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Intonation in the Aural-Skills Classroom

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INTONATION IN THE AURAL-SKILLS CLASSROOM

A Thesis Presented

by

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DEDICATION

To my family and friends who have ever believed in me.

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ABSTRACT

INTONATION IN THE AURAL-SKILLS CLASSROOM

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The goal of the thesis is to explain intonation perception and cognition, as well as the vocal mechanism and techniques, to help aural-skills instructors teach vocal intonation skills to students who struggle with intonation. The thesis explores comprehensive information on intonation perception and cognition and introduces basic vocal technique for an over-all understanding of the skills involved with accurate vocal intonation.

CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The goal of my thesis is to help aural-skills students who struggle with intonation problems to sing in tune. My aim is to accomplish this by discussing two topics: intonation perception and cognition, and vocal production. Musicians sing out of tune when their pitch cognition skills, vocal skills, or both are underdeveloped. This thesis presents and discusses comprehensive research in intonation perception and cognition so that music students and instructors can better understand how intonation is processed in order to sing more in tune. The thesis also introduces the basics of healthy singing and the anatomy of the vocal mechanism so that music students may have a general understanding of vocal production.

It is my belief, as both a teacher and a student, that a skill is easier to improve when one understands various aspects of the skill; therefore, the thesis takes a comprehensive approach to understanding how the mind perceives and processes intonation and how the body correctly produces it.

The intended audience for this work is instructors who wish to aid aural-skills students in improving their singing intonation. This also extends to anyone interested in intonation cognition and perception.

Though the main focus of this thesis is on college-level aural-skills students, it is also important to consider intonation acquisition and improvement in younger people. To understand how musicians are able to sing with accurate intonation, it is helpful to discuss how they progress to this point. For college-level students who have difficulty

singing in tune, information on how children learn this skill may shed light on the college-level students' past deficiencies in the realm of vocal technique and aural-skills building.

Before further discussion, it is important to ask if college students are able to improve their vocal intonation. The available literature offers many ways to improve vocal intonation through practice and exercises. When answering the question "Who can sing?" Christy (1981) replies: "Any person with a normal speaking voice who can 'carry a tune' or learn to do so – this means nearly everybody…. All normal human beings possess an adequate vocal instrument awaiting only liberation and knowledge of how to use it for pleasing tone production." Furthermore, Christy suggests that "proper training will improve both singing and speaking voice" (p. 2).[1] No student, especially the uncertain singer,[2] should be discouraged from seeking vocal improvement, especially with the information available to them in this area.

Singing is an important skill for musicians to develop because it is a basic means of musical expression and communication. In general, musicians must sing with good intonation to sing correctly and communicate musical ideas more effectively. Through singing, even instrumentalists can exchange musical ideas in situations where they are without their instruments. Another reason why singing with good intonation is important is that singing is a way for instructors to evaluate students' aural processes, to distinguish whether or not students are "hearing" the correct pitches with the mind's ear (auralizing). For example, different instrumentalists can strike a key or set down a finger to produce a

[1] Christy refers to George Oscar Brown's and Kenneth C. Mook's (1952) book, *Song and Speech* (p. vi) to strengthen his claim.
[2] The term "uncertain singer" is used by Don L. Collins in his book, *Teaching Choral Music* (1999) to describe students who have difficulty with vocal intonation without negatively labeling them.

pitch without auralizing the pitch. But for singing in tune, musicians must auralize correctly.

Aural-skills students should minimally be able to sing with good body alignment, efficient and effective breathing, and a healthy tone. Their intonation should be such that instructors can determine that their auralizing process is correct. Aural-skills students should sing to communicate the correct notes and clearly indicate functional harmonies of arpeggiated chords and melodic lines. Only after these basic skills are achieved can students further improve their intonation to reach the ideal goal of singing pitches that reflect their awareness of musical context and attention to coloration in a melodic line. Students should also be able to sing independently in duet settings and small ensembles with accurate intonation.

The thesis discusses both vocal and instrumental studies. Though playing in tune on instruments is affected by techniques specific to individual instruments, studies with instrumentalists include valuable information regarding how musicians perceive accurate intonation. In aural skills, students' aural abilities are evaluated through their vocal production; similarly, for many studies using instrumentalists, the subjects' aural perception is evaluated through the use of their main instrument.

The scope of research in intonation perception and cognition presented in this document is broad. However, the discussion on vocal production is intended to be basic, but thorough. This is because well-trained musicians should have strong intonation perception and cognition skills, whereas vocal technique, though important for singing in tune, does not necessarily need to be at an advanced level for all musicians. The thesis

will not discuss vocal problems that must be treated by a physician or voice therapist, or physical hearing disabilities.

One goal of thorough musical training is to develop a musician's sense of intonation. First, it is important to discuss the matter of what it means to be "in tune." Simply stated, *intonation* is defined in *The Oxford Dictionary of Music* (Revised Edition) as "the act of singing or playing in tune." However, accurate intonation is relative. When a stringed instrument is tuned from A3 or A4 so that each string is a perfect fifth away from the next without beats present, the lowest string (G4 for violin, C3 for viola, and C2 for cello) will inevitably be too flat when compared to an equal-tempered instrument. Which instrument is correct? The answer is both, depending on the tuning system selected.

Unfortunately, there is no research to date that determines the range of what musicians' perceive as acceptable intonation. Generally, the accepted standard for intonation is based on intervals in equal temperament. This is not surprising since the pitches in the equal-tempered system are used to build keyboard instruments such as piano and organ, as well as wind and brass instruments[3] (Backus 1977, 155). However, musicians who play instruments from different instrumental families (as well as singers) sometimes perform using intervals that deviate from those in the equal-tempered system. For example, multiple studies have shown that both string players and choral singers are considered to use Pythagorean intervals rather than equal-tempered or just because of

[3] Though wind instruments are built based off of intervals in the equal-tempered system, all pitches cannot be perfectly in tune with this system because the same hole (or combination of holes) is used to produce different notes (Backus 1977, 156). This requires wind players to use musical judgments for intonation performance.

their performance of wider major thirds and narrower minor thirds[4] (Backus 1977, 149). This is important because it shows the fluidity of intonation, and the varied perceptions of what musicians consider to be in tune.

The tuning systems discussed in this thesis are equal temperament, Pythagorean, and just (pure) tuning. A basic explanation of each system appears in Appendix A, with a brief discussion of advantages and disadvantages in practical performance settings. To understand intonation, one must understand the measurement used in order to make a more accurate judgment of what it means to be in tune.

Lastly, it is the role of instructors to be good vocal models for students. Instructors often act as the metaphorical ears and voice of their students until the students are able to auralize and vocalize correctly on their own. Uncertain singers rely on their instructors to correct intonation and to guide aural and vocal development. Effective instructors are like mirrors, showing students what skills they need to improve so that students can begin the process of understanding how to improve. Be it through intensive remedial work to develop effective aural processes, or minor corrective strategies for students in need of slight fine-tuning, instructors need to help identify deficiencies with students' intonation production and to be guides to help improve singing.

[4] See references in Backus (1977), p. 159.

CHAPTER 2

PITCH PERCEPTION AND COGNITION FOR INTONATION IMPROVEMENT

Pitch Perception and Cognition Skills

Most skills can be improved through understanding and practice. Vocal intonation is often one of these skills. Two factors are equally important for improving vocal intonation: pitch perception and cognition (processing), and vocal production. Accurate vocal intonation is dependent on correct pitch perception and cognition; therefore, to improve vocal performance it is most helpful to understand how we make sense of sound.

Audiation and Auralizing

To gain a better understanding of intonation perception, it is important to understand how people cognitively process music in a meaningful way. Anyone without a physical hearing deficit is able to "hear" music. But to improve musicianship and to further understand what it means to be in tune, one must be able to generally understand music within a larger context.

Firstly, musicians should be able to mentally reproduce music through auralizing. According to Karpinski (2000), the ability to auralize, or of "hearing music mentally in the absence of physical sound," is of the utmost importance (p. 49). Karpinski examines procedures for students to auralize correctly to perform well in aural skills, in particular the subject of staying in key through establishing the diatonic collection[5] and the tonic.

[5] Karpinski (2007) defines *diatonic collection* as "all the diatonic pitches from a given key signature" (p. 49).

Procedures for this are explained in a later section. Nevertheless, the thesis will discuss pitch-matching and pitch-memory skills first because they are more rudimentary than establishing the diatonic collection and the tonic, and must be mastered before other work in intonation improvement is possible.

Secondly, musicians must also be able to audiate. According to Gordon (2007), "Sound becomes music through audiation when you translate sounds in your mind and give them meaning" (p. 3). Furthermore, audiation is the "process of assimilating and comprehending music we have just heard performed or have heard performed in the past" (pp. 3-4). Audiation can also take place without the presence of sound when musicians read notation and "hear" it using their mind's ear. Audiation is different than aural perception. People aurally perceive sound the actual moment it is produced, while audiation occurs after a delay (p. 4). Without audiation, meaningful and more permanent learning is not possible.

Pitch Matching

To sing with accurate intonation, aural-skills students must be able to match pitch and remember pitches previously heard. Karpinski (2000) explains the difference between these two concepts: "Pitch matching involves producing a sound to match a stimulus *while* that stimulus is sounding" (p. 33). This skill is more basic than pitch memory, and must be acquired before undertaking work in pitch memory. Pitch memory is described as "a delay between stimulus and response" and can include such short-term delays as "a few milliseconds to perhaps several minutes" (p. 36).

Problems in pitch matching can be perceptual, vocal, and even psychological.[6] Problems with vocal production require attention, and may include lack of experience and improper use of the voice. This will be discussed in chapter 4. For students with slight difficulties with pitch perception and cognition, corrective work with instructors may help them develop more effective practicing strategies. However, more pronounced difficulties in pitch perception and cognition require much work and practice to remedy and may be addressed using several approaches.

One approach to pitch matching that Karpinski (2000) suggests is using beat elimination to produce perfectly tuned unisons and other pure intervals (p. 34). Beats[7] are heard when two pitches are slightly mistuned to each other, creating what Miles (1972) calls a "pulsation of sound" (p. 497). Many instrumentalists use beat elimination to tune their instruments (string players tune using just fifths, for example). Karpinski explains how pitch matching is more difficult with complex tones, including the voice and piano. Therefore, in the aural-skills classroom, the difficulty of pitch matching for struggling students may be compounded by the use of a piano with its different timbre compared to the voice. Working with an instructor's voice without a piano would be more beneficial. Kodály ([1941] 1965) believed that young singers need to sing along with experienced singers instead of an instrument (such as the piano) because of the matching tone-color of voices (p. 2).[8]

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[6] Karpinski (2000) describes an instance when a university student was labeled a "nonsinger" in grade school and this label negatively affected her throughout her study as a music student (p. 34).

