation were entered into a Microsoft Excel spreadsheet and converted to absolute cents deviation which were used for all subsequent analysis. Considering
that Frère Jacques repeats melodic content every other measure, absolute cent deviation for each second measure was used for all analyses (see Figure 3.4). The first measure was treated as a warm-up period to allow the participants to adjust their pitches to the accompaniment. Additionally, absolute cent deviation means were used only for notes E♭, G, A♭, and B♭ (scale degrees 1, 3, 4, and 5) in the selected measures. These notes were selected because there were multiple performances of each note by participants per section analyzed for each accompaniment condition (E♭, n = 5; G, n = 3; A♭, n = 2; B♭, n = 4).

Analysis of Intonation Study Questionnaire

Data from the Intonation Study Questionnaire (ISQ) were entered into a Microsoft Excel spreadsheet which was divided into three sections. The first section included demographic information: primary instrument, school attended, reported age, reported years of experience performing their primary instrument, level of study (collegiate or high school), grade level, and course of study. The second section reported participants’ preference for accompaniment (cello,
piano, oboe, or violin). The third section detailed the participants’ perception of their tuning accuracy.

*Figure 3.4. Analyzed measures and notes (inside bold squares and underlined).*
CHAPTER FOUR
RESULTS

Purpose Statement

The purpose of this study was to examine the effects of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. The research questions were as follows:

1. Are there differences in tuning accuracy of melodic content between accompanied and unaccompanied conditions among string musicians?
2. Are there differences in tuning accuracy of melodic content between accompaniment octaves?
3. Are there differences in intonation accuracy between string, oboe, and piano accompaniments?
4. Are there differences between the number of flat, sharp, and in-tune responses of participants?
5. Are there differences in string musician preferences between accompaniment types?
6. Are string musicians’ self-perceptions of tuning accuracy associated with performed pitch accuracy?
7. Are there differences between age and experience of participants in intonation accuracy with various accompaniment types?

Participants (N = 103) were collegiate music majors who were enrolled at Florida State University (n = 43) and high school students (n = 60) who were enrolled in their orchestra class at one of two nearby high schools. All participants were string musicians whose primary instrument was the violin (n = 55), viola (n = 22), or the cello (n = 26). Participants performed Frère Jacques in E♭ major in unison or in octaves in various conditions: accompanied with the cello, oboe, piano, violin, and as a solo. The performances were audio-recorded using a pick-up microphone connected to a MacBook Pro and saved as a WAV file. After performing Frère Jacques, the participants completed the Intonation Study Questionnaire which collected demographic information and measured participants’ preferences to accompaniment and perception of their tuning accuracy.
Audio files were analyzed using a pitch and note transcription software, Tony (v. 2.0) (Cannam et al., 2018), which calculated directional cent deviation of each performed pitch. Directional cent deviation were then converted to absolute cent deviation which were used for all subsequent analyses. Data obtained from audio files and the ISQ were analyzed using IBM SPSS Statistics (v. 25). An alpha level of .01 was established a priori for all statistical tests.

Intonation

Raw data consisted of directional cent deviation from individual pitch analysis of the fundamental frequency in relation to equal temperament. Directional cents deviation were converted to absolute cents deviation and notes of the same pitch class were averaged together for each participant. Absolute cent deviation means were used for notes E\textsubscript{b}, G, A\textsubscript{b}, and B\textsubscript{b} (scale degrees 1, 3, 4, and 5). A four-way analysis of variance was conducted to determine if there was a significant difference in within-subjects variables (accompaniment type and the four notes) and between-subjects variables (level of participants and primary instrument). A Mauchly’s Test of Sphericity indicated that the assumption of sphericity was violated for accompaniment type, notes, and accompaniment type by notes. Therefore, the Greenhouse-Geisser correction was used for subsequent analysis with those factors.

For the within-subjects analysis, a significant main effect was found between accompaniment conditions (cello, oboe, piano, violin, and solo), $F(2.37, 229.85) = 9.69, p < .01, \eta^2_p = .091$. Significant differences were found using pairwise comparisons with a Bonferroni correction between solo and oboe, solo and violin, solo and cello, and piano and oboe ($p < .01$). No other significant differences were found between remaining pairs. Participants performed with higher cent deviation during the solo condition compared to the cello, oboe, and violin accompaniment conditions. Standard deviations were also much higher for the solo condition compared to accompaniment conditions (see Table 4.1). Additionally, participants performed with higher cent deviation performing with the piano accompaniment than with oboe accompaniment. Means and cent deviation of participants in each accompaniment condition can be found in Table 4.1. Additionally, a significant main effect was found between deviations of the analyzed notes, $F(2.36, 228.63) = 8.89, p < .01, \eta^2_p = .084$. Pairwise comparisons with a Bonferroni correction found significant differences between notes A\textsubscript{b} and E\textsubscript{b}, and A\textsubscript{b} and B\textsubscript{b} ($p < .01$). The A\textsubscript{b} (subdominant) had higher mean cent deviation than the E\textsubscript{b} (tonic) and B\textsubscript{b}
Table 4.1

*Mean and SD of Cent Deviation of Participants in Accompaniment Conditions*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oboe</td>
<td>9.54</td>
<td>5.67</td>
</tr>
<tr>
<td>Violin</td>
<td>10.04</td>
<td>5.85</td>
</tr>
<tr>
<td>Cello</td>
<td>10.25</td>
<td>6.06</td>
</tr>
<tr>
<td>Piano</td>
<td>11.00</td>
<td>5.58</td>
</tr>
<tr>
<td>Solo</td>
<td>13.15</td>
<td>10.41</td>
</tr>
</tbody>
</table>

Table 4.2

*Mean and SD of Cent Deviation of Notes Analyzed*

<table>
<thead>
<tr>
<th>Note</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>E♭</td>
<td>9.71</td>
<td>6.20</td>
</tr>
<tr>
<td>B♭</td>
<td>9.90</td>
<td>6.33</td>
</tr>
<tr>
<td>G</td>
<td>10.59</td>
<td>7.00</td>
</tr>
<tr>
<td>A♭</td>
<td>12.98</td>
<td>8.86</td>
</tr>
</tbody>
</table>

Table 4.3

*Mean and (SD) of Cent Deviation of Instruments in Octave Groupings*

<table>
<thead>
<tr>
<th>Participant Instrument:</th>
<th>Violin</th>
<th>Viola</th>
<th>Cello</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Octave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oboe</td>
<td>6.69 (1.82)</td>
<td>6.86 (1.74)</td>
<td>6.46 (1.75)</td>
</tr>
<tr>
<td>Violin</td>
<td>7.56 (1.91)</td>
<td>7.91 (1.84)</td>
<td>6.87 (1.85)</td>
</tr>
<tr>
<td>Lower Octave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cello</td>
<td>7.71 (1.27)</td>
<td>7.96 (1.22)</td>
<td>7.99 (1.22)</td>
</tr>
<tr>
<td>Piano</td>
<td>6.83 (1.55)</td>
<td>7.27 (1.49)</td>
<td>7.53 (1.50)</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solo</td>
<td>7.17 (2.19)</td>
<td>7.46 (2.11)</td>
<td>7.25 (2.11)</td>
</tr>
</tbody>
</table>
Table 4.4  
Analysis of Variance Results for Absolute Cent Deviation  

