THE EFFECTS OF PITCH DISCRIMINATION TRAINING ON ACHIEVEMENT IN MELODIC INTERVAL DISCRIMINATION

by

CHRISTIAN SEBASTIAN LOH

(Under the Direction of Robert Maribe Branch)

ABSTRACT

The improvement of aural skills through ear training is part of the formative education received by beginning college music students. Current practice in many college music programs, including the University of Georgia, relies heavily on computer-assisted instruction (CAI) to develop and improve the listening skills of college music students through pitch discrimination tasks such as interval identification.

Despite the number of inquiries into the effects of Web-based instruction (WBI) for education and the efforts to integrate technology into classrooms, there is currently a wide gap in the literature on the use and effects of innovative technology and WBI for music learning at the college level. This study investigated the effects of Web-based pitch discrimination training on college music students' achievement in melodic interval discrimination.

Mona Listen, a Web-based learning module for pitch discrimination, was developed as a training and data collection tool for the study. Practice records, participants' feedback, and achievement scores of pretest, posttest and follow-up posttest served as the data for a repeated measure design study. Data analyses were conducted using *t*-tests and analysis of variance. A focus-group interview provided additional data not collected with the online instrument.

This study suggested that: (a) Web-based pitch discrimination training had an overall positive effect on achievement in melodic interval discrimination, (b) pitch discrimination training using melodic intervals recorded in guitar sound has a larger positive effect than piano sound on achievement of melodic interval identification, and (c) the amount of time spent on-task was not a good predictor of achievement, possibly due to other underlying factors.

These findings suggest a need for music educators to reconsider current classroom practice for pitch discrimination training. Instructional technologists and music researchers should collaborate to improve future music education through technology-enhanced and Web-based music instruction.

INDEX WORDS: Ear Training, Melodic Pitch Discrimination, Web-Based Music Instruction, Music Learning Theory.

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DEDICATION

To the Lord Jesus, thank You for Your provision and protection.

To my wife, Sylvia, and my pride and joy, Ariel and Ashriel, thank you for your love, patience, longsuffering, and companionship.

I love you all.

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"I have discovered powdered water, but what do I add to it?" – Anonymous.

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God bless y'all.

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CHAPTER 1: INTRODUCTION

Introduction

The beauty of the sound of music is in the ears of the listeners. According to the historical research conducted by Beament (2001), it is possible that the first pitch producing instrument was of the woodwind family, possibly a panpipe or a primitive flute. Because the woodwind family is monophonic, capable of producing only one note at a time, the first musical intervals had to be selected from a pair of *successive* (melodic) pitches, rather than *simultaneous* (harmonic) ones. It is believed that through trial and error musicians eventually became acquainted with musical intervals and learned to reproduce those that sounded more pleasurable to their ears.

Since then, music making has persisted in human history as acts of worship, forms of art, and simple modes of enjoyment for many millennia. Even in early biblical records, there are numerous references to music making and its therapeutic effect, as when David soothed the tormented King Saul by playing on a harp (1 Samuel 16:23). Regardless of the time period and style of music, singers and musicians have spent considerable amounts of time in practicing their crafts, both in instrument playing and music listening. The aim of such endeavors is to develop the intonation skills necessary to play in tune with their instruments or with one another during a performance.

Intonation, which denotes one's ability to sing or play an instrument in tune, is a paramount issue to musicians; lacking which, the music-making activity will most probably result in cacophony. Burns and Ward (1982), as well as Killam, Lorton, and Schubert (1975), documented that successful musicians are able to identify scores of musical intervals readily and accurately. Musicians who can identify many musical intervals accurately by hearing must therefore possess good pitch discrimination and intonation skills.

Pitch discrimination, which is one's ability to differentiate musical pitches, forms the foundation upon which musicians have built and continue to build their intonation skills. A survey of music history reveals that musicians have become increasingly adept and sensitive in their ability to discriminate musical pitches. This is demonstrated through several innovations and technological advancements, including:

1. Establishment of the Pythagoras Tuning from proportionism studies circa 500 B.C., which led to the development of melodic intervals and the modern day twelve-tone musical scales (Beament, 2001)
2. Guido d'Arezzo's use of the monochord as an advance learning tool for ear training, as well as his invention of the musical notational method known as the Guidonian Hand during the 12th century A.D.
3. John Shore's invention of the tuning fork circa 1711 A.D.
4. Establishment of the Kammertone, or Concert pitch at A-440 Hz, circa 1939 A.D.

Since the time of the world's first ear training instructor (commonly considered to be Guido d'Arezzo), musicians of old and educators of modern-time have developed various instructional methods and tools for the training and instructing of their apprentices and students. Although many of these instructional methods and teaching tools may have evolved over time, the basic goal for music learning has remained very similar, if not the same: Music students must be able to recognize and comprehend the sounds they call music. Pitch discrimination of melodic intervals is their first building block in appreciating far greater musical structures.

Definition of Key Terms

According to the 1960 American National Standard Institute definition, **pitch** is that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high (Howard & Angus, 2001, p. 119). The New Grove's Dictionary of Music and Musicians (online version) defines **musical pitch** to be the attribute of auditory sensation in terms of which sounds may be ordered on a *musical scale*; that is, the attribute in which variations constitute melody. Because pitch is an auditory sensation interpreted by the listener's brain, the measurement of musical pitch is necessarily a "subjective" perception.

A music textbook definition of **interval** usually alludes to some imaginary steps, or the distance between musical pitches (see Benjamin, Horvit, & Nelson, 1998). This study adopted Beament's (2001) definition of interval, based largely on the definition of musical pitch given above, as the *sensations* created by a pair of notes regardless of the instrument on which they are produced. Musical intervals comprised of two simultaneously sounded musical pitches are known as harmonic intervals, and those of two consecutively sounded music pitches, melodic intervals.

The term **discrimination** is defined by Merriam-Webster (online) Dictionary as the process by which two stimuli differing in some aspects are responded to differently. **Pitch discrimination** has its root in psychoacoustic studies. These psychoacoustical studies commonly entailed the tuning of two pitches, usually pure tones (from sine wave), where the first pitch is typically fixed, and subjects are asked to adjust the second variable pitch by turning a knob or pressing up-down keys on a computer keyboard, to match a musical interval as named by the investigator. **Melodic pitch discrimination**, usually one of the first pitch discrimination tasks taught in basic music theory classes, is a learned process involving the identification of two successive auditory sensations from a musical scale. A person's achievement in melodic pitch discrimination is commonly measured by the individual's ability to detect the differences between the intervals and to identify them by name. The term **ear training** denotes a training process by which individuals may improve or enhance the musical aural skills necessary for the identification of deeper structures in music.

The term **Web-based** is used to denote any kind of instruction designed for online delivery through the Internet and retrievable using any kind of Internet appliances, including the various type of computers available to date, such as desktops, laptops, handhelds, and palm-size computers. This study will make use of sampled instrument sound as a sound source for pitch discrimination to investigate the effects of Web-based ear training, over time, on participants' aural skill achievement in discriminating pairs of successively musical pitches known as melodic intervals.

Pitch Discrimination and Ear Training

Musicians, by nature of their professions, are required to distinguish "by ear" the various pitches that form the melody and harmony of a musical piece. **Audiation**, the ability to hear and comprehend music for which the sound is no longer or may never have been physically present, is a fundamental process to music learning (Gordon, 1993; Walter, 1989a). While aural perception of sound occurs the moment it is heard, audiation occurs a moment after the sound is heard as the hearer gives meaning to the sound. People with no comprehension of what they hear will often have problems reproducing or distinguishing the differences in pitches. Hence, one integral part of music education and training for college music students is to learn to hear

(Kraft, 1967). Ear training allows musicians to develop the aural skills needed to experience music more completely.

Conceptually, ear training enhances the pleasure of music listening and sensitizes a musician's ears for the study, comprehension, performance, and creation of music. Operatively, ear training enables a musician to identify intervals, chord qualities, and rhythmic patterns, as well as to audiate harmonic and melodic phrases necessary for creating and performing music. Because better listeners make better musicians (Worthington & Szabo, 1995), students who hope to improve their musical ability should develop their musical pitch discrimination ability to become better listeners. Thus, college music programs prescribe ear training as the means to help develop the college music students' ability to identify pitches. This study focused on melodic intervals comprised of two consecutively sounded musical pitches, rather than harmonic intervals involving two simultaneously sounded pitches.

Pitch Discrimination and Human Aural Perception

Pitch discrimination was once a favorite research topic in the field of psychoacoustics. Pitch discrimination experiments would scientifically measure if people were able to discern two steady tones to be audibly different or identical. Sometimes, the participants were asked to adjust one of two tones, generated by tone generators, either to match each other in pitch or to form a harmonic or melodic interval.

Nowadays, inquiries into human pitch discrimination can also be found in several fields of research, including music education and music psychology. Scientific discoveries show that humans recognize pitches and musical intervals through either (a) *absolute* pitch or (b) *relative* pitch (Abrams, 2001). People who possess absolute pitch can allegedly name musical pitches by the tonal personality and color, likened to telling apart red from blue. Ward (1999) estimated that *true absolute pitch* is a rather rare phenomenon with an incidence rate of only 0.01%, or one in 10,000 people. It is believed that the overwhelming majority of people possess *relative pitch*. This type of pitch recognition requires an external reference point, such as a tuning fork or a reference note from an instrument, to correctly identify any musical intervals.

The origin of absolute pitch has remained a mystery, despite research efforts from the fields of medicine, psychoacoustics, and music psychology. Although scientists are equivocal as to the origin of perfect pitch (Deutsch, Henthorn, & Dolson, 1999), recent study suggests that all babies may be born with perfect pitch, only to lose it after language acquisition (Saffran & Griepentrog, 2001). Because 99.99% of the adult population no longer possesses perfect pitch, ear training has become the most widely accepted process in music instruction by which a person's sensitivity to musical pitches may be improved or regained.

Pitch Discrimination in Music Theory Classes

College music programs typically mandate ear training as one of the components in freshman and sophomore core music theory classes. Ear training sessions in a basic music theory class are typically face-to-face, with one instructor to many students. The instructor plays a musical interval using the classroom instrument, and the students identify the performed interval.

Instruments for Ear Training

Because an acoustic piano can produce over seven octaves of musical notes, much more than any other acoustic instrument, it has received wide acceptance as an instructional tool within a music classroom; hence also for ear training. While the piano may be useful in teaching a variety of musical topics from a pedagogic point of view, having only one instrument sound in ear training is of little practical value to players of other instruments. Because each class of instrument has its own unique timbre and hours of individual practice are required to produce recognizable skill for any student, instrumental players often develop a very strong bond with their instrument and the sound it produces. *Timbre* is the attribute of auditory sensation that allows listeners to distinguish two steady complex tones with the same loudness and pitch as being different (Rasch & Plomp, 1999). For example, the timbre produced by the string family is very different from the timbre of the brass and wind families. A string player who has no problem recognizing an interval played with a string instrument could have difficulty in identifying intervals played using a brass or wind instrument.