[7] Backus (1977) describes a *beat* as a "resulting sound [that has] a periodic rise and fall in amplitude that is heard as a periodic change in loudness" (p. 49).

[8] In his book, *Let Us Sing Correctly* ([1941] 1965), Kodály includes 107 short, three to twelve note exercises designed to be practiced simultaneously by a teacher and student. It was his belief that for students to sing melodic intervals with accurate intonation, they need to hear and feel how harmonic, simultaneous intervals are sung. Furthermore, he believed that "singing depends on the acoustically 'natural' intervals, and not on the tempered system" (p. 2).

Another difficulty with using a piano is the limited amount of time for pitch matching given the decay in amplitude that occurs immediately after a piano key is struck. This may make pitch matching between voice and piano through beat elimination difficult due to timbre differences and the limited amount of time that the target pitch is audible. Because of this, Karpinski (2000) suggests using the instructor's voice to produce the target pitch. He also suggests pairing students with instructors of the same gender. This is because the register difference between a man's and woman's voice may result in an octave difference, as well as timbre differences, adding one more layer of difficulty to the pitch-matching exercise[9] (p. 35).

If students have difficulty matching the instructor's target pitch, Karpinski (2000) suggests that students sing a pitch first for instructors to match (pp. 33-34). Once this is successful, instructors can smoothly slide the pitch up or down and ask the students to follow. From here, instructors should change the pitch by step or small skip and instruct the students to match this vocally. Once students are comfortable with this, instructors should produce the first pitch and students should attempt to match it. It is important for instructors to stay within the vocal range of their students (p. 34).

When practicing this approach, students should be aware of the concept of intratonal space.[10] Intratonal space is the "acoustic world underlying musical hearing and singing" (Jaccard 2004, 5). Jaccard has written an English-language version of Edgar Willems's concept, which was based on his background as a teacher of the Kodály

[9] Timbre has been found to affect intonation perception. In Geringer's (1999) study there was a direct correlation between the brightness of timbre and perception of sharpness, and conversely, darkness of tone quality and flatness in pitch (p. 135).

[10] For more on intratonal space, please see Edgar Willems ([1956] 1987), *Les Bases Psychologiques de l'Education Musicale* [Psychological Foundations of Music Education]. English translation by Jerry L. Jaccard [2002], Bienne, Switzerland: Editions Pro Musica.

method. Willems explains that "the voice is full of sound," meaning it is not just a set of fixed pitches (Jaccard 2004, 5). Sound exists between the tones that students must be able to perceive and to sing. In order to sing pitches correctly, it is important to be able to distinguish the sounds in between the notes. The goal is to teach students how to use this intratonal space and be able to move through it comfortably.

The previous exercises have used audio feedback to improve intonation. Both visual and verbal feedback may also help improve pitch-matching performance. Exercises with visual feedback include the use of a stroboscopic tuner or match-needle device, giving direct and accurate feedback for intonation accuracy (Karpinski 200, 35-36). Students of all levels can easily work on intonation improvement through self-directed practice with these electronic devices. Furthermore, these portable devices give students accurate feedback without an instructor being present. For students who have difficultly with pitch accuracy and are in need of remedial work, the match-needle and stroboscope are invaluable tools for developing sensitivity to intonation (p. 36). This strategy is also effective for mid-level students who wish to improve intonation perception. Verbal feedback, on the other hand, is effective but requires instructors to tell students which specific pitches need correction and in what direction. Ultimately, if students understand the specific inaccuracies of their performance, they have a better chance to improve.

Another approach for improving pitch matching is vocal modeling, defined as the instructors' use of the voice as a model for students to emulate. A dissertation by Green (1987) examines the effects of vocal modeling on pitch-matching accuracy in children. Subjects were asked to listen to and sing along with a sample recorded by an adult

female, adult male, and child (pp. 32-33). The results of this study indicate that more subjects matched pitch accurately to the female and child models as compared to the male model, with more responses for the female model correct than incorrect (p. 39). Matching pitch to the child model resulted in more correct responses from the subjects than either the adult female or adult male model (p. 60). Green suggests that children matched pitch less accurately to the male model due to the octave difference; children had difficulty matching pitch when the stimulus was below their range, resulting in more incorrect responses.

Pitch Memory and Staying "In Key"

Pitch memory is essential when distinguishing differences between two or more pitches not sounded together (Karpinski 2000, 36-37). Karpinski explains two elements used in pitch memory: recognition and recall. Recognition is used to compare two pitches with a period of silence or new audio stimulus (interference) in between, and to determine if the second pitch is the same or different than the first. The longer the period of time or the more interference between two pitches, the harder it is to accurately recognize pitches. Pitch recall, on the other hand, is the ability to reproduce a pitch that has been heard (p. 37).

Pitch memory is also important to staying in key while singing. To practice and check if students are singing with the correct tonic in mind, Karpinski (2000) suggests that students pause periodically and sing the tonic in the middle of sight-singing practice.

Another more remedial exercise for students to practice is singing while playing a tonic drone on a piano or tone generator[11] (p. 170).

Some students sing out of tune when they perceive pitches incorrectly due to not firmly establishing the key in which they are singing. Similarly, students may also get "knocked out of key" by accidentals, modulations, and incorrectly-sung intervals. For students who do not intuitively establish the diatonic collection and the tonic aurally, Karpinski (2007) suggests a simple procedure to establish where the whole steps and half steps are in the diatonic collection as well as the tonic-dominant perfect fifth and leading tone[12] (p. 50). This procedure should be performed out loud so instructors can tell if students are auralizing correctly. When students are more confident and their aural skills are more well-developed, this procedure should be performed silently (p. 51).

Once students have successfully learned how to establish the diatonic collection and the tonic, more work may be needed to strengthen auralizing skills. Collins (1999) suggests singing various scales to improve intonation, including the whole-tone scale and chromatic scale, both ascending and descending, using solmization syllables (p. 312). This can also be done in two parts, with one voice beginning at the higher octave and descending while the other voice begins at the bottom of the scale and ascends (pp. 314-315).

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[11] Marylou Speaker Churchill, former violin professor at the University of Massachusetts Amherst and New England Conservatory, instructed students in her studio to practice from Schradieck's *The School of Violin-Technics* (1986) while listening to a tonic drone. This technique uses beat elimination to produce pure intervals and was intended to train the mind's ear as much as the fingers.

[12] See Karpinski (2007) for the procedure to establish the diatonic collection in major mode (pp. 50-51) and minor mode (pp. 88-89).

Teaching Methods and Techniques for Intonation Improvement

Students can practice many exercises on their own to improve their intonation, but in many instances students may need help from their instructors. Jaccard (2004) stresses the importance of a good teacher-model, with teachers who not only have good ears for intonation, but have the ability to "demonstrate good singing that reflects the core attributes of the treble singing voice" when singing with children (p. 6). For the best results, instructors should sing in the same range as the students they are teaching.

Instructors should remember that aural skills will only be learned comprehensively in the aural-skills classroom. In a study by Dennis (1975), vocal pitch-matching skills were improved more for students in a vocal pitch-matching group, and instrumental pitch-matching skills were improved more for students in an instrumental pitch-matching group. Though there are overlapping concepts and skills learned throughout the college music curriculum, improvement on specific skills relies on practice in the specific area (pp. 77-78). Intense study and practice in instrumental intonation, while possibly strengthening intonation perception and cognition skills, will not necessarily transfer to vocal intonation accuracy in aural skills. It is incumbent on aural-skills students and their instructors to work on vocal skills specifically, without relying on other areas of music study to hone these skills. In some cases, remedial work and practice with a tutor or instructor is essential to vocal intonation improvement.

Instructors should consider various teaching methods when working with students. Graves (1963) outlines three different methods used to improve intonation: aural, visual, and conventional. In the first group, students who were taught through the aural method played to an accompaniment of chords on an electric organ. Students were

instructed to compare their intonation to the chords and discern and correct resultant beats. In the second group, students assigned to the visual method used a stroboscopic device to detect deviation in intonation and were instructed to correct it. Instructors working with a third group of students using the conventional method spent time teaching these students about music theory so that they understood chord construction, the pitch tendencies and nuances of their instruments, and the function of pitches within certain contexts in order to inform their intonation performance (p. 46).

Subjects in Graves's (1963) study received ten minutes of private instruction once a week over a five-week period that focused on intonation problems (p. 47). The results of this study showed that each method was useful for improving the subjects' intonation. Over a period of eighteen weeks, the different methods showed varied amounts of improvement in instrumental intonation performance. Overall, the conventional method was found to be generally most effective. The author reports, however, that each method resulted in intonation improvement in instrumental performance (p. 47). It seems that ten minutes a week of private instruction focused on intonation in fifteen weeks of study showed marked improvement in intonation performance skills. This signifies how important it is for uncertain singers to work specifically on intonation with an instructor in a one-on-one setting to strengthen intonation skills. Since each method resulted in intonation improvement, students may benefit when instructors incorporate all three in their teaching.

The type of feedback students receive on their performance is also very important for intonation improvement. A study by Salzberg (1980) focuses on feedback as a tool for intonation improvement. Salzberg examines four different types of feedback:

contingent verbal feedback, tape-recorder playback, model performance, and free practice (p. 43). Intonation accuracy in this study was measured in regard to the Pythagorean tuning system.[13]

Salzberg's (1980) findings indicate that verbal feedback was the most effective technique for intonation improvement (p. 44). This is the simplest means of feedback, which does not require expensive equipment. The only requirement for student improvement is a qualified instructor with strong skills in detecting intonation inaccuracies. This is supported by Graves (1963), discussed previously, who states, "the effectiveness of any of these [intonation improvement] methods…is conditioned by the quality of teaching involved and the desire to improve in this aspect of musical performance" (p. 47).

Positive reinforcement paired with a successive approximation[14] method of teaching is a less conventional way to improve intonation but has shown positive results. In a study by Dennis (1975), the experimenter attempted to shape behavior and guide the subjects to sing pitches that were closer to the target pitch. He accomplished this by decreasing the interval range in which the subject could sing to receive positive reinforcement (p. 143). Findings showed that positive reinforcement through the experimenter's shaping (using successive approximation) resulted in improved intonation accuracy. No subjects in other study groups reached the desired target of ten consecutive

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[13] One topic that is worthy of note is Salzberg's choice to use the Pythagorean tuning system as the base for her study. Her rational was that, based on different studies, string instrumentalists tend to conform more to Pythagorean tuning (Salzberg 1980, 44). The issue of tuning systems as it pertains to accurate hearing and performance will be explored in more depth in the following chapter.