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>ηp²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between-subjects effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument (I)</td>
<td>420.25</td>
<td>2</td>
<td>210.12</td>
<td>.40</td>
<td>.37</td>
<td>.008</td>
</tr>
<tr>
<td>Level (L)</td>
<td>14849.37</td>
<td>1</td>
<td>14849.37</td>
<td>28.04</td>
<td>&lt; .01</td>
<td>.224</td>
</tr>
<tr>
<td>I x L</td>
<td>1135.99</td>
<td>2</td>
<td>567.99</td>
<td>1.072</td>
<td>.45</td>
<td>.022</td>
</tr>
<tr>
<td>Error (between)</td>
<td>51375.92</td>
<td>97</td>
<td>529.65</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Within-subjects effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accompaniment (A)</td>
<td>2789.28</td>
<td>2.37</td>
<td>1175.84</td>
<td>9.69</td>
<td>&lt; .01</td>
<td>.091</td>
</tr>
<tr>
<td>A x I</td>
<td>686.04</td>
<td>4.74</td>
<td>144.76</td>
<td>1.19</td>
<td>.34</td>
<td>.024</td>
</tr>
<tr>
<td>A x L</td>
<td>812.72</td>
<td>2.37</td>
<td>342.98</td>
<td>2.83</td>
<td>.05</td>
<td>.028</td>
</tr>
<tr>
<td>A x I x L</td>
<td>190.00</td>
<td>4.74</td>
<td>40.09</td>
<td>.33</td>
<td>.89</td>
<td>.007</td>
</tr>
<tr>
<td>Error (within)</td>
<td>27883.60</td>
<td>229.85</td>
<td>121.31</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Note (N)</td>
<td>2938.70</td>
<td>2.36</td>
<td>1246.81</td>
<td>8.89</td>
<td>&lt; .01</td>
<td>.084</td>
</tr>
<tr>
<td>N x I</td>
<td>389.77</td>
<td>4.71</td>
<td>82.69</td>
<td>.59</td>
<td>.70</td>
<td>.012</td>
</tr>
<tr>
<td>N x L</td>
<td>1024.77</td>
<td>2.36</td>
<td>434.78</td>
<td>3.10</td>
<td>.04</td>
<td>.031</td>
</tr>
<tr>
<td>N x I x L</td>
<td>425.74</td>
<td>4.71</td>
<td>90.31</td>
<td>.64</td>
<td>.66</td>
<td>.013</td>
</tr>
<tr>
<td>Error (within)</td>
<td>32062.10</td>
<td>228.63</td>
<td>140.24</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>A x N</td>
<td>242.42</td>
<td>6.90</td>
<td>35.16</td>
<td>.72</td>
<td>.65</td>
<td>.007</td>
</tr>
<tr>
<td>A x N x I</td>
<td>474.24</td>
<td>13.80</td>
<td>34.40</td>
<td>.71</td>
<td>.77</td>
<td>.014</td>
</tr>
<tr>
<td>A x N x L</td>
<td>203.77</td>
<td>6.90</td>
<td>29.56</td>
<td>.61</td>
<td>.75</td>
<td>.006</td>
</tr>
<tr>
<td>A x N x I x L</td>
<td>548.46</td>
<td>13.79</td>
<td>39.77</td>
<td>.82</td>
<td>.65</td>
<td>.017</td>
</tr>
<tr>
<td>Error (within)</td>
<td>32582.46</td>
<td>668.82</td>
<td>48.72</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

*Note.* Greenhouse-Geisser correction was used for all within-subjects effects analysis.

A significant main effect was also found for the between-subjects factor of level of participants, $F (1, 97) = 28.04, p < .01, \eta^2_p = .224$. High school participants performed with a higher overall cent deviation ($M = 13.72, SD = 5.80$) than college participants ($M = 7.87, SD = 5.32$). There was not a significant main effect for the factor of instruments, $F (1, 97) = .40, p =$
Performances of violinists and violists with the violin and oboe accompaniments were similar, mean deviations ranged from 6.69 to 7.91 cents. Similarly, performances with lower octave accompaniments by cello and piano deviated with a range of 6.83 to 7.96 cents. Cellists deviated similarly (an average of 6.60 cents) performing with accompaniments one octave above (oboe and violin) while deviating no more than approximately 7.76 cents on average performing with accompaniments in a similar octave (cello and piano). Mean cent deviation of instruments by octave grouping can be found in Table 4.3. No additional significant main effects or interactions within or between subjects were found (see Table 4.4 for four-way ANOVA results).

**Overall Pitch Tendency**

As mentioned, a significant difference was found between the level of participants (high school and college) after conducting the four-way ANOVA. As such, two separate Chi-square tests were conducted to see if there was a difference in the overall number of in-tune, flat, and sharp responses by high school and collegiate participants. The participants’ individual performed responses for E♭, G, A♭, and B♭, were coded as in-tune if the directional cent deviation value was within ±6 cents of zero (Karrick, 1998), similar practices have been performed in previous studies (Byo & Schlegel, 2016; Byo et al., 2011) Any pitches deviating more than -6 cents were coded as flat and pitches deviating more than 6 cents were coded as sharp.

**Tuning tendency for high school participants**

Results of a Chi-square analysis indicated a significant difference between frequency of tuning responses by high school participants, $\chi^2 (2, N = 4200) = 67.12, p < .001, \phi_c = .089$. As seen in Figure 4.1, there were more in-tune (±6 cents) responses than flat responses. Additionally, there were more sharp responses than there were in-tune and flat responses, which indicates a general propensity towards sharpness.

Additional Chi-square tests were conducted to see if there was a significant difference between in-tune, flat, and sharp responses to each of the individual accompaniment conditions. Significant differences were found between categories for all accompaniment conditions except for the piano condition (see Table 4.5 for results). High school participants performed in-tune (±6 cents) and sharp more frequently than flat for the four accompaniment conditions. Performers were the least in-tune when unaccompanied with higher frequencies of sharp and flat responses than in-tune responses.
Figure 4.1. Overall pitch tendency for high school participants

Table 4.5
Pitch Responses for Accompaniment Conditions by High School Participants

<table>
<thead>
<tr>
<th>Condition (N = 840)</th>
<th>Flat</th>
<th>In-tune</th>
<th>Sharp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Cello</td>
<td>194</td>
<td>23</td>
<td>306</td>
</tr>
<tr>
<td>Oboe</td>
<td>224</td>
<td>27</td>
<td>330</td>
</tr>
<tr>
<td>Piano</td>
<td>247</td>
<td>29</td>
<td>298</td>
</tr>
<tr>
<td>Violin</td>
<td>211</td>
<td>25</td>
<td>311</td>
</tr>
<tr>
<td>Solo</td>
<td>278</td>
<td>33</td>
<td>238</td>
</tr>
</tbody>
</table>

*Note: *Denotes significant difference with Bonferroni correction ($p < .01$)

Tuning tendency for collegiate participants

Results of a second Chi-square analysis indicated a significant difference between frequency of tuning responses by collegiate participants, $\chi^2 (2, N = 3010) = 678.24, p < .001, \phi_c = .336$. As seen in Figure 4.2, in-tune (±6 cents) responses occurred more frequently than flat and sharp responses. Additionally, there were more frequent sharp responses than there were flat responses, which indicates a propensity towards sharpness over flat pitches.
Subsequent Chi-square tests were conducted to see if there was a significant difference between in-tune (±6 cents), flat, and sharp responses to each individual accompaniment condition. Results indicated significant differences between categories for all accompaniment conditions (see Table 4.6 for results). Collegiate participants performed in-tune responses most frequently for all conditions and sharp responses occurred more frequently than flat responses regardless of performance condition. Performances with the oboe, violin, and then cello accompaniment produced the highest number of in-tune responses. Additionally, the solo condition accounted for the least in-tune responses and most frequent sharp responses. Performances with the cello produced the lowest frequency of flat responses.