Several commercial ear-training applications have chosen to provide students with a large selection of music timbres to be used indiscriminately for pitch discrimination tasks. What is the pedagogic relevance and basis for this practice? Do timbres used in pitch discrimination have any effect on pitch discrimination achievement of students? This study begins the process of answering these questions by examining the effects of different instrument sounds on achievement in pitch discrimination of melodic intervals.

Piano Versus Electronic Keyboard

On one hand, musical pitches produced by an acoustic piano are considered impure from a psychoacoustic point of view. The acoustic piano is said to produce a *composite sound* rich in harmonics and overtones because each note is produced by a group of two to three vibrating strings. An acoustic guitar, with a single, freely vibrating string produces a less complex sound in comparison to an acoustic piano. Additionally, because harmonics and overtones found in composite sounds could easily confound a person's aural perception, researchers in the field of psychoacoustics insist on using pure tones for inquiries into pitch discrimination.

On the other hand, depending on the sophistication of the synthesis process, the instrument timbre synthesized by an electronic keyboard could sound sterile and artificial to acoustic instrument players. The sound produced by an acoustic instrument is a complex tone consisting of many harmonics and overtones and the result of that complex tone resonating against the body of the instrument. The choice of wood used in crafting an instrument can affect the quality of the musical notes produced, which is why no two acoustic instruments sound exactly alike.

Electronic keyboards recreate the timbre of a reference instrument mathematically using a variety of synthesis approaches, thus keyboards of the same make can produce identical timbres because they are electronically generated from the same mathematical process. However, electronic instruments can, depending on the audio synthesis process adopted, be perceived to lack color and warmth when compared with real instruments. Apart from the psychoacoustic considerations from a performance point of view, an instrumentalist's primary concern is the intonation of his or her instrument. A performer's skill is judged partially on his or her ability to stay at pitch on the instrument and in tune with the rest of the ensemble. Therefore, pitch discrimination skill is an important skill for musicians.

Improving Current Practice in Ear Training

Although current classroom practice is an end result of what has worked in the classrooms over the years, advances in technology and the development of new instructional tools and methods can often help to improve current practices. As music educators seek to improve music instruction in the classrooms, instructional technologists, such as the investigator of this study, are interested in the improvement of classroom instruction through the innovative use of instructional design and the integration of new technology. Since the 1970s, instructional technologists have considered using emerging and prevalent technology of the time to improve instruction in a number of subject areas. The following sections discuss the advent of computer-based instruction in music learning, describe how computer technology was harnessed for the improvement of music instruction, and finally present the case for the development of a Web-based learning module for pitch discrimination training.

Computer Assisted Instruction (CAI) for Ear Training

College music students taking basic music theory classes are usually required to learn the audible differences of the musical intervals. Traditionally, they have accomplished this through repetitive practice, much like the way young children learn the letters of the alphabet. As classes increase in size, music educators have, naturally, become interested in finding alternate and more effective means of ear training, rather than relying on face-to-face classroom instruction. Computer-assisted instruction (CAI) has proven to be a feasible substitute for classroom music instruction (Deihl, 1971; Kuhn & Allvin, 1967). Alternatively referred to as computer-based instruction (CBI), CAI is considered a reasonable and effective ‘tutor’ (Taylor, 1982), capable of assisting students’ learning within the instructional paradigm of ear training, and many other subject areas (Kemmis, Atkin, & Wright, 1997).

The success of CAI for ear training can be traced back to the days of the mainframe computer. Since the 1970s, CAI for ear training has been used effectively for music learning (Killam, 1984; Wittlich, 1987) and is still widely used in today’s music classroom. The Graded Units for Interactive Dictation Operations, or G.U.I.D.O., was the first ear-training “software” developed in the mid 1970s. This program used the PLATO mainframe to provide programmed instruction to college music students for the recognition of intervals, melodies, chords, harmonies, and rhythms (Hofstetter, 1978; Peters & Beiley, 1995). Reports of the positive effects of the early use of CAI for aural skills development eventually led to the incorporation of CAI into the college music theory curriculum (Davis, 2001; Eddins, 1981). The recent educational reform to put more computers into classrooms and campuses means that the trend will probably persist for some time to come.

According to a nationwide study (Spangler, 1999), more than 90% of 209 music schools surveyed in the U.S. reported that they made extensive use of ear-training CAI in their college music theory classes. However, instructors from approximately 80% of the music schools surveyed indicated that a key problem is the lack of student access to ear-training CAI, either because of limited copies of software or limited number of computers for student use. The concern of the instructors is that even though ear-training CAI has been deemed effective for music instruction, the lack of access may negatively impact student achievement. The instructional problem is that music students cannot effectively practice the ear-training exercises needed to improve their aural skills. This situation results from limited physical and computer-based resources such as available laboratory time, number of computers for practice, and copies of ear-training software.

Rationale

Before the development of CAI for ear training, human instructors had to evaluate their students' pitch discrimination skills by first playing the musical intervals on a piano in a one-to-one or one-to-many setting, then grading that student's dictation. Additionally, music students may have been required to check out audio cassette-tapes from the music library to continue their ear training outside of regular class time. The advent of CAI for ear training made possible individualized instruction for the students and simultaneous assessment for the instructor. Unlike human instructors, a computer is able to continue working repeatedly and tirelessly.

Beginning music students who are interested in improving their listening skills can thus practice with the provided software as frequently as desired, for any length of time, and still receive timely feedback on their performance. Studies about flow theory (Csikszentmihalyi, 1975) and learners' motivation (Keller & Suzuki, 1988) have demonstrated that CAI is a viable and motivational solution in an educational setting, suitable for overcoming the mundane drill-and-practice materials (Taylor, 1980) found in subjects such as mathematics and musical ear training. The use of ear-training CAI for out-of-classroom learning can also ease other administrative restrictions, such as burgeoning class size and conflicting course schedules.

Nevertheless, the implementation of CAI means that music schools have to set up a computer laboratory and schedule all students for computer access. The resources needed to maintain a computer laboratory or purchase enough licenses for adequate student access can be prohibitive to music schools (Deihl, 1971). Averaging only about $700 monthly per music major, music schools generally do not have adequate budgets to operate a sizeable computer laboratory catering to the needs of their student population. The operating cost that frequently involves hardware maintenance and software upgrades is often beyond the reach of the music schools.

There are additional issues to be considered besides the administrative budget. While many music students are enthusiastic about using CAI for ear training and believe CAI to be effective and contributive to their learning (Dobbe, 1998; Fortney, 1993; Taylor, 1982), others complain about the lack of humanity (Davis, 2001), and how time consuming certain CAI can be (Pembrook, 1986). The competency approach adopted in many CAI programs can be a two-edged sword in raising student achievement, for at times it also increases student frustration

(Hofstetter, 1979). Both the students' and the instructors' attitudes towards the use of CAI can also affect the success, or failure, of CAI implementation (Spangler, 1999).

Several groups of students will probably not benefit as much from using CAI in ear training as their peers (Brooks, 1997). For example, aspiring performing artists who already possess a higher musical skill set may not benefit from the CAI as much as their peers with lower musical skills. Students who lack self-discipline may become disgruntled with having to adhere to laboratory time on a regular basis. Students who thrive in classroom social activities have also been found to be unwilling to work exclusively with CAI and instead prefer to work in groups. Further, many music instructors observe that if the ear-training exercises are not graded, students tend to become lax and not use the CAI at all (Spangler, 1999). Because the completion of ear-training exercises is believed to translate into students' achievement in aural skills (Davis, 2001), many colleges have resorted to attributing 10% to 15% of academic grades to the ear-training component in an attempt to motivate students to be more conscientious in completing the exercises. Another effective motivation strategy is the use of ear-training CAI in the form of instructional games (White, 2002). Some students seem to enjoy the gaming component, which makes the uninteresting repetitive drills more appealing.

The advent of the Internet has led to current trends in online learning, and has given rise to new opportunities for Web-based ear training. Because appropriately designed educational Websites have been shown to be motivational to students (Arnone & Small, 1999; Loh & Williams, 2002), instructors should make use of the widely available World Wide Web (Web) resources for instruction. Moreover, Web-based instruction (WBI) will make possible self-paced learning in an "anytime anywhere" manner.

During the early days of CAI implementation, computer hardware and peripherals such as sound cards and electronic keyboards were very expensive. Many students thus could not afford the necessary hardware to perform ear-training CAI at home. As online learning becomes increasingly popular, students are more able to connect to the Internet for information, research, and instruction through public workstations, personal laptops, and even mobile computing devices.

The acceptance of the Web as a tenable education resource has created opportunities for many instructional designers and developers. While some developers expanded existing CAI to include the Web as an additional resource, others viewed the Web as the sole delivery medium. These developers considered the platform-independent Web to be a good delivery medium because the WBI needs only to be developed once and is operable on most computers, therefore significantly reducing the cost of development (Lake, 2002). The gradual metamorphosis of the Internet into some kind of an operating system has been suggested as the beginning of a new wave of computer-based music instruction (Bowyer, 2000). Many advantages found in earlier generations of CAI, such as individualized instruction, timely feedback, and repeatable instruction, have been retained in WBI, with the addition of self-paced instruction and on-demand delivery of online instruction via the Internet. A potentially larger group of students is now able to access WBI at a time and space of their convenience and of their choosing, beyond the physical constraints of classrooms and computer laboratories.

Importance

Early generation CAI lacked several advantages and affordances that have been made possible with the advent of Internet technology. Current Web browsers are able to display not only plain text and graphics, but also multimedia, such as movies and sound. Brooks (1997) pointed out that the Web will eventually be used for instruction delivery "regardless of what teachers think, feel, or do" (p. 28). As a low-cost delivery system for information and multimedia, the Web holds great potential in mass delivery of instruction into classrooms and beyond.

The availability of Web-based music instruction (WBMI) also means that music students will no longer be required to congregate at a music laboratory for "drill-and-practice" exercises in ear training. Because many college students now have easy access to the Internet and Web resources from campuses and dormitories, there will be more opportunity for music students to improve their ear training skills should online ear training become more readily available. Table 1 outlines a number of affordances commonly associated with Web-based learning and instruction.

