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Relationships among auditory representations and overall musicianship of classical and non-classical music students

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RELATIONSHIPS AMONG AUDITORY REPRESENTATIONS AND OVERALL MUSICIANSHIP OF CLASSICAL AND NON-CLASSICAL MUSIC STUDENTS

by

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Dedication

To Lexie the Great for teaching me the impossible can happen.

To Jack the Brave for teaching me how to persist with joy.

To Thomas for happily carrying us on your shoulders.

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None of this would have been a possibility without you, my sweet Thomas. You are an amazing man, incredible father, and a fairy-tale husband. Thank you for seeing who I could be in the midst of who I am. I am the luckiest and I would choose you over and over again.

RELATIONSHIPS AMONG AUDITORY REPRESENTATIONS AND OVERALL MUSICIANSHIP OF CLASSICAL AND NON-CLASSICAL MUSIC STUDENTS

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ABSTRACT

The focus of this study is on the relationships among three basic auditory representations as well as their interaction with a measure of overall musicianship (sight-singing) among a group of classical and non-classical university music students (N = 112) selected from three different universities. Students were enrolled in level one of an aural skills course at the time. Basic auditory representations included were tonic centrality, measured by Colwell's (1968) *Feeling for Tonal Center*, tonal grouping, measured by Colwell's (1968) *Auditory-Visual Discrimination*, and harmonic function grouping, measured by a revised version of Holahan, Saunders and Goldberg's (2000) assessment. I evaluated relationships by correlating scores on each measure and also compared these relationships among classical and non-classical music students.

The participants in this study were the most skilled at forming auditory representations of tonic centrality and non-classical musicians significantly ($p = .002$) outperformed classical musicians in this area. Tonic centrality was also most strongly correlated with overall musicianship ($\tau = .45$, $p < .001$) within the sample, and this relationship appeared to be stronger among non-classical musicians ($\tau = .52$, $p < .001$) than

among classical musicians ($\tau = .39, p < .001$). This difference may be accounted for by the increased reliance on grounding in a tonal center required by the musical activities of a typical non-classical music student.

Given the changing balance of musical endeavors present in tertiary music schools today (Lehmann, Sloboda, & Woody, 2007), educators are encouraged to better understand the particular strengths non-classical musicians may bring to the classroom in terms of ear-based musical abilities. Likewise, music educators on each level are encouraged to incorporate ear-based activities such as improvisation and playing by ear to the benefit of musicians of all genres.

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Introduction

As an aural skills instructor at a school of music where both classical and non-classical musicians pursue undergraduate degrees, I have observed the unique abilities these groups of musicians possess. I use the term "non-classical" following Creech et al.'s (2008) definition: a broad term that encompasses popular, jazz, folk and Broadway music. The researchers claimed that students who specialize in such idioms begin their musical studies later in life than do classical musicians, and they often learn music aurally, by listening to and copying music from other musicians or recordings. Classical musicians, in contrast, typically begin studying music at an early age, and they rely on learning music from notation. In addition, classical musicians place a lower priority on ear-based forms of musicianship such as improvisation than do non-classical musicians.

Regardless of genre-specialization and musical background, all music students enrolled in American tertiary schools are required to learn and use notation (NASM, 2009), primarily through music theory and aural skills courses. As an aural skills instructor, I have witnessed students who have used music notation all of their lives and yet struggle to perform a sight-singing exercise as well as students who have seldom used notated music. A broad range of background and ability present among students from both backgrounds in every aural skills class underscores the need for differentiated instruction. In order to understand and address the nature and particular needs of each student in my classes, I felt the need to approach the matter from a cognitive perspective and break down sight-singing into more discrete tasks.

As I began to investigate what discrete tasks might comprise sight-singing, I found many studies in which pianists were the subjects of research. Studies such as Wolf (1976), Kopiez and Lee (2006, 2008), and Udtaisuk (2005) seemed to reveal component skills of sight-reading at the piano, yet the researchers cautioned that their findings might not apply to sight-reading on other instruments, especially on instruments such as the violin or the voice, in which pitch is not so fixed. Specifically, researchers noted that the role of inner hearing, or auditory imagery, might be more important in studies of sight-reading that did not involve pianists. Thus began my examination of the relationship between auditory imagery and sight-reading.

Music reading and musical meaning. In non-improvised idioms, performers read music notation as a visual cue to help determine which musical patterns should be executed in the manner that a composer intended. Lehmann and Kopiez (2009) noted that a beginning music reader engages in "a tedious matching of symbols to sounds to meanings," but an expert reader "has automatized the process . . . of transforming the signs into embodied action" (p. 344). Lehmann, Sloboda, and Woody (2007) claimed, "the sequence and probability of certain events help us establish meaning—for instance, that a dominant-seventh chord resolves in the tonic, that most melodies are four to eight bars long, or that certain tactile patterns on the keyboard form chords" (p. 112). Moving towards expertise in music reading, then, means moving towards expertise in establishing musical meaning. Expertise depends upon a store of music patterns constructed through music experiences, such as listening, performing, and improvising, and generation of expectations based on those patterns.

A special case of music reading, "sight-reading is the ability to perform music from a printed score or part for the first time without benefit of practice" (Wolf, 1976, p. 143). As with all cases of music reading, sight-reading "may be regarded as a reconstructive activity that involves higher-level mental processes" (Lehmann & McArthur, 2002, p. 135); however, psychologists presume that, as musicians rehearse, they begin to generate expectations based on their mental representations, or abstractions (Lehmann, Sloboda, and Woody, 2007), of the patterns in the specific music at hand. In contrast, psychologists propose that sight-reading musicians generalize based on mental representation of idiomatically similar music in order to generate expectations (Sloboda, 2005).

Sight-reading is a skill that is not expected of most modern-day professional musicians. As Lehmann and Kopiez (2009) indicated, "our modern performance traditions have come to favour polished performances and relegated sight reading to a useful craft" (pp. 344-345). The researchers wrote that psychologists, on the other hand, always have shown interest in sight-reading:

> Starting with the early music psychology experiments of the 1920s (published in Jacobsen 1941) and the development of sight-reading tests (Watkins 1942, and the Watkins–Farnum Performance Scale), all aspects of skills relating to sight-reading attracted renewed interest in the 1970s (e.g. Sloboda 1974, 1976, 1977) and have continued to do so. (p. 345)

Sloboda (1984) pointed toward one reason for psychologists' interest in examining the behavior of sight-reading under various controlled conditions: "quantifiable aspects of the performance [of sight-reading]" are "capable of shedding some light on the underlying cognitive processes" (p. 223). In other words, by examining sight-reading we can learn something about mental representations that not only underlie music reading, but also "underlie the whole range of musical skills, starting with remembering music to reproducing and creating it" (Lehmann, Sloboda, & Woody, 2007, p. 21).

Mental representations. Sloboda (2005) explained that such "core representations" (p. 165) cut across musical activities (e.g. reading, performing, improvising) within particular musical idioms:

> There are many regularly occurring patterns (e.g., chords, scales and arpeggios) and someone exposed to an idiom will rapidly become familiar with them. Patterning also occurs on a larger scale. Thematic repetition is a cornerstone of most music, certain harmonic progressions are ubiquitous, and so on. The master can make use of all this patterning when building up a representation of a piece of music (Sloboda, 1985, p. 4).

When Sloboda indicated that representations of musical patterns are idiomatic, he also implied that musical patterning is culturally dependent. An example of culturally generated expectation comes from an experiment by Castellano, Bharucha, and Krumhansl (1984) in which participants listened to a short passage of Indian classical music, and then judged the goodness of fit of a tone played subsequently. This technique was intended to test sensitivity of the listeners to the underlying tonal structure of the music. Half of the listeners were Indian, and had lengthy exposure to Indian classical music, whereas the rest of the listeners were Westerners with minimal exposure to the idiom. Both groups rated basic pitches such as the tonal center to be a good fit, but differences between the two groups emerged when they considered pitches not found in the major and minor diatonic pitch collections of Western music. The researchers observed that the Western listeners did "not appear to be able to extract from the experimental contexts the designation of certain tones as scale members" (Castellano, Bharucha, & Krumhansl, 1984, p. 410). In other words, through normal exposure to their native idioms and culture, the Indian listeners possessed sensitivity to nuances of Indian musical patterning that Western listeners did not.

Researchers theorize that human beings begin the process of constructing musical patterns early in life. For example, Krumhansl and Jusczyk (1990) presented six-month-old and four and one half-month-old infants with sections of Mozart minuets that were either segmented according to phrase structure or by random means. The infants showed a significant preference for those sections that were segmented according to phrase structure. Krumhansl and Jusczyk concluded that even infants were sensitive to the way rhythms and pitches are normally grouped within their culture.

Musical enculturation continues throughout life, happening naturally through exposure to music rather than by formal music tuition. The Castellano, Bharucha, and Krumhansl (1984) experiment suggested that is the case, as have other experiments involving *priming* in which participants first hear a chord and then are asked how well a second chord is related to the first. If it is true that exposure to music, rather than formal music education, informs musical patterning, then there should be no differences between musicians and non-musicians in priming experiments. Bigand, Poulin, Tillmann, Madurell, D'Adamo (2003), for example, found only a very weak influence of musical expertise, concluding that nonmusicians and musicians have "similar perceptual behaviors" (Bigand et al., p. 169).

Researchers also theorize perception and organization of musical patterns. Bregman (1990), for example, called the process by which we perceptually group sounds together *auditory streaming,* which he divided into *simultaneous streaming* and *sequential streaming.* Simultaneous streaming refers to auditory events that overlap in time, whereas sequential streaming refers to auditory events that are similar in register but do not overlap in time.

Building on Bregman, Jackendoff and Lerdahl (2006) theorized that sequential and simultaneous auditory events consist of "pitch, timbre, intensity and duration" (p. 37), which they call the *musical surface.*

According to these researchers, beyond the musical surface exist two hierarchical organizations of rhythm and pitch:

> The basic unit of metrical structure is a beat, a point in time usually associated with the onset of a note in the musical surface. Beats are combined into a metrical grid, a hierarchical pattern of beats of different relative strengths. . . .The basic unit of pitch structure is a note belonging to a tonal pitch space characteristic of the musical idiom; the concentrated notes of a melody are combined hierarchically to form a pattern of tension and relaxation called a reduction. The understanding of a piece of music involves all of these structures simultaneously. (p. 37)

Jackendoff and Lerdahl (2006) elaborated on temporal hierarchies, claiming that a beat is a point in time where we ordinarily clap, stomp a foot, and expect the onset of a pitch. Metrical groupings include both strong and weak beats. At the next level in temporal hierarchies are metrical grids that, in Western classical and popular music, typically are regular and symmetric. There are exceptions, however: syncopation overrides the principle of regularity and the insertion of a three-beat grouping into a duple meter piece violates the principle of symmetry. Elaborating on tonal hierarchies, the authors claimed that most of the world's tonal systems are heard in relation to a "tonic or tonal center" (p. 45). Although the tonic might occur constantly, might be implicit, or might change during the course of a piece, it is heard as a stable reference point. Next in a tonal hierarchy is a pitch space, which is a group of other pitches, "each a specified interval (a specified frequency ratio) away from the tonic" (Ibid.). In Western music, a taxonomy of pitches can be heard, beginning with the tonic, continuing to the dominant, and then filling in the major or minor tonic triad. The diatonic pitches of the scale form the next layer of the taxonomy, followed by a layer of the chromatic scale. The last layer includes "the entire pitch continuum out of which glissandi and microtonal inflections arise" (p. 47).

Mental representations of music "need not be solely of an auditory nature" (Lehmann, Sloboda, & Woody, 2007, p. 20). In fact, "Listening to music, learning to play an instrument, formal instruction, and professional training result in multiple, in many instances multisensory, representations of music, which seem to be partly interchangeable and rapidly adaptive" (Altenmüller, 2001, p. 273). Altenmüller (2001) offered up four modes of musical representation: symbolic, visual, sensory-motor, and auditory. Of these different modes, researchers have been most interested in those that are auditory. "They [cognitive psychologists] would say that musical ability is a particular sort of acquired cognitive expertise, entailing at its core the ability to *make sense* of musical sequences, through the mental operations that are performed on sounds (whether real or imagined)" (Sloboda, 2005, p. 266).

Measuring mental representation. Cognitive psychologists interested in auditory representations presume that the musical surface and subsequent hierarchical organization of temporal and tonal patterns are ways in which we develop and organize our auditory representations of Western music. The challenge in testing these theories of perception and cognition, however, comes from our inability to observe auditory representations directly. According to Sloboda (1985) "we have to infer their existence and nature from observations of the way in which people listen to, memorize, perform, create, and react to music" (p. 3).

Thus, we must first decide which music behaviors to use as measures from which to infer mental representations, as well as the specific conditions under which those musical behaviors will occur.

Given my employment teaching aural skills courses to college musicians, I was interested in three types of auditory representation, each construed narrowly, and the relationships between these three types of auditory representation. First, I was interested in my students' sense of tonic or tonal center. Colwell's *Feeling for Tonal Center* test (1968) is constructed so that a four-measure melody or a brief, four-chord sequence in major tonality is presented to a participant. In the melodies, the passage may end on a pitch other than tonic, but in the four-chord items, the final chord of each sequence contains the tonic in soprano and bass voices. Regardless of whether the initial stimulus is a melody or four chords, the participant then hears three individual pitches and must determine which of those three pitches is the tonic (the participant is also presented with the option, "none"). Although the chords and pitches are presented both visually and aurally, presumably those who answer an item correctly would require an auditory representation of the centrality of tonic.

Second, I was interested in how my students grouped pitches together. Another of Colwell's measures is the *Auditory-Visual Discrimination* test (1968), in which a four-bar phrase is presented to the participant in both visual and auditory modes. The participant compares what is seen with what is heard and marks any one of the four bars that contains a discrepancy. There is also an option to indicate that no discrepancy was detected. As Schön and Besson (2005) concluded, visually presented notation should elicit auditory expectations. So it seems, in order to be successful on the *Auditory-Visual Discrimination* test, a participant must form an auditory representation of the score, most likely in the form of generic pitch groupings, in order to detect violations.

In addition to generic pitch groupings, I was also interested in grouping according to harmonic function. Holahan, Saunders, and Goldberg (2000) constructed a measure of tonal pattern discrimination where a participant listens to a three-note pattern followed by another three-note pattern. The participant responds by indicating whether the two patterns are the same or different. The researchers selected patterns from Gordon's taxonomy of tonal and rhythm patterns (Gordon, 1976), and each pattern represented a tonic, subdominant, or dominant harmonic function. Holahan, Saunders, and Goldberg maintained that, to identify whether two patterns are the same or different, a participant must create and maintain "mental representations of these relatively simple stimuli in the encoding and working memory phases of cognition" (p. 174). In order to facilitate the discrimination between the two patterns that they hear, participants presumably must form auditory representations of the two patterns grouped according to harmonic function.

Presuming that these three tests can stand as proxies for three narrowly construed types of auditory representation—centrality of tonic, pitch grouping and harmonic function—and given the conditions of the tests, how do developing musicians perform on these measures, and what can we infer about the relationships between these three types of auditory representation from their performances?

Furthermore, given that the population under study is divided between classical and non-classical musicians, is there a difference in the relationships between auditory representations between these two groups? As noted in the introduction, there seem to be differences between classical and non-classical musicians' developmental trajectories as well as the emphasis given to various type of musicianship. It may be the case that the different emphases place different demands on the formation of auditory representations between these two groups and that the different developmental profiles result in less automaticity in reading notation among the non-classical students.

Recall that my initial practical dilemma was differentiating instruction for college students who demonstrated a broad range of ability in sight-reading, so I was interested in how they would perform not only on isolated musical tasks, but also on a more holistic test of sight-reading. According to Schön and Besson (2002), music notation is typically presented as a visual stimulus, but then a type of transcoding occurs, which might be "singing-like (visual to auditory transcoding), playing-like (visual to motor transcoding), or naming-like notes (visual to verbal transcoding)" (p. 877). Henry constructed the *Vocal Sight Reading Inventory (VSRI*; 1999) out of eight novel melodies in major tonality. The notation for each melody is presented in visual mode only, the participant has 30 seconds to examine the melody, and then the participant is asked to sing the melody. To use Schön and Besson's term, this measure is singing-like (a visual stimulus is presumed to become an auditory representation). I was interested in the extent to which transcoding was implied in my students' sight-reading performance. Finally, and perhaps most importantly, I was interested in any relationships that might exist between types of narrowly construed auditory representation and the transcoding presumed to take place in the sightreading task.

Summary and Need for the Study

Variation in sight-singing ability among college students enrolled in aural skills classes perplexed me and caused me to seek a deeper understanding of discrete tasks involved in sight-reading. I discovered that auditory imagery is implicated in sight-reading (cf. Kopiez and Lee, 2008), and that auditory representations underlie not only music reading, but other musical skills such as improvisation, performing by ear, and performing from memory. Sloboda (2005), for example, maintained that there were core representations common to all forms of musicianship, and McPherson (1993) found correlations between sight-reading and improvisation, playing from memory and playing by ear. Further, I discovered that the challenge in measuring auditory representations is that they cannot be observed directly; instead, such mental representations must be inferred through individuals' performance or creation of music.

So, considering the body of theoretical literature related to music reading, and to sight-reading in particular, there always exists need to make more informed inferences about auditory representations and transcoding. Especially in "singing-like" transcoding where pitches may be less fixed than in "playing-like" transcoding (Schön and Besson, 2002), making informed inferences can be challenging. An examination of correlations of three types of auditory representation—tonic inference, generic pitch grouping, and discrimination of harmonic function—may offer more nuanced information about whether these representations are related and the nature of their relationship. Furthermore, assessment of the relationships between these types of representation and a process of "singing-like" transcoding, may provide more nuanced understanding of sight-singing and the auditory representations that may be central to all forms of musicianship. By conducting this investigation with musicians who were neither rank novices nor recognized experts, additional information may be gained into how auditory representations might strengthen as the musician matures. The snapshot of skills among a first-year cohort also sheds light on the skills students may bring with them into their tertiary studies.

Recall that my interest in this topic began while teaching aural skills to a population of students pursuing careers in both classical and non-classical music. Lehmann, Sloboda, and Woody (2007) acknowledged "conservatories and university music departments increasingly encompass communities of musicians that are engaged in diverse musical genres" (p. 231). Due to the increase of non-classical majors in tertiary schools and reinvigorated research into how we might apply non-classical practices into formal teaching contexts (Green, 2008), it is helpful to have a snapshot of the varying skills first year students in classical and non-classical genres may possess in regard to general musicianship. The music reading required in aural skills courses may not be as relevant to the careers of non-classical majors as to those of classical majors (Green, 2002), but other forms of musicianship such as improvisation and performing by ear, which may hold core auditory representations in common with music reading (McPherson, 1993), certainly are. While it is possible that classical musicians may have a developed ability to transcode information from the visual domain to the aural, this may not always be a given for non-classical musicians based on their diverse experiences (Green, 2002). Similar to the sample population employed by Creech et al. (2008), non-classical majors may have begun to use notation at a later age and may not be as fluent as a result. It is therefore of special interest to compare these two groups of musicians as a way of investigating whether there are differences in relationships of mental representations and/or differences in the relationship of mental representations to overall musicianship between them.

Understanding mental representations and how they might be strengthened as a musician matures can, in turn, inform pedagogy. Lebler, Burt-Perkins, and Carey (2009) suggested that the "narrow focus of the traditional learning system" (p. 243) in schools of music may not prepare graduates for the "wide range of musical and paramusical activities" (Ibid.) they will encounter in their professional lives. Certainly skills such as sight-singing are under scrutiny as members of the traditional system. Given the current state of diversity in the musical learning of students coming into the undergraduate curriculum (e.g., Creech et al., 2008) and the diverse outcomes of their training (e.g., Hannan, 2006), this study may address the relevance of including sight-singing in the undergraduate curriculum and support the relationships between sight-reading and other forms of musicianship, such as improvisation, performing by ear, and performing from memory. It may also serve to support the expansion of the more traditional conservatory model present in many American tertiary institutions to be more inclusive of non-classical musics and ways of understanding music inherent in non-classical musical training.