Preferred Accompaniment Condition

After the participants completed the performance task, they were asked to complete the Intonation Survey Questionnaire (ISQ). The participants rated each accompaniment condition (cello, oboe, piano, and violin) on the ISQ with the anchors most preferred (1) to least preferred (4). A significant difference was found between participants’ ranking of the four accompanied conditions using a Friedman ANOVA by Ranks test, $\chi^2_r(3) = 46.47, p < .01$. Pairwise comparisons with a Bonferroni correction indicated a significant difference between oboe and cello, oboe and violin, oboe and piano, and cello and piano ($p < .01$). No other significant differences were found. The participants’ least preferred accompaniment
Table 4.6

*Pitch Responses for Accompaniment Conditions by Collegiate Participants*

<table>
<thead>
<tr>
<th>Condition (N = 602)</th>
<th>Flat</th>
<th>In-tune</th>
<th>Sharp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n )</td>
<td>%</td>
<td>( n )</td>
</tr>
<tr>
<td>Cello</td>
<td>77</td>
<td>13</td>
<td>333</td>
</tr>
<tr>
<td>Oboe</td>
<td>100</td>
<td>17</td>
<td>356</td>
</tr>
<tr>
<td>Piano</td>
<td>99</td>
<td>16</td>
<td>307</td>
</tr>
<tr>
<td>Violin</td>
<td>93</td>
<td>15</td>
<td>348</td>
</tr>
<tr>
<td>Solo</td>
<td>99</td>
<td>16</td>
<td>281</td>
</tr>
</tbody>
</table>

*Note:* *Denotes significant difference \((p < .01)\) with Bonferroni correction

was the oboe compared to other instrumental accompaniments. Additionally, they also preferred to perform with the cello accompaniment more than the piano accompaniment.

Additional Friedman ANOVAs were completed for high school participants and collegiate participants separately. A significant difference in accompaniment preference was found for high school participants, \(\chi^2\) (3) = 21.28, \(p < .01\), and college participants, \(\chi^2\) (3) = 31.52, \(p < .01\). For high school participants, pairwise comparisons with a Bonferroni correction indicated a significant difference between oboe and cello accompaniments, oboe and violin accompaniments, and cello and piano accompaniments \((p < .01)\). For college participants, a significant difference was found in pairwise comparisons with a Bonferroni correction between oboe and cello accompaniments, oboe and piano accompaniments, and oboe and violin accompaniments \((p < .01)\). No other significant differences between pairs were found. Similar to that of the overall analysis, the oboe appeared to be the least preferred accompaniment by participants. Mean ranks for preferred accompaniment can be found in Table 4.7.

**Perceived Performance of Intonation**

In addition to ranking their preferred accompaniment, participants were asked to indicate their perceived intonation while performing with accompaniments on the ISQ using an 11-point scale with *not accurate* (0) and *very accurate* (10) as anchors. A three-way analysis of variance was conducted to calculate if there was a significant difference in perceived intonation ratings
Table 4.7

*Mean Ranks for Preferred Accompaniment*

<table>
<thead>
<tr>
<th>Condition</th>
<th>HS</th>
<th>College</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
<td>2.04 (1)</td>
<td>1.81 (1)</td>
<td>1.95 (1)</td>
</tr>
<tr>
<td>Violin</td>
<td>2.23 (2)</td>
<td>2.51 (3)</td>
<td>2.34 (2)</td>
</tr>
<tr>
<td>Piano</td>
<td>2.73 (3)</td>
<td>2.33 (2)</td>
<td>2.56 (3)</td>
</tr>
<tr>
<td>Oboe</td>
<td>3.00 (4)</td>
<td>3.35 (4)</td>
<td>3.15 (4)</td>
</tr>
</tbody>
</table>

*Note:* Ranks are noted in parenthesis.

Table 4.8

*Mean and SD of Perceived Intonation in Accompaniment Conditions*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean Rating</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
<td>7.89</td>
<td>1.33</td>
</tr>
<tr>
<td>Violin</td>
<td>7.45</td>
<td>2.01</td>
</tr>
<tr>
<td>Solo</td>
<td>7.29</td>
<td>2.29</td>
</tr>
<tr>
<td>Piano</td>
<td>7.21</td>
<td>1.62</td>
</tr>
<tr>
<td>Oboe</td>
<td>6.67</td>
<td>1.91</td>
</tr>
</tbody>
</table>

*Note:* Shown in order of perceived accuracy.

between accompaniment type, level of participants, and primary instrument. A Mauchly’s Test of Sphericity indicated that the assumption of sphericity was violated for the variable of accompaniment. Therefore, the Greenhouse-Geisser correction was used for subsequent analysis with accompaniment.

A significant main effect was found between the level of the participants (high school and college), $F(1, 97) = 14.58, p < .01, \eta^2_p = .13$. High school participants rated their intonation ($M = 6.83, SD = 1.29$) as less accurate than college participants ($M = 7.77, SD = 1.19$). No main effect was found between primary instrument of participants, $F(2, 97) = .55, p = .58$, and no significant interaction was found between primary instrument of participants and level, $F(2, 97) = .60, p = .55$.  

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A significant main effect was found for perception of intonation between accompaniment conditions, $F(3.56, 344.92) = 8.27, p < .01$, $\eta^2_p = .08$. Pairwise comparisons with a Bonferroni correction indicated a significant difference between cello and oboe accompaniments ($p < .01$) and cello and piano accompaniments ($p < .01$). No other significant differences were found between remaining pairs. Participants perceived their intonation to be more in tune with the cello accompaniment than they did with the oboe and piano accompaniments. See Table 4.8 for mean and standard deviations of perception scores.

No significant interactions were found for accompaniment and primary instrument, accompaniment and level, and accompaniment, primary instrument, and level (see Table 4.9 for complete three-way ANOVA results).

**Correlation Between Perceived and Performed Tuning Accuracy**

Five Spearman rank order correlation coefficients were calculated to determine if participants’ perception of their intonation performing with accompaniment was related to actual intonation measured by mean absolute cent deviation of each note ($E^b$, $G$, $A^b$, and $B^b$) and the
Table 4.10

Spearman Correlations between Perceived Intonation and Absolute Cent Deviation of All Participants

<table>
<thead>
<tr>
<th>Condition</th>
<th>E\textsuperscript{b}</th>
<th>G</th>
<th>A\textsuperscript{b}</th>
<th>B\textsuperscript{b}</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
<td>.30*</td>
<td>.33*</td>
<td>.27*</td>
<td>.09</td>
<td>.27*</td>
</tr>
<tr>
<td>Oboe</td>
<td>.17</td>
<td>.20</td>
<td>.29*</td>
<td>-.03</td>
<td>.20</td>
</tr>
<tr>
<td>Piano</td>
<td>.18</td>
<td>.26*</td>
<td>.21</td>
<td>-.08</td>
<td>.15</td>
</tr>
<tr>
<td>Violin</td>
<td>.20</td>
<td>.28*</td>
<td>.20</td>
<td>.26*</td>
<td>.48**</td>
</tr>
<tr>
<td>Solo</td>
<td>.32*</td>
<td>.44**</td>
<td>.37**</td>
<td>.23</td>
<td>.34*</td>
</tr>
</tbody>
</table>

Note. *Indicates \(p < .01\); **indicates \(p < .001\).

Table 4.11

Spearman Correlations between Perceived Intonation and Absolute Cent Deviation of College Participants

<table>
<thead>
<tr>
<th>Condition</th>
<th>E\textsuperscript{b}</th>
<th>G</th>
<th>A\textsuperscript{b}</th>
<th>B\textsuperscript{b}</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
<td>-.25</td>
<td>.16</td>
<td>-.01</td>
<td>-.22</td>
<td>-.19</td>
</tr>
<tr>
<td>Oboe</td>
<td>-.27</td>
<td>-.27</td>
<td>.35</td>
<td>-.37</td>
<td>-.19</td>
</tr>
<tr>
<td>Piano</td>
<td>.04</td>
<td>-.25</td>
<td>.01</td>
<td>-.43*</td>
<td>-.41*</td>
</tr>
<tr>
<td>Violin</td>
<td>.11</td>
<td>.05</td>
<td>.06</td>
<td>.16</td>
<td>.21</td>
</tr>
<tr>
<td>Solo</td>
<td>.16</td>
<td>.14</td>
<td>.18</td>
<td>-.20</td>
<td>-.02</td>
</tr>
</tbody>
</table>

Note. *Indicates \(p < .01\)

average of all four notes together. Significant low positive correlations were found between participants’ perception of their intonation and their actual performance for the cello accompaniment (\(r_s = .27, p < .01\)) and the solo condition (\(r_s = .34, p < .001\)). A significant moderate positive correlation was found for the violin accompaniment condition (\(r_s = .48, p < .001\)). Spearman coefficients for individual notes can be found in Table 4.10.