Table 1

Affordances of Web-based Learning & Instruction

Affordances	*Description (Citation)*
Anytime Anywhere Learning	"Access can be from wherever there is Internet access" (Brooks, 1997, p. 28).
Portability	"Web applications run similarly on many platforms," such as Macintosh, Windows, and Linux (Lake, 2002, p. 182)
Easy Maintenance	WBI modules may be updated and kept current easily with just a small cost (Bourne, McMaster, Rieger, & Campbell, 1997)
Interactivity	The branched, non-linear instruction of the Web encourages active learning and promotes the construction of meaning (Brooks, 1997)
Instant Feedback	A Web-based quiz provides quiz takers with automated, instant feedback, thus increasing learning (Bourne et al., 1997)
Self-paced Learning	WBI modules allow students to learn at their own pace (Brooks, 1997)

Since the introduction of the Internet into the classroom, educators and researchers have learned a great deal about the Internet and WBI (Berge, 2000; Starr, 1997), design guidelines (Berge, Collins, & Dougherty, 2000; El-Tigi & Branch, 1997), and motivational effects of the Web on learners (Loh & Williams, 2002; Small, 1997). Many innovative instructors have taken advantage of WBI to deliver lessons in instructional areas ranging from chemistry, to geography, to language arts. However, there appears to be a general lack of WBI for music learning that was developed based on rigorous pedagogic practice, and this has impeded music educators from taking advantage of the Web for music instruction. Spangler (1999) reported that some music educators have gone so far to remove Internet access from the music lab to prevent students from "wasting time" surfing the Web. Certainly, more WBMI development is needed in the future. Who will take up the task? Certainly, techno-savvy music educators have done it before (e.g., Hofstetter, 1975; Kothman, 2000), and commercial software developing companies are still doing it. This study is an example of a collaborative effort between a group of music educators who supplied the content and an instructional technologist who designed, developed, and evaluated the resulting application.

Some educator-researchers have taken notice of the need for more WBMI and established the Technological Directions in Music Learning Conference (TDML) in 1994 as a step in the right direction. The TDML aims to provide a forum of discussion on the use of computing technology in music theory, learning, and practice. Reports from innovative music educators (Estrella, 1999, 2001; Kothman, 2000) have demonstrated the feasibility of the Web for music learning using technology such as JavaScript and the Beatnik Player. While the Beatnik Player is no longer supported, other innovative software authoring tools such as Macromedia Flash and Director are fast maturing into highly usable tools suitable for the design of instruction and the development of educational games (Lim, 2002). The platform-independent applications, Flash and Director, both developed by Macromedia, are particularly useful for the instructional development of multimedia-based online instruction. The increasing pace for WBI adoption around the world is laying the ground for music educators and instructional designers to explore the feasibility of WBI and its potentials in music instruction.

Instructional technology is a field of study that incorporates innovative technology for the purpose of instruction and instructional development. Changes in technology have brought about many authoring tools that are suitable for non-programmer educator-developers (Khan, 1997). An online ear-training module named Mona Listen has been developed for use in this study using several innovative technologies, namely Macromedia Flash MX, PHP Hypertext Processor (PHP), and MySQL database. This study will contribute to the field of instructional technology by creating new opportunities for instructional designers and technologists to work with music instruction. The development of WBMI will further prepare the way for other music courses geared towards online certification. The design and development of a Web-based instructional module for pitch discrimination to improve the achievement of music students in interval discrimination is, therefore, of value to both fields: music instruction and instructional technology.

Research Questions

The increasingly ubiquitous Internet means a Web-based approach to ear training is viable. People who may benefit from a Web-based approach to ear training include college music majors who need more practice, music non-majors who are interested in getting some grounding in basic ear training, or amateur musicians at large. An online approach to ear training further provides greater flexibility in instructional delivery, convenience, accessibility, and anytime anywhere learning than CAI for ear training housed in a computer lab.

Despite the number of inquiries into the effects of WBI on education, and the efforts to integrate technology into classrooms, there is currently a wide gap in the literature on the use and effects of innovative technology and WBI for music learning at the college level. This study investigated the effects of a WBMI for pitch discrimination (ear training) on college music students' achievement in melodic interval discrimination. The research questions of the study were:

1. What are the effects of Web-based pitch discrimination training on achievement in melodic interval discrimination?
2. Do different instrument sounds used in pitch discrimination training affect achievement in melodic interval discrimination?
3. Does the amount of time spent in pitch discrimination training affect achievement in melodic interval discrimination?

Because the investigator is an instructional design technologist by training and not a music educator, the Web-based learning module used in this study has been developed in consultation with certified music educators. Mona Listen, the Web-based learning module for pitch discrimination training relied on carefully integrated technology to enhance lesson delivery and assessment of students' learning. The module employed sampled instrument sounds of high fidelity to provide both the musical context for music learning and the pedagogic values of ear training for aspiring instrumentalists. The next chapter presents a review of relevant literature about (a) pitch discrimination and music learning, (b) the use of computer-based instruction in aural skill development, and (c) the trends towards Web-based instruction for music instruction.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

Pitch discrimination is important to college music students because higher-level music classes often require students to have a firm foundation in basic listening skills. Ear training for pitch discrimination provides the means for first year music students to learn the relationships of musical pitches and to attain good listening skills. Because better listeners make better musicians (Worthington & Szabo, 1995), college music students with better listening skills are more likely to succeed as musicians. Ear training is currently the prescribed method used in formative music education for the development of aural skills. Computer-based ear training instruction has long been established as an effective means of instruction for music students (Deihl 1971; Hofstetter, 1975, 1985). The growing interests in online learning and the increasingly ubiquitous Web have brought about the possibility for new development in WBI for ear training and music instruction at large.

This study deals exclusively with melodic pitch discrimination, whereby participants of the study were asked to listen, memorize, recall, and identify successive musical pitches presented in the form of melodic intervals. This chapter presents a review of relevant literature from the fields of (a) psychoacoustics, (b) music psychology, (c) music education, and (d) instructional technology to serve as basis for the study. Although the majority of inquiries on pitch discrimination originated from psychoacoustics and music psychology, research findings from these fields had little direct application in music education (Klonoski, 2000). Therefore, the investigator sought to synthesize the knowledge of pitch discrimination from the fields of psychoacoustics and music psychology for practical application in music education from the instructional technology perspective.

This study examined the effects of a Web-based pitch discrimination instructional module on the achievement of melodic interval identification in first year college music students. The review of literature is presented in three sections: (a) literature on pitch discrimination and music learning studies, (b) literature on computer-based music instruction for aural skill development, and (c) literature showing a trend towards Web-based instruction for music learning.

Section I: Pitch Discrimination And Music Learning

Sound and Pitch Discrimination

Sound is produced through vibration, such as a plucked string or a struck gong. A faster vibration (measured in cycles per second) will yield a higher frequency and a higher perceived pitch, whereas a lower pitch is achieved with a slower vibration. The American National Standard Institute defines *pitch* as the "attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high" (Howard & Angus, 2001, p. 119). Scientifically speaking, the vibrating object causes air particles around it to go through a series of compressions and decompressions, and when this "wave" of compressed and decompressed air particles reaches a person's ear, the vibration is interpreted and perceived by the human brain as sound. Music psychologists have ascertained that different types of sound assert different psychological effects on the hearers (Siegel & Siegel, 1977), meaning the choice of sound used is of importance in pitch discrimination training, and may affect outcomes.

The Effects of Pure Tones on Pitch Discrimination

When a pure sine wave is electronically converted to audio with a tone-generator, a single steady pitch is produced. This is commonly known as a "pure tone" and is typically depicted in textbooks as a series of repeating peaks and grooves (see Figure 1).

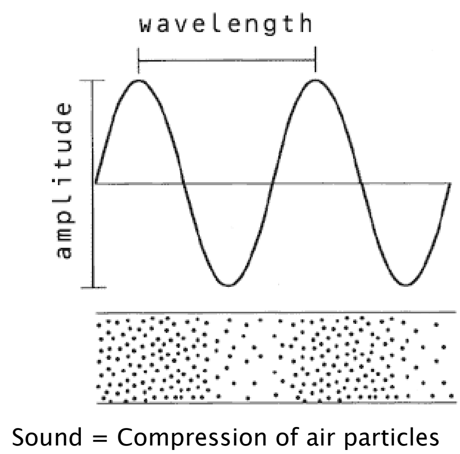

Figure 1. The Components of a Sound Wave

Researchers in the fields of psychoacoustics and music psychology generally prefer using pure tones in pitch discrimination studies to ensure the reproducibility, consistency, and validity of the research data. However, pure tones are physical anomalies because natural sounds, such as the sound of musical instruments, exist as *complex tones*. As shown in the following sonogram, the auditory signatures between an electrically generated pure tone and a naturally produced complex tone are very dissimilar (see Figure 2).

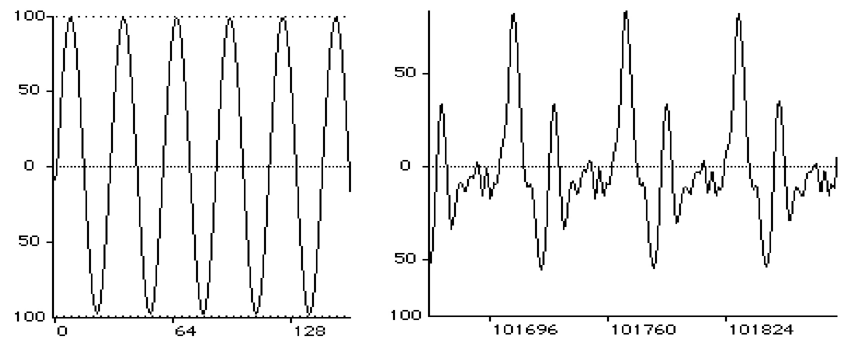

Figure 2. Sonograms of Pure Tone (Left) and Complex Tone (Right)

Psychoacoustic findings have further confirmed that human ears perceive pure tones differently from complex tones (Walker, 1990). Sergeant (1973) concluded that a pure tone was not suitable for musical pitch discrimination in a learning situation because it was devoid of musical context. Instead, Sergeant recommended the use of complex tones, such as the recorded sound of acoustic musical instruments, for music learning because "the stimuli used in the process of measurement must be compatible with the context in which the musical learning took place" (p. 15). Furthermore, since college music students are usually required to pick an acoustic instrument (including voice) as their major instrument, it makes good pedagogical sense to use the sounds of the student's acoustic instrument for pitch discrimination.

Choosing an Instrument Sound for Ear Training

Due to many limitations such as cost, storage, and portability, it is impractical to supply acoustic instruments of every timbre as complex-tone generators for ear training in music classrooms. Furthermore, it is also unreasonable to expect music instructors to be able to manage or play all of those instruments in class. A compromise has to be made. Typically, an acoustic piano was chosen to be the complex-tone generator for ear training in a classroom scenario. An acoustic piano can produce over seven and a half octaves of musical pitches and has proven to be an extremely useful classroom instrument to music instructors teaching intervals and chord discrimination.