Purpose and Research Questions

The purpose of this study was to examine the sight-reading of first-year college music students as an indicator of their developing musicianship. In this study, college students' musicianship was measured with Henry's *Vocal Sight Reading Inventory* (VSRI; 1999), and auditory representations, which theoretically underlie all musicianship, were measured with Colwell's *Feeling for Tonal Center* (1968), Colwell's *Auditory-Visual Discrimination* test (1968), and Holahan, Saunders, and Goldberg's tonal pattern discrimination test (2000). Questions orienting the study were:

1. How do first-year college music students perform on a musicianship measure?
2. How do first-year college music students perform on three measures of auditory representation: tonic centrality, tonal grouping, and harmonic function grouping?
3. Considering the college music students' performance only on measures of auditory

representation, what relationships exist between these measures?

4. Considering all measures, what relationships exist between college music students' auditory representations and their overall musicianship?
5. Considering college music students' performance on all measures, what differences exist between classical musicians and non-classical musicians?

Chapter Two

Literature Review

In the current study, I focus on the relationship(s) among three basic auditory representations as well as their relationships with a measure of overall musicianship (sight-singing) within a group of classical and non-classical university music students. The literature that formed a framework for the study comes from the field of music psychology and, more specifically, music cognition. Sloboda (2005) considered one of the two central subject matters of music cognition to be "the nature of musical knowledge or representation" (p.98). The following review of literature situates my study within the current understandings of auditory representations in the context of experiencing music in general and notational audiation in particular. I also present literature which compares and contrasts the musical skills of non-classical musicians with their classical counterparts in order to establish a basis for considering if and how music reading might be indicative of musicianship among a population that does not rely on it as a central skill.

Researchers use a variety of terms to discuss auditory representations of music inside the music cognition literature. A*uditory representation* is the most global of these terms*,* but other terms such as *auditory imagery, musical imagery, thinking in sound,* and *audiation* refer to similar concepts. Hubbard (2013), following Intons-Peterson (1992), considered *auditory imagery* to be a specific type of auditory representation that happens only in the absence of an auditory stimulus. Auditory imagery can be involuntary or voluntary (Hubbard, 2010). Examples of involuntary imagery include auditory hallucinations and songs that get stuck in one's head versus voluntary introduction and perhaps manipulation of inner auditory events (Ibid.). Another term in the literature, *musical imagery*, may be thought of as a "special case of auditory imagery" (Brodsky, Henik, Rubinstein, Zorman, 2003, p. 602), though Keller (2012) offered a more expansive definition that included the "visual, proprioceptive, kinesthetic and tactile properties of music-related movements" (p.206). Some researchers use the phrase *thinking in sound* to describe voluntary auditory representation (*cf.* McPherson, 2005), while music educators may recognize the concept as *audiation* (Gordon, 1975). Gordon (1999) described audiation as that which takes place when we "hear and understand in our minds music that we have just heard performed or have heard performed sometime in the past" and also "when we hear and understand in our minds music that we may or may not have heard but are reading in notation or are composing or improvising" (Gordon, 1999, p. 42). So, for Gordon, audiation is not merely the representation of music in the mind, but the comprehension of it as well.

Auditory Representations in the General Population

As with other types of mental representation, auditory representations are idiomatic and culturally dependent. This means that, over time, patterns of sound become constructed in particular ways in a given culture and individuals living in that culture develop expectancies for the musical patterns they will hear. Bharucha and Stoeckig (1986) conducted an experiment—now considered classic—that tested Western listener's cultural expectations as they heard two chords. The authors assumed that, upon hearing the first chord, listeners were primed to expect only a few possible chords, based on years of enculturation to Western harmony. In other words, listeners internally represented the first chord as a member of a few possible keys and used that representation to judge the fit of the second chord.

Bharucha and Stoeckig tested for effects of priming indirectly, as the participants were never asked to judge the relatedness of the chord, but were asked to make decisions such as if the chord was major or minor (Experiment 1) or if the chord was in tune or not (Experiments 2 and 3). Each target chord identified by the researchers as being related or unrelated in key to the priming chord and the differences in discriminations by the subjects were analyzed according to the relatedness of the target chord. In Experiment 1, the researchers found that participants identified target chords as major more accurately and quickly when the target chord was related to the prime. In Experiments 2 and 3, participants identified in-tune targets more quickly and out-of-tune targets more slowly when they were related than when they were unrelated, revealing an effect of harmonic priming. Throughout the three experiments, researchers found the use of representations among participants to generate expectations about what sounds come next in the music. Bharucha and colleagues have continued exploring musical expectations using a variety of paradigms (cf. Tillman, Janata, Birk, & Bharucha, 2009; Curtis & Bharucha, 2009). General use of auditory representations to generate expectations in music will be discussed in more detail below.

In addition to the role representations play in generating expectations, researchers have also investigated how auditory expectations help performers plan motor coordination. Many of these studies have been conducted with pianists due to the ease with which researchers can observe the output (see Wristen, 2005 for a review). One group sought to apply such an investigation to laryngeal movement. Pfordresher and Halpern (2013) conducted an experiment assuming an "inverse model of a perception/action system that guides motor planning on the basis of the anticipated outcomes (goals) of the action" (p. 747). They hypothesized that participants would use auditory imagery to plan laryngeal movement. More specifically, the researchers were interested in identifying whether the auditory imagery of poor-pitch singers was somehow deficient.

Each of 118 psychology students engaged in a warm-up exercise, and then was asked to find a comfortable singing pitch. Participants then produced six pitch imitation trials at, above, and below the comfort pitch. For each trial, researchers calculated the participant's deviation from the pitch presented. Next, each participant engaged in a pitch discrimination exercise where he or she was asked to tell which of a pair of pure tones was higher. Finally, the participants completed the Bucknell Auditory Imagery Scale (BAIS; unpublished), a self-report consisting of two subscales: Vividness of Auditory Imagery and Control of Auditory Imagery. The percentage of trials sung in tune was significantly correlated with participants' self-reported vividness of auditory imagery ($r = .28, p < .01$). Although there was a positive correlation between in-tune singing and participants' self reported control of auditory imagery, it was not significant ($r = .11, p > .10$). The researchers concluded that the association between in-tune singing and vividness of auditory imagery was "independent of musical experience, height of the imitated pitch, and pitch discrimination ability" (p. 752). The construct of vividness was based only on generating an auditory image, in contrast to the construct of control, which was based on both generation and manipulation of an auditory image. Consequently, the researchers suggested "poor-pitch singing involves an imagery deficiency at a very basic level" (p. 752).

The studies above suggest that members of the general population form auditory representations when experiencing music and that the population uses these representations to generate expectations about the music. The vividness of auditory representations among the general population also bears a relationship to subsequent motor output of that representation. It is therefore reasonable to assume that the music students in the current study may also utilize basic auditory representations regardless of their skills as musicians.

Evidence of Notational Audiation

Gordon posited that if, when musicians read music, they "hear musical sound and give meaning to what [they] see before [they] perform it, or as [they] write it, [they] are engaging in notational audiation" (2007, p. 7). So, within the realm of audiation, there exists an even more specific type that is applicable to music reading and writing. Many researchers have empirically explored the extent to which the theoretical concept of notational audiation happens among musicians by studying the act of sight-reading. There is a tendency in psychological literature to distinguish musical sight-reading as a special case of music reading (cf., Sloboda, 1984). Many more researchers explore sight-reading rather than the reading of a piece of music that is familiar; therefore, the information we have from experimental literature is largely in reference to sight-reading. According to some music educators, however, the divide between sight-reading and the reading of familiar music is somewhat false to begin with. Gordon (2007) posited that sight-reading and reading are the same:

> "If one can sight-read, one has to be able to read. If one can read, one can sight-read…one either reads or does not read, and no matter how many times a piece of music has been read, if it is being audiated, something new is being seen and given back each time it is read" (p.125).

In other words, sight-reading is analogous to the act of fluently reading a language.

Brodsky, Henik, Rubinstein, and Zorman (2003) characterized musical imagery as a special case of auditory imagery in which "musical images are generated in real time, encode fairly precise information about tempo and pitch, and contain information concerning melodic and harmonic relationships" (p. 602). In these ways, musical imagery is similar to real-time music perception. Consequently, Brodsky et al. noted that musical imagery and perception share similar brain structures and topographies. They further asserted that the ability to experience musical images "may be the outstanding mark of a musical mind" (p. 603) given the evidence that musically untrained people performed similarly to highly trained musicians on visual imagery tasks, but significantly worse on auditory imagery tasks involving both music and everyday sounds.

Of particular interest in the Brodsky et al. study was the theoretical concept of *notational audiation*, a kind of musical imagery in which the reading of musical notation triggers musical imagery. Empirical evidence for notational audiation was not in existence at the time of the study. The researchers sought to substantiate the existence of notational audiation using an embedded melody task.

In a non-distracted *embedded melody* task, a well-known theme was made visually indiscernible by changing the register, shortening the length, or adding pitches between the notes of the original melody all while keeping the original melody, phrase structure, and harmonic plan intact. The researchers asked a number of potential subjects identified as expert musicians to silently read the embedded melody score, then listen to a melody without the score in sight and determine if that melody was the embedded theme or not. The researchers chose 18 subjects who correctly identified 9 out of 12 embedded melodies to participate in two experiments that introduced distraction conditions. All remaining participants were included in a third experiment, discussed below.

In the first two experiments, the researchers used the embedded melody task described above as the normal reading condition. Use of distractions in two additional conditions allowed the researchers to further interrogate the nature of notational audiation.

On the basis of previous studies in the field, the authors proposed that auditory imagery in general may not have a single locus in the auditory realm but may also involve motor processes such as subvocalization, or the "experience of an inner voice without vocal output" (p. 602). Hence, in Experiment 1, the musicians performed the embedded melody task in three ways: 1) a non-distracted condition (NR); 2) a distracted condition where they tapped a steady beat while hearing another task-irrelevant rhythm (RD); and 3) a distracted condition where they hummed a folk song aloud (PI). Participants correctly accepted the target melodies and rejected the melodic lures (melodies which were not the embedded ones) significantly more in the NR condition than in the RD and PI conditions ($p < .001$ and $p < .0001$, respectively). There were no significant differences in correct responses for the two interference conditions, but there was a decreasing level of hits and an increasing level of false alarms (i.e., the participant incorrectly accepted the target melody) spanning from NR to RD to PI, indicating an increased level of impairment across these conditions. The PI condition produced the longest response times of the three conditions and these were significantly longer than those for NR and RD ($p < .01$ and $p < .025$, respectively). There was no significant difference in the response times for NR and RD. These results led the researchers to conclude that phonatory interference caused more distraction than rhythmic tapping, but it was unclear if this effect was due to the act of using the voice or the perception of the sound produced by the voice.

In Experiment 2, the researchers replicated Experiment 1, but they replaced the rhythmic tapping interference with the act of hearing one's own voice singing. There were no significant differences in the correct responses for the three conditions, nor were there significant differences in the response times between the listening condition (LA) or NR condition. There were, however, significant differences in the response times between the PI condition and the other two ($p < .025$ for NR and $p < .05$ for LA), leading the researchers to conclude that it was the act of using one's voice and not hearing it which was causing the interference.

For the final experiment, the researchers asked the participants who did not score high enough for inclusion on the EM task to perform an additional block of trials in which the embedded melody was heard aloud and then compared to an aurally presented target melody. These participants posted both faster response times ($p < .01$) and more accurate responses ($p < .0001$) in the heard-aloud condition vs. the normal reading condition.

Brodsky et al. concluded that notational audiation was "the silent reading of notation resulting in auditory imagery involving kinesthetic-like phonatory processes" (p. 610) and notational audiation could be substantiated through the use of an embedded melody paradigm. Out of the 74 musicians initially recruited for their study, 65% failed to perform better than a 75% accuracy threshold on the task, indicating that even advanced musicians often do not possess the aural skills necessary for successful notational audiation. However, even though the percentage of musicians who demonstrated the use of notational audiation was small, it was not as small as other researchers claimed.

In my study the measure of overall musicianship may require the use of notational audiation. Given that notational audiation involves the triggering of musical imagery by notation and also given Brodsky et al's definition of musical imagery as an encoding of pitch information as well as melodic and harmonic relationships, it is also possible that the measures of basic auditory representations used in this study will deploy cognitive mechanisms similar to those recruited by notational audiation.

Simoens and Tervaniemi (2013) provided further evidence of the strong and immediate relationship between music reading and auditory representations. Working under the assumption that the delay between score reading and auditory feedback elicits storage of the musical information in short-term memory, they sought to test the hypothesis that a cross-modal translation occurs, resulting in information storage in the form of an auditory representation rather than a visual one. Contrary to previous studies the researchers only investigated instances in which notational audiation presumably occurred (i.e., correct responses to the experimental tasks) in their analyses.

The researchers recruited 15 professional instrumentalists, specializing in both classical and non-classical genres, to participate in a measure containing four conditions. The first condition resembled an actual score reading situation in that the participants saw a notated dyad while hearing an irrelevant dyad, then heard a second dyad while seeing an irrelevant dyad and had to compare what they heard in the second instance with what they previously read. Time in between the dyads resembled the time it takes for a musician to read notes then hear them (about 1 second). Through the collection of EEG data, the researchers compared the participants' brain activity during the first condition to three other conditions: 1) participants saw one dyad while hearing another, then saw and heard another pair of dyads and were asked to compare only what they heard; 2) the same as the former, but participants were asked to compare only what they saw; 3) participants saw and heard one pair of dyads and had to compare what they heard with what they saw.

Researchers were especially interested in the brain activity occurring between 1200 and 1600 milliseconds, when working memory processes would be happening. As they compared the data from the different conditions, they found that conditions in which participants compared visual stimuli to later auditory stimuli and those in which they compared auditory stimuli to later auditory stimuli did not differ during the time window of interest, indicating that both comparisons utilized the same parts of the brain. In contrast, the brain activity showed different amplitudes in the left frontal and occipital electrodes between the condition in which participants compared visual stimuli to auditory stimuli and when they compared visual stimuli to visual stimuli during the time window of interest. This indicated that the musical notation was stored as auditory information in the visual-auditory condition, but not in the visual-visual condition.

In addition to the EEG experiment, the researchers conducted a behavioral experiment using the same stimuli as the first condition above: they asked participants to compare the notation in the first pair with the auditory portion of the second pair. Unlike the EEG experiment, the researchers introduced four types of distractors (notated dyads, auditory dyads, spoken interval names, written interval names) in between the two pairs in order to assess which type interfered the most with short-term memory storage. There were also items in which no distractor was present. For this task, the researchers assumed that the more similar the distractor was to the type of short-term encoding involved, the graver the effects of the distraction would be. The 15 professional musicians from the EEG experiment plus 16 more professional musicians and music students participated in the behavioral portion of the study, then completed interviews concerning the strategies they used to complete the task.

Participants took longer to respond ($p < .05$) to the stimuli when auditory interference occurred between the visual information and the auditory information than when there was no interference between the stimuli. The other types of interference did not result in significantly longer response times. Similarly, in the post-experimental open-ended interviews, the majority of participants reported that the auditory interference was the most distracting.

Simoens and Tervaniemi concluded that the evidence from all three parts of the study pointed to the likelihood that highly trained musicians convert visual notation into an auditory cue during the working memory stage of cognition. In my study, the participants were first year music students rather than professional musicians, so it was possible that they may not have converted visual notation to auditory representations as automatically as the professional musicians did in the study above. Formation of the basic auditory representations of interest in the current study may therefore have interacted with music reading ability only for those participants who were converting the visual information to auditory information.

In light of the evidence provided by Brodsky et al. (2003) and Simoens and Tervaniemi (2013) that some musicians employ notational audiation when they read music, it seems likely that Kalakoski's work (2007) was pointing to the same phenomenon. Kalakoski's study helps us better understand the process of representation construction by way of comparison between musicians and non-musicians.

Kalakoski grounded his study in the idea from research in general expertise that experts must quickly "encode pieces of stimulus information into meaningful cognitive units" (p. 87). Groups that are meaningful are easier to hold in working memory and they are given this meaning based on patterns abstracted from experience with music, stored in long-term memory. Kalakoski asserted that auditory representations mediate the construction of these groups. Thus, if musicians have the ability to use auditory representations to construct meaningful groups and non-musicians, who have less experience and fewer abstracted patterns in long-term memory, do not, then musicians have an advantage in remembering visually presented notes, as they can be stored both aurally and visually.

In two pilot experiments, Kalakoski presented 12 musicians and 12 non-musicians with a melody one note at a time. Each of the 13-15 notes was visible for two seconds, with one second in between each note. After presentation of all of the notes for a given melody, Kalakoski asked the participants to recall as much of the melody as possible. Both musicians and non-musicians were better able to recall melodies that were musically well-formed better than those composed of random notes. Kalakoski assumed that musically well-formed melodies may also exhibit visual well-formedness, aiding the non-musicians in the task. In the second pilot experiment, he controlled for visual gestalt by using backwards versions of the "good" melodies rather than randomly composed melodies, resulting in similar visual organization and intervallic content, but very different auditory effect. Only the musicians in this experiment could recall the well-formed melodies better than the mirrored versions, indicating that musicians were relying to a certain extent on auditory imagery of the notation. Kalakoski argued that musicians were able to construct more robust mental images through the use of pre-learned knowledge.

Eight professional musicians and advanced music students and eight non-musicians participated in Experiment 1. Kalakoski presented 18 melodies and their mirrored counterparts, simplified into quarter and eighth notes, in a random order. Musicians were able to recall all melodies better than non-musicians ($p < .001$) and the whole sample recalled musically well-formed melodies better than their mirrored counterparts ($p < .01$). However, when the sample was separated by expertise, it became apparent that the musicians were able to recall well-formed melodies better than their mirrored counterparts ($p < .05$) and the non-musicians were not. Kalakoski supposed that musicians were able to keep the individually presented notes active in working memory long enough for long term memory to aid in encoding the notes as meaningful groups.

A new group of 12 advanced music students and professionals and 12 non-musicians participated in Experiment 2. Melodies were presented for recall either on a staff or as letter names (e.g., C1, A2). Musicians were able to recall these melodies better than non-musicians, regardless of presentation type ($p < .01$). Further error analysis on the letter naming condition revealed that the musicians made more musically meaningful errors (e.g., contour was retained, but exact pitch height was not), while non-musicians were more likely to accidentally shift the octave of letter names (e.g., C2 instead of C1), thus changing the contour of the presented melody. These results led Kalakoski to believe that the expertise effect in this experiment was not due to perceptual visual chunking, since that mechanism was not available during the note naming condition. Rather, "experts are able to rapidly transform any representation format to one that allows the use of pre-learned knowledge" (p. 93).

These findings pertain to the present study in a few ways. First, they provide an example of musicians employing notational audiation in a way that non-musicians do not. The present sample included students who were presumably at different levels of music reading expertise and therefore may or may not have been employing notational audiation. Second, they highlight the use of pre-learned knowledge in bringing meaning to notation. Those who were more adept at sight-reading in the current study were most likely connecting the notation they were seeing to their own pre-learned knowledge, which was likely to be very different for each student depending on that student's musical background.

The work of Kopiez and Lee (2006) adds credence to the idea that abilities in notational audiation can vary greatly not only among musicians, but among levels of sight-reading difficulty. The researchers compiled a list of 23 possible factors in sight-reading skill from the literature and arranged them into major groups: general cognitive skills (e.g., short term memory capacity), elementary cognitive skills (e.g., simple auditory reaction time), and expertise related skills (e.g., notational audiation, which the authors refer to as "inner hearing"). They then asked 52 piano majors, graduates, and postgraduates to complete measures of the predictor variables and to sight-read five pieces of increasing complexity while accompanying a solo line. All 23 predictor variables were correlated to and then regressed onto the performance ratings for the subjects in each level of complexity.