Additional Spearman correlation tests were conducted separately for participants grouped by education level: high school and college participants. A significant moderate negative correlation was found between college participants’ perception of intonation and actual overall intonation when performing with the piano accompaniment (\(r_s = -.41, p < .01\)). It appears that as college participants rated their perceived intonation higher when performing with a piano
accompaniment, their intonation accuracy decreased particularly on B♭. No other significant correlation scores were found. All correlation coefficients for college participants can be found in Table 4.11.

A significant moderate positive correlation was found among high school participants between perception of intonation and intonation when performing with the violin accompaniment ($r_s = .42, p < .01$) and performing as a solo ($r_s = .40, p < .01$) among high school participants. It appears that for overall cent deviation, high school students who perceived their intonation more accurately with the violin accompaniment and as a solo, also tended to perform with more accurate intonation. Spearman coefficients for individual notes performed by high school participants can be found in Table 4.12.

Table 4.12

*Spearman Correlation between Perceived Intonation and Absolute Cent Deviation of High School Participants*

<table>
<thead>
<tr>
<th>Condition</th>
<th>E♭</th>
<th>G</th>
<th>A♭</th>
<th>B♭</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
<td>.39*</td>
<td>.11</td>
<td>.16</td>
<td>.14</td>
<td>.22</td>
</tr>
<tr>
<td>Oboe</td>
<td>.25</td>
<td>.40*</td>
<td>.22</td>
<td>.09</td>
<td>.32</td>
</tr>
<tr>
<td>Piano</td>
<td>.11</td>
<td>.32</td>
<td>.03</td>
<td>-.06</td>
<td>.10</td>
</tr>
<tr>
<td>Violin</td>
<td>.30</td>
<td>.36*</td>
<td>.26</td>
<td>.26</td>
<td>.42*</td>
</tr>
<tr>
<td>Solo</td>
<td>.26</td>
<td>.41*</td>
<td>.31</td>
<td>.30</td>
<td>.40*</td>
</tr>
</tbody>
</table>

*Note. *Indicates $p < .01*
CHAPTER FIVE
DISCUSSION

Purpose Statement

The purpose of this study was to examine the effects of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. The research questions were as follows:

1. Are there differences in tuning accuracy of melodic content between accompanied and unaccompanied conditions among string musicians?
2. Are there differences in tuning accuracy of melodic content between accompaniment octaves?
3. Are there differences in intonation accuracy between string, oboe, and piano accompaniments?
4. Are there differences between the number of flat, sharp, and in-tune responses of participants?
5. Are there differences in string musician preferences between accompaniment types?
6. Are string musicians’ self-perceptions of tuning accuracy associated with performed pitch accuracy?
7. Are there differences between age and experience of participants in intonation accuracy with various accompaniment types?

Summary of Results

Question 1: Tuning accuracy between accompanied and unaccompanied conditions.

The type of instrumental accompaniment was a significant factor in the intonation of high school and college level violinists, violists, and cellists. Participants performed with higher cent deviation performing as a solo compared to their performances with the oboe, violin, and cello accompaniments. Additionally, participants performed more in tune with the oboe accompaniment than with the piano accompaniment. Participant performances produced lower cent deviation while performing with an oboe, violin, and cello accompaniments compared to performing as a solo.
**Question 2: Tuning accuracy of melodic content due to octave of stimuli**

Although a significant effect of accompaniment type was found between performance conditions, no significant effect was found between violinists, violists, and cellists. Cent deviation of violinists and violists were similar regardless of the octave of the accompaniment condition. Likewise, cent deviation of cellists were very similar whether they were performing in unison with an accompaniment or an octave below the accompaniment. Octave did not appear to affect intonation of string musicians.

**Question 3: Intonation accuracy of performers between string accompaniments and non-string accompaniments.**

Participants performed with the least cent deviation while being accompanied with the oboe. Additionally, of the four instrumental accompaniments, participants performed with the highest cent deviation performing with the piano accompaniment. Participants performed more in tune with the violin accompaniment than they did with the cello accompaniment; however, those performances were not as accurate as performances with the oboe accompaniment. Although a significant main effect was found for accompaniment conditions, there was no significant difference between string and non-string accompaniments. The only pair of accompaniment conditions that was found to be significantly different was between oboe accompaniment and piano accompaniment.

**Question 4: Are there differences between frequencies of flat, sharp, and in-tune responses of participants?**

Pitches categorized as sharp occurred more frequently with high school students than in-tune responses and flat responses indicating a tendency to perform with sharp intonation. After further analysis of each accompaniment condition, sharp responses occurred more frequently for cello and violin accompaniments as well as in the solo condition. Additionally, in-tune responses (±6 cents) occurred most frequently with the oboe accompaniment.

Responses categorized as in-tune occurred most frequently by collegiate participants compared to high school students; however, sharp responses still occurred more frequently than flat responses. While in-tune responses occurred most frequently with the oboe accompaniment, sharp responses were produced more frequently with the solo condition than other accompaniment conditions. Performances with the cello accompaniment produced the least amount of flat responses of all accompaniment conditions.
**Question 5: String musicians’ preferences for accompaniment type.**

The following are accompaniment conditions ranked by the participants from most preferred to least preferred: cello, violin, piano, and oboe. Considering significant differences were found in pairwise preference rankings between the oboe and the rest of the accompaniment conditions, it appears that participants did not prefer to perform with the oboe accompaniment. Although the cello accompaniment was rated as most preferred, the only additional significant difference was between the cello and piano accompaniments.

An additional analysis was performed with high school participants only. High school participants ranked each accompaniment condition similar to that of the overall analysis from most preferred to least preferred: cello, violin, piano, and oboe. However, significant differences in ranking were found between the cello accompaniment and the piano and oboe accompaniments. High school participants preferred the cello accompaniment over the piano and oboe accompaniments. Additionally, violin accompaniment held a significantly higher ranking than the oboe accompaniment.

The order of ranked conditions was slightly different with college participants, from most preferred to least preferred they listed cello, piano, violin and oboe accompaniments. Similar to that of all participants, a significant difference in rankings was found between the oboe accompaniment and the other accompaniments. College participants preferred to perform with the cello, piano, and violin accompaniments over the oboe accompaniment.

**Question 6: String musicians’ perception of tuning accuracy and association with performed pitch accuracy.**

Participants were asked to rate their perceived intonation while performing with the excerpt both accompanied and unaccompanied. The order of their perceived intonation accuracy rating means from highest to lowest was cello, piano, solo condition, violin, and the oboe accompaniment. A significant main effect was found between ratings of accompaniment conditions. Pairwise comparisons indicated a significant difference in rating scores between the cello accompaniment and the oboe accompaniment as well as the cello accompaniment and the piano accompaniment. Participants indicated that they perceived their intonation as most accurate performing with the cello accompaniment compared to performance with the oboe and piano accompaniments.
Several Spearman correlation tests were conducted to measure the relationship between participants’ perceived intonation and their actual performance of intonation. The highest significant correlation found was a positive moderate correlation for the violin accompaniment condition ($r_s = .48$). Participants who rated intonation accuracy high with violin accompaniment also tended to be accurate in performance. Other significant correlations occurred between self-perception and when performing with the cello ($r_s = .27$) and as a solo ($r_s = .34$). A correlation test consisting of only collegiate participants found a significant negative correlation when they performed with the piano ($r_s = -.41$).