Although the acoustic piano is commonly used in ear training, there are several reasons that an electronic keyboard may be a better tool for pitch discrimination as compared to the piano. An electronic keyboard is often smaller, cheaper, and more portable; therefore, more keyboards may be purchase for the cost of one acoustic piano and be moved around serving different purposes. Additionally, an electronic keyboard has no physical strings like the acoustic piano and therefore does not require regular tuning. Best of all, because the sound of an electronic keyboard is generated using a computer chip or processor, the keyboard is capable of synthesizing a variety of electronic sounds by pressing a few buttons or by turning a dial. Hence, an electronic keyboard is also known as a synthesizer.

Nevertheless, it is unlikely that music departments will soon make synthesizers the *de facto* instrument in every ear-training classroom. Compared with the acoustic piano, a highly portable synthesizer is a likely target for theft and can easily be taken out of a classroom, whereas a large and heavy acoustic piano, with essentially one timbre, is less portable and not easily stolen.

The Quality of Synthesized Sounds in Pitch Discrimination

The sound quality of an electronic keyboard is another issue for consideration. Although any complex tone may be mathematically reconstructed from pure tones using a variety of synthesis models and processes, a synthesized tone is never the same as the complex tone produced by a real acoustic instrument. Professional grade synthesizer manufacturers continue to make use of more powerful computer chips to perform the complex mathematical calculations needed to create complex tones that more accurately mimic original instruments. While the fidelity of the synthesized sound may be high enough so as to be indistinguishable to casual and untrained listeners, trained musicians with good listening skills can usually differentiate a synthesized instrument sound from an authentic acoustic timbre through other inherent sonic characteristics such as resonance, harmonics, onset transients, and tone colors. Many instrumentalists have also been noted to prefer the *warmer* sound produced by an acoustic instrument to the electronic sound of synthesizers (Krumhansl, 1990).

Although synthesized sounds may be less than ideal for ear training, an electronic keyboard can still offer the classroom music instructor a much wider selection of instrumental timbres than an acoustic piano. Although ear training with a student's "instrument of specialization" is pedagogically better for the much-needed musical contexts (Sergeant, 1973), the investigator could find no previous study that examined the effects of different instrumental timbres on achievement in pitch discrimination. This study will begin the process by examining the effects of two different timbres, namely guitar and piano, on first year college music students' achievement in melodic interval discrimination.

Using Sound Sampling Technology to Improve Fidelity

An alternative to synthesizing instrumental timbres electronically is to record the sound of real instruments through *sampling*. Historically, storage of sampled sounds from real instruments within an electronic keyboard is a difficult and expensive process. Before recorded sounds of an instrument can be used in digital keyboards, the sounds must first be converted from the analog format into a digitized format. Depending on the computer used in the digitization process, the sound samples may be stored in one of several native formats, such as AIFF or WAVE.

Although native sound samples can be very high in fidelity, meaning they so closely resemble the instrument from which the samples come from that most people find them virtually identical, the enormous storage required by these sampled sound files hamper their widespread use. Recent advances in technology finally brought about the advent of better transform coders, such as the Motion Picture Expert Group Level-3 specification (MPEG-3, or MP3) and Ogg Vorbis (OGG) formats (Slashdot, 2000). Table 2 provides a comparison among several aurally identical recordings of a musical recording in WAVE, MP3, and OGG format and the download time needed (using a 56k modem as an example). The original recording was the movement Siciliana from the Recorder Sonata XI in F major by George F. Handel, with a playtime of 1 min 11 sec.

Table 2

File Size Comparisons Among Transform Coders

	WAVE File	MP3 (128kbps)*	OGG (100kbps)*
File Size	12,274 kB	1,122 kB	880 kB
Download Time (56k modem)	3 min 39 sec (219 sec)	20 sec	16 sec

* Represents CD-quality.

Certain transform-coders, such as MP3 and OGG, are able to compress the audio file from 12 MB down to approximately 1 MB, or by a ten-to-one (10:1) compression rate. The greatly reduced file size thus allowed an enhanced Web-based delivery and helped to promote widespread use of sampled sounds within the music industry. This study took advantage of sampled instrument sound in MP3 format to achieve high fidelity and short download time for Web-based ear training.

Learning Pitch Discrimination

Pitch discrimination is highly dependent on the acuteness of a person's auditory perception. Pitch is a transient phenomenon occurring when the wave of compressed and decompressed air particles impacts upon the eardrum. Most humans do not retain indefinitely the memory of a pitch they have heard, as the accumulation of sounds would cause great confusion. Miller (1956) demonstrated that most people can remember up to 7±2 tones at any one time. When a musical pitch is initially perceived by the ear, it is stored for a time within the short-term, or working (aural) memory (Holahan, Saunders, & Goldberg, 2000). The auditory information stored in the short-term working memory will decay if not acted upon immediately, and is eventually replaced by arriving new pitches (Schunk, 2000). Although the pitch frequency of a musical note may be retained by the working memory of most people for about a minute without distraction (Dowling, 1982), the accuracy in retention rate of a reference pitch can be severely affected when participants are subjected to randomly generated musical notes (Sloboda, 1985). Gaps of silence and randomly spoken numbers appear not to affect short-term memory of musical notes, indicating that the brain processes sound and music differently (Dowling, 1982). Furthermore, the complexity of the musical phrases and the listener's prior experience and training can also affect a person's ability to remember and discriminate pitches.

The Effects of Musical Training on Pitch Discrimination

Even though untrained listeners may be able to implicitly discriminate two successive musical tones as being identical or different, they lack any explicit knowledge on the value of the intervals, ratio of pitch frequencies, and quality of the tones (Sloboda, 1985). Because the effect of training and rehearsal has been well documented in various learning subjects (Schunk, 2000), beginning music students desiring to become proficient in naming and identifying intervals should undergo appropriate training to acquire the pitch discrimination skill set.

The effect of musical training is even more telling when atonal music, or music devoid of a tonal center, is used as test material for pitch discrimination. Dowling (1982) showed that successive pitch discrimination using atonal intervals removed from any musical context can be very difficult for participants because the musical notes sound “random.” However, the participants’ performance quickly improved when asked to listen repeatedly to the note patterns. Dowling believed that “training facilitates the application of [a learned] system to new materials” (p. 427). Training by rote and repetition thus appeared to be a fairly important factor in the initial phase of learning new materials, particularly in ear training.

Tuning of one’s instrument on a regular or daily basis is also a great way for musicians to improve their listening and pitch discrimination skills. Guitarists and other string (violin, viola, cello, and bass) players are required to detune their instruments for storage to better preserve the strings’ lifespan and to avoid undue strain on the instruments’ infrastructure. This means that before a string instrument can be used again, the player must tune the string again to the required pitches. Many string players such as violinists professed to an internal imprint of the pitch of A_4 (Bachem, 1937). Ward (1999) suggested that repeated tuning and listening to the sound of the instruments have left a lasting effect on the musician’s pitch discrimination ability, forming some sort of a phantom tuning fork. Experienced piano tuners who spend years tuning pianos can likewise distinguish themselves from the amateur ones by their abilities to tune the keyboard instrument by ear alone (Beament, 2001), no longer needing to rely on the electronic tuning device used by inexperienced tuners.

This study made use of repetitive listening as a learning strategy to improve the pitch discrimination ability of the participants. Because music students of today are more familiar with the contemporary equal-temperament tuning at the standard concert pitch of $A_4 = 440$ Hertz, the sounds of acoustic music instruments used in this ear training study complied with these standards.

Ear Training for Beginning College Music Students

Ear training is widely used in basic college music theory classes to help first year college music students sharpen their aural perception and listening skills, serving as the foundation for more advanced music classes. Learning tasks involving *melodic* and *harmonic* pitch discrimination form a major part of ear training activities in the initial months of freshman music learning activities. Melodic pitch discrimination, in this case, means identifying successively played musical notes, and harmonic pitch discrimination refers to simultaneously played notes.

Although the pitch discrimination tasks for melodic and harmonic intervals may appear similar by name, the mental processes for the two are dissimilar. Moreover, melodic pitch discrimination has been shown to develop at a different developmental stage in children than does harmonic pitch discrimination. Thus, researchers generally view the two pitch discrimination tasks to be separate cognitive processes (Hair, 1971). Apart from being cognizant of the differences between intervals by listening, trained musicians are expected also to identify the intervals by size and quality. The acquisition of the specialized set of music vocabulary is important to musicians because it allows them to express their musical knowledge explicitly, while further facilitating communication with other musicians (Sloboda, 1985). The vocabulary associated with melodic pitch discrimination typically consists of the size and quality of the melodic intervals. Figure 3 shows 14 possible chromatic intervals found in the scale of F, starting with the perfect prime (PP), or unison (P1), and ending with the perfect octave (P8). The letters in these intervals refer to its quality (ascending, descending, augmented, diminished, minor, major, etc.), and the numbers refer to its general intervallic size (second, third, fourth, fifth, etc.). Some intervals, such as augmented fourth (A4) and diminished fifth (d5), have the same size but different names; they are known as *enharmonic*.

Figure 3. Melodic Intervals in the Key of F Major

Melodic Intervals Discrimination Skills of Good Musicians

Knowing the proper naming conventions and symbolic representations of the musical intervals is essential for beginning college music students because it serves both as music literacy and the foundation for advanced classes. Basic music theory classes in college music programs typically entail ear training in conjunction with the learning of interval names as part of the musical vocabulary acquisition process.

Competent musicians have been found to accurately recognize the twelve intervals of the musical scale more than untrained listeners (Killam et al., 1975). Professional musicians can even identify up to 32 categories of melodic intervals, consisting of both ascending and descending intervals from unison to the major tenth (Burns & Ward, 1982). Untrained or amateur musicians are generally unable to perform this task readily. This study dealt exclusively with melodic interval discrimination, whereby participants of the study were asked to listen, memorize, recall, and identify musical pitches presented in the form of melodic (successive) intervals.

Music Learning Theories and Perceptual Skill Development

Knowledge in the naming convention and symbolic representation of musical intervals may be classified as conceptual skills. This is different from the perceptual skills required for pitch discrimination and ear training. Some music educators advocate that music learning can not be adequately explained by conceptual learning theories and should instead be approach from a perceptual perspective (Klonoski, 2000). The rise of a number of music learning theories in recent years has helped lend credibility to the study of musical behavior as a separate and legitimate *domain* of knowledge (Taetle & Cutietta, 2002).

Amidst the music learning theories, what interests the music educators most is how people really learn music. More practically, are people born with certain musical talent? Can musical abilities be trained? What kind of training is most useful? The following section represents a collage of current research findings and researchers' beliefs. Readers should bear in mind that many of the questions asked remained to be answered conclusively and some of them, not without extensive research.

Inherent Music Ability

The belief that people possess an inherent musical talent is not new. Runfola and Swanwick (2002) reported a series of terminology used over the years, ranging from the concept of inherited musical *talents* in 1938, to musical *intelligence* in 1961, musical *abilities* in 1966 and *aptitude* in 1997. Howard Gardner (1999), one of the notable educators of today, postulated that people are born with various degrees of "intelligences" whereby "musical intelligence" is but one of the nine proposed. Gardner asserted that a child's ability to enjoy a bird song and a composer's ability to compose a musical concerto, are different manifestations of inherent musical intelligence. The difference Gardner noted is that people with highly developed musical intelligence will be able to experience greater sensation, perception, and cognition when working with music.