Results yielded a different combination of subskills for each level of complexity. For example, notational audiation, measured with the embedded melody paradigm (Brodsky *et al.*, 2003), was not significantly related to outcomes in level 1 (p = .073); in level 2, it was the fourth highest correlated predictor (r = .39, p = .002); in level 3, it was the fifth highest correlated predictor (r = .35, p = .006); in level 4, it jumped to second place (r = .47, p < .001); and in level 5, it dropped to seventh place (r = .34, p = .006). Despite the fluctuation in rank order, notational audiation maintained a fairly consistent level of correlation in levels 2-5. In the multiple regression analyses for each level, the model for fourth level was the only one to include notational audiation. In this model, it was the most important predictor, accounting for 17% (p = .022) of a total 45% of variance in sight-reading skill. The authors noted this was the first instance of evidence that "the skill of imagining the sound of a score can also be of advantage in sight-reading" (p. 115).

Kopiez and Lee interpreted the fluctuation in the importance of inner hearing to be reflective of the time it takes to audiate, interpreting the drop in correlation in level 5 as an indication that the sight-reading in that level was too difficult to audiate in real-time. They interpreted the lower ranking of notational audiation in levels 1-3 as an indication of the sufficiency of technical piano ability, general working memory capacity, and accumulated practice in sight-reading up to the age of 10 for sight-reading execution. It appears, then that notational audiation may contribute to music reading ability up to the point at which the reader is overwhelmed by the incoming information. In the population of developing musicians who participated in the current study, this point was likely to occur at widely varying levels.

Brodsky, Henik, Rubinstein, and Zorman (2003) provided the first evidence of the use of notational audiation among musicians, though their paradigm allowed for its detection only among a small portion of their sample. Kopiez and Lee (2006) used the same paradigm to detect the presence of audiation among sight-readers, allowing for interaction with musical technical abilities and experience, finding it to be a factor in sight-reading in cases where the music was neither too easy nor too difficult. Kalakoski (2007) and Simoens and Tervaniemi (2013) provided additional information regarding the nature of notational audiation: 1.) Musicians are able to employ notational audiation better than non-musicians and better in music that is well-formed 2.) Conversion of visual information to auditory representation happens very rapidly for musicians, in the working memory stage of cognition.

Taken together, these studies provide important implications for my study. First, musical imagery consists of three types of information, pitch information, melodic information, and harmonic information (Brodsky et al., 2003), which are reflected in the current measures of basic auditory representations. As a result, there should be relationships between these basic auditory representations and a more specific type of musical imagery: notational audiation.

Next, there is evidence of the development of notational audiation when comparing non-musicians to musicians (Kalakoski, 2007). Within a group of musicians there is a distinction between those who can form auditory representations of aurally presented music to those who can additionally form auditory representations of a notated score (i.e., notational audiation) (Brodsky, et al., 2003). So, I expected to find a wide variance in music reading ability in the current population of developing musicians. For example, if students found the music too difficult to perform, they would likely not employ notational audiation (Kopiez & Lee, 2006). Likewise, if a student's conversion of notated score to auditory representation was too slow (i.e., it did not happen automatically in working memory), then there may be little relationship between basic representations and reading ability (Simoens & Tervaniemi, 2013).

Finally, musical background (i.e., activities of classical vs. non-classical musicians) would likely be a factor in participants' abilities in overall musicianship. Kalakoski (2007) highlighted the role of pre-learned knowledge in notational audiation and Kopiez & Lee (2006) found background experiences, such as experience sightreading, to be key factors in participant ability in sightreading overall. It would, therefore, be of interest to examine which types of pre-learned knowledge (i.e., auditory representations) and general background experiences aided in performance on the current overall musicianship measure.

As the evidence suggests, musicians employ notational audiation to varying degrees. Another prominent line of research provides information regarding the purpose these auditory representations may serve.

Role of Auditory Representations in Music Reading

Waters, Townsend, and Underwood (1998) proposed two possible roles auditory representations may have in music reading: as a "source of information allowing the reader to determine the accuracy of the performance" (p. 126) and as a priming mechanism for representations of other musical structures. These two roles are echoed throughout the literature on notational audiation as researchers often focus on the feedback and/or expectations they produce. In an example of a study focused on auditory representations as a vehicle for feedback on accuracy, Simoens and Tervaniemi (2013, detailed above) sought to determine if visual notation was indeed converted to auditory imagery in short-term memory before it was compared to delayed auditory feedback. Their results supported their hypothesis.

Schön and Besson (2003) presented a good example of a study focused on auditory representations being used as a priming mechanism when confronted with a visual score. They intended to test the hypothesis that "musicians have an auditory-like representation of written music before they actually play it" (p. 193). In order to do so, they primed the participants with visual notation and then presented them with an auditory stimulus that either matched what they saw or differed in the last note. They extended their paradigm further by manipulating the harmonic stability of the last note, assuming that notes which were harmonically stable would be easier to anticipate.

Musicians (no *N* reported) listened to a 5-note melody while looking at a musical score and had to judge whether or not the last note they heard matched the one on the score. One set of trials had written last notes that were harmonically stable while the other had unstable endings. In the cases of a mismatch, some of the endings were plausible and some were not. The researchers measured the response times of each judgment as well as Event-Related Potentials (ERP) measured by Electroencephalogram. Response times were shorter for the items containing stable endings and for those in which the endings matched the score. The researchers concluded that, even if the musicians could visually prepare themselves for an unstable ending, that ending was still surprising and caused a delay in response.

ERP data for the matching conditions supported the idea that it was more difficult for the musicians to anticipate unstable endings. For the mismatching conditions, the implausible endings elicited a larger response than the plausible endings, indicating a greater violation of expectancies. It also confirmed the behavioral data that stable endings were easier to anticipate than instable ones.

Both types of data supported the conclusion that musicians were building auditory representations from the musical score and that those expectancies influenced how the aural presentation was perceived, but the outcomes were heavily influenced by the stability and plausibility of the last note. The study highlighted the dependency of auditory representations on pre-learned knowledge and schemas from a given musical idiom. In other words, we base these predictions on how the music “should go.”

Measures of basic auditory representations in my study also reflected the two possible roles of auditory representations in music reading: storage for feedback purposes and development of expectations. One measure required storage of one pattern for later comparison with another and the other two focused on the development of expectations. Of these two, one was unimodal (auditory input to auditory expectation) and the other was multimodal, as in music reading (visual input to auditory expectation). As noted above, there is also evidence of the use of auditory representations to form expectations in non-music reading circumstances (Bharucha & Stoeckig, 1986).

Auditory Representations as a Basis for Musicianship

Lehmann, Sloboda, and Woody (2007) underscored the notion that internal mental representations "underlie the whole range of musical skills, starting with remembering music to reproducing and creating it" (p. 21), basing their claim in part on McPherson (1993). McPherson (1993) explored the interactions between five different types of musicianship—playing rehearsed music from notation, sight-reading, playing from memory, playing by ear, and improvising—among 101 high school trumpet and clarinet players. The impetus for the study was recognition that, while some students learn to play through visual notation and others learn to play by ear, the state of instrumental education in Australia at the time focused almost exclusively on the former. Drawing from the results in previous empirical research, McPherson argued for a more balanced approach including what he called visual, aural, and creative forms of performance with the aim of honing students' abilities to "think in sound" (p. 4).

Participants received scores from the Australian Music Examinations Board (AMEB) for their rehearsed performances and McPherson measured sight-reading skill using the Watkins-Farnum examination, form A (1954). Participants studied short melodies from notation and were then asked to play back what they saw without the notation present in order to measure how well they played from memory. Assessments of participants' abilities to play by ear happened in two ways: First, they played familiar melodies (e.g., Happy Birthday) by ear; second, they listened to an unfamiliar melody and had to play it back once in the heard key and twice in a new key. Finally, McPherson assessed improvisation abilities by asking the participants to play 5 different types of improvisations, including improvisation of an answer phrase in response to a question phrase, improvising a melody constrained by a particular rhythmic pattern, improvising a melody constrained by a particular motif, improvising a melody to align stylistically with a given accompaniment, and improvising freely.

McPherson then compared the participants' scores across the measures and compared the measures between two groups based on the grade of the AMEB exam each participant completed. These correlations provided empirical evidence for the assertion that audiation is central to many different types of musicianship. For example, over the entire sample and within each group, the highest correlations existed between playing by ear and improvisation ($r = .51 - .77$, $p < .01$ for all). Correlations between sight-reading and improvisation were stronger (lower AMEB grades, $r = .42$, $p < .01$; higher AMEB grades, $r = .68$, $p < .01$) than those between sight-reading and performing rehearsed music (lower AMEB grades, $r = .31$, $p < .05$; higher AMEB grades, $r = .54$, $p < .01$) for both groups. Participants' ratings on the four skills other than performing rehearsed music proved to be more highly correlated with each other than with that one ability. McPherson suggested that all of these types of musicianship required "ability to audiate for successful completion of the tasks involved" (p. 231).

Classical vs. Non-Classical Musicians

If the formation and manipulation of auditory representations is the basis for varying forms of musicianship, as was indicated by McPherson (1993), then the presence of these representations should also be common among musicians who are involved in notation-based music making (classical musicians) and ear-based music making (non-classical musicians). The two groups do not divide along a clearly defined boundary, as there are certainly musicians who feel comfortable in both notation and ear based musical idioms (Green, 2002); however, as the following researchers have found, there are considerable differences between the musical biographies of the two groups which likely lead to differences in how they experience music making.

Creech, et al. (2008) studied the differences between advanced classical and non-classical musicians in attitudes toward the "importance of musical skills, relevance of musical activities, and nature of musical expertise" (p. 215). They grouped popular, jazz and Scottish traditional musicians into the "non-classical" group under the assumption that these musicians had not been educated through relatively well-established programs like the classical musicians. Earlier research on expertise in music revolved mostly around classical musicians and suggested that expertise is a combination of "neurophyscobiological potential, enculturation, and specific sonic and musical experiences" (p.216) that interact with the musician's early musical and social environment. The researchers sought to examine the possibility, based on Bonfrenner (1979), that a musician's development is "unconstrained by age and fundamentally influenced by social interaction within the social-ecological environment" (p. 217).

In a survey of 244 undergraduate, postgraduate, and older adult musicians from both classical and non-classical genres, the researchers asked a range of questions covering importance of musical skills, relevance of various musical activities, attitudes toward performance, age that respondents began to engage with music, music making influences, and time per week engaged in various musical activities. In terms of early experiences, they found that classical musicians began to engage with music earlier (M = 6.6 years old) than their non-classical counterparts (M = 8.4 years old) and also that they began lessons earlier (M = 8.8 years old for classical musicians vs. 12 years old for non-classical). Classical musicians were more likely to be influenced musically by their parents, instrumental or vocal teachers and formal groups, whereas non-classical musicians were typically most influenced by well-known performers or informal groups.

They also asked the participants to rate the importance of a variety of musical skills. Both groups agreed that practicing, rehearsing, taking lessons, and giving performances were very relevant to their musical lives. They also agreed that experts possess skills that can be transferred to other musical genres and domains; however, the content of these activities and skill sets seemed to be where the genres diverged. The classical musicians rated notation-based music making as significantly more important ($p = .002$) than their non-classical colleagues. In contrast, the non-classical musicians rated the ability to improvise and memorize as significantly more important than their classical counterparts ($p < .001$). In a survey assessing attitudes toward performance, non-classical musicians also agreed least with the statement that expert performers are more competent in reading music notation. These results demonstrate a clear divide between classical and non-classical musicians over the importance of music reading ability.

Different emphases according to musical genre can give rise to different musical skills. Woody and Lehmann (2010) found this to be the case among a population of 24 classical (referred to as formal) and non-classical (referred to as vernacular) music majors as they explored the differences in ear-playing between these two groups. The researchers argued that playing by ear and reading music were related approaches to music making, contrary to some literature that casts them as opposite approaches. The authors assumed ear-playing was a two-stage process involving encoding the material that is heard into working memory and then translating the material to singing, which they assumed to be a direct encoding, or to a music instrument, which they assumed to be mediated by technical efficiency. Furthermore, they assumed that there could be two bottlenecks in the ear-playing process: one bottleneck could occur with goal imagery, and the other could occur with instrument technique. Accordingly, the researchers selected two basic melodies from beginning band books, and they asked participants to sing back one melody and play back the other on their instruments. They hypothesized that the classical musicians would be able to sing back the melody after a similar number of hearings to their non-classical counterparts, but that the motor output of the classical musicians would not be efficient.

Results showed a significant main effect of musician type (F (1, 22) = 55.13, p < .001). Vernacular musicians required fewer trials to reproduce the melodies either in singing or on their instruments than formal musicians required. Furthermore, there was a significant main effect for performance mode (F (1, 22) = 13.33, p < .001). Overall, all musician-participants required fewer trials to reproduce a melody by singing than they did to reproduce a melody on their instruments.

The authors also conducted retrospective think-aloud protocols with participants to determine strategies that were used for encoding and reproduction. Several of those strategies were held in common among all musicians, including listening for musical patterns and dividing each melody into shorter phrases. The authors noted, "the musicians' use of mental representations was very evident in their comments" (p. 109). However, there were also differences between the vernacular musicians' strategies and the formal musicians' strategies. Many of the vernacular musicians described the melodies as "predictable," compared to the formal musicians who described them as "unpredictable." Furthermore, the vernacular musicians reported that they thought in terms of harmonic progression, whereas the formal musicians reported that they thought in terms of intervals and fingerings, slide positions, or mallet strokes on their instruments. Finally, the musicians reported their past experiences related to playing by ear, transcribing, improvising, and composing, and the authors found that vernacular musicians were more experienced with all of these activities.

Based upon the performance and interview evidence, the authors concluded, "singing seemed to be more closely connected to the musicians' goal images" (p. 112). Although all musicians seemed to rely on memory to connect the sounded melody to their performance on a music instrument, the vernacular musicians did so by way of their conceptual understanding of music, including harmonic progression. The authors suggested that this kind of conceptual representation led to more efficient reproduction than did mental representation of intervals or fingerings. In conclusion, the authors suggested that regularly engaging in activities such as playing by ear, transcribing, improvising, and composing might lead to more efficient mental representation.

In my study, two of the basic representations were measured using strictly aural paradigms, which could possibly confer an advantage to the non-classical musicians, who appear to be more aurally based. The inference of tonic would be especially relevant to non-classical musicians if they were more inclined, as Woody and Lehman concluded, to form a representation of the music they hear that is tied to harmonic function. An ability to represent melodies according to harmonic function would also aid non-classical musicians in comparing melodies when they differed according to that function. Furthermore, the researchers argued for a connection between playing by ear and music reading, indicating that skill in the former may bear a relationship to skill in the latter.

Sightsinging as a Measure of Overall Musicianship

Klemp (2009) argued that, "in order to successfully sight-sing, performers must rely on their own internal reference point to accurately produce the sound suggested by the written notation" (p.37). This is in contrast to sight-reading on an instrument, in which "instrumentalists tend to rely on their recollection of fingering patterns in order to perform what is notated in the score" (p.33). Certainly this is not a strict dichotomy, but it does seem that sight-singing provides a better insight than sight-reading on an instrument into the internal representations that are cued by the notation provided the participants have sufficient vocal motor control to produce the required motor output (Pfordresher and Brown, 2007). It should be noted, though, that even singers encounter difficulties attaching printed notation to an auditory image, often relying instead on very quick auditory feedback from an accompanying instrument or surrounding singers to find a pitch (Bennett, 1984). Woody and Lehman (2010) additionally provided some evidence that vocal production is closely linked with auditory imagery. Likewise, Kopiez and Lee (2006) found technical ability to be one factor that can crowd out the use of notational audiation when the music is not difficult. Removal of instrumental technique in the current study may have provided sufficient room for notational audiation to be useful.

One problem in using sight-singing as a measure of overall musicianship is the effect that experience with reading music notation may have on the task. We might assume that those with less experience with or who have placed less emphasis on notation, such as non-classical musicians, would have a harder time converting the written notation into an auditory representation. However, as McPherson (1993) and others have pointed out, the basis for reading notation is the formation of auditory representations and that basis is shared among many different forms of music making. Furthermore, musicians in the study by Simoens and Tervaniemi (2013), some of whom were non-classical musicians, very rapidly converted the visual score to an auditory representation. From the point of conversion on, it seems musicians deal with the information in the aural realm—a realm in which non-classical musicians seem to possess an advantage.

Conclusion

In this chapter I have reviewed research that has helped to confirm the presence of auditory representations while experiencing music (Bharucha and Stoeckig, 1986). The research indicated that the vividness of the auditory representations might influence musical outcomes (Pfordresher & Halpern, 2013). Notational audiation was confirmed to exist among at least a portion of the musician population (Brodsky, Henik, Rubinstein, & Zorman, 2003) and it was influenced by the level to which the music conformed to idiomatic norms (Kalakoski, 2007; Schön & Besson, 2003). Musicians use auditory representations to hold sound in short-term memory for delayed comparison (Simoens and Tervaniemi, 2013) and also to form expectations about how the upcoming music should sound (Schön and Besson, 2003). Auditory representations were of interest in this study, but they certainly do not operate in isolation. They may cue or be cued by other forms of imagery such as visual or kinesthetic imageries. Finally, there is a basis for considering sight-singing to be a measure of overall musicianship because of its link to auditory imagery. It may be valid for use with non-classical musicians because of the basic auditory representations on which it relies, consistent with other forms of musicianship in which non-classical musicians participate.

In the next chapter, I lay out a method for the empirical observation of some basic types of auditory representation and their relationship to each other, a comparison of these representations between classical and non-classical musicians, and an examination of a broader application of these representations via a sight-singing measure. What I hope will emerge from this study is a more nuanced understanding of the types of representations we form and use when making music and how the specific focus of our music making (classical vs. non-classical) may influence those representations.

Chapter Three

Design and Methods

The purpose of this study was to investigate auditory representations of first year college music majors and to compare these representations between classical music majors and non-classical music majors. Three auditory representations (tonic centrality, tonal grouping, harmonic function grouping) were selected for this investigation, and the musicians' performances on these measures were compared. Furthermore, relationships between the musicians' performances on the three measures of auditory representation were compared to their performance on a more general measure of musicianship. To address the research questions, I employed a correlation design with both simple and predictive correlations.

The correlation design was most appropriate as I felt it would provide a snapshot of first year music students in this region of the country. A true experimental design was not conducive to the necessary use of intact classes or to my desire to introduce as little disruption of learning for these students as possible. A quantitative methodology allowed me to collect statistical data that offered me an understanding of the relationships among variables in a way that a qualitative paradigm would not have. In addition, the methodology provided a manner of exploring significant differences between the two populations of interest (classical and non-classical). The design is limited in that it does not render conclusions regarding causation. It also does not answer the question of why the relationships may be related. These are important questions to consider, but the starting place in this initial study is one of exploration of relationships.

Sites and Participants

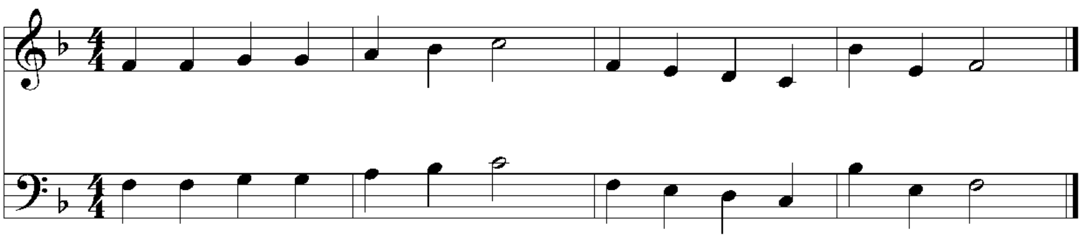
College freshmen (N = 112) enrolled in the first level of aural skills at three universities located in a Southeastern state participated in this study. I selected the universities due to their proximity and the similarity of their level one aural skills courses, which focused on tonal music. Three sections of level one aural skills courses (n = 52) participated form University A, which was a private university that drew students from 35 states; it offered degrees in classical music and non-classical music (performance or composition in jazz, pop, country, etc.). In the aural skills courses, students learned how to sight-sing using solfège with moveable do and do-based minor. University B was a state university with a population of students from rural locations within the state. The university offered degrees in classical music. In aural skills classes, music majors learned how to sight-sing using solfège with moveable do and do-based minor. Students enrolled in four sections of level one aural skills (n = 45) participated in this study. Thirteen students (one section of level one aural skills) participated from University C, which was a public university offering degrees in classical music and non-classical music that enrolled students from urban areas in two Southeastern states. Students at University C were given the option of using numbers or solfège (moveable do, do-based minor) for sight-singing. All participants signed a consent form (Appendix D) indicating their awareness that their identities would be kept confidential and only aggregate data would be reported.