**Question 7: Age and experience of participants and accuracy with accompaniment.**

Participants consisted of a high school group and college group. A significant main effect was found between the two groups. High school participants performed with higher mean cent deviation ($M = 13.72, SD = 5.81$) than college participants ($M = 7.87, SD = 5.33$). While it is not surprising that high school students enrolled in orchestra were more out of tune than college students who were majoring in music, it seems surprising to find that no significant interaction was found between type of accompaniment and the level of students. It appears both high school and college participants performed most in tune when performing with the oboe and most out of tune when they performed as a solo. It is interesting to note that high school and college participants appeared to be consistent in terms of their intonation accuracy between the different accompaniments, except for the solo condition. Although both groups were most out of tune as a solo, high school participants had higher cent deviation in the solo ($M = 17.37, SD = 10.77$) compared to the college participants ($M = 8.83, SD = 9.89$).

**General Discussion**

The present study explored the effect of different instrumental accompaniments on the intonation of violinists, violists, and cellists in a melodic context. The study considered different timbres and octaves for the accompaniment, participants’ preference of accompaniment, participants’ perception of intonation during each accompaniment, and how participants’ perception of intonation relates to their actual intonation. Results from the study indicate that participants do perform differently between accompanied and unaccompanied conditions. Participants also do not prefer accompaniments that are of a different timbre than their own.
instrument. Additionally, participants generally perceive their intonation differently than their actual performance with different accompaniments.

**Accompaniment type**

Participants were more accurate when they performed with an accompaniment compared to performing as a solo, which is consistent with previous research (Garman, 1992; Geringer, 1978). Additionally, participants were most in tune with the oboe accompaniment with significant differences between the oboe and piano accompaniments as well as the oboe accompaniment and solo condition. This corroborates previous studies which provide evidence that musicians tend match pitch to the oboe more accurately than to other tuning sources (Benson, 1995; Byo et al., 2011; Hayslett, 1990).

**Tendency to perform with sharp intonation**

A tendency to perform with sharp intonation over flat intonation was found among high school and college participants. This appears to align with the predominant theme that instrumental musicians have a tendency to perform with sharp intonation (e.g., Byo & Schlegel, 2016; Geringer, 1978; Yarbrough, Karrick, & Morrison, 1995) as well as string musicians (e.g., Geringer & Sasanfar, 2013; Kantorski, 1986; Salzberg, 1980; Yarbrough & Ballard, 1990).

High school participants had a higher frequency of sharp responses than in-tune and flat responses. This perhaps may be attributed to the unfamiliarity and lack of confidence of performing in E\textsubscript{b} major among high school students. During the two-minute practice period, many high school participants were observed performing the beginning of the excerpt in E major, rather than E\textsubscript{b} major. Although most of the participants corrected themselves, in some cases I reminded the participant to check the key signature. During the recording process, some participants still forgot the key signature and performed notes that approximated E major. While this was most evident during the solo condition, a majority of them were able to adjust their hand position and fingers to the appropriate key signature during the accompaniment conditions. Although high school participants had more frequent sharp responses than in-tune or flat responses overall, they had the most frequent in-tune responses (±6 cents) and least frequent sharp responses with the oboe accompaniment compared to the other accompaniment conditions. This could provide further evidence that high school participants are able to match intonation with oboe accompaniment more accurately than other accompaniments.
Collegiate participants had a higher frequency of in-tune responses (±6 cents) than sharp and flat responses indicating better pitch accuracy than high school participants. Although in-tune responses occurred more frequently, sharp responses occurred more frequently than flat responses. The college participants were able to perform in E♭ major with more accurate pitches than the high school participants. This is likely due to the fact that collegiate string students who study music are better trained and have more confidence performing a flat key signature than high school students. After comparing frequency responses between pitch categories in each accompaniment condition, performances with the oboe accompaniment produced more in-tune responses than other accompaniments. Additionally, sharp responses occurred with more frequency during the solo condition while flat responses were least frequent during the cello accompaniment.

Preference for accompaniment type

From the most preferred accompaniment to the least preferred accompaniment, participants overall ranked each accompaniment in the following order: cello, violin, piano, and oboe. The participants may have preferred string accompaniments over non-string accompaniments due to their familiarity with the string timbre. String musicians may spend a lot of time with other string musicians. A majority of participants indicated that they first started to learn their instrument in the public school. When students begin string orchestra, they are typically placed in a class of only string instruments. It is rare for schools to have a full symphony orchestra at the elementary and middle school level, even less than half of high schools that offer strings offer a full orchestra (Smith, Mick, & Alexander, 2018). Therefore, young string musicians may not have experience performing with non-string instruments unless their high school offers a full orchestra, they enroll in a youth orchestra, or perform in small ensembles with classmates enrolled in the band. The order of preferred accompaniment did not change when the analysis involved only high school participants. High school participants rated string accompaniments as most preferred over non-string accompaniments.

When the ranks were analyzed with college students only, the order of rankings changed slightly from most preferred to least preferred to cello, piano, violin, and oboe accompaniments. There was not a significant difference between the cello and piano accompaniment pairing. Collegiate participants preferred the cello, piano, and violin accompaniments more than oboe accompaniment. When string musicians enter college, they still perform with other string
musicians. Much of the standard chamber repertoire for string musicians is orchestrated for string quartets (two violins, viola, and cello). String musicians are placed in studios grouped by instrument, they also perform for each other as a string studio and rarely perform for woodwind, brass, percussion, and vocal studios. Additionally, string musicians start to rehearse with a piano accompaniment for recital and studio performances. With more time being spent with a piano, string musicians start to familiarize themselves with the piano timbre and the temperament of the instrument. String musicians are constantly surrounded by string timbre and they are more exposed to the piano timbre. At the same time, they are rarely exposed to an oboe timbre outside the large orchestra setting. There are few opportunities for string musicians to perform in a small ensemble with an oboe. As such, due to the amount of exposure collegiate string musicians have with cello, piano, and violin, they may prefer to perform with those instruments over the oboe.

**Perception of intonation and actual performance**

Participants perceived their intonation to be most accurate with the cello accompaniment and least accurate with the oboe accompaniment. This is consistent with the finding that participants most preferred to perform with the cello accompaniment and least preferred to perform with the oboe accompaniment. Considering a majority of participants performed an octave above the cello ($n = 77$), it is possible that participants prefer to perform to instrumental accompaniments an octave below their performed range. In the pedagogical texts for wind instrumentalists, tuning to the tuba is a recommended strategy for tuning a large ensemble (Feldman & Contzius, 2011; Jagow, 2007) which has become a common practice among U.S. school band directors (Scherber, 2014; Silvey, 2013). It is possible that this strategy of listening to a pitch lower than the performed pitch could have transferred to string teachers. When string quartets tune to a reference pitch, the reference pitch is often provided by the cellist. Additionally, Hamann and Gillespie (2013) recommend that string teachers teach students to match a fingered pitch with an open string. This task could occur with students who check a pitch with the open string below such as a violinist checking a third finger D on the A-string with the open D-string below. String musicians may be familiar with the task of listening to the cello, or a lower octave, as a reference point for performing a melody in unison or octaves they may have conflated the familiarity of the task with actual performance accuracy.