According to Gembris (2002), current research in the development of musical abilities assumes that "every human being is musical and that it is possible and promising to develop this musicality" (p. 489). Although there is yet to be any unifying theory on musical intelligence, available findings suggest that music development is culturally and historically embedded, and that it is possibly a lifelong process. Lamont (1998) found melodic perception development in human beings to occur in early childhood, beginning from the age of 6 months, up to about the age of 11. However, once over the age of 11, the accuracy of melodic perception will only be improved if the person remains active musically, such as playing an instrument or engaging in musical training.

Enculturation

Several views have been put forward to explain how one acquires musical ability. Sloboda and Davidson (1996) postulate that music learning happens through a process of *enculturation.* They suggest that enculturation begins with the onset of auditory stimuli in a human fetus and is reinforced through the parents' voices, lullabies, language acquisition (Deutsch et al., 1999), and various musical experiences encountered as one grows up. The sum of musical enculturation eventually determines what is *musical* to a person. While enculturation can result in some basic music abilities such as recalling songs, learning new ones, and even telling different types of music apart, it is insufficient for the cultivation of higher musical abilities (Lamont, 1998). Successful musicians require active training and regular practice to achieve proficiency in pitch discrimination and instrument playing.

Musical Training

Much like Lamont, Gordon also believed that a person's music aptitude would level off before adolescence (Gordon, 1967, 1997). However, the leveling off in aptitude did not mean that there would be no room for improvement. Because every human being possesses at least some degree of musical aptitude, it was possible to benefit from musical instruction "despite individual differences in innate capacities" (Grembris, 2002, p. 489).

Dowling (1982) and Sloboda (1985) likewise asserted that a person's music achievement could be further affected by (a) quality training, (b) practicing, and (c) having a positive attitude towards musical training. Explicit musical knowledge, such as the naming and discrimination of melodic intervals, can only be acquired through musical training and experience (Krumhansl, 1990; Walter, 1989b). Similarly, Lamont (1998) believed that being musically active can help to advance a person's melodic perception accuracy beyond adolescence, hence the need for musical training. Based on Lamont's work, pitch discrimination achievement was a function of active training, not mere exposure to musical environment through enculturation.

Mental Processes of Music Listening

Although researchers cannot be certain about how music listening takes place, they generally consider the mental processes to be in several stages. Fiske (1985) suggested a three-stage process for the musical learning of pitch discrimination: (a) perception, (b) comparison, and (c) *schemata* formation. Hence, when two successive music notes arrive at a person's ear, the successive sounds must first be processed as aural perceptions, and the differences in intervallic distance compared. The brain eventually forms the necessary schema needed for the recognition and recall of the melodic interval.

Ruttenburg (1994) proposed that the music learning process takes place in four stages, progressing from sensation, to perception, to cognition, to creativity. According to Rutenberg's four-stage process, pitch discrimination of a melodic interval occurred when two successive sound waves first arrived at the human ears as *sensation* and was subsequently perceived by the brain as an aural *perception*. Trained music students would recognize the perception of intervallic distance through *cognition* and identified the melodic interval accordingly. Ruttenburg suggested that each successive stage would demand more processing from the brain, and hence require a progressively longer time. Therefore, while sensation might take place within a fraction of a second, and aural perception within a few seconds, the act of cognition could take as long as 30 to 60 seconds. Creativity using learned musical intervals would occur only at a much later stage, and only after laying the foundations for the earlier stages.

Hierarchy of Music Learning

Based on numerous years of his music teaching experience and research work, Edwin Gordon (1967) contends that people are born with varying amounts of music aptitude. A person's musical aptitude is defined as his or her potential for excellence in music and is considered to be an innate ability. Gordon's works led him to believe that a person's music aptitude can be increased through one's upbringing, environment factors, and music training at an early age. Although it is suggested that a person's music aptitude stabilizes around the age of 9 or 10, further training in adulthood can help prevent the aptitude from regressing to the level at birth (Taggart, 1989). A person's musical aptitude should not be confused with one's musical achievement. Musical achievement is defined as the skill level accumulated as a product of one's music aptitude, life experience, and music training.

Gordon's (1967, 1997) theory for music learning thus echoes contemporary ideas of other researchers, such as Gardner's (1999) music intelligence and Sloboda's (1985) music enculturation. However, instead of theorizing the developmental process of music learning like other music researchers of his time, Gordon was more interested in a hierarchical learning process that is of practical value in music education. Gordon's Music Learning Theory is now recognized nationally as a prescriptive learning sequence for music learning. Figure 4 presents the hierarchy of music learning, divided into two subsections: discrimination learning, and inferential learning (Walter, 1989b).

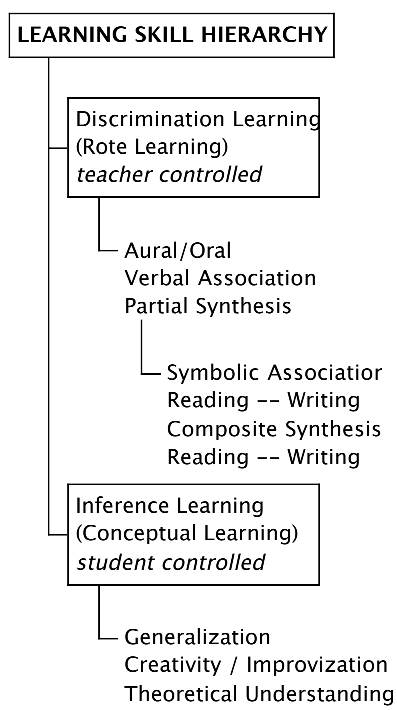

Figure 4. Gordon's Learning Skill Hierarchy for Music

(adapted from Walter, 1989b)

Gordon (1997) emphasized that the basic, rote-type, discrimination learning must necessarily precede the more conceptual, higher-level, inference learning, else the learners would fail to grasp the differences in the sound heard. Moreover, inference learning had an internal locus of control within the learner and might take an indefinite amount of time to occur. Walter (1989b) described inferential learning to be some sort of epiphany, occurring when pieces of learning that were acquired previously would suddenly come together. Because the locus of control for inferential learning typically rested upon the students, who, in this case, were completely unaware of their own learning, there was no telling when the epiphany (inferential learning) might take place. This study focused on discrimination learning of musical intervals, which had a more manageable timeframe, with an external locus of control apart from the learners.

Music Learning by Audiation

Also central to Gordon's theory is the concept of "audiation." Just as *visualization* is to the seeing of mental images, *audiation* is to the hearing of sounds that are not present at the moment (Shuter-Dyson, 1992; Walter, 1989a). Audiation only implies people's ability to "hear" music in their heads and should not be equated with musical understanding. Audiation can occur at anytime in life and at any level of complexity. The ability in recalling a familiar song (such as "Twinkle, Twinkle Little Star"), identifying the tempo of a piece of music, and knowing what instrument is being used in a piece of music, are all examples of *simple*, or *surface*, *audiation*. Other forms of audiation include listening to music, sight-reading (or performing music from notations), playing by ear, improvising, composing, and dictating music. Walter (1989a) asserted that "audiation skills…are fundamental to music understanding" (p. 7) for anyone aspiring to become more skillful in music beyond simply listening for pleasure.

"Rote First" Methodology

Because audiation is based upon a person's hearing, the development of aural skill necessarily takes precedence over the notation (note reading) skill. Therefore, Gordon's Music Learning Theory subscribed to the *rote first* methodology, which was supported by advocates such as Orff, Dalcroze, Kodaly, and Suzuki (Dalby, n.d.). Contrary to the *note first* methodology that teaches the understanding of music notes before hearing the corresponding musical sound, the *rote first* methodology requires students to learn the "sensation of sound" by rote through audiation, before tackling the more symbolic musical notations. According to Walter (1989b), Gordon believed that "all content is perceived aurally" and music notation "should not occur until aural readiness has been acquired" (p. 14). Mona Listen adhered to this guideline and required the learners to concentrate on the listening tasks (audiation) only without introducing notation. Although letter representations of the melodic intervals, such as P5/P4/M6/m3, were used in the study to provide each interval with a name, the learning module did not introduce musical notations.

Tonal Solfege and Tonal Patterns

Gordon (1997) also advocated using the moveable-doh system during the aural/oral level of the learning hierarchy for optimal discrimination learning. The singing of the notes in solfege (doh-re-mi-fah-soh-la-ti) instead of letter names (C-D-E-F-G-A-B) was believed to strengthen one's auditory image of the tonal patterns and establish familiarity for tonal content (Dalby, 2001). Gordon also suggested the smallest unit of learning for audiation to be the tritonic arpeggio patterns. However, because diatonic intervals had proven useful as aptitude test materials (Boyle & Radocy, 1987), the investigator believed diatonic intervals were worthwhile candidates for audiation. Participants of the study were encouraged to hum or sing along in solfege with the movable-doh system to strengthen their auditory images of the melodic intervals. For example, singing “doh-soh” for P5, and “doh-fah” for P4.

Teaching Pitch Discrimination in College Music Classrooms

Music education researchers, such as Gordon, have provided music teachers with a fairly comprehensive music learning theory, elucidated on the relationship between musical aptitude and achievement. While the positive effects of training on musical achievement have been demonstrated, the question remains: “How do educators go about teaching pitch discrimination in college music classes?” Knowing that the musical aptitudes of college music students would have tapered off since their adolescent years, the only means of improving students’ musical achievement is through music training. Ear training is a known and effective way to improve college music students’ pitch discrimination abilities.

Ear training is usually carried out as drill-and-practice with a small teacher-student ratio in a face-to-face setting within a college music classroom. However, some common operational problems for teaching ear training in a classroom setting include: (a) waiting for one’s turn, (b) fatigue factor of students and instructors, (c) lack of consistency in subject treatment among instructors, (d) differing lecture delivery styles among instructors, (e) individual learner differences, and (f) conflicting schedules and logistic problems. The need for audio media and equipment further compounded the problems faced by classroom instructors. Some of the logistic problems include the breakdown of audio equipment, while others include inflexibility in the playback sequence and the general wear-and-tear of storage media such as magnetic tapes.

Diversity of students’ prior musical training experience is another issue faced by instructors. Beginning college music students entering a music program may have had different musical experiences, prior training, and learning differences, resulting in varying abilities to perceive music. Traditional classroom pedagogy for ear training with such a diversified group of college freshmen was to teach them *analytical* skills, such as singing in solfege to match pitch, or counting tones and semitones, or letter names, in order to figure out the correct intervals (Parncutt, 1994). Many music students might also recall ear training in the form of a student workbook with pre-recorded sound sources in cassette tapes (Benward, 1974; Kraft, 1967). However, no one single instructional method would be completely effective due to individual differences.