[14] The Glossary of Behavioral Terminology in Madsen, Greer and Madsen (1975) in which Dennis's article was published defines *successive approximation* as "behavioral elements or subsets, each of which more and more closely resembles the specified terminal behavior" (p. 275). An alternate term to successive approximation is *shaping*, which is defined as "taking the behaviors that an organism already has in his repertoire and reinforcing those that are similar to the goal behavior, gradually requiring that the organism's behavior be more and more similar to the goal behavior to be reinforced" (pp. 274-275).

pitches correct, while thirteen of fifteen subjects in the shaping group reached the experimental goal (p. 144).

Subjects in the successive approximation/shaping group received fifteen minutes of training during the experiment. Even though incorrect pitches were positively reinforced, narrowing down the acceptable range through shaping was shown to be more effective than the typical classroom setting where only correct pitches are positively reinforced. To support this view, Dennis (1975) cites that subjects who only received positive reinforcement for correct pitches were generally more frustrated and asked to terminate their participation in the experiment (p. 149).

For students who cannot sing accurately in the music classroom, positive reinforcement for only correct pitches would be equally frustrating. Unfortunately, most classroom settings do not adhere to a shaping technique for teaching vocal intonation. Students at the elementary level, who are considered uncertain singers, often remain that way unless teachers and students take extra time in musical training. These uncertain singers sometimes advance to the college level as instrumentalists, where they find themselves struggling in the aural-skills classroom. The techniques that failed students in elementary school need not be attempted again in the same frustrating manner. Though shaping reinforces incorrect notes, it still encourages uncertain singers to use their vocal muscles and practice vocalizing. This builds vocal skills in a positive environment, rewarding not absolute correctness but improvement. Teaching is about improvement, not about instant perfection. Therefore, more teaching techniques that use shaping may be advantageous in the classroom setting.

Most teaching takes place in a classroom (group) setting rather than through private instruction. A study by Green (1994) focuses on the benefits of group singing compared to solo singing. Results showed that children sing with better vocal pitch acuity when singing in unison in a group than they do alone (p. 105). Green acknowledges that her findings contradict those in prior studies.[15] She explains that an adult's voice was present in group-singing tasks of prior studies. Therefore, the addition of the different timbre (adult voice) may have affected the children's performances (p. 111). Group singing in classroom settings of all levels may help uncertain singers to sing with better intonation. However, care should be taken regarding timbre differences in groups (adult with children; men with women) that may negatively affect intonation performance. The intonation of uncertain singers may improve if they practice with strong singers who serve as a vocal model for pitch matching. This can be done in a classroom setting or in a small, student-directed study group.

[15] See Green (1994), pp. 113-114 for references.

CHAPTER 3

FACTORS THAT AFFECT INTONATION PERCEPTION

Introduction

In order for musicians to sing in tune they must have accurate intonation perception. This chapter discusses various factors that affect intonation perception of both performers and listeners, including experienced musicians and non-musicians. Aural-skills students come to the classroom with varying backgrounds and experiences as both instrumentalists and vocalists. Therefore, this section includes discussions and studies using various pitched instrumental families and voice types to accommodate this fact.

Musical Context

When working with sight-singing, students and instructors should take musical context into account. Intervals may be perceived and performed with slightly different intonation inflections when in different contexts. For example, an interval that is in tune with the equal-tempered system when sung in isolation may not seem appropriate in a melodic context or in a chord that is meant to express functional harmony. Furthermore, studies show that intonation performance is judged differently depending on the context. What people perceive as in-tune in one context may be perceived as inaccurate in a different context.

Studies have shown that intervals presented within a melody are judged more accurately as being in tune or out of tune than were the same intervals presented in

isolation. In a study by Wapnick (1982), musicians were able to identify intervals within a melodic context as well as discriminate between flat, standard, or sharp intonation more accurately than the same intervals in isolation. Wapnick concludes that a melodic context causes listeners to be more sensitive to intonation inaccuracies (p. 35). An experiment performed by Rakowski (1990) also supports this finding, showing that smaller intervals without a musical context tend to be tuned narrower, whereas larger intervals are tuned with wider intonation (when compared to the equal-tempered system) (pp. 60-61). This indicates that practicing intervals in a melodic context may be more beneficial for gaining intonation sensitivity than practicing the same intervals in isolation.

Sight-singing exercises may also be performed in a harmonic context using duets, trios, and such. Therefore, it may be useful to know that intonation is also affected by functional harmony and ensemble practices. One experiment by Stoffer (2004) indicates that flutists tend towards playing major thirds within a pure tuning system (as opposed to Pythagorean or equal-tempered tuning) in order to avoid beats, regardless of the functional harmony of the chord in which the major thirds were found (p. 77). Instructors should be aware of this tendency of some instrumentalists in order to make informed decisions concerning the tuning of certain intervals. For example, should the leading tone of a dominant chord be sung sharper to show its pull towards the tonic, or should it be sung lower to accommodate pure tuning?

Pure tuning is also a subject of interest in harmonic context for unaccompanied singers. A study by Sundberg (1982) found that singers in barbershop quartets tend to use pure intervals without vibrato. This experiment examined two semi-professional barbershop quarters for their intonation tendencies. Each quartet was instructed to

perform warm-up exercises in which the group members focused on intonation within the chords they produced. The frequency of their vocal cord vibrations were measured during these warm-up exercises. The results indicate that the intervals for these barbershop quartets more closely approximate the pure tuning system (p. 58).

Sundberg (1982) also compared the intonation tendencies of barbershop quartets with that of string trios, in which the intervals measured are wider and more closely approximate the Pythagorean tuning system. This compares different ensemble practices to understand performance tendencies and perceptual differences between various instrumental and vocal groups. The author concluded that pure tuning is not necessary in string ensemble performance because vibrato masks beating between the harmonic intervals that are not tuned to the pure tuning system (p. 54). Instructors might consider using less vocal vibrato when working on pitch matching with students so that intonation is more clearly distinguishable between the two voices.

It would be worthwhile to consider the physical and acoustical tendencies of instruments played by uncertain singers in order to better understand how playing different instruments may influence students' perceptual intonational nuances. For example, pianists may audiate leading tones as flatter than cellists do, or percussionists might find beat elimination techniques to be more difficult than wind players. This may have implications for instructors working with students on slight intonation problems, so instructors can make recommendations for students' intonation practicing techniques based on knowing the students' intonation performance backgrounds.

Accompaniment

Singing or playing with an accompaniment has pedagogical advantages and disadvantages. When an accompaniment is present, musicians are able to tune notes to the accompaniment part for better intonation. When listeners were asked to indicate which sample recording was more in tune, Geringer (1978) found that subjects perceived an accompanied performance of scales to be more accurate than unaccompanied scales (p. 37). Results show that subjects perceived intonation more accurately for accompanied samples as compared to unaccompanied samples. The accompaniment gave a context to pitches so listeners were able to compare the pitches in the performance to those in the accompaniment. For unaccompanied scalar patterns, intonation deviated in the sharp direction resulting in an octave stretch (pp. 37-38).

The presence or absence of accompaniment, however, may interfere with judgment of out-of-tune notes. Results from a second experiment by Madsen and Geringer (1990) indicate that accompanied samples of "bad" intonation were judged as having better intonation than the same samples heard without accompaniment. The authors conclude that an accompaniment creates a more pleasing harmonic environment that fosters a more positive perception of mistuned intonation (pp. 127-128). This experiment supports the view of not using piano accompaniment in an aural-skills setting. In order for instructors to make judgments on intonation accuracy, no accompaniment should be present that may affect the instructor's perception of students' vocal performance.[16] Whereas the addition of piano accompaniment is effective in a

[16] As a violin teacher, I have experienced this change of perception between a classroom and performance setting. A violin student's performance, including intonation, always appears to be of a higher quality in a recital setting with the addition of a piano accompaniment when compared to unaccompanied performance in private lessons.

performance setting, and can sometimes help students strengthen intonation, it also may obscure musical problems and is not always appropriate for a classroom or tutoring session in which detecting intonation problems is paramount.

Voicing

Students should be able to sing in tune when singing different voice parts in duets. The voice part to which subjects draw their focus is also important. When a melody line and bass line are played together, as in an experiment by Rasch (1985), listeners judged melodic mistuning as more disturbing than bass line mistuning (p. 441). Rasch's results show that melodic intonation in a melody line is perceived more accurately and is thus considered more important to listeners than intonation in a bass line. Consequently, the intonation of harmonic intervals that result from simultaneously sounded melody and bass lines is less accurately perceived than melodic intervals (p. 456). Therefore, students should take more time strengthening their intonation in bass line parts so that all parts are performed with equal accuracy.

Intonation performance is also affected by which voice part musicians are playing. An experiment by Karrick (1998) using experienced wind instrumentalists found that, when asked to play the bottom voice of a duet with a prerecorded melody, players performed less in tune than when they played the top voice. When performing the bottom line, more mistunings occurred, especially deviation in the sharp direction for the intervals of thirds and sixths (p. 121).

One might conclude that these studies indicate that musicians in general should practice performing all voices equally with intonation in mind. For example, musicians

who play treble instruments should also practice performing middle and bottom voice parts to strengthen their intonation skills. Zoltán Kodály composed short exercises with pitches both above and below a held note in his book, *Let Us Sing Correctly* ([1941] 1965). His intention was for students to sing these exercises with teachers and exchange voice parts for best results (p. 3). In this way, students would learn how to accurately sing both top and bottom pitches of intervals at an early level of study.

Experience

In the previous studies, musicians tempered their intonation practices to fit specific performance contexts. Prior musical experience led these musicians to make intonation choices. For instructors, knowing the background and types of musical experiences students have had (number of years, instrument or voice type, etc.) may be very helpful for diagnosing deficiencies and for designing remedial exercises.

The number of years a musician has been studying music is also important for intonation perception. In a study by Morrison (2000), students with more years playing experience were more accurate in matching a prerecorded melody than students with less experience (p. 39). Not only was there a direct correlation between years of experience and intonation accuracy, but a preference for sharp intonation was also found[17] (pp. 48-49).