Instruments and Procedures for Administration

Musical background questionnaire. Participants completed a 29-item, pencil-and-paper questionnaire (Appendix A) that contained questions about basic demographic information and musical backgrounds. This questionnaire was completed at the conclusion of individual testing. Initially, I believed that some demographic information might be useful for this study, but I used it only to classify each participant as a classical music major or a non-classical music major.

Overall musicianship measure. As an indicator of overall musicianship, I used the Vocal Sight Reading Inventory (VSRI; Henry, 1999), which consisted of eight melodies built around tonal patterns taken from Gordon's taxonomy of tonal patterns and rhythm patterns (1976). The first four melodies were four measures long and the second four melodies were eight measures long. Henry produced Form A and Form B of the VSRI and a test of parallel forms reliability (p. 125) revealed no significant differences between the two forms ($t = -.49$, $df = 320$, $p < .62$). I chose Form B to avoid a chromatically altered pitch that appeared early in the sequence of Form A (recall that many students do not use chromatically altered pitches in the first level of aural skills classes). The first melody of Form B is presented in Figure 3, and other melodies are similar. Although items in VSRI are written with simple rhythms (quarter notes) and pitches are grouped into measures (in 4/4 or 3/4 time), rhythm accuracy is not a factor in the scoring procedures.

Figure 1. A Melody from the Vocal Sight Reading Inventory (Henry, 1999)



I administered the VSRI Form B (Henry, 1999) to participants during individual examinations, with a format I created using E-Prime software v.2 (Psychology Software

Tools, Pittsburgh, PA): First, each participant viewed written instructions (see Appendix B for transcript), and then saw the first VSRI melody. For each of the melodies, the computer program played a waveform audio file (WAV) of a I-IV-V-I pattern in the key of the melody, followed by the first pitch of the melody. I followed Killian and Henry's (2005) procedures, allowing 30 seconds of preparation time; then the computer played another tonic chord and starting pitch. The participant sang the melody on a neutral syllable, and only one attempt was allowed for each melody. Each participant's performance was recorded on a Zoom H4 Recorder (Tokyo, Japan: Zoom Corporation) so that I could score the melodies after the participants had completed the measure.

According to Henry, the VSRI can be scored two different ways. In the note-by-note system, each pitch is counted as correct or incorrect and the number of correctly sung pitches serves as a score (151 possible points). In the component-skills system, one point is awarded for each of Gordon's tonal patterns (n=28) sung correctly across the eight melodies. Henry found the correlation between these two scoring systems to be very high (*r* =.94-.97; p.124). I chose to use the longer scoring method because it produced a broader range of scores and thus appeared to be a more precise assessment of sight-reading.

I obtained a score for each melody by reviewing the individual pitches sung with WaveSurfer version 1.8.51 (Sjölander & Beskow, 2005), which rendered frequency outputs for the pitches. I notated the pitches that participants sang correctly in the scoring sheets for each participant, following Henry's (1999) original scoring guidelines:

1. The first pitch the participant sang was used as a reference tonic for each example, even if the participant's first note was not the first note given by the computer program.

2. If a participant repeated a note, only the first attempt was assessed.
3. [Exact] intonation was not evaluated. If the participant had the correct concept of the pitch, credit was awarded.[1]
4. …A student may have initially vocalized an incorrect pitch, but correctly adjusted the pitch within the rhythmic time frame. In these instances, credit was awarded.
5. The function of the pitch had to be correct within the established key. Accurately performed intervals did not count if the function was wrong. If a student missed a pitch but performed the next interval correctly, credit was not awarded.
6. Once a new key feeling was clearly established, pitches were evaluated relative to the new tonic. (pp. 118-119)

Measures of auditory representation. Three measures served as proxies for three narrowly construed types of auditory representations: tonic centrality, tonal grouping, and harmonic function grouping. These representations might be ordered in a hierarchical fashion, such as that implied by Jackendoff and Lerdahl (2006), with tonic centrality occupying the most basic level. I was interested in the relationships among participants' scores on these measures as well as the relationship between participants' scores on each of the three measures and the measure of overall musicianship.

Tonic Centrality. This measure assesses participants' abilities to infer tonic from a pitch collection. In the literature, this ability was considered important for "intonation and reading activities in performance and for recognition of mode, modulation, and form in

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[1] Following the guidelines set forth in Pfordresher and Halpern (2013), I maintained a 50-cent threshold on either side of the intended pitch. (Fifty cents equals half of the distance from one semitone to the next.)

listening" (Colwell, 1969, p. 112) and stood at the most basic level of Jackendoff and Lerdahl's (2006) theory of tonal hierarchies. I took the measure, *Feeling for Tonal Center*, from the second part of the second Musical Achievement Test (MAT II; Colwell, 1968). In the manual for the test, Colwell (1969) reported the reliability of MAT II, part 2 to range from $r = .42\text{-}.85$ ($p < .01$). Colwell also reported criterion-related validities for the entire battery of the MAT as compared to the Farnum Music Notation Test ($r = .53\text{-}.66$, $p < .01$), the Knuth Achievement Tests in Music ($r = .53\text{-}.84$, $p < .01$), and the Gaston test of musicality ($r = .42\text{-}.69$, $p < .01$).

I administered the test in a group setting, after consent forms were collected. On the first subtest, participants heard 10 four-part cadences. Each cadence consisted of four chords, and each cadence ended on the tonic in the soprano and bass lines. Participants were to choose among three pitches as the tonic, or they could select the answer "none." For the second subtest, the stimuli were 10 four-bar phrases of a melody with harmonic accompaniment. Three of the melodies ended on a pitch other than tonic and one of them ended on the tonic in a different octave than the one presented as an answer choice. Again, participants were to choose among three pitches as the tonic, or they could select the answer "none."

I scored the measure by hand using the published answer key. Participants received credit for each item that was answered correctly and received no credit for items answered incorrectly or left blank. I then merged the scores of the two subtests resulting in a single tonic centrality score for each participant.

Tonal grouping. The premise behind this measure is that the participant must form auditory representations of the printed phrase while listening to the recorded phrase for comparison. Part 3 of the second Music Achievement Test (Colwell, 1968), *Auditory-Visual Discrimination,* is a standardized, group-administered test that has two 12-item subtests—one for pitch and one for rhythm. Only the section on pitch was used in this study. The test, a basic error detection design, has been widely used in music education research *(cf.* Autry, 1975; Steckman, 1979, and Steeves, 1984). Colwell (1968) reported reliabilities ranging from $r = .74\text{-}.96$ ($p < .01$). Shuter-Dyson (1981, p. 290) reported criterion-related validity for the entire exam as correlated to the Farnum Music Notation test (.52-.66, $p < .01$), the Knuth Achievement Tests in Music (.53-.84, $p < .01$), and the Gaston Test (.42-.69, $p < .01$).

On the test answer sheets were 4-measure phrases of music notation with boxes underneath each measure of the phrase. Under the testing conditions, participants listened to a recorded example and compared it with the notation. They were to indicate discrepancies between the recording and the printed music by filling in the box underneath the measure in which the discrepancy occurred. There was also a blank to fill in if no errors were heard.

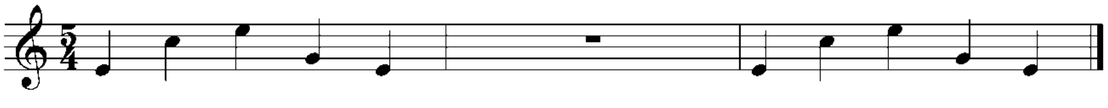
I scored the answer sheets by hand using the key provided with the test. First, I inspected the answer sheet to ensure that the participant did not fill in every blank. Next, I evaluated the answers. If participants indicated the correct measures in which a discrepancy occurred, they received one point for that item.

Harmonic Function Grouping. One way to encode auditory information into memory is to group it by harmonic function. I tested this ability by using a measure in which the variation to be detected by the listener is a result of one altered note which often results in a harmonic shift: a modified version of the original measure (Holahan, Saunders, & Goldberg, 2000) that I revised and piloted for this study. I present a detailed description of the pilot testing in Appendix C.

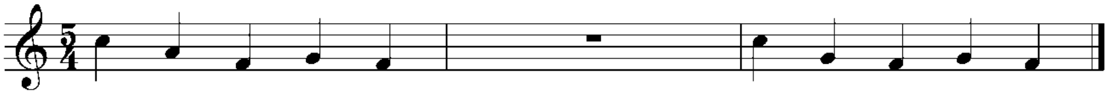
Holahan, Saunders and Goldberg (2000) originally developed an aural tonal pattern recognition measure in which participants judged two aurally presented tonal patterns to be the same or different. All patterns came from the taxonomy of tonal patterns by Gordon (1976) in which he organizes simple patterns by harmonic function and difficulty level. Each of the two tonal patterns consisted of five notes (see Figure 2 for an example). Six of the 31 items in my revision of this measure were "same" items. Of the remaining items, one had a difference in position 1, eight had differences in position 2, ten in position 3, five in position 4, and one in position 5. The 25 different items varied in the intervallic distance between the two different notes. Eleven items had differences a 2nd apart, ten items had differences a 3rd apart, and four items had differences a 4th apart. Thirteen of the different items constituted a harmonic shift, while the other 12 different items remained in the same harmonic function even though one note changed. All 31 items were balanced across four melodic contours (all up, all down, up then down, down then up) and three harmonic functions (tonic, subdominant, and dominant). A complete listing of the pairs appears in Appendix C.

Figure 2. Same and Different Trials from the Harmonic Function Grouping Measure

Same



Different



Participants viewed instructions on a computer screen indicating that they should rest their index fingers on the letters S and D. If the two patterns were the same, they should press S and if they were different, they should press D. After receiving feedback on two practice trials, participants heard the 31 pairs in random order.

I administered this test via computer using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA), which also scored the examples for accuracy. The program also recorded response times, which were necessary in order to determine if the answers participants gave were valid or random guesses. For items in which there was no difference in pitch, I assumed the participant would have to listen to the entire second pattern to be able to make a valid choice. I therefore excluded answers in which the participant responded before the second pattern was finished (a false hit). For items in which there was a difference in pitch, I excluded answers registered before the difference occurred.

Summary of administration procedures. For each intact class (n = 9), I attended a regularly scheduled meeting in the regularly scheduled classroom. After introducing myself and explaining the study to the students, I distributed and collected consent forms. I then administered the measures that could be delivered in a group setting, which were the measures of tonic centrality and tonal grouping. For these measures, I used a stereo sound system consisting of a Mac Book Pro 3 running Microsoft Windows XP (2004) and two Harman-Kardon studio speakers. I presented the tonic centrality measure first, followed by the tonal grouping measure (the standard order in the MAT), using the original answer sheet and the published recordings (see published manual for transcripts of recorded directions; Colwell, 1968). Total group testing time did not exceed 25 minutes.

During the week of group testing or the subsequent week, participants scheduled and attended an appointment with me to complete the overall musicianship measure, the harmonic function grouping measure, and the musical background questionnaire. Measures were presented in random order. Testing time for the individual measures took approximately 20 minutes all together. Participants who did not appear for their individual sessions were rescheduled in an effort to decrease the effects of participant mortality in the present study. Appointments took place in a faculty office in the music building of each school, and I made every effort to keep the testing area free from distraction.

Data Preparation

I evaluated the data before beginning the main analysis in order to reduce effects of mortality. The final population equaled 112 participants after four of the original participants were excluded from data analysis: two were unable to keep their individual appointments after the group testing, one individual neglected to turn in the answer sheet from the group testing session, and another individual proved to be an outlier on the tonic centrality measure.

Data Analysis

I scored all measures using absolute criteria (e.g., computer analysis, standardized scoring procedures) and used Statistical Package for the Social Sciences (SPSS, version 7.0) to calculate all statistics. All measures except the musical background questionnaire were evaluated for internal reliability using Cronbach's Alpha and I calculated descriptive statistics (e.g., mean, standard deviation, range) for each measure to determine how the data were distributed, removing outliers as necessary ($n = 1$). Finally, I selected statistical procedures that would allow me to analyze the data to address each of my research questions:

Research Question 1. In order to answer Research Question 1 (How do first-year college music students perform on a musicianship measure?), I scored the VSRI and calculated descriptive statistics.

Research Question 2. In order to answer Research Question 2 (How do first-year college music students perform on three measures of auditory representation: tonic centrality, tonal grouping, and harmonic function grouping?), I scored each of the three measures and calculated descriptive statistics.

Research Question 3. The third question (Considering the college music students' performance only on measures of auditory representation, what relationships exist between these measures?) required more comparative analysis. Scores from each measure of auditory representation were checked for distribution and outliers, and then correlated using Kendall's tau.

Research Question 4. I treated this question (Considering all measures, what relationships exist between college music students' auditory representations and their overall musicianship?) in the same manner as question 3.

Research Question 5. The final question (Considering college music students' performance on all measures, what differences exist between classical musicians and non-classical musicians?) required comparisons between the two groups (classical and non-classical majors) on each of the 4 measures, using the Mann-Whitney test (with appropriate correction applied to protect against Type I errors) to determine the significant differences on specific measures. Additionally, I examined Kendall's tau between each measure of auditory representation and the measure of overall musicianship for each of the two groups.

Once all the data were collected, I moved forward with analysis and began to consider the implications of the results of my study. I present results in Chapter 4 and discuss the implications of these results in Chapter 5.

Chapter Four

Results

In the current study, I sought to explore relationships between the formation of a few basic auditory representations of pitch, the relationship of these representations to overall musicianship, and the differences that may exist between classical and non-classical musicians in regard to these. I collected data by administering pre-existing measures meant to indirectly measure four musical attributes: auditory representations of tonic centrality, tonal grouping, and harmonic function grouping, and an overall measure of musicianship. To address the research questions, I employed a correlation design to data collected from first year college music students.

Demographics

Participants (N = 112) were members of intact classes enrolled in the first semester of ear training or aural skills at University A (n = 52, 46.43% of the sample), University B (n = 46, 41.07% of the sample), and University C (n = 13, 11.61% of the sample). According to self-reports, none of the participants possessed absolute pitch. The mean age of the participants was 19.02 years with a range of 18.10 years - 24.15 years at the time of testing.

A questionnaire regarding musical background revealed that a majority of the participants were vocalists or wind players (n=68, 60.71% of the sample), though guitar, piano, percussion, and string players were represented as well (Table 1). The number of non-classical majors (n = 45) comprised 40.18% of the sample and consisted of the 38 non-classical performance majors as well as 7 non-music majors who indicated that they principally studied non-classical genres leading up to college. For a more detailed breakdown of principal instruments and majors, see Table 1.

Table 1
Participants' Principal Performing Mediums and Major Courses of Study (N=112)

	n	% of sample
Principal Performing Medium		
Voice	35	31.25
Winds	33	29.46
Guitar	18	16.07
Piano	10	8.93
Percussion	8	7.14
Strings	8	7.14
Major Course of Study		
Music Education	45	40.17
Non-Classical Performance	38	33.93
Classical Performance	15	13.39
Non-Music Majors	11	9.82
Composition	3	2.68

For the comparison of classical vs. non-classical majors, I classified participants according to the category into which their private lessons fell. So, for example, a non-music major studying classical guitar would be classified as a classical musician whereas a student studying electric guitar would be in the non-classical group.

The majority of music students from University A (n = 52) studied non-classical performance (styles such as jazz, pop, country, etc.) and came from cities spread across the eastern half of the United States. I tested three level 1 aural skills classes of approximately 17 students each in the middle of the fall semester of 2009. Though I was an employee of this university, I was not the instructor of any of the participating classes. All classes consisted of music majors (n = 45, 87%), music minors (n = 2, 4%), songwriting majors (n=3, 6%), and audio engineering technology majors (n = 2, 4%). Most of the music majors were studying performance (n = 37, 71%). Sixteen of the students were studying classical music (31%) while the other 36 (69%) were studying non-classical genres.

I tested an additional 47 participants, all considered classical majors, from University B (four classes of approximately 12 students each) in the middle of the fall semester of 2009. These students were mostly from rural communities in one southeastern state (only one participant was not from this state). Thirty of the participants (67% of University B students) were pursuing degrees with a focus on instrumental music performance or education. Forty-one participants (91% of University B students) were music education majors with the other four majoring in composition (2 participants, or 4% of University B students) or non-music education (2 participants, or 4% of University B students).

A third group of 13 students attended University C and comprised the only level 1 aural skills course offered in the fall of 2009 at that university. University C offers degrees in music education (considered a classical degree) and non-classical music performance. The present sample consisted of 9 non-classical musicians and 4 classical musicians. Eight participants hailed from metropolitan areas in the state in which the university is located while the remaining five came from metropolitan areas in the south and Midwest regions of the United States.

Measures and Reliability Analysis

Measures are described in detail in Chapter 3. As a reminder to the reader, I assessed overall musicianship by evaluating participant performance on a sight-singing measure (VSRI, Henry, 1999). The three basic auditory representations of interest in this study were those of tonic centrality, tonal grouping, and harmonic function grouping. I used Colwell's *Feeling For Tonal Center* from part 2 of test 2 of the Music Achievement Test (MAT2, 1968) to indirectly measure the first representation. I drew another subtest from part 3 of the MAT2 (Auditory-Visual Discrimination) to indirectly measure tonal grouping. To measure harmonic function grouping, I revised a measure constructed by Holahan, Saunders and Goldberg (2000), making it more suitable for the present population.

Each of the above measures demonstrated suitable reliability in the original populations for which they were constructed. In the current population, I calculated Cronbach's Alpha in order to determine the reliability of the measures (Table 2) and found all to demonstrate acceptable reliability levels of .70 or above (Kline, 1999).

Table 2

Reliability of Measures

	Overall Musicianship	Tonic Centrality	Tonal Grouping	Harmonic Function Grouping
Reliability (α)	.89	.88	.79	.74

Descriptive Statistics

Question 1. *How do first-year college music students perform on a musicianship measure?*

The scores for the test of overall musicianship (VSRI) among this sample covered a

124-point spread out of a possible 151 points. Visual inspection of the histogram and normal Q-Q plot of the data set revealed a normal distribution (Fields, 2005), confirmed by a non-significant Kolmogorov-Smirnov test, $D(112) = .07, p = .20$. The mean score was 100.24, with a standard deviation of 31.15 (Table 3), which is higher than the theoretical mean of 75.5 for this measure. As the data were normally distributed, the median was very close to the mean (Mdn = 100) and the Interquartile Range was fairly consistent with the standard deviation, lying between 78 and 128.50. The author of this measure, Henry (1999), used a short-scoring system and found a mean of 10.2 out of a possible 27 points among 42 high school students. For the sake of comparison I also scored the musicianship measure using Henry's short scoring system (M = 14.59), indicating that the first year college students in the current sample showed a greater ability in sightreading than the high school students in Henry's sample. It is not possible to ascertain whether this difference is statistically significant. A comparison of scores on this measure according to University revealed that students from University A scored significantly better on this measure than participants from University B ($p = .001$) and C ($p < .001$) and that participants from University B scored significantly better than those from University C ($p < .001$). I will discuss possible reasons for this difference in Chapter 5.

Table 3

Descriptive Statistics for Measure of Overall Musicianship

N = 112	Mean	SD	Median	IQR	Range	
					Actual	Possible
Overall Musicianship	100.24	31.15	100	78 -128.50	27-151	0-151

Question 2. *How do first-year college music students perform on three measures of auditory representation: tonic centrality, tonal grouping, and harmonic function grouping?*

In order to address this question, I examined means, standard deviations, medians, interquartile ranges, and ranges for each variable (Table 4). I also checked for normal distributions of the data acquired with each measure.