Music educators must necessarily employ a wide range of learning methods to reach out to their students. Taggart (1989) advocated for the individual's differences during an ear-training instruction. Walter (1989b) recommended that a student should learn to listen, or audiate, in solo to ensure effective learning and to facilitate accurate evaluation of learning. The requirement to practice by oneself, while not always possible in a large classroom setting, is easily achieved in a technology-enhanced instructional environment.

Section II: Technology-Enhanced Music Learning

Computer-Based Instruction for Aural Skill Development

Computer-based instruction (CBI), or computer-assisted instruction (CAI) as it is also called, has had some 30 years of history since the early 1970s. The first major attempt to utilize CBI for music learning was an ear-training program named Graded Units for Interactive Dictation Operations, abbreviated as GUIDO that appropriately pointed to the historical first ear-training instructor, Guido d'Arezo. Due to its versatility in providing individualized instruction (Hofstetter, 1975), GUIDO had demonstrated its viability as an alternative method for formal ear-training instruction.

Since GUIDO, researchers have documented much developmental work in computer-based music instruction (CBMI) for ear training (Berz & Bowman, 1994; Bowyer, 2000; Spangler, 1999). Classroom instructors who have the need for individualized training but find it difficult to devote time to every student in a traditional classroom find CBMI an asset. Because CBMI allows the repetitive learning tasks to be moved outside of normal classroom time (Parrish, 1997) and into the computer labs, music instructors can now concentrate on problematic topics during class time and have students practice their listening tasks in the ear-training laboratories. The limited commodity of class time can thus be utilized for less routine, but otherwise important, activities such as question-and-answer, focus sessions, and instructor-student interaction time.

The Affordances of a Technology-Enhanced Classroom

There are several ways in which music instructors have made use of CBMI in the classrooms. Some have used CBMI as a supplement to their day-to-day teaching, while others have chosen to substitute CBMI for classroom instruction altogether. Whichever the case, early use of CBMI in college music classrooms appeared to be feasible and managed to generate a number of positive reports (Alessi & Trollip, 1991; Kulik & Kulik, 1991). The CBMI in ear training likewise received a number of favorable reviews (Taylor, 1982; Wittlich, 1987; Worthington & Szabo, 1995). Music students, in general, have an affinity towards technology and the use of CBMI seems particularly suited for this learning community (Holland, 1989). Students reported liking CBMI for its providence for self-paced learning, individualized instruction, and instant feedback. Additionally, the change in instructional delivery medium afforded by CBMI alleviated many existing logistic problems in the music classrooms of the time.

First, repeated use of storage materials for music excerpts, such as magnetic tapes, led to distortion and loss of fidelity in audio recordings. Replacing these magnetic materials commercially could be costly, and making copies of the materials be time consuming for the instructors. Though cheaper in cost, making a copy is always less than ideal because the process may introduce hiss and lead to degradation in the sound quality. As sound files used in CBMI are mostly digital audio files, or MIDI instruction, they do not become distorted with use. Digital files are very durable and are ideal for standardized testing purposes.

Second, sound recordings stored on magnetic tapes could only be played-back linearly, that is, from beginning to end. Repeating a particular section of recordings required rewinding of the magnetic tapes, which led to stretching. Digital audio files used in CBMI are standalone entities and may be played over and over again simply by pressing a button (Davis, 2001). They may, moreover, be played back in any desired order.

Finally, through the use of proper algorithms in programming, quizzes were graded immediately and students received immediate feedback. As an *instructor*, the computer do not become fatigued like its human counterpart, who is also unable to simultaneously grade a large number of responses, let alone provide immediate feedback for each student. Digital audio files used in CBMI also made copying and distribution an easy task, and instructors could hand out music excerpts as part of a take-home assignment.

By the 1990s, some 71% of college music programs in the U.S. reported using CBMI (Hess, 1995). Subsequent accreditation requirements by the National Association of Schools of Music (NASM) prompted wide incorporation of music technology and CBMI in music schools across the country. A report in 1999 showed that the music college adoption of CBMI has escalated to over 90%, and at this level of technology adoption, it can be assumed that music instructors are well aware of and familiar with the use of CBMI. Table 3 shows the list of CBMI for ear training used in the U.S. college music program in that report (Spangler, 1999).

Table 3

List of Computer-Based Music Instruction for Ear Training

Computer-Based Music Instruction for Ear Training	Mac	Win	Adoption
Practica Musica	✓		43%
MacGamut	✓		32%
Music Lab Melody	✓	✓	6%
Auralia		✓	3%
Curriculum for Aural Training	✓		3%
ETDrill		✓	3%
Others (covering Mac/Win/Linux platforms):			
- Computerkolleg Music, GUIDO, Teoria, Musique, and other instructor created exercises			7%

As shown in Table 3, over 80% of the CBMI software was developed for the Macintosh platform. Though a star product in the 1980s, the aging DOS- and Windows-based GUIDO has been steadily losing its grip on the ear-training market share, and was finally retired by its software publisher in the late 1990s.

Developing Aural Skills With Computer-Based Music Instruction

Compared with the extensive pitch discrimination research in psychoacoustics and music psychology, and the voluminous research about the use of CBI in learning, the amount of research on pitch discrimination in the music classroom with CBI is very limited. There are even fewer CBI pitch discrimination studies with college students as participants (Coffman, 2000). Available CBMI studies for aural skill development are presented in the following section and cover pitch discrimination, identification of musical intervals, and music dictations. Both primary sources and secondary sources of research literature, including doctoral dissertations, master theses, reports, and reviews of CBMI research have been consulted in order to provide an adequate coverage of relevant research in the area of CBMI for ear training.

Comparison Studies: CBMI Versus Traditional Instruction

Most of the early research with CBMI fell into the category of comparison studies against traditional classroom instruction. This kind of research tended to yield inconclusive findings citing "no significant differences" and had been sharply debated in the instructional technology community for decades (see Clark, 1983; Joy & Garcia, 2000; Kozma, 1991, 1994). The following selections are presented to provide readers with a sense of the research direction (or lack thereof) during the 1980s.

The drill-and-practice form of CBMI has been reported to be effective in a number of areas, which include the instruction of instrument identification, the learning of music fundamentals, identification of note names, and key signatures (Jacobsen, 1986; King, 1988). The drill-and-practice ear training was also found to be a viable alternative to traditional instruction, both within and out of the classrooms (Dobbe, 1998). Students who used CBMI performed significantly better than those using traditional classroom instruction (Arenson, 1982; Parker, 1980; Taylor, 1982). Some studies reported statistically significant differences between pretest and posttest score means (Brown, 1990; Eisele, 1985), although no effect sizes were mentioned. Other researchers claimed CBMI to be no more effective than traditional instruction (Jacobsen, 1986; Shannon, 1982). One common perspective developed from this period was to interpret such studies with "no significant difference" as "just as good" or "just as effective"

(Berz & Bowman, 1994; Webster, 2002). Proponents of computer technology continued to accept CBMI as a workable alternative in providing classroom instruction.

Comparisons of commercially produced CBMI products versus homegrown, or instructor-developed, CBMI yielded similar conclusions. Examination of CBMI for the development of intonation and instrument tuning skills of learners (Brown, 1990; Gill, 1988) showed no difference from traditional instruction (King, 1998; Parrish, 1997). While instructor-developed CBMI may lack the features found in commercial products, the former more than made up for it by drawing on learning theories with careful pedagogic consideration. Researchers remain equivocal to the value of comparison studies in justifying the incorporation of CBMI in music classrooms.

Positive Perception Towards Technology

One key advantage of CBMI over traditional, face-to-face, classroom instruction appeared to be the use of technology itself. Technology was useful in addressing mundane and repetitive work and expediting administrative overhead through better management. Instructors were able to reduce time wasted on the checking-out and setting-up of audio equipment, while gaining more time for classroom interactions.

Music students reportedly have a higher affinity towards technology than college students from other departments. Many music students consider CBMI to be helpful in assisting them to learn a musical concept outside of the classroom (Dobbe, 1998). Students also reported CBMI to be more exciting than "boring" traditional classroom instruction (Watanabe, 1981). Fortney (1993) reported that music students displayed a significantly positive attitude towards the use of CBMI. Music students generally welcome the use of (a) *multimedia*, such as video tapes (Gill, 1988), (b) *hypermedia*, such as computer-controlled audio CDs (Fortney, 1993; Lin, 1994), and

(c) interactive CBMI (Worthington & Szabo, 1995) within a music classroom. Improvement in software design continued to elicit positive response (Holland, 1989) and greater enjoyment (Glenn, 2000; Placek, 1974; Worthington, 1995) in the students. The incorporation of audio, video and streaming media in CBMI have a definite positive impact on students' perceptions of music learning.

Same Achievement, Shorter Time

Participants using CBMI appear to have a faster rate of learning. Although test scores are comparatively similar, students using CBMI are able to achieve the results in a much shorter timeframe than students using traditional instruction. Thus, CBMI was believed to be more effective because students require less class time and less teacher intervention (Bowman, 1984; Taylor, 1982). Although CBMI allowed for *faster* learning, it did not appear to have any effect on the magnitude of achievement. Although the test score of both "high-score" and "low-score" groups would increase after training, participants from the "high-score" group would still outperform the "low-score" group (Ozeas, 1991). Because environmental and instructional factors have been shown not to play a significant role in the development of aural skills (Heritage, 1986), researchers believed there were other extraneous factors involved that would better account for the effect of CBMI than simply computing technology.

Individual Differences

One of the advantages of CBMI is its capability to cater to individual differences. This approach ensures that students who need remediation will be redirected to receive additional practice and that students who show competency are "promoted" to the next task skill. While students generally enjoy the challenge provided by CBMI (Kuhn & Allvin, 1967), researchers have reported that an extremely high level of competency (more than 85%) may frustrate students and lead to complaints about CBMI (Hofstetter, 1979; Pembrook, 1986). Inclusion of self-paced learning, prompt feedback, and personalized learning routines will make CBMI an appropriate learning tool that takes into account individual differences found in learners.

Gender is another individual difference often highlighted by feministic researchers. The differences in learning styles between male and female students are often compared to justify any differences in achievement found (Caputo, 1994). An instructional approach that favors rational thinking was alleged to contain hidden biases that would set the female students up for failure. However, there is no strong evidence to suggest that gender differences play a significant role in pitch discrimination achievement.