The findings in a study by Karrick (1998) (discussed in the previous section) were similar when considering experience and a tendency for playing sharp when comparing professional wind instrumentalists and students. Aside from having more overall

[17] See Morrison (2000) pp. 50-51 for references to more studies on the tendency of experienced musicians to perform sharp.

mistunings, the student group performed less sharp than the professional group when playing below the stimulus (p. 112).

The instrument with which a student has experience may also have an influence on intonation performance and perception. In a study by Edmonson (1972), vocalists as a group performed with more intonation accuracy than instrumentalists, while woodwind players showed less consistency as a group (p. 252). In a study by Loosen (1995), violinists predominantly chose Pythagorean tuning as more accurate, pianists chose equal-tempered tuning as more accurate, while subjects with no musical experience did not show a specific preference for one system over the other (p. 291).

Melodic Contour and Scale Direction

The findings in multiple studies indicate that, besides a preference for playing sharp, musicians are generally more accurate in performing ascending scales or intervals than performing the same scale or interval when descending. Students and instructors should consider this finding when working on sight-singing or other exercises. Edmonson's (1972) findings suggest that, when singers perform without accompaniment, ascending intervals are often performed more accurately compared to the same descending intervals (p. 254). Results showed that, overall, unaccompanied ascending intervals were sung with more accuracy than descending intervals. However, it is interesting to note that some individuals consistently sung descending intervals with more accuracy (p. 252). Though the results show a common trend, it is important to note that differences in individual students do exist.

The findings were similar in Ballad and Yarbrough's study (1990) of student string players, in which subjects as a group played sharper for ascending scalar patterns compared to equivalent descending patterns. Subjects tended to play out-of-tune pitches with sharp intonation rather than flat intonation. This was true for both ascending and descending scales (p. 21).

Tempo

It is common knowledge among musicians that performance intonation is often more accurate when musicians perform at a slower tempo. This is likely the result of the extra time available to auralize and accurately produce pitches. However, tempo also has an effect on intonation perception. According to a study by Duke (1988), listeners judged slower presentations of musical passages as being lower in pitch and faster presentations as higher in pitch when compared to the original orchestral excerpt (p. 122). Further, non-music majors' pitch perception was more affected by tempo changes than the pitch perception of music majors. This would seem to indicate that musical training mitigates the deleterious effects of tempo on intonation perception. This illustrates yet another way that music experience affects perception (p. 114). Lastly, instructors might consider the importance of keeping a steady tempo when working with students' intonation in order to rule out the effects of tempo perception on singing accuracy.

CHAPTER 4

THE VOCAL MECHANISM, VOCAL PRODUCTION, AND TECHNIQUES

The following chapter aims to give students an overview of the form and function of the vocal mechanism. The chapter introduces healthful ways to sing without excessive tension on the vocal cords, and techniques for singing that promote healthy vocal habits.

Basic Vocal Mechanism Anatomy

In the same way that players are taught the names and functions of the parts of their instruments, singers should know and understand the various parts of their vocal mechanisms and how they function. The vocal pedagogue Oren Brown states "I suggest that the more you understand the anatomy and physiology of voice production, the better equipped you will be to sing or to teach singing" (Brown 1996, 169). Singers should understand the basics of the vocal mechanism for a good understanding of its functions. Much attention is given to the larynx and vocal cords. However, the parts of the voice necessary for singing are not restricted to these areas. The pharynx (the area above the larynx at the back of the throat), sinuses or nasal cavity, soft and hard palate, and the respiratory system (including the lungs and diaphragm) are also important for proper vocal production. Additionally, correct body alignment is critical for effective breathing for singing. Singers should also be aware of how they move their heads and chins, since this affects the larynx by slightly changing its shape and location, which in turn affects tone quality (p. 213).

The larynx (also known as the voice box) is located in the throat, in the upper region of the trachea (windpipe) situated in front of the esophagus (Titze 1996, 4). It is made up of various cartilages, soft tissues, membranes, ligaments, and is attached to the hyoid bone. Since it consists of soft tissue, and is only attached to the hyoid bone that is not fixed to the skeleton, the larynx is very flexible and mobile enough to allow functions such as breathing, swallowing, yawning, and sound production (p. 4). The epiglottis (thin flap of cartilage) attaches to the base of the tongue and the hyoid bone, closing the chamber of the larynx to seal the trachea when swallowing (p. 10). Phonation is possible when intrinsic muscles (muscles within the larynx as opposed to extrinsic muscles of the throat) close the epiglottis. Air flows through the opened epiglottis for breathing (Brown 1996, 176). (See Figures 1-3 in Appendix B.)

The larynx houses muscular bundles that make up the vocal folds (Titze 1996, 12). These bundles contract to draw the cartilages of the larynx forward, thickening and stiffening the bundles through this contraction (p. 13). For the voice to produce lower pitches, the vocal folds are shortened from back to front and thickened vertically, causing the folds to vibrate throughout their entire length, depth, and width. Higher pitches are produced through lengthening and vertical thinning of the vocal folds causing more tension from back to front, with only the upper edges vibrating (Brown 1996, 176). For the intrinsic muscles to function properly, the extrinsic muscles of the throat should be relaxed (p. 177). All muscles of the throat and face affect the intrinsic muscles of the larynx, so these muscles should be in a condition of release (p. 180).

Basic Vocal Production

Proper vocal production is exceedingly important to healthy singing. If the voice is used improperly, correct pitches, especially in the extremes of a singer's range, are exceptionally difficult to produce. Effective singing is achieved through freeing the voice so that it is used as naturally as speaking (Christy 1981, 3). A useful way to improve singing is focusing on the feeling associations that are present when singing is done correctly that give singers physical feedback other than audio feedback[18] (p. 14). The following sections describe ways to develop a healthy singing voice.

Alignment

Brown (1996) states, "to breathe freely, the body needs good alignment" (p. 18). Good alignment can be achieved by developing a sense of ones own skeletal and muscular structure, or *kinesthesia*[19] (p. 21). Good alignment often does not come naturally, but must be habituated both in a music setting and outside to feel natural (Christy 1981, 19). The study of the voice often begins with correcting alignment to achieve the most efficient air flow.

Collins (1999) explains good singing alignment as beginning with the placement of the feet beneath the hips so that one foot is slightly more forward than the other. Standing weight is on the balls of the feet, not the heels, and knees are loose instead of locked for good blood circulation. Singers should have flexible abdomens that are responsive to breathing and elevated chests with "floating" ribs. He suggests feeling a

[18] For additional information on healthy sing and feeling associations, see Oren Brown's book, *Discover Your Voice* (1996).

[19] *Webster's New World Dictionary* (3rd Edition) defines *kinesthesia* as: the sensation of position, movement, tension, etc. of parts of the body, perceived through nerve-end organs in muscles, tendons, and joints.

stretch in the lower spine without curving it too much to negatively affect breath flow. The singers' hands should hang loosely at their sides with their shoulders relaxed and gently pushed back. Singers should avoid tension in the neck, and tilt the forehead slightly forward (pp. 212-213). Be aware that tilting the head too far forward crowds the larynx, whereas tilting the head too far back creates tension (Quinn 1996, 3).

Other techniques for checking alignment are looking in a mirror for instant visual feedback, or using a video camera to check both alignment and sound production (Brown 1996, 21). However, once students know and understand what good alignment is on an intellectual level, they must feel what good alignment is through kinesthesia.

Correct body alignment is sometimes easier to feel when people are lying down without gravity pulling down on the spine. Brown (1996) instructs students to lie on their backs on the floor, feeling a space between the floor and the small of the back. Students should feel the spine lengthen down towards the pelvis and up through the neck, with the chin slightly tucked in as if trying to look at the toes. They should focus on loose limbs and how the breath becomes deep and relaxed (p. 21). When standing, students should try to maintain this feeling of elongation and relaxation (p. 22).

After students are standing again, they should place their fists against their sides at the waist, just below the ribcage so that the thumb is touching the bottom of the ribs. They should focus on how the spine stretches and the back expands as they slightly bend their knees, keeping heels on the floor, and let the head hang loosely in front. Slowly they may straighten the knees, feeling a firming of the lower abdomen, keeping spine elongated and back expanded. Finally, they should raise their heads back up slowly, standing tall, while focusing on relaxed breathing (Brown 1996, 22).

Another way to encourage students to stand tall is for them to imagine trying to touch something hanging from the ceiling with the tops of their heads, or feel that they are hanging from a string like a puppet, creating the sensation of being tall but still without tension. Imagining the different body parts resting on each other like a marionette is also helpful (Brown 1996, 22).

Christy (1981) also notes the importance of relaxation to good alignment. However, the muscles used for singing must be "alive and flexibly tense." The body should feel ready for action and be energetic. He describes this tension as "resistant" and "balanced," like that applied to a stretched rubber band. Singing cannot occur without muscles contracting, but the muscles not used in singing like those in the arms, shoulders, and legs should be relaxed (p. 20).

Once students are comfortable standing tall with good alignment, Brown (1996) suggests walking with this alignment and viewing it in a mirror (p. 24). To walk with proper alignment, students can imagine a string attached to the navel, while keeping the stomach firm. The imagined sensation of the string pulling on the stomach helps keep the shoulders comfortably back with a gentle curve in the spine.[20]

Good alignment while sitting is also important, since standing while singing in a classroom setting is often unlikely. The upper body can maintain the same alignment when sitting as is used for standing. Students should be instructed to sit at the edge of their chairs, shoulders back from the chair, both feet on the floor, with the hips and shoulders feeling free to move (Quinn 1996, 3). To feel firm lower abdominal muscles, Brown (1996) suggests that students sit forward on their chairs with backs straight, and lift their feet a few inches off the ground while keeping their legs straight. Students

[20] Thanks to Marylou Speaker Churchill for the exercise for walking with proper alignment.

should spread their feet apart and slowly return them to center and then lower their feet again to the floor. Repeat this exercise, focusing on relaxed breathing while keeping the breath flowing through open air passages (pp. 22-23).

Breathing and Breath Management

Once students have learned to align their bodies, instructors can work on proper breathing and breath-management techniques. Breath management is important because it supports an even and free tone. Collins (1999) believes that school-age students begin to breathe with shallow breaths because they restrict the breath band (the area of the lower ribs) when they slouch at desks, whereas babies breathe more deeply because their bodies have not yet acquired poor habits (p. 213). Singing instructors often need to re-teach breathing to their students for controlled breathing and ample breath support.