Table 4

Descriptive Statistics for Measures of Auditory Representation

N = 112	Mean	SD	Median	Interquartile Range	Range	
					Actual	Possible
Tonic Centrality	16.34	4.16	18	14-20	5-20	0-20
Tonal Grouping	10.49	2.47	11	10-12	2-14	0-14
Harmonic Function Grouping	21.91	4.55	23	18.25-25	11-30	0-31

Tonic Centrality. The distribution of the data for the tonic centrality measure was significantly non-normal, $D(112) = .20, p < .001$. Forty participants (35.71% of the sample) scored perfectly on this measure and an additional 12 (10.71%) only missed one item, producing a negatively skewed histogram (skewness = -.95). The median score for the measure (18) reflected a 90% accuracy rate, with 53.57% of the population scoring at the median or higher. Originally, there was one outlier with a score of 2 on this measure. I excluded this participant from all analyses. In general, this sample demonstrated a strong ability to form an auditory representation of tonic.

Tonal Grouping. The data collected with the tonal grouping measure were also significantly non-normal, $D(112) = .24, p < .001$. Forty-one participants (36.61% of the sample) scored a 12 out of 14, while an additional 22 (19.64%) scored an 11 out of 14. As a result, the data were negatively skewed (-1.76). The median score for the measure (11) reflected a 79% accuracy rate, with 66% of the population scoring at the median or higher. Thus, the first-year college students in this sample were generally skilled at tonal grouping.

Scores for this measure fell clearly into two groups: a higher scoring group (n = 105) with scores ranging from 7-14 (mode = 12) and a lower scoring group (n = 8) with scores ranging from 2-5 (mode = 3). With these 8 removed, the variance in the measure is greatly reduced and scores are clustered at the top of the possible range (7-14 out of a possible 14), contributing to a low reliability score for the sample in this study ($r = .49$). The reliability with all subjects included was .79. I decided to include the lowest 8 cases in the final analysis because they appear to be a group unto themselves rather than true outliers. Possible reasons for this grouping will be discussed in Chapter 5.

Harmonic Function Grouping. The data in this measure were also non-normal in their distribution, $D(112) = .11$, $p = .001$; however, scores on this measure were less negatively skewed than they were for the measures of tonic centrality and tonal grouping. The median score for the measure (23) reflected a 74% accuracy rate, with 52% of the population scoring at the median or higher, indicating that participants in this sample were able to group pitches according to harmonic function, though their abilities to perform this skill were somewhat varied.

Question 3. *Considering the college music students' performance only on measures of auditory representation, what relationships exist between these measures?*

To answer this question, it was necessary to correlate the measures of auditory representation to each other. I utilized non-parametric correlations due to the non-normal distribution of the data (Field, 2005). These correlations rely on the conversion of raw scores to rankings, such that the lowest score gets a rank of 1, the second lowest, 2, etc. When scores are identical, they receive the same ranking. The presence of a number of tied ranks in the current data (i.e., many participants having the same score on a measure) and its small sample size necessitated the use of Kendall's tau. Although Kendall's tau typically yields smaller coefficients than Spearman's rho, Field asserted that it is considered a "better estimate of the correlation in the population" (2005, p. 131) than Spearman's rho. Using Cohen's (1988) rule of thumb to interpret the strength of correlations, those between .50 and 1.0 are strong, between .30 and .50 are moderate, and those between .10 and .30 are weak.

All relationships were positive and significant (Table 5). The moderate relationship between the tonic centrality measure ranks and the tonal grouping measure ranks was the strongest ($\tau = .32, p < .001$), followed by the weak relationship between the tonic centrality measure ranks and the harmonic function grouping measure ranks ($\tau = .21, p = .003$), and the weak relationship between the harmonic function grouping measure ranks and the tonal grouping measure ranks ($\tau = .18, p = .012$). The latter two correlations indicate that there was little to no relationship between the measure of harmonic function grouping and the measures of tonic centrality and tonal grouping. I examined these two relationships further using scatterplots (Figures 3 and 4), which clearly demonstrated the lack of a relationship between these variables.

Table 5

Relationship between Scores on Measures of Auditory Representations

	Tonal Grouping	Harmonic Function Grouping
Tonic Centrality	$\tau = .32, p < .001$	$\tau = .21, p = .003$
Tonal Grouping		$\tau = .18, p = .012$

Figure 3. Scatterplot of Relationship Between Tonic Centrality and Harmonic Function Grouping Measures

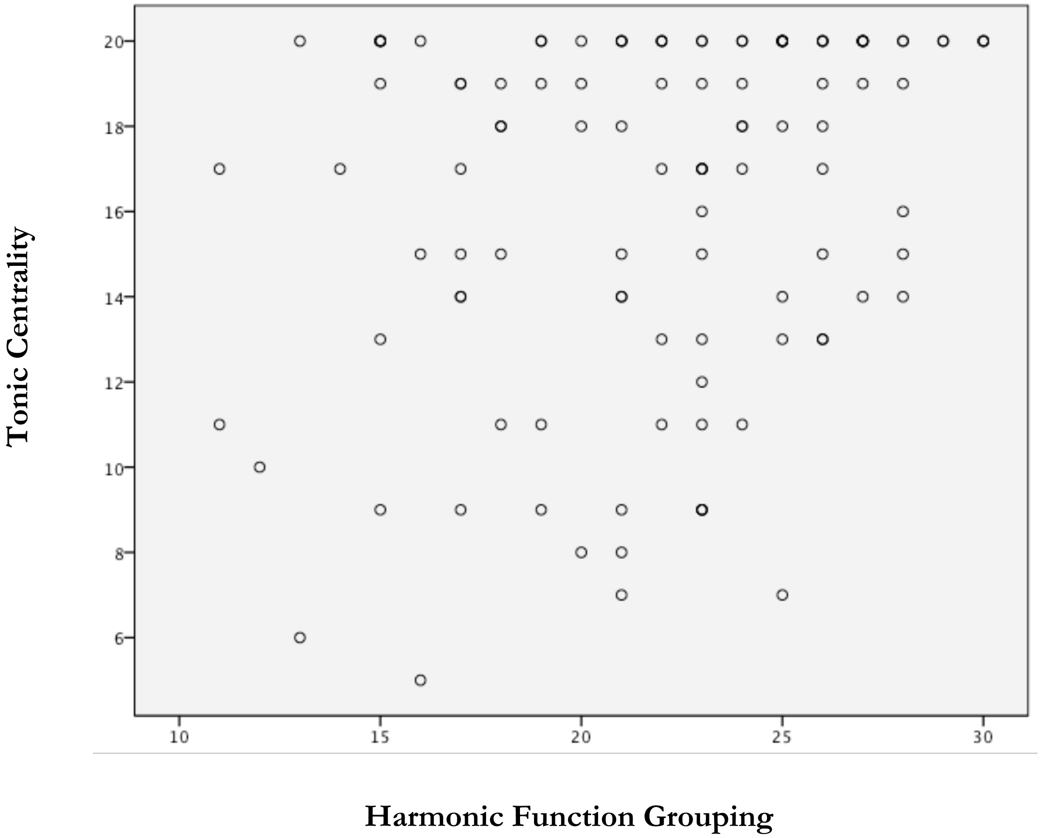
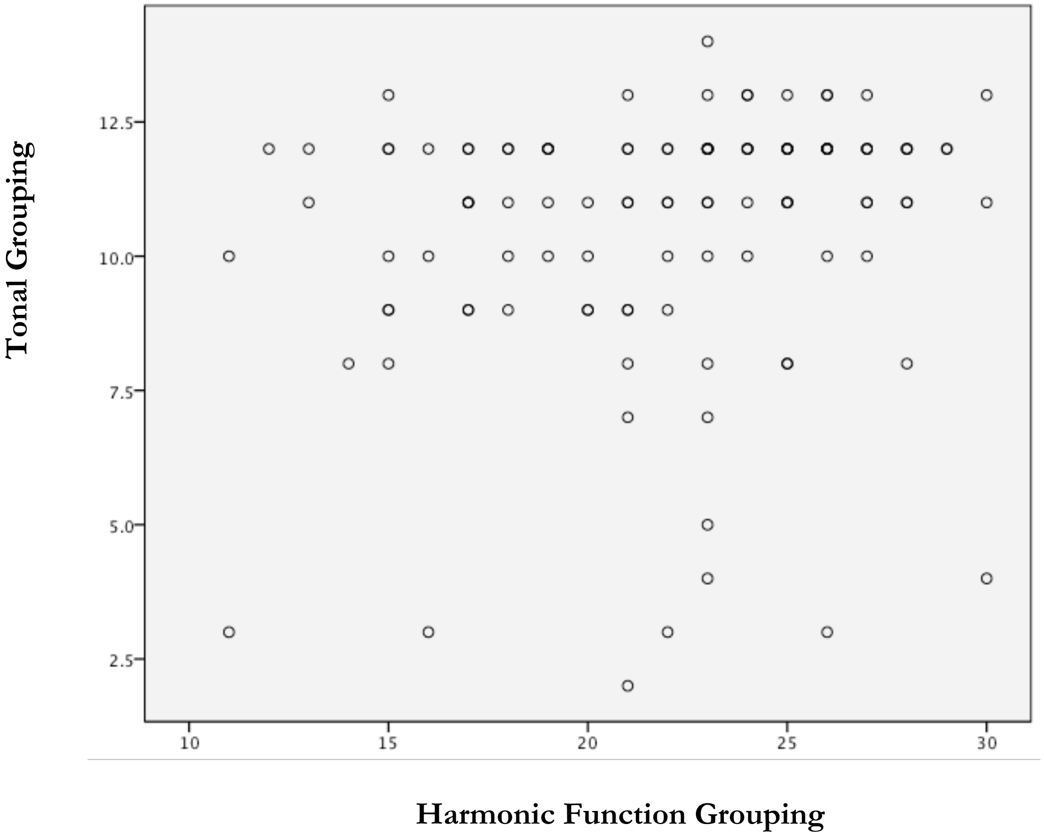


Figure 4. Scatterplot of Relationship Between Tonal Grouping and Harmonic Function Grouping



It was not possible to assess these relationships further using multiple regression analysis because the assumption of a linear outcome variable would have been violated by each of these data sets due to the non-normal distribution of the data for each measure (Field, 2005).

Question 4. *Considering all measures, what relationships exist between college music students' auditory representations and their overall musicianship?*

To address this question, I looked at the simple correlations between each measure of auditory representation and the measure of overall musicianship, all of which were positive and significant. The tonic centrality measure had a moderate relationship to the measure of overall musicianship, the strongest of the three ($\tau = .45$, $p < .001$), followed by the moderate relationship of the tonal grouping measure ($\tau = .43$, $p < .001$) and then the weak relationship of the harmonic function grouping measure ($\tau = .28$, $p < .001$). It is surprising to find that the measure of overall musicianship and the measure of harmonic function grouping did not exhibit a strong relationship as the two measures were based on the same taxonomy of tonal patterns (Gordon, 1976). I will discuss possible explanations for all of these findings in light of previous research in the next chapter. On the whole, these data indicate that overall musicianship in this sample was more closely related to the students' abilities to aurally represent tonic and to meaningfully group pitches than to their abilities to group pitches according to harmonic function.

Question 5. *Considering college music students' performance on all measures, what differences exist between classical musicians and non-classical musicians?*

Non-classical musicians scored higher than classical musicians on every measure except for the measure of tonal grouping (Table 8). On the measure of overall musicianship, non-classical musicians (M = 104.40) outscored classical musicians (M = 97.45) by 7 points, or 5%. On the measure of tonic centrality, non-classical musicians (M = 17.71) scored higher than classical musicians (M = 15.42), demonstrating an 11% difference. On the measure of tonal grouping, the classical musicians outscored the non-classical musicians by a narrow 3% margin (M = 10.67 vs. M = 10.22, respectively). Finally, non-classical musicians outperformed classical musicians on the measure of harmonic function grouping by a 6% margin (M = 23.09 vs. M = 21.12, respectively).

Table 6

Measures of Central Tendency for Classical and Non-classical Majors on All Measures

	Classical (N = 67)		**Non-Classical (N = 45)**	
Measure	**Mean (Mdn)**	**SD (IQR)**	**Mean (Mdn)**	**SD (IQR)**
Overall Musicianship	97.45 (95)	27.29 (79-119)	104.40 (113)	36.07 (74-138)
Tonic Centrality	15.42 (17)	4.29 (12-20)	17.71 (19)	3.59 (17-20)
Tonal Grouping	10.67 (12)	2.29 (10-12)	10.22 (11)	2.73 (9-12)
Harmonic Function Grouping	21.12 (22)	4.46 (18-25)	23.09 (24)	4.48 (20-27)

Note: Mdn = median; IQR = interquartile range

The lack of normal distribution necessitated the use of a non-parametric test to compare the means of the two groups. I conducted Mann-Whitney tests for each variable to determine if differences were significant. There was a significant difference between groups favoring the non-classical musicians on the measures of tonic centrality (U = 1003.50, p = .002, r = -.29) and harmonic function grouping (U = 1134.50, p = .026, r = -.21), but not on the measures of overall musicianship (U = 1284.50, p = .187, r = -.13) or tonal grouping (U = 1371.50, p = .408, r = -.08). The effect size (r) for all of these relationships was small.

Multiple comparisons performed on the same data set warranted an adjustment to guard against a Type I error. I applied the Bonferroni correction (.05/4 = .0125) and found the tonic centrality measure to be the only one in which a significant difference between groups was found. This is a very conservative correction, leading to the possibility of a Type II error. In order to guard against a Type II error, I also corrected comparisons by controlling the False Discovery Rate (α = .05), which is a more liberal correction. For the measure of tonic centrality (p = .002), p had to be less than or equal to .0125, so the difference between groups was significant. For the measure of harmonic function grouping (p = .026), p had to be less than or equal to .025, so the difference between groups was very close to significant.

Finally, I calculated correlations between measures of auditory representations and overall musicianship within the two groups. All correlations were significant at the .001 level except for the relationship between the harmonic function grouping measure and the measure of overall musicianship in the non-classical group; however, this relationship was significant at the .05 level (Table 9). The strongest relationships existed between the measure of overall musicianship and the measures of tonic centrality and tonal grouping in the non-classical group (τ= .52 and τ = .59, respectively). The measures of tonic centrality and tonal grouping were not as strongly related to the measure of overall musicianship in the classical group (τ = .39 and τ = .32, respectively). The measure of harmonic function grouping bore the weakest relationship to the measure of overall musicianship for both the classical (τ = .28) and the non-classical (τ = .20) group.

In general, these data indicate that the biggest difference between classical and non-classical musicians in this sample was their ability to aurally represent tonic. It also appears that the role auditory representations of tonic centrality and tonal grouping play in a student's overall musicianship may be related to the genre of performance, but further research is needed to investigate this possibility.

Table 7

Comparison of Measures of Auditory Representation and Overall Musicianship Within Groups

	Classical	Non-Classical
Tonic Centrality	$\tau = .39, p < .001$	$\tau = .52, p < .001$
Tonal Grouping	$\tau = .32, p < .001$	$\tau = .59, p < .001$
Harmonic Function Grouping	$\tau = .28, p = .001$	$\tau = .25, p = .020$

Summary of Results

The measures of auditory representation bore weak correlations to each other but the measures of tonic centrality and tonal grouping bore moderate correlations to the measure of overall musicianship. The non-classical group outscored the classical group on every measure except for that of tonal grouping; however, the difference was only statistically significant on the measure of tonic centrality. Visual comparison revealed that the two groups also appeared to differ in the way the scores on measures of auditory representations related to scores on the overall measure of musicianship.

Findings

The participants in this study were the most skilled at forming auditory representations of tonic centrality and non-classical musicians significantly outperformed classical musicians in this area. Tonic centrality was also most strongly correlated with overall musicianship within the sample, and this relationship appeared to be stronger among non-classical musicians than among classical musicians.

Chapter Five

Discussion

In this study, I sought to examine the relationships among measures of three basic auditory representations (tonic centrality, tonal grouping, and harmonic grouping), their relationships to a measure of overall musicianship, and any scoring differences that might exist between music students studying classical and non-classical genres. The key finding is the prevalent role of the tonic centrality measure in the study, which I will discuss in more detail later in this chapter. I will first address each research question posed in the study followed by a general discussion, implications for the profession, and directions for further research.

Research Questions

Question 1. *How do first-year college music students perform on a musicianship measure?*

The students in this sample scored well above the theoretical mean on the measure (M = 100.24 out of 151). They also scored higher compared to the high school students for which the measure was developed (Henry, 1999): using the short-scoring system, Henry's participants produced a mean of 10.2 out of 27, while my sample produced a mean of 14.59. Given that the measure was designed for high school choral students, it makes sense that students who are further along in their musical development, have selected to study music, and have been admitted into accredited music programs would produce higher scores.

The level of difficulty posed by the melodies in the measure of overall musicianship was comparable to the level of reading expected at the end of level 1 aural skills. Participants were about two-thirds through the level 1 course at the time of testing. All 8 measures were in major keys with only one accidental throughout. Each of the melodies followed the rules of conventional harmony and, as a result, did not violate expectations built up over a lifetime of exposure to Western music. Thus, even though my sample scored above the theoretical mean for the overall musicianship measure, I expected them to score better than they did. The criterion for passing a measure such as this one at University A was a 70% accuracy rate, while the sample in my study averaged a 66% accuracy rate.

Perhaps levels of accuracy among the participants in my study should not have come as a surprise. Aural skills teachers, even among elite music programs, have often commented on the surprising inadequacies in the music reading of incoming students (e.g., Pembrook & Riggins, 1990; Asmus, 2004). It could be that the level of musicianship instructors (myself included) expect from students entering freshman year is too high.

One possible explanation for the lower than expected scores is that the students who scored lower on this measure found the music too difficult to audiate in real-time (Kopiez and Lee, 2006). Participants may have perceived the music as difficult based on the level of proficiency they had in realizing music notation at the time of testing. A comparison of the scores between universities revealed that students from University A scored significantly higher on this measure compared to each of the other two universities ($p \leq .001$ in both comparisons). The difference may be explained by the level of familiarity students had with notation upon entering level 1 of aural skills. University A required a music fundamentals course for those students who did not demonstrate familiarity with notation upon entry to the program, so students in this sample from University A started the program with the requisite familiarity already in place. Universities B and C did not assess their students for familiarity with notation before enrolling them in level 1 of aural skills, so there was the possibility that these students would vary more in their levels of familiarity.

A third possible explanation is largely procedural. Based on comments made during testing, it seems that some students would have benefitted from singing on solfège or numbers instead of a neutral syllable while performing the measure. It would have perhaps been better to allow them to perform in the manner with which they were the most comfortable in order to ensure the most authentic assessment of the participants' reading abilities.

Question 2. *How do first-year college music students perform on three measures of auditory representation: tonic centrality, tonal grouping, and harmonic function grouping?*

Tonic centrality. Participants in this study produced the highest levels of accuracy on this measure out of the four included in the study. Compared to Colwell's sample set of high school students, the median score for the current population was in the 87th percentile. Given that the majority of students scored very highly on the measure, the auditory representation of tonic centrality does seem to be one that many of these participants were able to utilize.

Colwell (1969) included this measure in his battery of tests precisely because "the ability to hear the presence or absence of a tonal center is essential for understanding of all music" (p.112). This is especially true of music constructed within a tonal harmonic framework, such as most Western music. Corrigall and Trainor (2010) found that children living in Western culture, and thus exposed regularly to tonal music, have been enculturated to expect tonic closures by the age of 4-5. The ability to hear a tonal center may be essential for understanding music in Western culture, and it may be subject to early acquisition, but it is not a given that everyone has the ability to infer tonic. Researchers such as Krumhansl and Shephard (1979) have found variation in participants' abilities to infer tonal closures based on musical experience. Such evidence could help explain why, though the majority performed well, there were still participants who did not score well on this measure.

Tonal grouping. In general, as expected based on the work of Schön and Besson (2005), participants in this sample were able to detect violations of their musical expectations based on a printed score. They could not detect such a violation, though, when the error was the result of an altered note that stayed in the same place on the staff (i.e., the printed note was an F natural, but the heard note was an F sharp). Only two participants detected the one discrepancy that did not violate contour in the current measure. Schmuckler (2009) established the major role contour plays as an organizing mechanism in melodic perception. It is likely that participants' successes on the tonal grouping measure were based on their abilities to detect discrepancies between the contour of the heard melody and the contour of the written notation.