Amount of Time Spent on Training

Competitive instrumentalists are known to spend hours practicing a piece of music for competition. A musician's proficiency in an instrument has always been attributed to the amount of time spent on practicing (Sloboda & Davidson, 1996). Instrument players who must tune their instruments regularly, for example, violinists, have reportedly developed *quasi-absolute pitch* and been imprinted with the pitch of A_4 (Bachem, 1937; as reported in Ward 1999). This should not be confused with the exceedingly small group of *true* absolute pitch holders, who can identify musical pitches by name or sing accurately any named pitches without any external or internal reference (Wing, 1948). Because more experienced instrument players have also demonstrated a positive correlation between pitch discrimination and pitch matching ability (Morrison, 2000), it would suggest that regular and repeated exposure to certain musical notes might have an effect on pitch discrimination.

Bamberger (1991) likewise believed in multiple hearings of a piece of music to be beneficial for music learning. She believed that when individuals listened again and again to the same piece of music, each new hearing would bring about new understanding of the musical piece. This study took advantage of this knowledge and encouraged participants to listen repetitively to the melodic intervals intended for learning.

Students who use CBMI for ear training have been found to spend more time and effort in doing their practice outside of class. A positive correlation at the 0.05 significance level had been established between the number of *levels* learners achieved with the achievement score for ear training (Hess, 1995). The successful completion of ear training CBMI modules had been suggested to translate into higher sight-singing and dictation final test-scores (Davis, 2001). However, other studies have failed to establish a significant effect between access to CBMI and the amount of time spent on-task on student posttest achievement (Fortney, 1993; Heritage, 1986; Hess, 1994). This is intriguing because if the amount of time spent on practicing an instrument will help a musician improve his or her proficiency in an instrument, why then does the amount of time spent on training the ear, not translate into better achievement in pitch discrimination?

One suggestion may be the economic law of diminishing return. The lack of practice will fail to elicit a positive achievement, but over-training (or over-practice) can also lead to fatigue and other negative psychological factors. The patterns-of-use of students may better explain why students are achieving or underachieving. Bauer (1994) examined the patterns-of-use of students' access and reported that students who access CBMI in the 'Evening/Morning,' 'Late Morning,' and 'Afternoon' groups showed a greater relationship in terms of test score achievement than students from other groups. Thus, future studies of CBMI usage ought to examine closely patterns-of-use, which may yield more meaningful discussion than simply comparing different instructional approaches with test scores. This study analyzed the effects of the amount of time spent by participants on pitch discrimination achievements in melodic interval identification.

Music Instruction Based on Music Learning Theory

Because Gordon’s (1997) Music Learning Theory is relatively new, as compared to other conceptual theories, there have been few developers who incorporate Gordon’s theory into their CBMI development. A comparison study between a widely used ear-training text with researcher-developed materials based on Gordon’s Music Learning Theory showed the two methods to be equally effective for interval identification (Konecky, 1986). Subjects who practiced with a CBMI on pitch discrimination, and received aural/oral training in accordance to Gordon’s Music Learning Theories, developed better pitch discrimination skills than the control group (Brick, 1984). These studies showed that Music Learning Theory could result in a significant difference in student’s pitch discrimination ability.

Overcoming Problems of CBMI

Not all students are, in fact, comfortable with the changes and advances brought about by technology in a college music classroom. Because ear training is a kind of discrimination learning (Walter, 1989b), it required an initial phase of repeated practice and therefore, time. This brought about complaints from students who felt compelled to devote regular periods of additional out-of-class time to practice their aural skills in order to achieve proficiency or mastery.

One common complaint in the early 1980s had to do with the grading approach of CBMI of that time. Programmers of the first generation CBMI tended to adopt “competency-based training,” in which students were required to answer a certain number of quizzes correctly in sequence before they were allowed to progress to the next level. This approach dictated that each student must complete all levels of instruction as programmed in the sequence of instruction. Students who were already proficient with a particular task disliked such an approach because the program would not allow them to skip over the predetermined learning sequence (Hess, 1995; Hofstetter, 1978). Later generations of ear-training CBMI were user-friendlier, as developers learned from early mistakes and addressed the students' frustrations.

The improved CBMI was fairly well received by the learning community. Not only did the newer CBMI adopt an open-ended learner-controlled approach, but it also provided advisement and help when deemed necessary. For more than twenty years, CBMI was adopted for various aspects of music instruction in U.S. college music programs (Davis, 2001; Eddins, 1981). Several reports concerning the application of CBMI in college classrooms (Glenn, 2000), K-16 public education (Berz & Bowman, 1994), and general music instruction (Webster, 2002) have already been published. Although CBMI for ear training continues to receive attention from music educators and researchers, some issues still remain to be addressed.

Additional Barriers

Issues that acted as barriers to the successful implementation of CBMI include teacher barriers, lack of online guidance, poor quality of sound source, music examples that are out-of-context, discouraging grading systems of the CBMI, and system software bugs (Bresler, 1987). Other writers reported a similar lists of barriers which include instructors' and students' poor attitudes, limited student access to CBMI, limited computer platforms, software bugs, different learning styles, lack of advance exercise, lack in flexibility for customization, loss of student test scores, and poor record-keeping.

Some of the named barriers were primarily due to the limitations found in computer technology of the time. Prohibitive cost of computers, error-prone floppy diskettes, and limited processing speed of personal computers of the time all contributed to many of the problems, including limited student access, software bugs, poor record keeping and loss of student test scores.

Much like the advent of CAI helped alleviate many of the resource issues faced by classroom instruction, technology advances such as the Internet, online learning, and WBI can assuage the limitations posted by the aging CAI. New authoring tools with database management appear to be a feasible means to overcome these limitations, thereby removing more than 50% of the said barriers. Obviously, some barriers will have greater bearing towards instructors or students, whereas software bugs and loss of student records are likely to cause frustration to all parties. Special care should be taken to ensure and maintain the integrity of data collection so that student progress is well preserved for records.

The advent of the Internet has brought about a new Web-based learning environment for technology-enhanced music instruction. The following section will present the literature about the new learning environment. Compared with CBMI, a Web-based learning module at the college level has the added advantages of near ubiquitous access and low cost-of-ownership, yet without the hassles and hidden costs related to CBMI, such as audits of software titles, licensing, installation, maintenance, and upgrades.

Section III: Internet-Enhanced Music Learning

Trends Towards Web-Based Instruction

During the 1990s, the tremendous growth of the Internet, coupled with the push for classroom technology integration, left a mark on education. A whole generation of technology-savvy students has been borne out of the pervasiveness of computing technology in classrooms and at homes.

Based on the investigator's classroom experience, college students often do not distinguish between computers and the Internet and think of the Internet as but an extension of the computer, accessible simply by double-clicking an icon. Many high school seniors are now well familiar with computing technologies such as MP3, email, and the Internet (Webster, 2002). When these students gain entrance into college music programs, it is expected that they too will demand similar, if not greater, levels of usage and access to online resources. Several reports have likewise confirmed the trend of increased computer and Internet access among tomorrow's college students:

- The national average of K-12 computer-to-student ratio has decreased steadily from 1:125 in 1983, to 1:27 in 1997, and 1:6 in 2000 (Ely, 2002)
- Nearly all high school seniors auditioned for a college music program considered themselves to be computer-literate, and the majority had a computer at home, and access to the Internet (Hess, 1999)
- About 53% of teachers use software for classroom instruction, and 61% use the Internet in their teaching (Webster, 2002)

Perhaps somewhat surprisingly, music educators were reported as lagging behind many of their colleagues in taking advantage of the Internet as a learning resource. One survey revealed that only 16% of respondents from 493 schools in the state of Illinois indicated the computers in the music areas were connected to the Internet (Webster, 2002). Yet another survey revealed that fewer than 40% of music teachers integrated computer technology into classroom music instruction (Spangler, 1999). Integration at higher education institutions appeared more positive. Although more than 60% of the ear-training computers in higher education institution have a connection to the Internet (Spangler, 1999), no college reported using WBMI for ear training. Even more controversial is the report that instructors have intentionally removed the Internet connection from computers used for ear training to prevent students from "wasting time" surfing the Internet.

At a time when most traditional colleges and universities are trying to attract more technology-savvy students by increasing their offerings in online classes and creating more opportunities for online learning, it is indeed ironic that music instruction has lagged behind in this aspect and even curtailed the use of the Internet. This explains why there are almost no research studies on WBI for melodic and harmonic pitch discrimination or aural skill development. Certainly, this gap in research findings indicates opportunities for future studies.

Platform-Independent Distributed Learning Resources

The Web is no longer just a resource in education. As it becomes easier for students and instructors to gain access to a computer and the Internet (Ely, 2002), the Web is fast becoming *the* vehicle for education delivery. The North Central Regional Education Laboratory (NCREL) asserts that the Internet is now the single most used educational resource (Valdez et al., n.d.). Web-based learning, though similar to CBMI, presents a more valuable approach. Being platform independent and distributable, the Web is accessible by users without the hassles of limited computer platforms or fixed location of access. Because there need only be one development for all operating systems, WBMI allows for a much lower cost of development. With the advent of wireless network connectivity in recent years, WBMI will be accessed in even more places, including restaurants, cafés, and shopping malls, far beyond the walls of college campuses.

However, despite more than 90% of college music programs making use of ear-training CBMI of some sort, more than 45% of college music programs making used of two or more

CBMIs, and more than 50% having ten or more computers in computer laboratories for use with ear-training CBMI, there has been no report on the use of WBMI in college music programs. If WBMI indeed offers so many advantages, why is very little WBMI being used in college music programs? Considering that music instructors are well acquainted with the use of CBMI, the absence of WBMI suggests a serious lack of developmental work, and therefore, suitable materials for online music instruction.

Apart from a handful of early attempts at creating general purpose WBMI, there has been very little WBMI for ear training to date (Bowyer, 2000). The gap in WBMI availability thus presents an excellent opportunity for future research and development and new possibilities for "utilizing this resource to help students learn" (Bauer & Daugherty, 2001, p. 32). The accessibility and convenience, cross-platform functionality, interactivity, provision for instant feedback, self-paced learning, and ease of information updates all contribute towards making the Web a feasible vehicle for instruction delivery.

Technology integration in classrooms will increase the demand for WBMI. Emerging technologies, which included (a) reusable Web-based modular instructional units (e.g., learning objects and instructional components), (b) untethered Internet connectivity (e.g., wireless and microwave connection), (c) broadband connection, (e.g., Internet2 and 3G), and (d) streaming-media technology (e.g., Quicktime and Windows Media) will all further the trends of WBMI and interactive online learning. However, as Reeves and Reeves (1997) pointed out, "what is unique about WBI is not its rich mix of media… nor its linkages to information resources around the globe, but the pedagogical dimensions that WBI can be designed to deliver" (p. 59). They further advocate that "the design of WBI should be based upon sound learning theories" (p. 60). With greater improvement in Web-based authoring tools, there is no doubt that development of interactive learning objects will become easier. However, without proper support of student learning with better pedagogy and learning theories, it is meaningless to assume technology integration will improve instruction. A WBMI should never be developed to serve merely as a technological showcase, but must in addition be grounded in learning theory for effective learning and classroom pedagogy. This study incorporated Gordon's (1997) Music Learning Theory into the WBMI to better support students' learning.