Christy (1981) describes correct breathing as coming from the areas of the ribs (costal muscles) and diaphragm. Costal breathing expands the lower ribs and the back through inhalation and remains expanded through most of exhalation. The area at the front and top of the stomach a hand's width from the navel should also expand and be firm when singing (p. 26). However, Titze (1996) suggests not keeping the stomach muscles tight all the time because they need to be relaxed during inhalation so the diaphragm can expand downward freely (p. 75). Students should avoid breathing from the chest which results in shallow breaths (p. 26).

To feel how to use costal breathing, place hands at the base of the ribcage, just above the waistline. Breathe in through the nose so that the ribs expand under the hands. Slowly exhale through rounded lips. Keep the ribs expanded from the sides with a

feeling of fullness through to the end of the exhale. From a standing position, bend forward at the waist and let arms hang loosely above the head. Take a deep breath and feel how the lungs expand towards the back of the ribcage. Return to an upright position, and take a deep breath, trying to reproduce the feeling of expansion in the back. [21]

For more experience with costal breathing, students should raise their arms slowly to the sides and above their heads, palms down through the lift, breathing in slowly while counting to four and feeling the ribs expand. Holding this momentarily, they should focus on feeling the expansion of their ribs. To come out of this pose, students should slowly exhale on a hiss sound to the count of four and lower their arms while keeping the ribs expanded and spines stretched (Christy 1981, 28).

Effective breathing also comes from areas other than the sides of the ribs. To find an effective way of breathing, Brown (1996) instructs students to stand tall with good alignment, placing one hand on the chest and the other hand just below the ribcage in the front. Empty the lungs of all air, and then let the lungs fill up with air when needed. Students will feel the hand that is below the ribcage move more pronouncedly than the hand on the chest. Also try this exercise by opening the mouth after the lungs are empty to feel the same low expansion below the ribcage on a more automatic, reflexive level (pp. 28-29).

Once breathing feels natural and free, students can address breath management. Christy (1981) outlines four phases of breath management: inhalation, suspension, exhalation, and recovery. He instructs students to inhale through the nose and mouth simultaneously, breathing deeply and with relaxation, with a feeling of an open throat and

[21] Thanks to Marjorie Melnick, voice faculty member at the University of Massachusetts Amherst, for exercises on costal breathing.

body. Students should not breathe so deeply as to use more air than necessary (p. 27). Collins (1999) suggests inhaling so that students feel a cool spot on the roof of their mouths above the gum ridge from the air drying the tissue (p. 214). Suspension occurs the moment inhalation ends and the vocal cords prepare for the production of pitch. Once the vocal cords are prepared, exhalation begins with the production of sound (phonation). A brief period of recovery begins when the muscles relax after the exhalation and before the next inhalation (p. 27).

For strengthening breath management, Brown (1996) instructs students to inhale through the nose and fill the lungs over a ten-second period, then exhale through rounded lips for another ten-second period. Repeat this for eleven seconds, increasing the number of seconds for the exercise until students are no longer comfortable or they have reached twenty seconds (pp. 31-32). Daily repetition of this exercise may greatly improve breath management.

A similar exercise consists of inhaling through the nose with a sniffing sound and exhaling through the mouth with a puffing sound. Do this while walking, inhaling on each step for ten steps, then exhaling on ten steps. Vary the exercise by inhaling sniffs for a different number of steps than the number of exhaling puffs. For example, students could try six sniffs followed by ten puffs, etc. This helps students learn to measure and distribute their breaths (Brown 1996, 33).

Quinn (1996) suggests panting like a dog or imagining blowing out candles to strengthen exhalation. Start at a slow pace, and then increase the pace throughout use of the exercise. Also try making a sustained hissing sound. Instructors can signal students

to continue this sound through exhalation, pause and hold on cue, and then continue after the pause (p. 4).

Collins (1999) suggests blowing puffs of air through rounded lips to feel the activated muscles of the upper abdomen. Students should feel the lower abdominal muscles firm as if reaching towards the backbone (p. 216). It is also helpful to practice this exercise with a finger in front of the lips to feel the puff of air (Quinn 1996, 4).

Finally, for breath support through long phrases, Quinn (1996) suggests descending passages from *sol* through *do* on an aspirated syllable like *ha* or *ho*, with each syllable receiving a separate attack. As breath management improves, use longer exercises with this technique (p. 4).

Tone Production and Resonance

Vocal production begins when the breath is exhaled through the larynx causing the vocal cords to vibrate. The vibration cannot be heard by itself, but is amplified by resonating chambers. Resonating chambers include the pharynx, mouth, chest, and head cavities. The tongue and lips help guide air flow to these resonating chambers to produce tone. The throat and jaw should be loose and relaxed so that the air flow is free to reach the resonating chambers. The back of the tongue should also be relaxed and in a downward position as if to say "ah" (Collins 1999, 217).

The pharynx is used more to produce lower pitches with good resonance, whereas the head cavities are used for higher pitches. For mid-range pitches, it is best for singers to use a mixture of both resonating chambers (Collins 1999, 217). The singer should

mentally direct the tone towards the cool spot on the palate, with higher pitches aimed towards the eyebrows (p. 218).

The proper onset of tone should be clear, free, and focused, and requires a balanced breath. Singers should imagine the tone coming from the breath, not from the throat, in order to keep throat muscles relaxed (Christy 1981, 37). For intonation, singers should auralize the starting pitch before producing it (which gives the vocal cords time to adjust) and imagine approaching pitches from above (p. 38). This keeps the tone clear and discourages singing pitches flat.

Christy (1981) suggests avoiding a breathy sound or a throaty glottal attack at the onset of the tone. He explains that a breathy tone is produced when the breath begins before phonation. To solve this problem, singers should auralize the pitch first while using the mental image of approaching the note from above to adjust the vocal cords before phonation occurs. A throaty glottal attack occurs when the vocal cords are closed after inhalation, resulting in an explosive, percussive sound like a cough. Christy suggests leaving the vocal cords open after inhalation and imagining the formation of sound in the pharynx (p. 38). Titze (1996) suggests the use of sighing or exercises having a silent "h" at the onset of phonation to help relax the muscles (p.107).

Instructors should be aware of vocal problems in students because they are not only unhealthy for the voice, but can also lead to intonation problems. Brown (1996) describes various vocal production problems that are caused by either hyperfunction (too much use) or hypofunction (too little use). Some examples of hyperfunction are singing too loudly, pushing with the breath, straining for high notes, tension in the shoulders, neck, tongue, lips, or jaw, rigid posture, and breathing improperly (pp. 218-219).

Examples of hypofunction include insufficient breath for the phrase, lack of tone, whispered breath, and excessive breathiness (pp. 220-221). Some ways of solving the aforementioned problems are tension reduction and breathing exercises, sighing, and staccato exercises to treat breathy tone using the consonants “d,” “b,” and “p” (pp. 224-225).

CHAPTER 5

PEDAGOGICAL EXAMPLES

Every aural-skills student brings to the classroom a different set of musical perceptions and experiences. This is of great importance when considering singers who need improvement in intonation. This chapter discusses ways to diagnose perception, cognition, and vocal problems and how to design courses of action to correct these problems using examples of situations that instructors could encounter in the classroom. Examples discussed in this chapter are fabricated, and are not meant to generalize the skills and skill levels of different types of musicians.

Diagnostics

Before problems can be treated, they must first be diagnosed. When students come to an instructor seeking help in singing, the instructor needs to know their backgrounds before further work can be done. The instructor should know, at the least, why specifically the students are seeking help, what type of vocal experience the students have had prior to the class, what instruments they have played, and their understanding of written theory. Some students may be aware of their problems, which may indicate that their intonation perception is less of a factor, but instead lack the vocal control needed for singing in tune. Other students may seek help after outside factors, such as poor grades, make them aware that they have a problem. Still other students may have good basic auralizing and vocalization skills, but need help finding strategies for fine-tuning intonation.

Instructors should discern if students have deficiencies in intonation perception, vocal production, or a mixture of both, as well as the level of these deficiencies. For example, instructors should test the vocal production of students who have no prior singing experience. Additionally, if students have played only non-pitched or fixed-pitched instruments, instructors may want to test intonation perception first. Lastly, instructors may address theory skills of strong singers who seem to have good intonation perception, to identify if these students understand the basics of key signatures and placement of half steps in a melodic line, chord quality and inversion, or if sight reading and error detection skills are an issue. From here, instructors may have a better idea of the students' needs, and can begin remedial or supplementary work to develop auralizing and vocalization skills.

Underdeveloped Auralizing and Vocalization Skills

Students with underdeveloped auralizing and vocalization skills will most likely need extensive remedial work in order to improve vocal intonation. These students will need to develop auralizing and vocalization skills simultaneously in the same way children acquire these skills. Initially, the instructor needs to establish the students' level of perception and vocalization skills. Instructors should determine the students' vocal range, their ability to match pitch, their pitch recognition and recall abilities, and their understanding of basic music theory. Avoid sight-singing exercises at this time to rule out confounding problems with note reading and error detection.

At this time, let us consider an example of a first year percussionist who approaches his aural-skills instructor for sight-singing help. This student might have had

little or no singing experience. Therefore, he may have limited experience with audiation and with auralizing pitches. If the student is found to have deficiencies in pitch processing, work with his instructor on pitch matching and pitch memory is essential. However, if the main cause of poor intonation is lack of experience with these auralizing and vocalization skills and not necessarily a weakness in pitch processing, the instructor should begin with basic vocalization exercises, before moving on to exercises for auralizing, to work up these skills and give the student the foundation he needs.

Basic vocal exercises can be used to help determine any students' vocal range and to aid them in producing a free tone. Vocal exercises incorporating sliding and sighing work well at this level because they promote a smooth, flexible voice with connection between pitches. For these exercises, students need not attempt to match pitch or reproduce specific pitches. The goal of the exercise is to gain comfort with the voice and become accustomed to singing in front of an instructor. Once this is accomplished, the same sliding exercises may be used to develop auralizing skills. Sliding is a useful way for students to feel the sounds in between the pitches and to become familiar with using intratonal space. This technique is also useful for students who struggle with feeling and distinguishing higher versus lower pitches. Instructors should be aware that, for inexperienced singers who play non-pitched instruments (like the percussionist previously mentioned), this may be the first time they have needed to auralize pitches.

Let us now consider an example of a tuba player who is struggling with aural skills. This student may also have limited singing experience compounded by the fact that her voice is not in the same range as her instrument. The pitches with which she has experience auralizing and producing are generally out of the range sung in the classroom.

Because of this, she may need extra work away from her instrument and with an instructor's voice to practice auralizing pitches in her vocal range. The same exercises of sliding and matching pitch mentioned previously may apply.