It is of particular interest that participants’ least preferred and least accuracy ratings occurred with oboe accompaniment, even though they performed with the least deviation with
the oboe accompaniment. A similar disconnect was found by Byo et al. (2011) where high school wind musicians perceived the tuba as the easiest and oboe as the most difficult instrument to tune to compared to the clarinet, and flute, when they were actually most in tune with the oboe. However, when their study was extended to collegiate wind instrumentalists, participants tuned similarly to clarinet, oboe, electronic tuner, and tuba stimuli and they perceived the difficulty of tuning to each stimulus as just about the same (Byo & Schlegel, 2016). Musicians frequently confuse timbre and intonation (e.g., Ely, 1992; Geringer & Worthy, 1999; Madsen & Geringer, 1981; Worthy, 2000). The difference in timbre between oboe and strings may cause string musicians to listen more closely to the sounds, therefore they are able to match pitch more accurately with the oboe accompaniment. Although data was not systematically collected, a few violinist participants stated they could not hear the violin timbre even though the loudness level was increased. Considering the timbre of the violinists’ matched that of the violin accompaniment, it could be that the two instruments blended more making it difficult for the participants to hear. Additionally, many string players cited the oboe accompaniment as out-of-tune or harsh.

Although correlations were not high, an overall analysis of participants’ perceived intonation correlated the most with their actual performance in the violin accompaniment condition. Weaker correlations were found for the cello accompaniment and solo conditions. No correlation was found for the oboe and piano accompaniment conditions. This could indicate the string musicians believe that intonation is most accurate when they perform with a violin accompaniment. A lack of correlation with the oboe and piano accompaniments could indicate a lack of experience performing with those two instruments. Participants may have been relatively unfamiliar with the timbre of the oboe and less so with the piano to the point that they could have confused intonation with timbre differences, which has been repeatedly noted in previous research (Cassidy, 1989; Cummings, 2007; Ely, 1992; Geringer & Worthy, 1999; Vurma et al., 2011; Worthy, 2000).

**Age and experience**

The high school participants performed with greater overall cent deviation than the college participants. This is not surprising considering high school participants consisted of students who were enrolled in orchestra with an average age of 16.20 years and an average of 6.23 years of experience performing their primary instrument. This compares to college students
who were enrolled in university as music majors with an average age of 23.50 years and an average of 13.59 years of experience performing their primary instrument. Age and experience have been found to be prominent factors in pitch perception and performance (Duke, 1989; Geringer, 1983; Geringer & Allen, 2004; Geringer & Witt, 1985; Hopkins, 2014; Madsen, 1966, 1974; Madsen et al., 1969; Morrison, 2000).

High school participants also rated their perceived intonation lower than college participants. While there was no significant interaction by accompaniment condition and level of participants, it is of particular interest that college participants rated their solo intonation as second highest while high school participants rated it as second lowest compared to all other conditions. Considering high school and college participants were given the same rating scale, this could be indicative of lower level of self-confidence in music performance among high school musicians.

Implications for Music Education

The present study examined the effects of different instrumental accompaniments on the intonation of high school and college violinists, violists, and cellists in a melodic context. Additionally, it explored participants’ perception of their intonation performing with various instrumental accompaniments. Participants performed with less deviation performing in all accompaniment conditions, except for piano, compared to the solo condition. Additionally, performances with the oboe accompaniment produced the least deviation; however, the difference was significant only compared to the piano accompaniment and solo condition.

Learning to perform in tune is a long-term process. Musicians must be able to listen to their performed pitch and discriminate whether it is in tune compared to the previous note, compared to another similar pitch performed by another instrument, or compared to a dissimilar pitch performed by another instrument. Pedagogues recommend to teachers that they use a piano (Green, 2010) or perform as a duet (Kohut, 1973) with their students to teach intonation. Perhaps such techniques should continue well into the high school or collegiate level.

Participants across all levels indicated that they least preferred to perform with the oboe accompaniment and that their intonation was least accurate performing with the oboe accompaniment. However, their intonation was most accurate when performing with the oboe accompaniment. This could be an indication of their relative unfamiliarity with the oboe timbre,
especially when performing in a melodic context. As such, string musicians might be exposed to the oboe timbre as much as possible to gain experience and familiarity with the instrument. Additionally, the oboe may provide a stimulus that will enhance a string musician’s performance of intonation in melodic or non-melodic contexts. For example, an oboe timbre may provide an effective source for a drone accompaniment. String pedagogues have recommended drone accompaniments to improve intonation (e.g., Curry, 2011; Hopkins, 2012; Watkins, 2004), a technique that appears to be frequently used by instrumental music directors (Scherber, 2014). Recommended drone sources have been an electronic sound source (Curry, 2011; Hopkins, 2012), adjacent open strings (Curry, 2011; Hamann & Gillespie, 2013; Hopkins, 2012; Reel, 2005; Watkins, 2004), and other string instruments (Hopkins, 2012). However, I was unable to find any source that recommends an oboe stimulus as a drone even though musicians may tune more accurately to an oboe compared to other stimuli (Benson, 1995; Byo et al., 2011; Hayslett, 1990).

Limitations and Future Research

The following limitations should be considered when interpreting the results of the present study. Participants were recruited from one university and two local high schools with school orchestra programs. One high school had a fairly new orchestra program, one that was established in the past five years, while the other high school had been established for nearly 17 years. Additionally, the second high school had a freshman orchestra class in which participants were not recruited due to scheduling conflicts. Generalizations to the larger population of high school and college string musicians should be made with caution considering the sample of participants.

Another factor that may have influenced the results of the study could be the piece and its key signature. While collegiate participants had no issues performing Frère Jacques, some high school participants struggled. The key signature was in E♭ major which necessitated string musicians to use fingers for each pitch and avoid open strings. Even though high school participants were reminded of the key signature prior to performing, a few participants performed in a key signature that approximated E major. This was more noticeable if participants were assigned presentation Order D (see Table 3.1 in chapter 3) in which the solo condition was first. However, most participants adjusted appropriately once the instrument accompaniment
conditions began. High school participants who were cellists also struggled with the excerpt. In measure three (see Figure 3.1 in chapter 3), the cellist has to decide whether to shift to another position. In measure five, the cellist had to complete multiple shifts and/or string crossings. High school cellists who had less experience appeared to focus more time on when to shift rather than matching pitch with the accompaniment. A different key signature, or excerpt selection, that limited the amount of shifting for cellists may provide different results.

One additional limitation in the present study may relate to the use of vibrato. While preparing the stimulus recordings, I asked the musicians to perform each excerpt demonstrating accurate intonation without using vibrato. However, performing without vibrato was not included in the protocol for participants during data collection: no such instruction was given to the violin, viola, or cello participants. Considering that listeners tend to perceive a vibrated pitch near the center of the vibrato rather than towards the upper or lower vibrato extents for electronic (Iwamiya, Kosugi, & Kitamura, 1983; Shonle & Horan, 1980; Seashore, 1967) and acoustic stimuli (Allen, Geringer & MacLeod, 2009; Brown & Vaughn, 1996; Geringer & Allen, 2004; Geringer, MacLeod, & Allen, 2010; Geringer, MacLeod, Ellis, 2012), vibrato was intentionally left out of instructions as I wanted the participants to perform the excerpt with accurate intonation and musicality rather than treating the excerpt as an isolated tuning exercise.

Although the present study was to explore the effects of instrumental accompaniment type on string intonation in a melodic setting, additional research could explore the effect of accompaniment type in a harmonic setting. Considering that *Frère Jacques* can be performed in a round, this excerpt could be used to explore intonation accuracy in a harmonic context. Although harmonic intervals have been explored in previous research, it has been limited to individual intervallic relationships and chords (Brittin, 1993; Duke, 1985).

Accompaniment conditions in the present study were limited to violin, cello, oboe, and piano. Additional instrumental stimuli such as clarinet and flute could be investigated. Although there are not many situations where a string instrument would perform with a brass instrument in a small ensemble setting, brass timbres could also be investigated as well.

**Conclusion**

Participants in this study performed with higher tuning accuracy when performing with instrumental accompaniment compared to performing as a solo. Even though participants rated
their intonation with the oboe accompaniment as least accurate and rated the oboe accompaniment as least preferred, their performance with the oboe accompaniment produced the least cent deviation. Additionally, high school participants performed with higher cent deviation than collegiate participants, they also perceived their intonation to be least accurate overall when compared with their more experienced counterparts. Positive correlations were found between participants’ perceived intonation and actual intonation with string accompaniments and the solo condition, which could indicate less familiarity with non-string accompaniments.