The data for this measure very clearly divided into two groups: one group scoring 7 (out of 14) and above (n = 104) and one group scoring 5 and below (n = 8). The lower-scoring group consisted of three classical majors (two vocalists and one violist) and five non-classical majors (voice, guitar, percussion).

Extant literature offers an explanation for difficulties encountered by the low-scoring group. Simoens and Tervaniemi (2013) found that professional musicians converted visual information into auditory information very rapidly—in the early cognitive mechanism of working memory. It is possible that the students who scored poorly on this measure were not converting the visual notation into auditory information quickly enough to make the needed comparisons between the visual score and the heard recording.

Difficulty in converting visual notation into auditory information may also explain the low scores within this small group on the only other measure involving notation (the overall musicianship measure) as they also scored within the bottom 33% of the sample on that measure. All of these students attended University B and C. Neither school has a music fundamentals course or a similar screening mechanism. Perhaps these students lacked the musicians' experience with notation in Schön and Besson's (2005) study and were therefore not able to form expectations based on the visual notation before they heard the sound. At least, this process had not become automatic. It is also possible (especially for the instrumentalists) that notation signified a fingering or a key rather than an internal sound (Schleuter, 1997).

Harmonic function grouping. The students in this sample were able to group according to harmonic function moderately well (*Mdn* = 23 out of 31). Of the three auditory representations, the accuracy level reflected by the median score was the lowest overall for this measure, though it was still higher than that for the measure of overall musicianship.

Participants scored much lower on this measure than those in the sample used by Holahan, Saunders, and Goldberg (2000). Thus, the modified version I created for the present study seems to have been successful in providing more variation among college music students than the original measure would have. It differed from the original in the following ways: longer patterns (5 notes vs. 3), only 2 items with differences in outer notes (to reduce the effects of primacy and recency), and smaller intervals of difference between items (perfect 4th or less). The relative difficulty of the measure may be attributed to the absence of contour information as a helpful discriminating tool (Holahan and Saunders, 1997).

It is difficult to tell from these data if the measure was actually reflecting the students' abilities to form mental representations of different harmonic functions. This uncertainty arises from a few methodological issues. First, not every "different" item constituted a change in harmonic function. Of the 25 items that contained a difference, 13 of those differences constituted a harmonic shift. The other 12 items had differences that maintained the initial harmonic function, so students would have to detect a difference in the size of intervals from note to note rather than a harmonic shift in order to answer correctly.

Based on comments made during testing, some students answered with the wrong key once or twice in a session (pressed S when they meant to press D). Misfires could be avoided by employing a paradigm using a vocal response rather than a keyed one.

The original piloted measure was reduced from 40 items to 31 in order to avoid fatigue among the participants. Students still exhibited some fatigue and, as a result, may have started guessing randomly. The random presentation order of the items would have prevented any effect of fatigue on a particular item, but it still could have had an effect on performance on this measure overall.

Question 3. *Considering the college music students' performance only on measures of auditory representation, what relationships exist between these measures?*

In this sample, a moderate relationship exists between measures of tonic centrality and tonal grouping. This relationship is most likely a result of the role that representation of tonic centrality may play in tonal grouping. If students were likely to develop an expectation of what the printed notation would sound like (Schön and Besson, 2005), they could center that expectation on tonic and hear the notated pitches in terms of their relationship to tonic. Due to the moderate relationship between these variables, it seems that not all students were approaching the tonal grouping measure in this way.

Harmonic function grouping does not appear to be related to either tonic centrality or tonal grouping in this study. Though the harmonic function grouping measure contained items all from the same key (C), the alteration of harmonic function (I, IV, and V) among the items may have undermined that tonal center, thereby making retention of C as the tonal center difficult or irrelevant to the task and resulting in a low correlation between the tonic centrality measure and the harmonic function grouping measure.

As Dowling (1978) and others have found, melodic contour is one of the two major organizers of melodic perception. Melodic contour also seems to be the driving force in the ability of students to make the discriminations necessary to score well on the tonal grouping measure. This organizing mechanism is controlled for in the harmonic grouping measure and therefore unavailable. If discrimination of items in the harmonic grouping measure relies neither on grounding in a tonal center nor on a representation of melodic contour, it seems reasonable that scores on this measure bore little relationship to the other two.

Question 4. *Considering all measures, what relationships exist between college music students' auditory representations and their overall musicianship?*

The scores collected in this sample demonstrated moderate relationships between the overall musicianship measure and the measures of tonic centrality ($\tau = .45$) and tonal grouping ($\tau = .43$) and a weak relationship between the overall musicianship measure and the harmonic function grouping measure ($\tau = .28$). All relationships were significant ($p < .001$). Recall that I chose a non-parametric test to evaluate these relationships due to the non-normal distribution present in scores on three of the measures. Furthermore, I used Kendall's tau because it has an advantage over Spearman's rho when there are a high number of tied ranks in a set of scores. When comparing these values to those found in other studies, it is useful to remember that Kendall's tau is more conservative and therefore Spearman's rho yields higher correlation values for each of these relationships (ρ = .61, .56, and .40, respectively; all relationships were significant at the $p < .001$ level).

Tonic centrality measure. Recall that Colwell (1969) considered the ability to infer tonic basic to all forms of musicianship. It seems music reading can be considered one of these forms of musicianship. On the basis of extant research literature, Schmuckler (2009) also established tonality and contour as "the two primary characteristics of listeners' perceptions of melody" (p.132) and Simoens & Tervaniemi (2013) found music notation very quickly evokes auditory representations in musicians. Thus, reading a melody is a form of melodic perception and tonality is one of the two principle organizers of incoming information.

In the absence of absolute pitch, awareness of tonic is necessary to remain in the same key throughout a tonal sightsinging melody (Colwell, 1969). Such awareness, and the relation of other pitches to tonic, is the basis for the argument in favor of solfège or numbers with a moveable tonic (e.g., Smith, 1991).

Tonal grouping measure. Colwell (1969) called this measure "a reliable test of music reading" (p. 113) and it does appear that the measure assumes a basic familiarity with music notation. The current results support the notion that grouping by contour may be a key organizing mechanism for melodic perception and thus for melodic reading.

Harmonic function grouping measure. This measure shows only a weak relationship to music reading in this study, though other studies such as one conducted by Thompson (2004) have suggested that musicians who read music well employ knowledge of harmonic structures within the music to find correct pitches. Likewise, Karpinski (2000) noted that harmonic thinking while sight-singing employs the recognition of harmonic implications that underlie tonal melodies. He also noted that this skill depends on a reader's ability to "interpret harmonic implications in real time" (p.182). Perhaps the ability to employ harmonic function grouping is not automatic enough within this sample and/or at this level of musical development to be useful.

I did expect to find a stronger relationship between the harmonic function grouping measure and the overall musicianship measure because they are based on the same taxonomy of tonal patterns (Gordon, 1976). Perhaps the harmonic function grouping task puts constraints on the participants that impede them from using knowledge of basic patterns (taxonomy). For example, Dowling (1968) suggested that experienced musicians used "memory for contour combined with knowledge of the tonal scale framework" (p. 292) when comparing new melodies to those heard before. He further suggested that inexperienced listeners were using a "strategy involving pitch-interval representations" (p. 289). The current measure controlled for contour, so a memory for contour would not be very useful. Knowledge of the tonal scale framework may have also been of limited usefulness given that half of the different items did not shift harmonically. It could be, then, that students who did well in this measure were holding the pitches in their working memory through some other mechanism, such as an encoding of interval sizes between pitches—a method used most in Dowling's study by the most inexperienced musicians—and therefore, were possibly the weaker performers in the measure of overall musicianship.

Henry (1999) created the overall musicianship measure with two scoring options: one in which the rater assesses every note and one in which the rater assesses only the moments in which the students sing patterns from the taxonomy (i.e., the short scoring system). A final possibility is that using the short scoring system would have allowed for more meaningful comparisons to the harmonic function grouping measure because this system focused on specific tonal skills. This is unlikely, though, because the correlation between these two types of scoring in this sample was very high ($r = .95, p < .001$).

Question 5. *Considering college music students' performance on all measures, what differences exist between classical musicians and non-classical musicians?*

Though the non-classical musicians in this sample outscored their classical counterparts on every measure except for the tonal grouping measure, scores were significantly different ($p = .002$) between groups only for the tonic centrality measure. Upon applying the False Discovery Rate to correct for multiple comparisons, the harmonic function grouping differences approached statistical significance ($p = .026$, .025 would have been significant). Further investigation revealed that the relationships between the overall musicianship measure and measures of both tonic centrality and tonal grouping were much stronger for the non-classical musicians than for the classical musicians. It appears that the non-classical musicians may have had more facility in grounding themselves in a tonality and using that grounding to solve musical problems than their classical counterparts.

Based on Woody and Lehmann's (2010) study, I expected non-classical students to perform significantly better on the measure of harmonic function grouping. The results for this sample violated that expectation. It seems that, if the non-classical students were more adept at hearing harmonic function, they may not have applied this strategy to the overall musicianship measure. Dowling (1986) suggested that some listeners might perceive melodies as "sequences of pitch intervals" (p. 281). Non-classical musicians in the current study may have relied instead on a less powerful strategy like the one Dowling suggested. Of course, it is also possible that non-classical musicians do group more by harmonic function, but the measure in the current study was incapable of capturing that representation.

Results supported the notion that there is essentially a notation-familiarity threshold non-classical students have to meet in order to perform well on the overall musicianship measure. The relationship between the tonal grouping measure and the overall musicianship measure was much stronger in the non-classical group than in the classical one. Furthermore, when the non-classical musicians who appeared not to have reached a threshold of familiarity with notation (i.e., poor scores on the tonal grouping measure) were removed, the mean score for the overall musicianship measure improved to 109 (Mdn = 120) from 104 (Mdn = 113). The increase in ability was not as dramatic when I removed the classical musicians who met the same criteria. The mean score for the overall musicianship measure in that case improved to 98.72 (Mdn = 97) from 97.45 (Mdn = 95). It seems, then, that non-classical musicians who demonstrate the ability to form expectations about the music based on the written notation (as indicated by the tonal grouping measure) perform much better on the overall musicianship measure than their classical counterparts.

Creech et al. (2008) found the non-classical musicians in their study to have far more experience learning music aurally than classically trained musicians. Focusing on ear-based abilities, Woody and Lehmann (2010) reported more experience playing by ear, transcribing, improvising, and composing among non-classical musicians. The researchers also noticed a tendency for non-classical musicians to memorize music they heard in fewer attempts, indicating a better conceptual understanding and a more efficient encoding of music into memory. McPherson (1993) linked activities that are a regular part of the musical lives of non-classical musicians (e.g., playing from memory, playing by ear, improvising) to abilities in sight-reading. Combined with evidence from the present study, it seems that the ear-based activities of the non-classical musicians contributed to their greater efficiency in inferring tonic and enabled them to use a tonal framework to read music on par with their classical counterparts.

General Discussion

In light of the results discussed above, one general theme emerges: the dominance of the tonic centrality measure both in relation to the other measures in the study as well as in regard to classical vs. non-classical musicians. The finding also warrants a reflection on the theoretical framework posed in Chapter 1.

Dominance of the tonic centrality measure. A key finding in the current study concerns students' abilities to form auditory representations of the centrality of tonic. Though these students performed well on the measure, there was still quite a bit of variance, indicating that the students' abilities to ground themselves in a tonal center is not a given. Still, the formation of this representation was the dominant factor in scores on measures of overall musicianship and tonal grouping.

Non-classical musicians seemed to possess greater abilities in the formation of this representation and to use their abilities to infer and center themselves on tonic to their advantage in performing the sight-singing task. It seems to have been especially true if they had a certain threshold of familiarity with notation.

This finding has a precedent in the literature. Henry (1999) found that high school students' abilities to end on tonic in the measure of overall musicianship bore a strong correlation to overall skill in the measure ($r = .77, p < .05$). Students would certainly have to possess an awareness of tonic to make this correlation appear. It is possible that establishing a tonic for one's own performance (as in the overall musicianship measure) is a slightly different task than inferring tonic from another source (as in the tonic centrality measure), which could contribute to the weaker relationship between the tonic centrality measure and the overall musicianship measure in this study ($\tau = .45, p < .001$).

As previously noted, the students in the present study also scored better in general on the overall musicianship measure than the high schoolers in Henry's study, indicating that they are a bit farther along in their development as musicians. It could be that the importance of tonic centrality lessens as musical skills integrate. In other words, as musicians develop, their ability to infer tonic could become more and more of a given, and thus it would not come to bear (statistically) as much on their ability to read music. It seems, then, that in other samples, a group that exhibited a wider variance in their abilities on the tonic centrality measure would be most likely to produce scores that bear a relationship to the overall musicianship measure and a group that produces scores clustered at the top (almost all perfect) would not.

Reflection on the theoretical framework. The theoretical framework introduced in Chapter 1 allowed me to propose questions about the hierarchical nature of the basic auditory representations of interest in this study. It appears from the results that the auditory representation of the centrality of tonic is indeed paramount among these representations, followed by the auditory representation of music into sets of generic tonal groups, most likely governed by contour. This is apparent not only in the accuracy rates on the individual measures, but also in the degree to which the measure of overall musicianship related to these individual representations.

Furthermore, non-classical musicians showed a significant advantage in the ability to represent tonic when compared to their classical peers. Non-classical musicians' overall musicianship scores were also more strongly tied to a grounding in tonality and the tonal grouping of pitches than were the scores of their classical counterparts. Thus, it does appear that the different emphases placed on musicians studying different genres of music have an effect on the formation and development of the representation of tonic centrality and perhaps tonal grouping.

Implications for Educators

My study carries implications for music educators on all levels. The discussion below begins with implications for music educators in primary and secondary levels, followed by those for music theory pedagogues, and ends with those for my personal practice.

Implications for K-12 music educators. The findings of my study seem to support the notion that ear-based forms of musicianship such as those employed by non-classical musicians can help develop auditory representations that rival or surpass the quality of those developed in an education based mostly on musical notation. Furthermore, as Creech et al. (2008) noted, non-classical musicians typically begin pursuing their musical interests in upper elementary school (around age 8). It seems necessary and fair to allow a place for such ear-based activities and types of musicianship to flourish in our K-12 curricula. Far from detracting from the goals of music education, these activities would likely enhance them. Inclusion involves making space for these activities in the curriculum, effort toward teaching or facilitating them effectively, and possibly rethinking the desired outcomes of a K-12 music education in order to better align it with the goals of our students as current and lifelong music learners.

In terms of specific musical abilities, if the ability to infer and refer to tonic is at the center of musicianship, then all musicians could benefit from grounding in tonality and tonal awareness. This is certainly not a new idea, as evidenced in the early singing schools in America. More recently, major contributors to music education have made this grounding central to their ideas (e.g., Gordon). Yet, as was the case in my sample, some students are making their way through primary and secondary education without this fundamental awareness. Given the current resources, it is not entirely clear why this is happening. In the primary curriculum, Orff, Kodaly and Gordon all utilize moveable do, emphasizing the importance of the resting tone. The presence of sight-singing evaluation at American choral festivals and vocal auditions has raised awareness of the importance of tonic centrality (Demorest, 2001) and educators such as Dodson (1989) have urged teachers to use vocalization [presumably with a tonal center] as an aid to audiation with instrumental students. Perhaps this foundational skill is getting lost in the other requirements teachers must meet during the course of instruction. A constant reminder to students of what tonic is and what it sounds like in any piece of music (including the singing of the tonic pitch) at any level of instruction would be an easy move toward raising tonic awareness among our students.

At an even broader level, melodic perception is grounded in tonic centrality (Schmuckler, 2009), so we do a disservice if we do not help our students understand the role of tonic and help them hear music in relation to it. Results of this study highlight the importance of such grounding in music reading (one type of music perception). It seems likely that other forms of musicianship rely on a similar grounding (Colwell, 1969; McPherson, 1993); therefore, an awareness of tonality and function would lead to better, more independent musicianship on many levels.

To this end, it may be useful for educators to look to sight-singing as a way to inculcate basic auditory representations that are central to all forms of musicianship. There is probably very little value if the focus is only on singing the right notes in the right sequence. As Michael Rogers (2004) noted:

> The purpose of sightsinging is not to provide a sight-reading service for music-department choral groups or to develop articulate vocal response—although these may be worthwhile fringe benefits. The goal again is to produce a listener who can hear musical patterns (p. 100).

Sight-singing gives students an opportunity to incorporate different auditory representations into a real-time musical task. I would suggest using varied genres of music to form these representations in order to make the point to our students that these skills are valuable across genres.

Furthermore, if a student has the motor control to sing intended pitches (see Pfordresher and Brown, 2007), then singing may be a better route to developing auditory representations than playing an instrument because singers must develop "their own internal reference points to accurately produce the sound suggested by the written notation" (Klemp, 2009, p.38), as opposed to supplying the correct fingering, valve or key on an instrument. On a physical/cognitive level, development of auditory representations through singing is valuable due to the role of singing-like actions in the subvocalization that happens when musicians employ musical imagery (Brodsky, Henik, Rubinstein, and Zorman, 2003). Woody and Lehmann (2010) also found singing to be more closely related to musicians' auditory representation of a melody than playing an instrument.

For those who primarily perform on instruments with fixed fingerings (e.g., piano, woodwinds), sight-singing is valuable because it forces this internal representation of sound:

> Because instrumentalists can avoid the auditory internalization necessary for sight-singing, the skill levels of their pitch reading may be even more camouflaged than those of singers. Instrumentalists often learn to 'read' by simply applying a manual reaction to the written musical symbol. No inner hearing is necessary. (Bennett, 1984, p. 63)

Brodsky, Henik, Rubinstein and Zorman (2003) considered the ability to develop internal concepts of sound, or musical images, to be the "outstanding mark of a musical mind" (p.603). If our goal as educators is to produce musicians who can think in music rather than simply reproduce repertoire, then we must foster core auditory representations — especially that of tonic centrality — in our students.

Implications for music theory pedagogues. Much conversation in recent theory pedagogy literature has revolved around the inclusion of popular music (e.g., Rosenberg, 2014). In addition, the *Music Theory Spectrum* regularly includes articles on the stylistic conventions of popular music. Ear-based forms of musicianship such as improvisation (e.g., Palmer, 2014; Sarath, 2013; Marvin, 2012) and playing by ear (e.g., Woody, 2012; Musco, 2010) are vital to the development of the kind of musical thinking we hope to foster in our students. Researchers such as Woody and Lehmann (2010) and McPherson (1993) have also argued that ear-based musicianship is valuable to musicians in all genres. It is certainly not the case that these pedagogues are suggesting an elimination of more traditional classroom activities, but that we might achieve a balance of notation and ear-based activities for the benefit of our students. The results of my study seem to support this notion. I would also add that the reason we use any of these activities is not simply for instruction in that singular activity, but for the deep musical understandings (auditory representations) that may occur and strengthen as a result. If we take the view that the deeper musical understandings are the goal, then we can use exercises attuned to our students' musical goals to achieve these ends. For example, if the goal is to play in tune, students will benefit from an awareness of tonic and tonal function in order to play/sing notes according to where they lie in the scale or chord. Likewise, students benefit from the same awareness of tonic and tonal function if their goal is to quickly write out a chord chart for a song they have heard or composed.

I found in this study that, for classical musicians, abilities with notation may actually be a hindrance, as they may try to use their knowledge of notation to almost mathematically solve musical problems rather than hearing the notation in their heads. In order to avoid this problem, it is effective to remove the crutch and encourage them to perform for a while in a non-notated solfège system, to promote musical understanding through a functional understanding of what those pitches actually mean (Karpinski, 2000). After all, the goal is for them to be able to "perceive, organize, and then conceptualize" (Rogers, 2004, p.7) what they hear.

For non-classical musicians, the only barrier to better performance in theory work may be the lack of a common language with which to express what they hear (i.e., basic notation skills). In other words, these students may be able to hear what we are asking them to hear, but they simply do not know what to call it. Learning how to assign a functional solfège system to what they hear is an important first step. Transitioning into the application of that functional system to the staff can be aided by moving to a system in which the functional short-hand is written out not on a single horizontal line, but in reference to the height notes would assume on a staff. For example, "Do-Re-Mi" would be written in an ascending line. Most importantly here, it seems fair to address this deficiency among incoming music students before expecting them to attempt coursework grounded in a familiarity with notation.