Students at this level may benefit greatly from singing in unison with their instructors so that they have a clear model to emulate and a target pitch to produce that is in their vocal range. Since experience plays a major role in intonation accuracy, the more practice at this stage the better. Singing intervals while the instructor sustains one pitch may also be helpful for students to hear correct intonation and feel the beats produced between the two voices. Students should avoid using excessive vibrato in exercises, as vibrato masks intonation inaccuracies and interferes with beats produced by pure intervals. For the days when students do not practice with instructors, students may either work with peers or use visual feedback from electronic devices such as the match needle.

Underdeveloped Vocalization Skills

Some students may have developed auralizing skills but lack the vocal control needed to sing accurately. Students with this problem can usually hear that they are singing incorrectly. Many string players, for example, have good auralizing skills because of the intonation work they have done to play their instruments, but some may be inexperienced singers who struggle to produce the pitches they can auralize. Students such as these should begin with the basic vocal production exercises discussed in chapter 4 and the sliding vocalizations discussed in the previous section. Pitch-recall exercises may also be beneficial, as long as students take time before singing the target pitch so

that their vocal cords are able to adjust to the correct note. Practicing in a slow tempo is very important for these students. If this is done correctly enough times, students may be able to feel through kinesthesia how the vocal cords adjust when they auralize a pitch and prepare to sing.

For students who have minor vocal control issues, practicing with an instructor regularly may help strengthen their voices. Instructors should teach them exercises that expand the students' comfortable vocal range as well as cultivate a flexible voice. Basically, when vocal control problems are present due to students' lack of experience, instructors should introduce the fundamentals of vocal production so that students have a firm foundation from which to learn how to sing properly.

Sometimes singing incorrect pitches may cause students to lose the key in which they are singing. When this happens, students should take time to establish the diatonic collection and the tonic, focusing on singing half steps correctly. In this instance, vocalization and auralizing skills affect each other, though good vocal control may minimize this problem.

Underdeveloped Auralizing Skills

Students with well-developed vocal skills may still have intonation problems due to underdeveloped auralizing skills. Let us now consider different examples of vocalists who need help with auralizing skills. Some vocalists may rely too heavily on a piano accompaniment to keep them in the same key because of their experiences with a piano in private lessons and ensemble rehearsals. In these cases, vocalists should practice at a

piano only to check for tonic or for the correct pitch so they practice while consistently singing in the correct key. Aside from this, practice away from a piano is recommended.

Some vocalists, however, may have very little experience singing with a piano, and may find practice with a piano initially helpful to staying in key. Alternatively, steady work with an instructor's voice can serve the same purpose with the benefit of having a matching timbre between the two voices. The ultimate goal is for students to establish and stay in one key on their own without outside assistance.

When working with an instructor to stay in key, careful work with half steps and intervals may be beneficial for these students, as well as practicing whole-tone and chromatic scales, to strengthen auralizing skills. Because of the tendency for musicians to prefer sharper intonation, it is important for students to avoid stretching the octave during scale practice as it may result in modulating to a different key. Also, since some singers may have more difficulty singing descending intervals accurately due to less experience with them, descending scales should not be overlooked in daily practice.

Some students have generally good auralizing skills but need a little extra work to fine-tune intonation. Let us discuss this level of student using pianists because of their experience with fix-pitched instruments. Pianists as a group have experience auralizing pitches, but some may need extra practice focusing on intonation problems. Work with an instructor while being aware of pitches and intratonal space may be helpful in these cases. Attention to functional harmony when practicing simultaneously sounding or arpeggiated chords may also be beneficial to these students for fine-tuning intonation.

When strong singers have intonation problems with more difficult sight-singing exercises, instructors should determine whether or not students understand the theory

behind the exercise. For example, students might have difficulties singing certain intervals and skips if they do not realize that the pitches outline a particular chord. Instructors should work with students on how to identify the harmonic function of pitches in melodic sight-singing exercises for a more complete understanding of the exercise for faster, more effective auralizing techniques.

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Conclusion

Musicians must understand every facet of a skill in order to perform that skill at the highest possible level. This is also true for intonation accuracy in the aural-skills classroom. For musicians to sing in tune, it is important for them to understand how one perceives and processes intonation, as well as how to sing with correct vocal production. Auralizing and audiation are essential for correct intonation cognition. When uncertain singers approach their instructors for guidance in singing with accurate intonation, it is the instructor's task to diagnose auralizing and vocalization deficiencies as well as to design courses of action to help students develop this skill. For students with underdeveloped auralizing skills, pitch-matching and pitch-memory exercises and other such remedial procedures are indispensable for intonation acquisition. For students with underdeveloped vocalization skills, understanding the basics of the vocal mechanism and singing technique is greatly beneficial. Through steady practice with an instructor and a complete understanding of aural processes and the voice, these aural-skills students can improve their ability to sing in tune.

APPENDIX A

TUNING SYSTEMS

Equal Temperament

The equal-tempered system is based on dividing the octave, which has a frequency ratio of 2:1, into 12 equal parts, each called a semitone. Each semitone is tuned exactly the same distance from the next. Each equal-tempered semitone is comprised of 100 cents, with 2 semitones equaling 200 cents and an octave equaling 1200 cents. According to Backus (1977), a well-trained ear can detect a change of frequency of about 1 hertz, which is approximately three cents (when at the level of 500 hertz). This would imply that fractions less than 1 whole cent are unnecessary to calculate (p. 140).

The equal-tempered scale is used for fixed-pitch instruments such as keyboard instruments. This enables these instruments to be played in every key, or to modulate without resulting in devastating beats or intervals so mistuned that they are unacceptable to the ear. In the equal-tempered scale, enharmonic pitches are the same pitch.

This tuning system is considered a good compromise system, however, the equal-tempered system lacks pure intervals (except for the pure octave) that are found naturally in the harmonic series (Sundberg 1982, 50). Every interval except the octave will produce beats. It is quite common for instrumentalists and vocalists to perform with piano accompaniment and adhere to equal temperament, even though they do not strictly use the equal-tempered system in solo practice and performance due to different intonation tendencies and performance practices of different instrumental families. An

example is from a study by Kopiez (2003) which found that professional trumpet players adapted their performance to the equal-tempered system, even when presented with a stimulus sample in the just tuning system (p. 407). Brass instruments when played without valves produce pitches in the overtone series which does not perfectly fit the equal-tempered system.

Pythagorean System

The Pythagorean scale is named after the ancient Greek mathematician, Pythagoras (c.570-490 BCE). The ratios of intervals in the Pythagorean system are the unison as 1:1, the octave as 2:1, the fifth as 3:2, and the fourth as 4:3 (Nolan 2002, 272-273). The frequency ratios are not as small and concise for the remaining intervals, with the major second or whole tone as 9:8, major third as 81:64, minor sixths as 27:16, and the major seventh as 243:128 (Backus 1977, 138). Two different sized semitones exist in this scale, being the Pythagorean diatonic semitone as 256:243 and the Pythagorean chromatic semitone, a little larger than the diatonic semitone, at a quite large ratio of 2187:2048. The difference in enharmonically equivalent pitches, called the Pythagorean comma, is a ratio of 531441:524288 (Backus 1977, 139).

The Pythagorean scale is produced by stacking perfect fifths until all pitches of the diatonic scale are represented, and then placing their octave equivalents within the same octave (Sundberg 1982, 51). When Pythagorean intervals are compared to those in the equal-tempered system, it is much easier to use cents instead of frequency ratios. The Pythagorean whole-tone is 204 cents, compared to the equal-tempered whole-tone of 200 cents (Backus 1977, 140). If the trained ear can distinguish as little as 3 cents difference

in frequency, then the ear can detect the slight wideness of the 4 cent difference between the Pythagorean whole-tone and the equal-tempered whole-tone. The Pythagorean diatonic semitone is 90 cents, 10 cents narrower than the equal-tempered semitone of 100 cents, whereas the Pythagorean chromatic semitone is wider at about 114 cents, making a difference between the two different types of Pythagorean semitones of 24 cents, or almost a quarter of a semitone different (Backus 1977, 140).

Musicians often found fault with intervals in this scale. For example, major thirds tended to sound too wide, whereas minor thirds tended to sound too small (Backus 1977, 141). Instrumentalists would attempt to impart color into their performances by performing with intonation more closely approximating the Pythagorean tuning system than the equal-tempered system.

Pure Tone (Just) Intonation

The pure tone scale, or just scale, directly addresses the problems of beats between consonant intervals by attempting to make all intervals pure. Simply stated, the pure or just scale is built from the intervals found in stacked pure tonic, dominant, and subdominant triads (Sundberg 1982, 50). These intervals are expressed in small, whole frequency ratios. As noted above, the Pythagorean scale contains small-frequency ratios for the unison, octave, fourth, fifth, and whole tone, and large-frequency ratios for seconds and sevenths, thirds and sixths. For the pure scale, these intervals are found through the ratios of a major third as 5:4, a minor third as 6:5, a major sixth as 5:3, and a major seventh as 15:8 (Backus 1977, 143-144).

There are several drawbacks to the pure system of tuning. For example, the fifth within a supertonic chord will be too small, making it not a just fifth. While the just diatonic semitone is 16:15, or 112 cents, there are two different-sized whole-tones in this scale, which are 204 (the same as the Pythagorean whole tone with a ratio or 9:8) and a significantly narrower interval of 182 cents, with a ratio of 10:9 (Backus 1977, 144-145). Because of the difference in semitone found in this scale, it is difficult to modulate to other keys while retaining pleasant intonation (Sundberg 1982, 50).