If used appropriately, these findings could help music teachers find creative and effective ways to improve the intonation of their students. Additionally, it could help musicians understand why adjusting intonation while performing with different instruments presents different challenges. It is hoped that further understanding of how string musicians perceive and perform intonation with other instruments will help guide teaching, performing, and practice for current and future musicians.
APPENDIX A
FSU HUMAN SUBJECTS COMMITTEE APPROVAL MEMORANDUM

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 11/8/2018

To: John Rine Zabanal
Address: [Redacted]
Dept.: MUSIC SCHOOL

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Effects of different instrumental accompaniment on violin, viola, and cello intonation

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 11/6/2019 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.
APPENDIX B

LEON COUNTY SCHOOLS APPROVAL MEMORANDUM

BOARD CHAIR
Rosanne Wood

BOARD VICE CHAIR
DeeDee Rasmussen

SUPERINTENDENT
Rocky Hanna

January 28, 2019

Topic: The effects of accompaniment on musician intonation

Dear Mr. Zabanal,

The Leon County Schools Research Review Board has determined that the findings of your proposed study could be pertinent to our efforts and so we are initially consenting to your request for the research mentioned above. Now that you have procured principal’s consent you may move forward adhering to the following conditions:

• Communication – Communication between you and Leon County Schools’ personnel, regarding this study, are considered an integral part of this initial consent and subsequent approval, and are public record.
• Department Consent – Initial consent by the Research Review Board does not in itself constitute permission to carry out the research. You may now contact principals of the schools in your study. The principal has the final decision relative to research at each school. It is your responsibility to return the attached principal’s consent form signed by the principal(s) of the school(s) to be involved, prior to the start of any research. You may hand deliver, mail, or scan and email it to this office.
• Clearance – Leon County Schools requires proper clearance to enter schools. If you will be entering schools, you will need to contact Tala Hague at [redacted]. She will work with you to obtain security clearance, including fingerprinting, and proof of health and liability insurance. If you will not be entering schools, you will not need clearance.
• Time Period – Once you satisfy the conditions, your data collection period runs from January 25, 2019 through May 17, 2018. Should you desire to extend for the next school year, you must submit a Progress Report form, available on the LCS website. If you intend significant changes or amendments to the procedures or design, you must resubmit the Request for Research form.
• Submit Results – Leon County Schools is interested in your research partly due to the potential benefit the district may receive from your findings; therefore, we expect that you will send this office an executive summary with purpose, methods, results and discussion directly after concluding your study. We will place this information in our online research library.

We look forward to receiving your results.

Dr. Robin M. Krause
Research Review Board Chairman
Evaluation Specialist
Leon County Schools
Tallahassee, Florida 32304
(850) 487-7868

www.leonschools.net

“The Leon County School District does not discriminate against any person on the basis of sex (including transgender status, gender nonconforming, and gender identity), marital status, sexual orientation, race, religion, ethnicity, national origin, age, color, pregnancy, disability, or genetic information.”

Building the Future Together
APPENDIX C

PARTICIPANT CONSENT FORM

PARTICIPANT CONSENT FORM
(FSU Participants Only)
Different Instrument Accompaniment

My name is John Rine Zabanal and I am a Ph.D. candidate from the College of Music at Florida State University. You are invited to participate in a research study exploring the effects of different instrument types of violin, viola, and cello intonation. I am asking you to take part in the study because you are a music student at Florida State University whose primary instrument is the violin, viola, or cello. Please read this form and ask any questions you may have before indicating whether you wish to take part in the study.

The study: The purpose of this study is to examine the effects of different accompaniment type on intonation of the violin, viola, and cello musicians in a melodic context. You will sight-read an easy tune and perform it five times: accompanied with a recording of a violinist, cellist, oboist, pianist, and once performing solo. An audio recording of your performance will be created and it will be identified by participant number only. After your performance, you will be asked to complete a questionnaire. The questionnaire will ask you for your primary instrument, age, years studying instrument, where music instruction began, level of study, and program of study. The questionnaire will also ask you to rate your performance. Like the audio recording, questionnaire will be identified by participant number only.

Risks and benefits: There are no personal benefits to you for participation, but this knowledge will help orchestras direct and string teachers in their teaching. There are no risks in participation beyond those encountered in everyday life. Participants will not be identified in any portion of this study.

Compensation: There is no compensation for this study.

Confidentiality: The records of this study will be kept confidential, to the extent permitted by law. No identifiable information will be collected. All data collected in this study will be confidential, and participants will not be identifiable in any future reporting of results. The link between names/consent forms and participant recordings will be broken. Research data will be kept in a locked cabinet and a secured office.

Voluntary Participation: To participate in this study, you must be at least 18 years of age. Your participation in this study is completely voluntary and your decision of whether or not to take part will in no way affect your current or future relationship with Florida State University. If you choose to participate, you are free to withdraw at any time without affecting your relationship with the University. The researcher for this study is John-Rine Zabanal who is overseen by Dr. John M. Geringer, faculty advisor for the study. You may reach John_Rine_Zabanal at [email protected] or [email protected]. Please feel free to ask any questions you have now, or at any point in the future. If you have any questions or concerns about your child’s right as a research subject, you may contact the FSU Institutional Review Board (IRB) at 800.644.7900. You may also access their website at [https://www.research.fsu.edu](https://www.research.fsu.edu). You will be given a copy of this consent form for your records.

Your name (please PRINT):

Your signature:

Date:

FSU Human Subjects Committee approved on 11/07/2018, void after 11/06/2019. HSC #2018.25782
FSU Human Subjects Committee approved on (date). Void after (date). HSC #
Researcher: Mr. John-Rine Zabanal, [REDACTED]
Faculty Advisor: Dr. John M. Geringer, [REDACTED]
APPENDIX D

PARENT/GUARDIAN CONSENT FORM

PARENT/GUARDIAN CONSENT FORM
(High School Student)
Different Instrument Accompaniment

My name is John-Rine Zabanal and I am a Ph.D. candidate from the College of Music at Florida State University. Your child is invited to participate in a research study exploring the effect of different instrument types: on violin, viola, and cello intonation. I am asking your child to take part in the study because he/she is a high school student who is enrolled in orchestra for the 2018-2019 school year. Please read this form and ask any questions you may have before indicating whether you wish your child to take part in this study.

The study: The purpose of this study is to examine the effects of different accompaniment type on intonation of violin, viola, and cello musicians in a melodic context. Your child will sight-read an easy tune and perform five times: accompanied with a recording of a violinist, cellist, oboist, pianist, and once performing solo. An audio recording of your child’s performance will be created and it will be identified by participant number only. After your child’s performance, he/she will be asked to complete a questionnaire. The questionnaire will ask for the student’s primary instrument, age, years studying instrument, where music instruction began, and grade level. The questionnaire will also ask students to rate their performances. Like the audio recording, questionnaires will be identified by participant number only.

Risks and benefits: There are no risks in participation beyond those encountered in everyday life. There are no direct benefits to your child for participation, but this knowledge will help orchestra directors and string teachers in their teaching. The participants will not be identified in any portion of this study.

Compensation: There is no compensation for this study.

Confidentiality: The records of this study will be confidential, to the extent permitted by the law. No identifiable information will be collected. All data collected in this study will be confidential, and participants will not be identified in any future reporting of results. The link between names/consent forms and participant recordings will be broken. Research data will be kept in a locked cabinet and a secured office.