Educators and researchers such as McPherson and Gabrielsson (2002) and Gordon (2003) contended that ear-based musicianship should precede notation-based musicianship for all students in order to provide the necessary framework of sounds and experiences needed to bring meaning to written notation. We cannot assume that our students have the requisite auditory experiences prior to their entrance into the university to enable them to move ahead in a notation-based curriculum regardless of their chosen genre. Anything we teach through notation must be preceded and supported by auditory experiences throughout.

Implications for my own practice. The first thing that changed in my own practice as a result of this study was a reduction in notation-based work. While I was teaching at University A and conducting this study, my colleagues and I made a shift toward eliminating notation in the first level of aural skills. This shift was not a result of my work, but happened fortuitously at the same time. We handled tasks such as dictation and sight-singing by asking the students to respond to dictation exercises in solfège and by giving them exercises to sight-sing only in solfège rather than exercises printed on a staff. Anecdotally, I saw some improvement in my students' abilities in these areas and felt that the improvement would be bolstered by other opportunities outside of the aural skills classroom (which met for 2 hours a week) to practice these skills. A non-notation based approach helped both because students learned to think without notation and they were not handicapped by the temptation to use a staff (and with it an over-reliance on contour) to solve problems that were easier to solve functionally.

I have found in my own teaching that, across the first two levels of the class, students can "get away" with not really thinking in relationship to tonic by perhaps relying on interval identification or contour, but the third level brings new challenges to those who have not embraced a grounding in tonic. The focus on chromaticism and modulation that happens in that level is very difficult for those who cannot retain a representation of tonic or form one of a new tonic (as in the case of modulation). As a result, I have emphasized a tonic-centered, functional approach to melodic and harmonic exercises with a renewed vigor.

The second area affected by these results was in regard to my support of opportunities for students who lack prerequisite skills for successful participation in aural skills classes. The 66% accuracy rate with which the students in this sample responded to the measure of overall musicianship was somewhat alarming to me, as this rate is not considered passing in my classes. Given that sight-singing is "by far, the most ubiquitous means through which music-reading skills are developed and assessed" (Karpinski, 2000, p.145), it seems there are at least two possible reactions to this accuracy rate: 1. Set a lower standard of difficulty for the students so they can be successful at smaller increments. 2. Accept a lower accuracy rate as the lower threshold for passing and award students who achieve higher rates with higher grades.

The first reaction seems plausible from an educational standpoint. The difficulty lies in the dilemma that students are expected to pass through aural skills training in four semesters at many universities (Rogers, 2004), so there may not be time to move at such a pace. Of course, these students could always repeat levels of a class if they have not achieved proficiency. In reality, this has ramifications for student expenses in a climate of ever-increasing college tuition. One alternative would be to only admit students who have demonstrated a level of musicianship that would enable success in music school coursework, but the means for assessing these levels (and the accompanying resources for doing so) have been historically difficult to establish (Shuter-Dyson & Gabriel, 1981). Interestingly, some of the fundamental musical capacities that have shown a relationship to students' musical outcomes, such as tonal memory, are precisely the skills non-classical musicians rely on daily (Creech et al., 2008), so an entrance exam incorporating these skills would not necessarily favor students studying one genre over the other.

The second reaction, in my opinion, does a disservice to the students by perpetuating the difficulties of those who are not performing well. Courses in aural skills, music theory, and performance are cumulative, so allowing students to progress who are not ready to do so in the hopes they will eventually "get it" seems cruel.

A third reaction could be to provide pre-requisite courses to aid students who do not have the readiness to do well in music coursework, such as a music fundamentals course, which would help cultivate the auditory representations students will use in their lives as musicians (e.g., tonic centrality, tonal grouping) and provide the necessary skills to communicate in musical domains (e.g., tonal function, music notation). Although such a requirement could possibly add a course to a student's requirements, it seems much more humane to proactively set students who need this course up for success than to require that they repeat a course as a result of failure. Such a program is implemented at University A. Other music programs such as those at Indiana and Eastman address prerequisite needs through on-line training courses taken by students before they take their initial placement exams (Marvin, 2012).

The third area of my practice that has evolved as a result of this research concerns the role of sight-singing. I have become more aware of the role of sight-singing as a diagnostic tool rather than an end unto itself. This view, of course, has not begun with me (see, for example, Rogers, 2004). When I encounter students who are struggling in sight-singing, I find it easier now to take a step back and see what their struggles are telling me about their overall musicianship. Are they struggling to keep tonic in their heads? Perhaps they have noticed the same deficiency in practicing music for their private lessons. Are they singing pitches that do not agree with the solfège syllables they are using? They may have a misunderstanding of function and that note's relationship to tonic. Are they performing a melody with the right contour, but not the correct pitches within that contour? They may be exhibiting an over-reliance on the contour of notation and a lack of acuity in their representation of that melody. I have found anecdotally that this problem translates to students' abilities to remember melodies accurately by ear (a foundational skill for non-classical students). It has also been the case in my practice that aiding students in making connections between sight-singing skill and other areas of their musical lives often motivates them, because they understand how these skills may transfer into their chosen profession.

Suggestions for further research

The following suggestions range from specific recommendations for ways this particular study could be expanded to broader recommendations for related studies. I begin with an exploration of representations that seem to be related in my study.

The relationship between the tonic centrality measure and the tonal grouping measure warrants further investigation. It would be interesting to know the relative strength of the relationships between these representations and overall musicianship and any possible covariance that exists in these relationships. The two correlations are so close that further investigation using a multiple regression analysis may reveal a dominance of one representation over the other. In the classical group, the tonic centrality measure bore a stronger relationship to the overall musicianship measure than the tonal grouping measure did. In the non-classical group, this order of strength was reversed. Such a shift may indicate a difference in the way these two types of musicians use these representations.

In terms of the relationship between basic auditory representations and overall musicianship, an examination of basic representations by achievement group with performance in overall musicianship as the classifying variable would provide more information about how these representations interact as a musician develops. In other words, is the profile of representations different for the more developed musicians than for those in the beginning stages?

It would be useful to examine the types of errors made in each of these measures in order to determine if there are certain conditions that prove to be more difficult for students to answer correctly. For example, in the overall musicianship measure, analysis of performance on each pattern in the taxonomy (short scoring system) would yield interesting results about the accessibility of the patterns in this realistic performance setting. It would be useful to know if there were items on the tonic centrality measure that students consistently found to be more difficult and to determine why this was so. It would also be useful to know if there was a pattern among students who scored poorly on this measure. Were they perhaps consistently drawn to another scale degree or were they influenced by the order of presentation of the possible answers? In the tonal grouping measure, can the errors be categorized by distance from the printed note or by the location in the measure? Is there an effect of harmonic function, vertical note placement, or temporal note placement in the harmonic grouping measure?

Each measure could be expanded or modified to increase variance and further investigate each construct. One could expand the tonic centrality measure to include examples in which tonic was still statistically discernible, but not placed in a predictable voice part. In the current measure, tonic was most often placed in the soprano at the end of each cadence. One could also expand the tonal grouping measure to include more items that do not violate contour (only one exists in the current measure).

In addition, the measures could be assessed using different criteria. In experimental psychology, reaction times often serve as an indicator of cognition that may be a more sensitive indicator of underlying mental processes than accuracy (Luce, 1986). Reaction time to items that were different was the most interesting assessment in the original harmonic function grouping measure (Holahan, Saunders, and Goldberg, 2000). Reaction times were not used in this study because the paper tests (tonic centrality and tonal grouping) did not allow for collection of those data. It would be interesting to examine reaction times for different items in the harmonic grouping measure in relation to the overall musicianship measure to see if this is a more telling comparison than the accuracy data that I used. Along the same line, paper-based tests could easily be delivered via computer in order to assess reaction times across measures.

An examination of all measures among different instrument specialties would provide information on the link between auditory representations and specific types of training. For example, are pianists better at forming any of these representations due to the kinesthetic feedback of their piano training (Wöllner & Williamon, 2007)? How do singers, who have presumably developed efficient motor control of their voices (Pfordresher and Brown, 2007), perform on these tasks as a group? If string players started with the Suzuki method, do they have better developed auditory representations as a result? Do their results more closely resemble those of non-classical musicians given the emphasis on ear development in that method?

Expanding the scope a bit, a longitudinal study assessing differences in basic representations among classical and non-classical students would provide a deeper understanding of the current results. As each group grows stronger in their areas of weakness, do their differences remain or resolve? Studies such as Scripp's (1995) demonstrate that, as musicians develop, disparate skills become integrated and begin to work together toward a musical goal. It would be interesting to see if such integration can be observed among classical and non-classical musicians to a point at which the differences between the groups are diminished.

Further investigations could also use a similar study paradigm to assess other basic representations (e.g., memory for pitch patterns, functional understanding of heard pitches), providing us with a more detailed picture of how they relate to representations in the current study. Eventually, many more representations could be combined with a much larger sample size to explore the relative role each of them play in overall musicianship.

Finally, on a much larger scope, McPherson (1993) asserted that basic forms of musicianship such as improvisation, playing by ear, music reading and playing from memory require "an ability to audiate for successful completion of the tasks involved" (p.231). It would be useful to explore the role of these basic auditory representations in relationship to improvisation, playing by ear, and playing from memory to examine if and how the roles of basic auditory representations change from task to task. In a sense, my evaluation of basic representations among classical and non-classical students began to address this question due to the varying types of performing in which students in these genres regularly engage. An investigation of more specific relationships between representations and types of performances may lead to more conclusive results.

Conclusions

The participants in this study were the most skilled at forming auditory representations of tonic centrality and non-classical musicians significantly outperformed classical musicians in this area. Tonic centrality was also most strongly correlated with overall musicianship within the sample, and this relationship appeared to be stronger among non-classical musicians than among classical musicians. It should be noted that all findings presented in this study are generalizable only to similar populations. For a detailed description of the current population see Chapter 4 (Table 1).

What seems clear is that the non-classical musicians' experiences with auditory-based musicianship conferred them an advantage over those who perhaps did not have the same experiences in their musical biographies. With the changing population of American tertiary music programs and the diverse musical demands our graduates face as they begin careers in music, we are in a position to play to our strengths: namely, students who study non-classical genres and the experience with ear-based music that they bring. Perhaps we can widen the "narrow focus of the traditional learning system" (Lebler, Burt-Perkins, & Carey, 2009, p.

243) to include more focus on the auditory skills common to the diverse forms of musicianship required of today's professional musicians regardless of genre.

Appendix A

Musical Background Questionnaire

1. Subject code ____

2. Birth date____________________________________

3. Gender _____________________________________

4. Are you right or left handed?_____________________

5. Major_______________________________________

6. Principal instrument (including voice) ______________

7. Other instruments played (including number of years studied)

____

____

8. Have you ever sung in a choir? ______

9. If yes, how many years (count one semester as half a year)? ______

10. Were you ever taught sight-singing before college? *(If not, skip to question #14)* ___

11. If yes, did you use solfege? ______

12. If yes, did you use scale degree numbers? ______

13. If yes, did you use Curwen-Glover (Kodaly) hand signs? ______

14. Have you ever taken private voice lessons? ______

15. If yes, how long (count one semester as half a year)? ______

16. If yes, how old were you when you began voice lessons? ______

17. Prior to college, had you ever taken piano lessons? ______

18. If yes, how old were you when you began piano instruction? ______

19. If yes, how long did you take piano lessons (count one semester as half a year)? ______

20. How many semesters of piano have you had since entering college? _______

21. If you are currently enrolled in class piano (or private equivalent), in what level are you currently enrolled? _______

22. Have you ever been involved in an instrumental (not piano) ensemble? _______

23. If yes, how many years (count one semester as half a year)? _______

24. Have you ever taken private instrumental lessons (not piano)? _______

25. If yes, how many years (count one semester as half a year)? _______

26. Did you take any theory courses before entering college? _______

27. If yes, how many semesters? _______

28. Did you take AP theory? _______

29. If yes, what was your score on the exam? _______

30. What city is your hometown? _______

Appendix B

Transcript of Instructions for Measures

Tonic Centrality (Music Achievement Tests, Test 2, part 2)
Recorded Directions:

Section a: "This subtest measures your ability to determine the key tone in music. A key tone is the same as the home tone, number 1, or do. You will hear four chords followed by three single tones. The chords will establish a feeling for tonality, or where "1" or do is located. From the three single tones that follow the chords, you are to select the tone which sounds like the key tone. After you have listened carefully to the four chords, if the first single tone sounds like the key tone, fill in the blank marked "1." If the second single tone sounds like the key tone, fill in the blank marked number "2." If the third single tone sounds like the key tone, fill in the blank marked number "3." If none of the single tones sounds like the key tone of the chord pattern, fill in the blank marked "0."

"Two examples will be played. Answer these examples to make sure that you understand what you are to do. There is only one correct answer for each question.

"Example A…… The first single tone was the key tone. Notice that the blank marked number "1" has been filled in.

"Example B…..None of the single tones played was the key tone. You should have filled in the blank marked "0."

"Get ready for question 29." (Items 29-38 follow.)

Section b: "This subtest measures your ability to determine the key tone in a musical phrase. You will hear a short melody followed by three single tones. The melody will establish a feeling for tonality, or where "1," or do is located. You are to select from the three single tones following the melody, the tone which sounds like the key tone, or tonal center. After you have listened carefully to the melody, if the first single tone sounds like the key tone, fill in the blank marked "1." If the second single tone sounds like the key tone, fill in the blank marked "2." If the third single tone sounds like the key tone, fill in the blank marked "0."

"Two examples will be played. Answer these examples to make sure that you understand what you are to do. There is only one correct answer for each question.

"Example A….. The first single tone was the key tone. Notice that the blank marked '1' is filled in.

"Example B….. The third single tone was the key tone. You should have filled in the blank marked number '3.'

"Get ready for question 39." (Items 39-48 follow.)

Tonal Grouping (Music Achievement Tests, Test 2, part 3)
Recorded Directions:

Section a: "This subtest measures your ability to compare melodic notation with music that you hear. Follow the music written on your answer sheet and compare it with the music played on the record. You are to select the measures or measures written incorrectly.

"When one or more pitches written on your answer sheet are different from that played, count the measure wrong. The rhythm is always written correctly; look only for mistakes in pitch. Fill in the blank below every measure played differently in pitch from the notation. For example, if one or more pitches in a measure are written differently from the pitches played, fill in the blank below the measure. If the entire melody is played exactly as written, fill in the blank marked "0" at the end of the phrase.

"Remember, there may be more than one incorrect measure for each question.

"Two examples will be played. Answer these examples to make sure you understand what you are to do."

"Example A….The second measure was written incorrectly. Notice that the blank below measure '2' has been filled in.

"Example B….The second and fourth measures have been written incorrectly. You should have filled in the blanks below both measures '2' and '4.'

"Get ready for question 49." (Items 49-60 follow.)

*Overall Musicianship (*Vocal Sight Reading Inventory, Form B)

Instructions on computer screen: "This test is designed to measure sight-singing skills that occur in music you may sing in your Ear Training class, in private lessons, or in choral rehearsals. Only pitch will be evaluated. Your performance will be recorded to ensure that it is properly scored.

"You will hear a I-IV-V-I progression and the starting note as you see a melody on the screen. You will have 30 seconds to study the example. After 30 seconds, you will be instructed to sing the example on solfege or numbers. Choose any tempo, but keep it consistent. If you make a mistake, try to continue without stopping or starting over.

"If you have questions, you may ask the test administrator at this time. Press the space bar when you are ready to begin. (Subject studies and sings the first example.) Example two (Repeat this process for each of the trials.) You have completed this test."

Harmonic Function Grouping

The following directions were displayed on the computer screen:

"You will hear a short pattern of notes followed by a second short pattern. Your task is to determine if the pitches in the patterns are the same or different. The rhythms will stay the same. Indicate your choice by pressing 's' on the keyboard for 'same' and 'd' for 'different.' Please complete the task as quickly and as accurately as possible."

Appendix C

Pilot Test

The measure of harmonic function grouping (Holahan, Saunders and Goldberg, 2000) required modification and pilot testing before it was useable in the current study. Holahan, Saunders and Goldberg designed this measure for use in a study where the sample population consisted of 28% college music majors, and "the observed mean scores of the musician group [college music majors] were systematically higher than those for the nonmusician group on all three tests" (p. 169). The population for the present study consisted entirely of college music majors, and presumably, the test in its original form would have been too easy. Upon Holahan's recommendation (phone conversation, August 29, 2008; personal email, September 19, 2008; personal email, October 11, 2008), I decided to revise the original measure from the paper by Holahan, et al. to include five notes rather than three to increase the complexity of the measure. In principle this should have increased the variance in scores, which would help me to better discriminate between the abilities of the participants.

Holahan, Saunders and Goldberg (2000) developed an aural tonal pattern recognition measure in which participants judged two aurally presented tonal patterns to be the same or different. The researchers constructed three tonal tests, each consisting of 48 pairs of three-tone patterns in major tonality. All patterns came from the taxonomy of tonal patterns by Gordon (1976) in which he organizes simple patterns by harmonic function and difficulty level. In each of the three tests, 12 pairs were "same" items and 36 pairs were "different" items (Holahan, et al., 2000). Items were balanced across four melodic contours (ascending, descending, up-down, and down-up) and three harmonic functions (tonic, subdominant, dominant) across the tests. For college music majors, the test reliability ranged from *KR20* = .82-.89 ($p < .05$).

Holahan, Saunders, and Goldberg noted that items in which the different note was more than a perfect fourth away from the original note were easier to discriminate. Likewise, items in which the different note between the two patterns occurred either first or last were easier to discriminate. In order to make the revisions, I chose the items from the three original tests that mostly contained a difference not occurring in the first or last position (there was one item with a difference at the beginning and one with a difference at the end) and in which differences were smaller than a perfect fourth. I added two notes that fit into the harmonic function of the existing three notes before, after, or on either side of the existing three-note patterns and made every effort to ensure the added notes were musically meaningful in the context of the existing notes. The addition of extra notes to the original Gordon patterns did make the patterns in this measure slightly different than those actually found in the taxonomy, but the intact patterns were still embedded in the newly created ones. In the 40 items I constructed for this measure, 8 items contained identical patterns. The remaining 32 items consisted of one item with a difference in the first position, one in the last position, nine in the second position, twelve in the third position, and nine in the fourth position. The items were also balanced for harmonic function (I, IV or V) and contour (ascending, descending, up then down, down then up). My study did not consist of three separate tests of 48 pairs like the original study because the expansion of notes in each pair resulted in an extension of the time it took to run the measure. In order to obtain test-retest reliability for this newly constructed measure, I ran a two-round pilot study involving 36 first year college music majors.

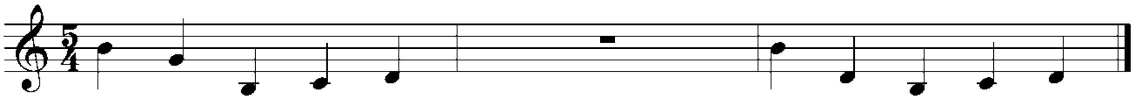
Pilot study participants viewed instructions on a computer screen indicating that they should rest their index fingers on the letters S and D. If the two patterns were the same, they should press S and if they were different, they should press D. After receiving feedback on two practice trials, participants heard the 40 pairs in random order. The software (E-Prime) that I used to create the measure recorded participants' responses, response times, and coded them as correct or incorrect.

At 40 items (average length of 12 minutes), the measure was producing considerable fatigue among participants in the pilot study. Several participants made comments indicating that they lost the ability to focus on the measure toward the end. I therefore decided to decrease the number of items on the measure. Item discriminations (also known as point-biserial correlations) were run on each item, with elimination of those items with low discriminations (< 0.2) in one or both rounds of pilot testing yielding a list of 31 items and a more manageable testing time of 9 minutes. The Cronbach Alpha of the remaining items also improved slightly over that of the original 40 ($\alpha = 0.77$ vs. $\alpha = 0.73$ for round one and $\alpha = 0.75$ vs. $\alpha = 0.71$ for round two).