APPENDIX B

FIGURES

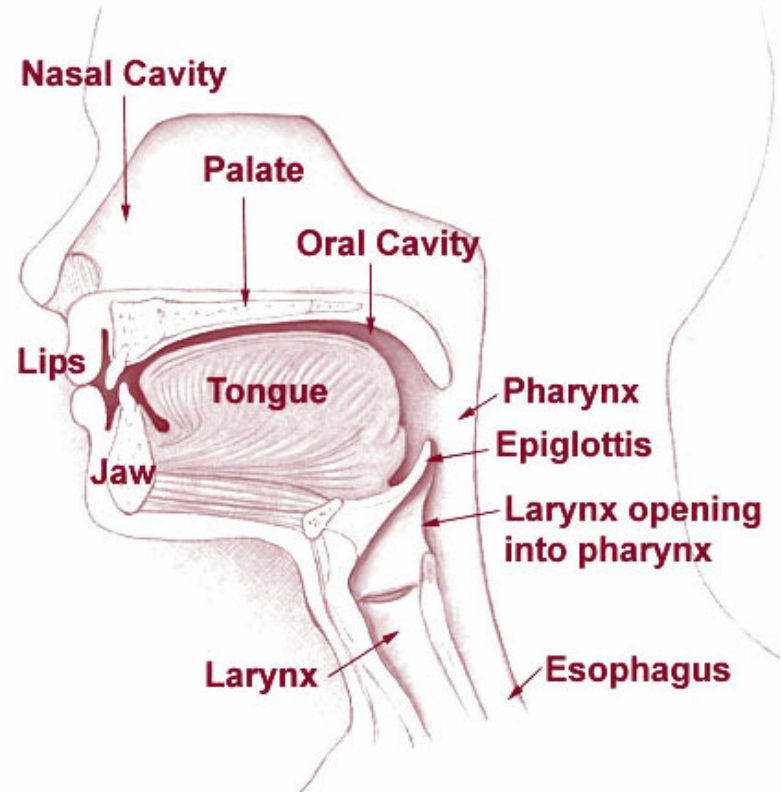

Figure 1. Sagittal section of the head showing position of larynx in throat.

Courtesy of The National Cancer Institute. Obtained from Wikimedia Commons, http://commons.wikimedia.org/w/index.php?title=File:Illu01_head_neck.jpg&oldid=42173836

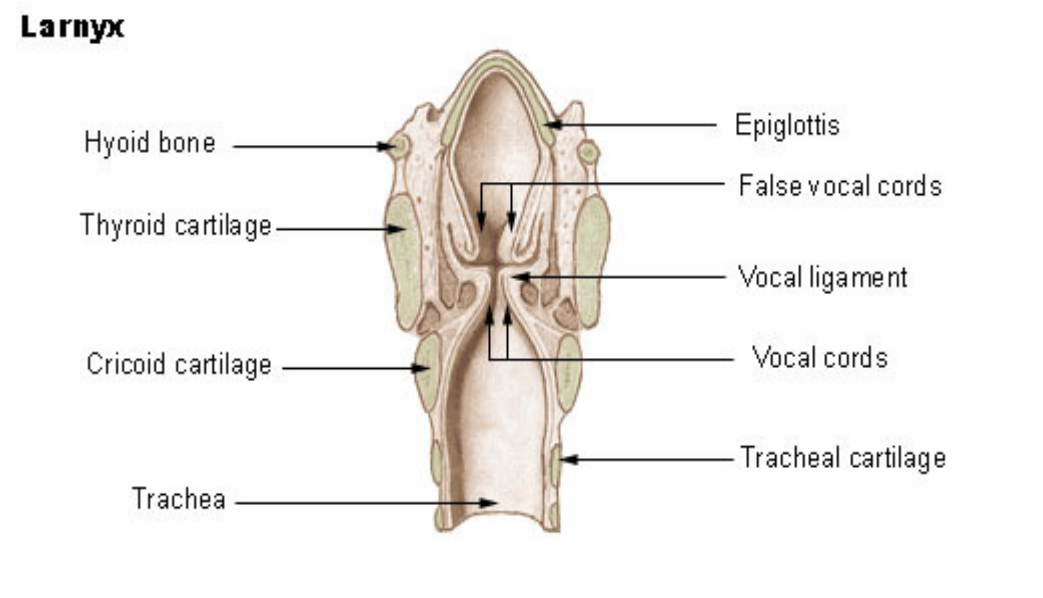

Figure 2. Sectional view of larynx from front.

Courtesy of The National Cancer Institute. Obtained from Wikimedia Commons, http://commons.wikimedia.org/w/index.php?title=File:Illu_larynx.jpg&oldid=38112602

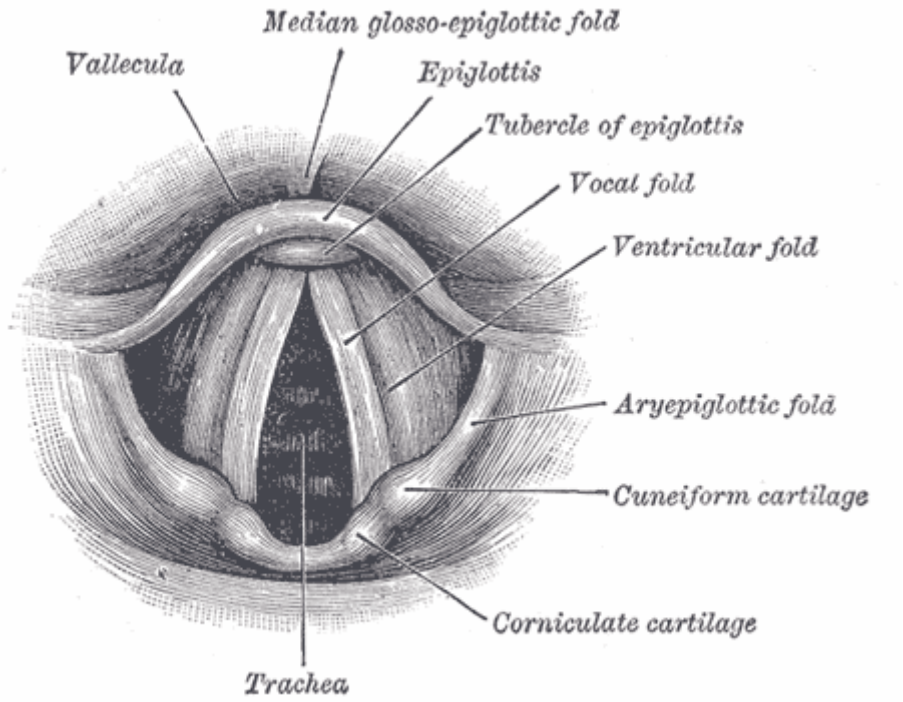

Figure 3. Ventral view of larynx.

Lithographic reproduction from Gray's *Anatomy,* 20th edition. Circe 1918. Courtesy of Wikimedia Commons, http://commons.wikimedia.org/w/index.php?title=File:Gray956.png&oldid=28012266

REFERENCES

Backus, John. 1977. *The acoustical foundations of music*. New York: W.W. Norton & Company Inc.

This book, written by a physicist, clearly explains the acoustics of music, including partials and harmonics, the harmonic series, and pitch discrimination. Also explained are different tunings and temperament and how they are formed.

Ballard, Dana, and Cornelia Yarbrough. 1990. The effect of accidentals, scale degrees, direction, and performer opinions on intonation. *The University of South Carolina. Department of Music* 8, no. 2: 19-22.

Results of this study indicate that scale steps 3 to 4 are treated with similar intonation accuracy as scale steps 7 to 8 (both intervals sharp) for string players. Enharmonic equivalents F-sharp and G-flat also had very little intonation differences in a study setting. Overall, string players tended to play ascending patterns with sharper intonation compared to descending patterns.

Brown, Oren L. 1996. *Discover your voice: How to develop healthy voice habits*. San Diego: Singular Publishing Group, Inc.

The author's method of teaching voice aims to guide readers to healthy vocal use through natural voice production. Having worked alongside medical doctors to help correct vocal problems in speech and singing, the author relates his experiences to help promote relaxation, good posture habits and others. Exercises and diagrams are included.

Christy, Van A. 1981. *Foundations in singing: A basic textbook in the fundamental of technique and song interpretation.* Dubuque, Iowa: Wm. C. Brown Company Publishers.

This book was written for the beginning vocal student or person seeking a basic understanding and training in vocal technique. A focus on healthful and natural singing is a theme throughout the text, and includes guidance in good posture, breath control, and vocal exercises.

Collins, Don L. 1999. *Teaching choral music, 2nd ed*. Upper Saddle River, New Jersey: Prentice Hall.

This text includes poor intonation tendencies in individual singing and choral settings as ways to anticipate them in teaching. Also includes vocal exercises to improve intonation and vocal production, including whole-tone and chromatic scales and ways to practice them.

Duke, Robert A., John M. Geringer, Clifford K. Madsen. 1988. Effect of tempo on pitch perception. *Journal of Research in Music Education* 36, no. 2 [Summer]: 108-125.

The results of this study indicate that changes in tempo have a possible effect on pitch perception as opposed to changes in frequency affecting the perception of tempo in both music majors and non-music majors. Also, music recordings played at slower tempi were perceived as being lower in pitch opposed to faster tempi.

Edmonson, Frank A. III. 1972. Effect of interval direction on pitch acuity in solo vocal performance. *Journal of Research in Music Education* 20, no. 2 [Summer]: 246-254.

Edmonson performed a study on the ability of vocalists and instrumentalists to sing ascending and descending intervals accurately. Descending intervals were less accurate than ascending. Also, the data found indicates that vocalists sing ascending and descending intervals with more accurate intonation than the solo singing of instrumentalists.

Geringer, John M. 1978. Intonational performance and perception of ascending scales. *Journal of Research in Music Education* 26, no. 1 [Spring]: 32-40.

In Geringer's study, music students from four instrument groups were asked to play ascending scales before and after differential verbal feedback. Subjects were then asked to play in order to compare the intonation of their two performances. Results showed that subjects preferred sharp intonation relative to the equal-tempered tuning system when judging their own intonation. Other results showed that unaccompanied scales had less accurate intonation than accompanied scales for both the subject's perception and performance.

Geringer, John M. and Clifford K. Madsen. 1981. Verbal and operant discrimination: Preference for tone quality and intonation. *Psychology of Music* 9, no. 1: 26-30.

Findings for this study support the theory that experienced musicians prefer sharp intonation deviations as opposed to flat intonation deviation. Intonation that was sharp or in-tune was a more important factor than tone quality conditions when rating the performance. Subjects rated their preferences for different performances verbally, and the time they listened to each example was also recorded.

Geringer, J., and Michael D. Worthy. 1999. The effects of tone-quality changes on intonation and tone-quality ratings of high school and college instrumentalists. *Journal of Research in Music Education* 47, no. 2 [Summer]: 135-149.

In this study, music majors, non-music majors who played in an ensemble, and high school ensemble players tended to perceive a pitch as sharper when the timbre of the pitch was brighter, and consequentially students perceived a pitch dark in timbre as being flatter. Results were even more extreme with less experienced subjects. Compared to the clarinet, the trumpet and trombone tones were perceived as better in-tune when played with bright or standard timbre. The clarinet tone was perceived as having worse intonation for the bright timbre over a standard or darker timbre.

Gordon, Edwin. 2007. *Learning Sequences in Music*. Chicago: G.I.A. Publications, Inc.