Voluntary Participation: Your child’s participation in this study is completely voluntary. Your decision of whether or not to allow your child to take part will not affect your current or future relationship with Florida State University or with your child’s school. If you choose to allow your child to participate, he or she is free to stop the study at any time. You are also free to withdraw your child at any time without affecting your relationship with the University or your child’s school. The researcher for this study is John-Rine Zabanal who is overseen by Dr. John M. Gerness, faculty advisor for the study. You may reach John-Rine Zabanal at [email] or [phone]. You may reach Dr. Gerness at [email] or [phone]. Please feel free to ask any questions you have now, or at any point in the future. If you have any questions or concerns about your child’s right as a research subject, you may contact the FSU Institutional Review Board (IRB) at 850.644.7900. You may also access their website at https://www.research.fsu.edu. You will be given a copy of this consent form for your records.

If you have any questions about your rights in the study, contact:
FSU Institutional Review Board (IRB)
Florida State University
Phone: 850.644.7900
Email: humansubjects@fsu.edu
Website: https://www.research.fsu.edu/research-ethics/human-subjects/

FSU Human Subjects Committee approved on (date). Void after (date). HSC #
Researcher: Mr. John-Rine A Zabanal, [phone]
Faculty Advisor: Dr. John M. Gerness, [phone]
PARENT/GUARDIAN CONSENT FORM
(High School Student)
Different Instrument Accompaniment

I ________________________________ (parent’s name) hereby authorize
my child ________________________________ (child’s name) to
participate in a research study under the direction of John-Rine A. Zabanal. I
understand that my child will be voluntarily participating in audio recordings of a
simple song that will be sight read. The recordings will last no more than 10
minutes and my child’s identity will remain confidential.

Printed name of participant (child)

Printed name of parent/guardian  Signature of parent/guardian

Relationship to participant  Date

FSU Human Subjects Committee approved on 11/07/2018, valid after 11/06/2019. HSC #2018.25782
APPENDIX E

STUDENT PARTICIPANT ASSENT FORM

STUDENT PARTICIPANT ASSENT FORM
(High School Student)
Different Instrument Accompaniment

My name is John Rine Zabala and I am a Ph.D. candidate from the College of Music at Florida State University. You are invited to be part of this research study because you are a high school student currently participating in orchestra.

String musicians perform with a variety of instruments. The purpose of this study is to examine how the intonation of string musicians are affected by the type of instrumental accompaniment. If you agree to participate in this study, you will perform a short excerpt with four recordings of accompaniments (violin, cello, piano, and oboe) and once as a solo. Your performances will be audio recorded, however your recordings will be identified only by participant number. You will also be asked to complete a questionnaire. The questionnaire will ask you for your primary instrument, age, years studying instrument, where music instruction began, and grade level. The questionnaire will also ask you to rate their performances. Like the audio recording, questionnaires will be identified by participant number only.

Audio recordings are for data analysis purposes and will not be shared or played in any public manner at any time. The study will be conducted during your normally scheduled orchestra class time in a quiet area in the performing arts building. You would only miss about 10-15 minutes of class time.

Participation in this study is voluntary. Your decision to participate or not will not affect your grade or standing at your school in any way. It will also not affect any current or future relationship with Florida State University. If you decide to participate in the study, you can choose to stop participating at any point of the study. There are no personal benefits to you for participation, but this knowledge will help orchestra directors and string teacher in their teaching. There are no risks in participation beyond those encountered in everyday life.

Please discuss your participation in this study with your parents prior to making a decision. If you decide to participate, your parents will need to give their written permission as well.

If you have any questions now or at a later time, please feel free to contact me at [email protected] or [email protected]. If you agree to participate, please print and sign your name below. You and your parents will be given a copy of this form after you have signed it. Thank you for your consideration.

__________________________________________________________________________
Student name (please PRINT):

__________________________________________________________________________
Student signature:

__________________________________________________________________________
Date:

FSU Human Subjects Committee approved on 11/07/2018, void after 11/06/2019. HSC #2018.25782

FSU Human Subjects Committee approved on (date). Void after (date). HSC #
Research: Mr. John Rine A Zabala
Faculty Advisor: Dr. John G. Geriner
APPENDIX F
INTONATION STUDY QUESTIONNAIRE

Intonation Study Questionnaire

Please complete the following questions. Subject Number: ______

1. What is your primary instrument? (Circle one)
   Violin  Viola  Cello

2. What is your current age? ________________

3. How many years have you been studying your instrument? ________________

4. Where did you start learning to play your instrument? (Circle one)
   Private Lessons  Public School  Other: ________________

5. What is your level of study? (Circle one)
   High School  Graduate-Masters
   Undergraduate  Graduate-Doctoral

6. If you are in high school, what grade are you in? If you’re in college, ignore this question (Circle one).
   Freshman (09)  Sophomore (10)  Junior (11)  Senior (12)

7. If you are in college, what is your program of study? If you’re in high school, ignore this question (Circle one).
   Performance  Music Education  Other: ________________

Flip to other side ➔
Intonation Study Questionnaire

8. Which instruments did you prefer to tune to the most? List from most preferred (1) to least preferred (4):

<table>
<thead>
<tr>
<th>Instrument</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cello</td>
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<td>Oboe</td>
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<tr>
<td>Violin</td>
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</tbody>
</table>

Rate your tuning accuracy for each performance of the listed condition below (circle a number):

1. Rate your intonation performing with the cello.

<table>
<thead>
<tr>
<th>0</th>
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<th>4</th>
<th>5</th>
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<th>10</th>
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<tbody>
<tr>
<td>Not Accurate</td>
<td>Very Accurate</td>
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2. Rate your intonation performing with the piano.

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<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Accurate</td>
<td>Very Accurate</td>
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</table>

3. Rate your intonation performing with the oboe.

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</thead>
<tbody>
<tr>
<td>Not Accurate</td>
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</table>

4. Rate your intonation performing with the violin.

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</thead>
<tbody>
<tr>
<td>Not Accurate</td>
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</table>

5. Rate your intonation performing as a solo.

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<tbody>
<tr>
<td>Not Accurate</td>
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</table>

Thank you for taking the time to participate in this study! I really appreciate it!
Zabanal Dissertation
Group Assignment by Instrument

Indicate the participant number within each instrument going down the line (i.e. Participant 1, violin; participant 2, viola; participant 3, violin; participant 4, cello; etc.). Demographic information other than instrument will be indicated in the survey.

<table>
<thead>
<tr>
<th>Group</th>
<th>Violin</th>
<th>Viola</th>
<th>Cello</th>
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</thead>
<tbody>
<tr>
<td>A</td>
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<td>B</td>
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<td>C</td>
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<td>E</td>
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REFERENCES


Benson, W. L., The effect of tuning stimulus vibrato, timbre, and frequency on tuning accuracy of university, high school, and junior high school instrumentalists (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (UMI No. 9533783)


BIOGRAPHICAL SKETCH

Name: John Rine Anacito Zabanal

Date of Birth: September 25, 1988

Birth Place: Manila, Philippines

Home Town: Elyria, Ohio, USA

Higher Education:

The Ohio State University
Columbus, Ohio, USA
Major: Music Education

Florida State University
Tallahassee, Florida, USA
Major: Music Education
Degree: M. M. E. (2014)

Florida State University
Tallahassee, Florida, USA
Major: Music Education
Degree: Ph. D. (2019)

Experience:

Freedom Middle School, Orchestra Director
Spotsylvania County Schools
Spotsylvania, Virginia, USA
Orchestra grades 6-8 (2010-2011)

Ni River Middle School, Orchestra Director
Spotsylvania County Schools
Spotsylvania, Virginia, USA
Orchestra grades 6-8 (2011-2016)

Riverbend High School, Orchestra Director
Spotsylvania County Schools
Spotsylvania, Virginia, USA
Orchestra grades 9-12 (2010-2016)

First Baptist Church of Tallahassee
Tallahassee, Florida, USA
Instrumental Music Director (2018-2019)