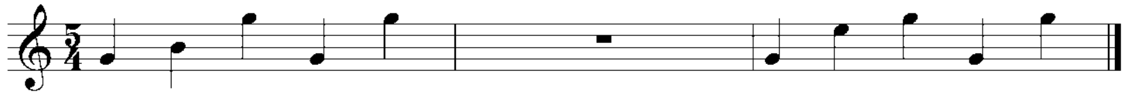
In the resulting pool of 31 items, six items were "same" items. Of the remaining items, one had a difference in position 1, eight had differences in position 2, ten in position 3, five in position 4, and one in position 5. The 25 different items varied in the intervallic distance between the two different notes. Eleven items had differences a 2nd apart, ten items had differences a 3rd apart, and four items had differences a 4th apart. Thirteen of the different items constituted a harmonic shift, while the other 12 different items remained in the same harmonic function even though one note changed. All 31 items were balanced across four melodic contours (all up, all down, up then down, down then up) and three harmonic functions (tonic, subdominant, and dominant). A complete listing of the pairs appears below.

Holahan et al. (2000) Harmonic Function Grouping Measure (rev. Yankeelov)
Each pair is labeled as follows:
difference location_original Holahan test #_original Holahan item #

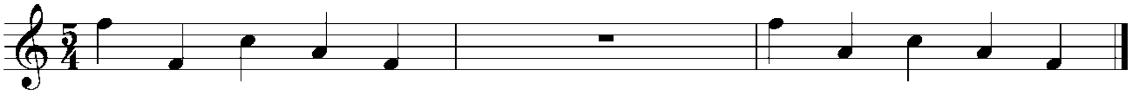
Item 1. 2_1_11



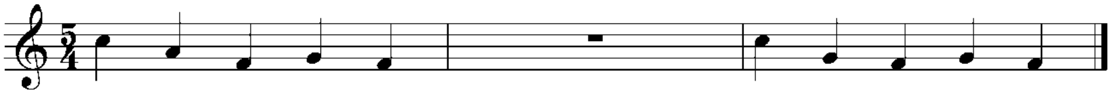
Item 2. 2_1_13



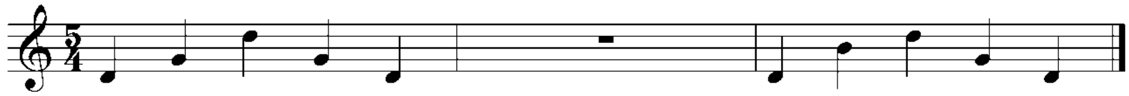
Item 3. 2_1_15



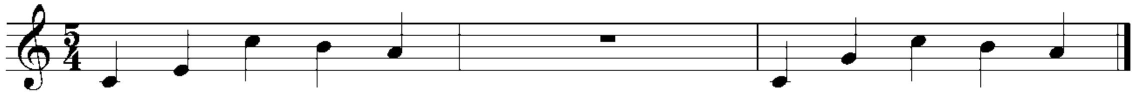
Item 4. 2_1_34



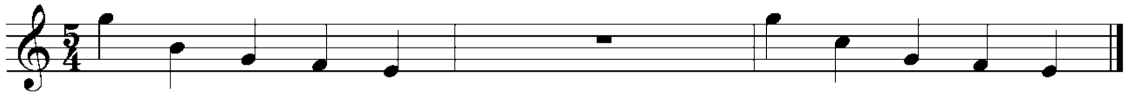
Item 5. 2_1_36



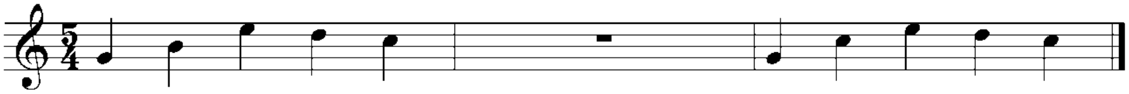
Item 6. 2_2_6



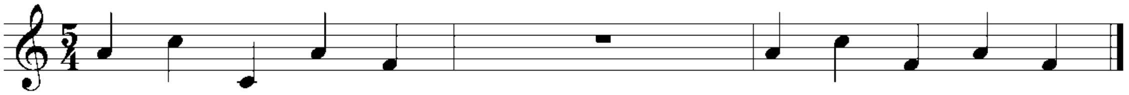
Item 7. 2_2_33



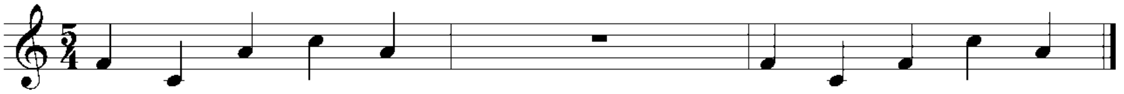
Item 8. 2_3_15



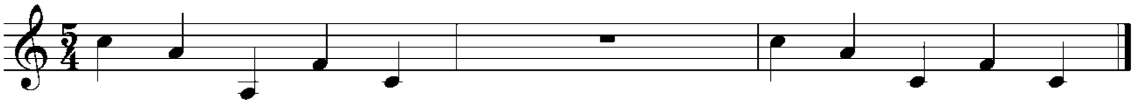
Item 9. 3_1_8



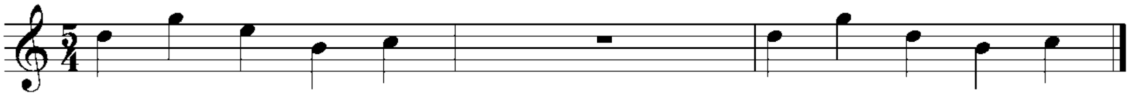
Item 10. 3_1_24



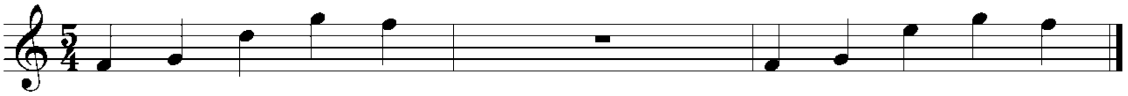
Item 11. 3_2_24



Item 12. 3_2_25



Item 13. 3_2_37



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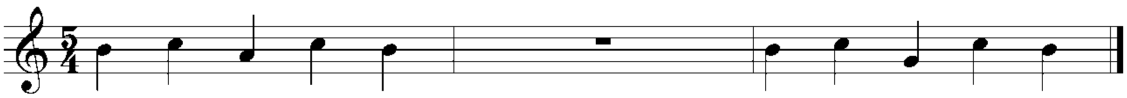

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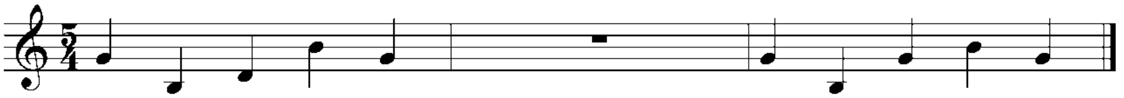

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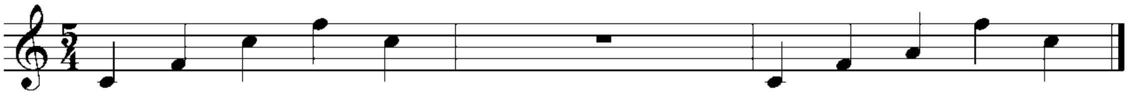

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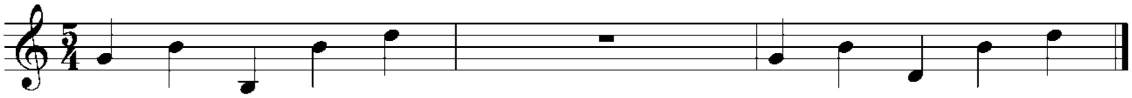

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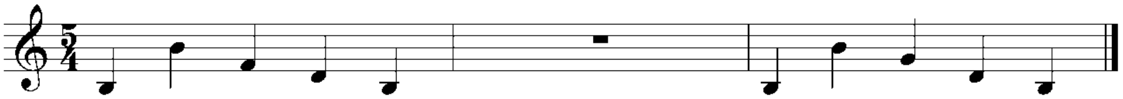

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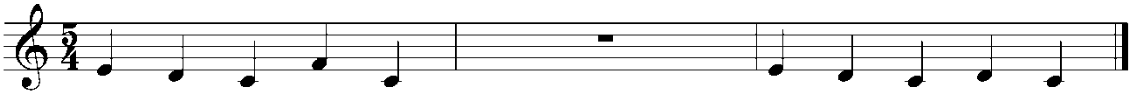

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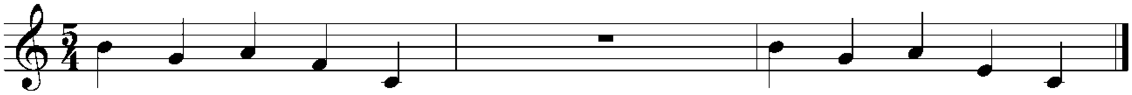
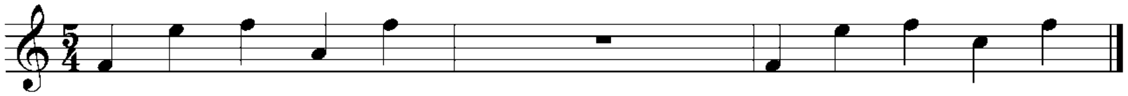


Item 21. 4_3_1



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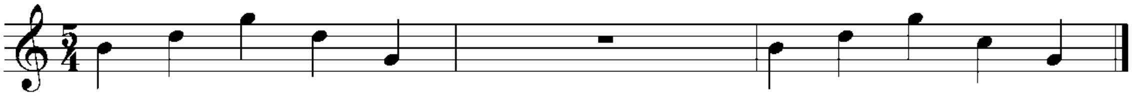

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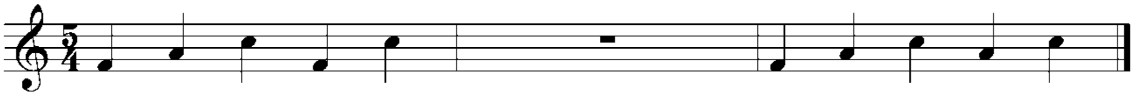

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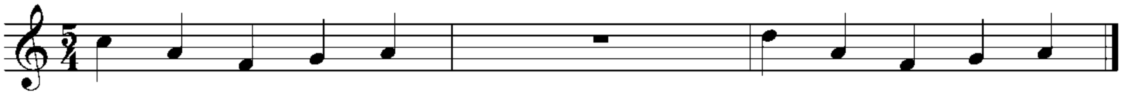

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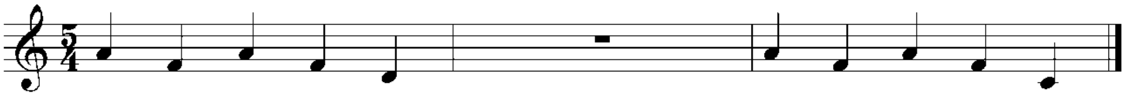

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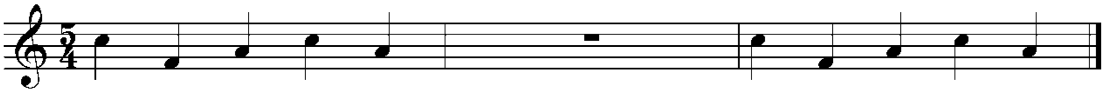

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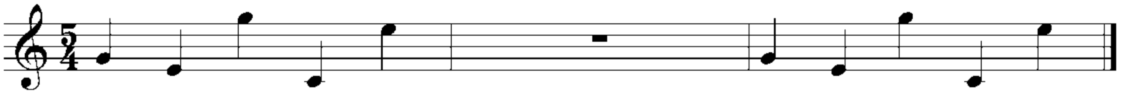

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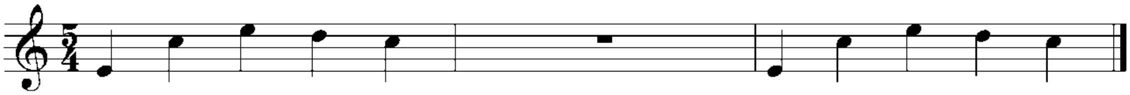

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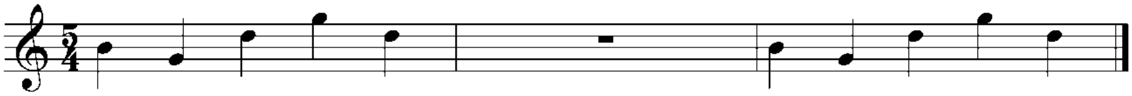

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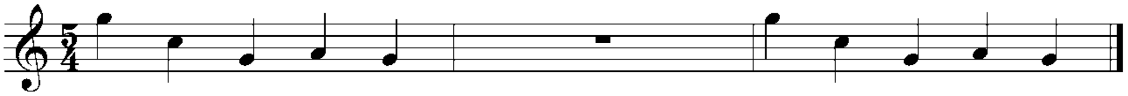

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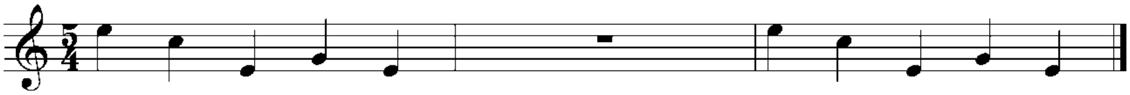

Appendix D

Consent to Participate in Research

Component skills of sight-singing
Margie Yankeelov
615-403-7972
August 13, 2009

Dear student,

You are being asked to be included in a research study that explores the component skills of sight-singing among college freshmen and sophomores. This study will be conducted by a doctoral student, Margie Yankeelov, operating as a researcher from Boston University. The study will draw approximately 150 participants from Belmont University, Tennessee State University, and Tennessee Tech.

You will be asked to commit to one 40 minute-session (it might take less time than this) outside of class in which you will participate in five short tests which measure your ability to sight-sing, to sing back a short phrase correctly, to identify the function of certain notes within a key, and to determine if two short melodies are the same or different by listening only and by looking only. Test scheduling will be very flexible and will accommodate your needs. These tests will be administered and recorded by a computer program to aid the researcher in reviewing them further. Three short multiple choice tests will take place in a group setting during one of your normal class sessions.

The only responsibilities you will have are to come to class the day of the group testing and to sign up for and attend the 40-minute individual testing session (35-minute session in class + 40-minute individual session = 75 minutes of total time commitment, only 40 minutes of which is "extra" time). You do not need to do anything else to participate. The tests and your choice to participate in them have no effect on your grade in this class or your relationship with the instructor.

Only the researcher will have access to the information collected in this project, which will be kept in a password protected computer file. All information will be held in strict confidence and may not be disclosed unless required by law or regulation. Your name or initials will not appear in any reports of this research. Questionnaire data will be stored in locked files and destroyed at the end of the research. You may request a report of your individual test scores at any time. These scores will be beneficial to you as they will help you discover your strengths and weaknesses in sight-singing which can help you improve this very important skill.

Participation in this research is voluntary. There are no known risks of participation in this study. You may choose not to answer any question at any time. You may rescind or withdraw your permission to participate at any time with no negative consequences to you.

Your participation will help teachers better understand how to teach sight-singing and how to help students learn more efficiently.

Component skills of sight-singing
Margie Yankeelov
615-403-7972
August 13, 2009

If you agree to participate, please indicate this decision on the signature line below. A copy of your signed letter will be returned to you at your individual testing session.

If you have any questions regarding the research or your participation in it, either now or any time in the future, please feel free to ask them. The research team, particularly Margie Yankeelov, who may be reached at 615-403-7972 or landgravem@yahoo.com, will be happy to answer any questions you may have. You may obtain further information about your rights as a research subject by calling David Berndt, who is the Coordinator of the Institutional Review Board for Human Subject Research of the Boston University Charles River Campus at 617-353-4365 or dberndt@bu.edu. If any problems arise as a result of your participation in this study, including research-related injuries, please call the Principal Investigator, Margie Yankeelov, at 615-403-7972 or landgravem@yahoo.com, or the investigator's Faculty advisor, Dr. Diana Dansereau, at 617-353-3341 or drd1@bu.edu, immediately.

Sincerely,

Margie Yankeelov

I have been told my information will be kept confidential and I grant my informed consent to be included as a subject in this research.

(Participant Printed Name) (Date)

(Participant Signature)

(Principal Investigator Signature) (Date)

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CURRICULUM VITAE

Marjorie Landgrave Yankeelov
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Austin, TX 78751

EDUCATION

Boston University- Boston, MA
Doctor of Musical Arts, 2016
Concentration: Music Education
Dissertation: Relationships Among Auditory Representations And Overall Musicianship Of Classical And Non-Classical Music Students

Cincinnati College- Conservatory of Music- Cincinnati, OH
Master of Music, 2001
Major: Oboe Performance

Belmont University- Nashville, TN
Bachelor of Music, 1998, Summa Cum Laude
Major: Oboe Performance and Music Education

TEACHING EXPERIENCE:

Lecturer, College of Fine Arts, University of Texas at Austin
  Student teacher supervisor
  Research assistant
Adjunct Instructor, School of Music, Belmont
  University (8/03–12/15) Oboe instructor,
  member of faculty woodwind quintet
  Master's Thesis advisor and committee member
  Course load included: Aural Skills I, II, III; Contemporary Issues in Music Education (graduate class); Music Education Freshman Seminar; Woodwind Methods II (oboe and bassoon); Foundations of Music Education (graduate class); Theory I, II; The Musical Experience
Double Reed Instructor, Tennessee State University (1/05– 5/10); founded first Double Reed Ensemble in the school's history
Private instructor in oboe, bassoon, piano, and voice spanning
  20 years (3/93–present) Commercial voice at Shuff's
  Music, Franklin, TN (5/03–8/05)
  Oboe and bassoon at MLK magnet school (8/03–5/07)
  Private oboe studio (3/93–present)
  Previous experience teaching piano in Sayville, New York and Nashville
Church Musician, Midtown Fellowship, Nashville,
  TN (8/2003–present) Arranged music and
  lead adult choir for special services
  Taught music and coordinated volunteers for children's ministry

Interim Minister of Music at New Life Community Church in Sayville, NY (1/02–2/03)

Developed choir, contemporary worship group, and band in both contemporary and traditional styles

Coached soloists and provided solo music for weddings and funerals

Music Teacher in Metro Nashville Public Schools, Wade and West Meade Elementary Schools (11/98–5/99) Developed chorus for Christmas program and spring festival

Taught music fundamentals

Accompanied fourth and fifth grade choruses

Theory tutor throughout undergraduate school (9/94–5/98)

CONFERENCES, PRESENTATIONS, AND INVITED LECTURES:

Musical Ear Conference, Indiana University *Component Skills of Sight-singing* (9/26/09)
Society for Music Perception and Cognition, poster *Music and the Phonological Loop* (8/12/11)
Music and Discourse Lecture *Dissecting Sight-Singing*, Belmont University (10/12/2011)
Music and the Brain Symposium, Vanderbilt University, poster *Auditory Representations of Pitch in Music Reading* (6/12/2014)

AWARDS, HONORS, OFFICES HELD:

Performed on Dame Myra Hess Concert Series, broadcast on NPR out of Chicago (Summer 2001)
Performed with Lucca Opera Festival Orchestra, Lucca, Italy (Summer 2000)
Graduated top of class, Belmont University, 4.0 (1998)
Presidential Scholarship, Belmont University (1994–1998)
Concerto/Aria Contest winner, Belmont University (1996 and 1998)
Dean's Advisory Council (1994–1998); Chairperson (1996–98)
President, MENC, Belmont Chapter (1996–1997)
Belmont University School of Music Outstanding Freshman, Sophomore, and Senior (1995, 96, 98)
Outstanding Freshman Citizenship Award, Belmont University (1995)

PROFESSIONAL AFFILIATIONS

Texas Music Educators Association
Music Educators National Conference
College Music Society
Society for Music Perception and Cognition
International Double Reed Society
American Federation of Musicians (Local 257)

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