The process of audiation is outlined in Gordon's book, and how it is essential to understanding music.

Graves, William L. 1963. Improving intonation: Three different methods evaluated. *The Instrumentalist* 18: 46-47.

Graves evaluates three different approaches to improving intonation: aural, visual, and conventional method. The aural method required subjects to play with a chordal accompaniment to improve intonation; the visual method required subjects to practice using a stroboconn; the conventional method required subjects to be knowledgeable of and understand music for a more informed performance.

Green, Georgia A. 1987. *The effect of vocal modeling on pitch-matching accuracy of children in grades one through six*. The Louisiana State University.

Results of this study indicate that elementary school students are able to match pitches more accurately to a child's vocal model as opposed to an adult female vocal model or adult male vocal model. The female vocal model was more successfully matched than the male vocal model.

Green, Georgia A. 1994. Unison versus individual singing and elementary students' vocal pitch accuracy. *Journal of Research in Music Education* 42, no.2 [Summer]: 105-114.

Contrary to prior research, elementary students were found to sing in unison with more pitch accuracy when in groups than they did individually. The study's author concludes that this may be because previous studies were performed where the adult investigator sang with the group, adding a different timbre that may have made singing in a group more difficult. Another result of this study showed that male students tended to sing with less accuracy than female students in this experiment.

Jaccard, Jerry. 2004. Intonation begins in kindergarten: The art and science of teaching music acoustically. *Kodaly Envoy* 30, no. 4: 5-11.

Jaccard outlines grade-appropriate vocal exercises and concepts for elementary school children in this article. The concept of "intratonal space" is also discusses in relation to how it can be used most effectively to teach students how to sing in tune. The importance of the teacher's correct vocal modeling is stressed in this article. Also discussed are the tendencies of certain intervals or solmization syllables to be out of tune within certain contexts.

Karpinski, Gary S. 2000. *Aural skills acquisition*. New York: Oxford University Press, Inc.

This book clearly explains the concept of auralizing and includes information on music perception. The book also discusses concepts and skills such as pitch matching, pitch memory, and establishing tonic and the diatonic collection. Basic vocal production is also outlined concisely as it relates to the aural-skills classroom.

Karpinski, Gary S. 2007. *Manual for ear training and sight singing*. New York: W.W. Norton & Co., Inc.

This manual is a concise text for sight singing, and includes exercises and definitions pertaining to aural skills. Includes exercises such as sequentials and interval practice.

Karrick, Brant. 1998. An examination of the intonation tendencies of wind instrumentalists based on their performance of selected harmonic intervals. *Journal of Research in Music Education* 46, no. 1 [Spring]: 112-127.

Subjects (8 professionals and 8 advanced students) were instructed to record a duet melody with a synthesized harmony line, and then record the harmony with a synthesized melody line. Target intervals were studied, with results indicating that tuning in equal temperament was more closely followed than a just system of tuning. Subjects played more in tune when playing the melody line (above the stimulus). When tuning deviated for the professional players, it tended to be sharp intonation.

Kodály, Zoltán. [1941] 1965. *Let us sing correctly*. London: Boosey and Hawkes.

This singing manual includes detailed instruction on how to teach and practice the exercises. The exercises are in two parts, based on the pentatonic "pillar notes," without semitones until the last few exercises. Kodály stressed the use of the voice instead of instruments to teach singers how to sing correctly, and favors moveable *do* solmization. The exercises are meant to be practiced with two parts together, not in unison, so students can tune their note against the teachers' note.

Kopiez, Reinhard. "Intonation of harmonic intervals: Adaptability of expert musicians to equal temperament and just intonation." *Music Perception* 22, no. 4 [2003]: 383-410.

This study examines two professional trumpet players' ability to adapt their intonation in order to coincide with either an equal tempered or just intonation audio sample. Results of this study indicate that both players were better able to adapt to an equal-tempered sample, possibly due to prior musical training with instruments that used the equal-tempered tuning system.

Loosen, Franz. 1995. The effect of musical experience on the concept of accurate tuning. *Music Perception* 12, no. 3: 291-306.

The focus of this study is on the perception of correct intonation in violinists, pianists, and non-musicians in scales of the Pythagorean, just intonation, and equal-tempered tuning systems. Violinists as a group tended to prefer the Pythagorean scale, while the pianists as a group tended to prefer the equal-tempered scale. Non-musicians as a group purportedly were unable to distinguish the difference between tunings. Results indicate that perception of accurate tuning is reliant on experience rather than inherent auditory system abilities.

Madsen, Clifford K., David E, Wolfe and Charles H. Madsen, Jr. 1975. The effect of reinforcement and directional scalar methodology on intonational improvement. In *Research in music behavior: Modifying music behavior in the classroom,* eds. Clifford K. Madsen, R. Douglas Greer and Charles H. Madsen, Jr., 68-78. New York: Teachers College Press.

Results from this study indicate that intonation accuracy in scales performed by sixth grade subjects improved with reinforcement exercises between a pretest and posttest. All subject groups showed improvement, with uncertain singers showing most improvement in descending scales.

Madsen, Clifford, K. John Geringer and J. Heller. 1991. Comparison of good versus bad intonation of accompanied and unaccompanied vocal and string performances using a Continuous Response Digital Interface (CRDI)." *Canadian Music Educator Research Edition* 23: 123-130.

This article discusses listener perception of "good" versus "bad" intonation of soprano, tenor, violin and cello performances recorded with and without accompaniment. Results indicate that listeners perceive better intonation, even when the performance is "out-of-tune" when accompaniment is present. The authors conclude that the reason for this is the harmonic nature of the accompaniment creates a more pleasing musical environment for the listener, thus making the overall performance more pleasing. Also of note is the preference of professional musicians to play with sharp intonation rather than flat.

Miles, Edgar M. 1972. Beat elimination as a means of teaching intonation to beginning wind instrumentalists. *Journal of Research in Music Education* 20, no. 4 (Winter): 496-500.

This article explains the phenomenon of beating and how the aural method of beat elimination may improve intonation in wind players.

Morrison, Steve J. 2000. Effect of melodic context, tuning behaviors, and experience on the intonation accuracy of wind players. *Journal of Research in Music Education* 48, no. 1 [Spring]: 39-51.

Results from this study indicate that the direction of approach of a target pitch does not affect intonation accuracy in students with between 1-7+ years performance experience on wind instruments; however, students with more experience overall tend to have more accurate intonation.

Nolan, Catherine. 2002. Music theory and mathematics. In *The Cambridge History of Western Music Theory*, ed. Thomas Christensen, 272-304. NY: Cambridge University Press.

Nolan discusses a brief history of Pythagoras and describes the Pythagorean tuning system.

Quinn, Susan. 1996. Choral intonation: A practical guide to the process and the development of skills necessary for acquiring and maintaining accurate tuning. *The Canadian Music Educator* 37, no. 3: 3-15.

Skills discussed in this article include correct posture, breathing, tonal awareness and audiation. Further discussion is present on overtone production, tuning systems and implications for choral singing, and singing in a harmonic versus a melodic context.

Rakowski, Andrzej. 1990. Intonation variants of musical intervals in isolation and in musical contexts. *Psychology of Music* 18, no. 1: 60-72.

Some results of these experiments were a tendency for smaller intervals to be tuned smaller without a musical context, and for larger intervals to be tuned larger when compared to equal temperament. Subjects were also able to recognize and reproduced smaller intervals more accurately than larger intervals. Data on cent deviation for intervals in melodic contexts compared to their equal-tempered counterparts was also collected.

Rasch, Rudolf. 1985. Perception of melodic and harmonic intonation of two-part musical fragments. *Music Perception* 2, no. 4 [Summer]: 441-458.

Results in this study indicate that mistuning in the melodic line is less acceptable than mistuning in the bass line when musically trained subjects listened to different mistunings of a synchronous melody and bass line. Harmonic mistuning was also less acceptable than melodic mistuning, but more acceptable than bass line mistuning. The tuning of the intervals was argued to play more of a role in perception in this study than beats between the intervals.

Salzberg, Rita S. 1980. The effects of visual stimulus and instruction on intonation accuracy of string instrumentalists. *Psychology of Music* 8, no. 2: 42-49.

In this study, string players received different forms of feedback concerning intonation in an experimental setting: verbal, tape-recorder playback, listening to a model performance, and free practice (no feedback control group). Pythagorean tuning was used as the standard tuning for this experiment since Salzberg explains that string players tend to play sharp which coincides with the Pythagorean tuning system. Results indicate that subjects who received verbal feedback from an instructor increased their intonation accuracy, with no improvement for the model performance group. Also, blindfolding was shown to have no effect on intonation accuracy.

Stoffer, Thomas. 2004. The influence of harmonic context on the tuning of thirds played by professional flautists. *Psychology of Music* 32, no. 1 [January]: 75-88.

Two professional flautists performed major and minor thirds within different harmonic contexts. The intervals performed were measured against pure (just), Pythagorean, and equal-tempered tuning systems. The results of this study indicate that pure tuning is preferred for major thirds independently of a harmonic context, whereas minor thirds are closer to pure tuning within a harmonic context.

Sundberg, Johan. 1982. In tune or not? A study of fundamental frequency in music practice. *Quarterly Progress and Status Report* 1982, no. 1: 49-78.

Sundberg's article discusses intonation in instrumental and vocal ensemble music in string trios compared to barber shop quartets as relates to the pure, equal tempered and Pythagorean scales. The article also discusses the use of vibrato to eliminate beats as well as octave stretching.

Titze, Ingo R. 1996. Principles of voice production. Englewood Cliffs, NJ: Prentice Hall.

This book is an excellent source for anatomy and function of the vocal mechanism as they pertain to singing and speech.

Wapnick, Joel, Gary Bourassa, Joanne Sampson. 1982. The perception of tonal intervals in isolation and in melodic context." *Psychomusicology* 2, no. 1: 21-37.

Results from this study indicate that musicians are able to more accurately discriminate intervals as being sharp, flat, or in tune when heard in a melodic context as opposed to the same intervals in solmization. Subjects were also tested for absolute pitch and relative pitch ability before the study was conducted. Results for subjects with absolute pitch were not significantly more accurate than those for subjects with good relative pitch.

Willems, E. [1956] 1987. Les bases psychologiques de l'education musicale [Psychological foundations of music education]. Quoted in Jerry Jaccard. 2004. Intonation begins in kindergarten: The art and science of teaching music acoustically. *Kodaly Envoy* 30, no. 4: 5-11.

This non-English language primary source is used in Jaccard's article concerning the concept of intratonal space.