Initial Efforts in Web-Based Music Instruction Development

Based on the initial report provided by the 1998 Proceedings of the Technological Directions in Music Learning Conference (TDML), it can be said that the WBMI is a fairly new undertaking by researcher-developers in recent years. Readers are referred to the TDML Conference for updates on the latest WBMI endeavors. The following list outlines some of the WBMI development pertaining to ear training, as reported at the TDML Conference since 1993:

Music Dictation and Error Detection (2 reports):

1. Development of a WBI for error detection (Gonzales, 1998)
2. Development of a blended-approach aural dictation: Students select and listen to a Web-archive of MIDI sample through a graphical user interface with a CD-ROM. This Windows/Macintosh dual-platform CD-ROM was developed using Macromedia Director (Koozin, 2001)

Ear Training (3 reports):

1. Development of a Web-based "Aural Training Diagnostic Test" using JavaScript and QuickTime (Estrella, 1999)

2. Development of a Web-based Ear Training module named WebET, using Beatnik plug-in technology (Murray, 1999)
3. Development of a WBI for ear training using Beatnik player controlled by JavaScript (Kothman, 2000)

Music Listening (4 reports):

1. Development of a Web-based resource and online quiz for a music listening course (Murphy, 2000),
2. Development of a WBI for teaching of music appreciation using Macromedia Director (Lipscomb, 2000)
3. Development of a Web-based music appreciation and listening course using QuickTime and MP3 files (Murray, 2000)
4. Development of a Pocket Guide to Music Listening using Beatnik player controlled by JavaScript (Estrella, 2001)

The first generation of WBMI for ear training primarily made use of a software sound player, either QuickTime or Beatnik, controlled by JavaScript. However, the publisher of Beatnik has since chosen to discontinue support for the product, thus forcing researchers to search for an alternative technology for Web-based audio delivery. The practical issue of finding a viable technology that is easy to learn and yet has the capability to deliver high-fidelity musical sound files remains.

New Tools for WBMI Development

The advent of user-friendly Web editors and powerful authoring tools can help educator-researchers overcome hurdles for developing suitable WBMI for ear training. Authoring tools such as Macromedia Flash, as well as scripting languages, are easier to understand and may be learned in a relatively short time (Khan, 1997) when compared with programming languages such as C++ and JAVA. Many of the educators who want to develop interactive WBMI for their students may now do so without incurring too much overhead (Estrella, 2001). Additionally, the availability of transform coders has allowed for the creation of attractive WBMI modules that make use of recorded sound with high fidelity for music learning, yet light on download time for speedy delivery.

The establishment of the TDML Conference provided a forum for educators and researchers to share and discuss the application of computing technology to music theory, learning, and practice. Over the past years, several efforts of WBI development for music instruction have been reported at the TDML Conference (e.g., Estrella, 1999; Kothman, 2000). However, several issues remained to be overcome if WBMI is to make any impact in music learning at all.

Motivational Web Sites

A search on the Web using Google, in conjunction with the ear training resources provided by Spangler (1999), found only three active sites, as the rest of the Web sites listed have since become defunct. Several issues prevent these Web sites from becoming useful in music instruction. First, these ear training Web sites were simplistic looking, text-based, and contained only ear training quizzes (an example is presented below as Figure 5).

Figure 5. Screen Image of an Ear Training Web Site
[http://www.ossmann.com/bigears/]

Presumably, these Web sites intend only to target amateur musicians who are interested in ear-training exercises. Nevertheless, studies have shown that Web sites intended for education require motivational elements to better engage learners. Motivational elements of educational Web sites include appropriately designed instruction, supplemented with a good color scheme, sound, graphics, and motivational content (see Arnone & Small, 1999; Loh & Williams, 2002). Text-based Web sites are sterile and simplistic looking with their grey backgrounds, and will quickly lose their audience because there are far too many “cool” and well-designed Web sites to compete for users’ attention.

Second, these Web sites make use of MIDI files for instrument sound playback. Although MIDI allows for simulation of up to 128 different sounds, the quality of sound generated by MIDI is highly dependent on the make, cost and quality of the synthesizer chip. Even professional synthesizer manufacturers have since moved away from synthesizing lower quality sound using software synthesis and turned towards high fidelity sampled sound for better consistency in playback. The availability of transform coders such as MP3 finally made Web-based delivery of high fidelity sampled sound files a reality. Embedding MP3s as audio files in WBMI is more viable for college music instruction because on-campus high-speed Internet is increasingly ubiquitous. The ear-training module developed for this study took advantage of new authoring tools and transform coders to deliver high-quality, sampled instrument sound to potential user-learners across the Web for the purpose of music instruction in ear training.

Online Tracking of Students' Progress

As existing ear training Web sites were not developed with online learning in mind, instructors have no means of tracking the progress of students using these sites. This renders all existing ear training Web sites unsuitable for classroom use.

Based on the available technology resources and the need to create suitable WBMI in ear training for classroom use, the investigator developed a Web-based learning module for ear training with the help of an advanced scripting language and online database to keep track of students' progress records. The combination of an attractive and friendly user interface with online database capability afforded the Web-based learning module with interactivity and tracking of users' activities, found commonly in commercial e-learning Web sites with extensive learning management systems. The availability of this Web-based learning module for ear training means:

1. Students can now have the benefit of immediate feedback when using WBMI
2. Students can now access the WBMI anywhere, on and off campus
3. Students' progress is properly preserved in a centralized online database, eliminating the need for housekeeping and storage of removable media
4. Instructors can keep track of students' scores anytime via any Internet connection

5. Instructors can change the number of questions in the quiz, add to the item-pool, and modify the contents of instruction, at will.

Since the Internet is available 24/7 and becoming more ubiquitous, even wireless, students can benefit from the WBMI as a mobile learning tool using wireless laptops and other personal computing devices.

Tracking the Amount of Time Used

The amount of time spent on learning is an important issue for consideration in ear training research. Murphy reported a positive correlation between frequent use of Web-based learning materials and increased performance by students in a music listening course. Because Murphy's (2000) Web site was protected by password, he was able to track students' logins as a means to measure the number of times they visited the Web pages and determine if the number of logins correlated with performance. This study made use of a similar mechanism to track the students' usage of the Web-based ear training modules and to ascertain if the amount of time spent online by participants did, in any way, affect their pitch discrimination achievement scores.

Summary

The improvement of aural skills through ear training is part of the formative education received by beginning college music students. Current practice in many college music programs relies on CBMI to develop and improve the listening skills of college music students through pitch discrimination tasks. While online learning has become an acceptable and viable mode of instruction in higher education institutes, there is currently very little suitable WBMI for use in college music programs, ear training in particular. The advent of new Internet-related technologies has provided new avenues for enhancing existing CBMI for use with the Web and new WBMI development.

The music learning community needs more WBMI that is not only pedagogically appropriate, but also instructionally useful, motivating, and usable to both the music instructors and students. Pitch discrimination tasks in ear training that make use of real instruments instead of MIDI-synthesized sound would add advantage, but those that made use of the sound of a musician's primary instrument would be an even more authentic approach. Authentic acoustic instrument sounds should be used in aural perception learning because it is important for student musicians to become as familiar as possible with their primary instrument of study, as their skill with the instrument could directly affect how successful they are to be in their careers as musicians.

The advent of digital-audio transform coder technology, such as MP3, has made it possible to incorporate realistic sound sources with high fidelity into WBMI. A WBMI environment further provides the student musicians with advantages such as (a) a "safe" environment to fail without being threatened by public disgrace, (b) a place for self-paced learning where students can try over and over again, and (c) a convenient means to access the learning schedule of a time and place of their choosing. Based on all of these needs for a better WBMI for ear training, the investigator developed an online learning module for melodic pitch discrimination named Mona Listen for this study. The data gathered by Mona Listen as college music students engaged in online pitch discrimination training were used to test the null (H_0) and alternative (H_A) research hypotheses for the following research questions:

1. What are the effects of Web-based pitch discrimination training on achievement on melodic interval discrimination?

   $H1_0$: Web-based pitch discrimination training will have a negative or no significant effect on achievement in melodic interval discrimination.

$H1_A$: Web-based pitch discrimination training will have a positive significant effect on achievement in melodic interval discrimination.

2. Do different instrument sounds used in pitch discrimination training affect the achievement in melodic interval discrimination?

$H2_0$: Pitch discrimination training in different instrument sounds will have a negative or no significant effect on achievement in melodic interval discrimination.

$H2_A$: Pitch discrimination training in different instrument sound will have a positive significant effect on achievement in melodic interval discrimination.

3. Does the amount of time spent on-task in pitch discrimination training affect achievement in melodic interval discrimination?

$H3_0$: The amount of time spent on-task will have a negative or no significant effect on achievement in melodic interval discrimination.

$H3_A$: The amount of time spent on-task will have a positive significant effect on achievement in melodic interval discrimination.

CHAPTER 3: METHODOLOGY

Introduction

The preceding review of the literature revealed that Web-based music instruction (WBMI) for ear training is a viable solution for overcoming a number of problems faced by college music instructors teaching pitch discrimination using traditional, even computer-assisted, instructional methods. A well-designed WBMI should be pedagogically sound, based on perceptual learning theory, able to keep track of students' progress, and motivational. Additionally, as the Internet becomes increasingly ubiquitous, WBMI should allow instructors easier access to student information. Recent advances in audio technology have made it possible to include authentic instrument sounds as a sound source for incorporation as learning resources and test items in the WBMI for ear training. Sampled instrument sounds offer much higher fidelity than the sounds generated using MIDI synthesis that are commonly found in other computer-assisted instruction (CAI) for pitch discrimination.

Product development using the new generation of authoring tools has become easier because these tools are now created with non-programmers in mind. This means that even researchers who have very basic programming skills will be able to work with these tools to develop new modules or customize existing modules to their needs. An online learning module named Mona Listen was developed for the purpose of data collection in this study. The effects of pitch discrimination training on achievement in melodic interval discrimination of college students were investigated using data collected from Mona Listen.

Figure 6. Screen Image of Mona Listen
[http://monalisten.csloh.com]

Prior to data collection, a pilot study was conducted to test and validate the online learning module and to improve the research design of the study. Subsequent sections in this chapter describe the research situation, research design, participants, procedure, materials, data collection, and data analysis design.

Description of the Research Situation

The research was conducted in the form of a WBMI, or online music course. Participants were able to gain access to the online course at anytime, from anywhere, using any computer with a high-speed Internet connection; this included most computer clusters on the campus. The only hardware accessory required for the playback of sound was either a pair of headphones or computer speakers. Software requirements included a recent version of Internet Explorer and the latest Macromedia Flash plug-in. Prior to the study, computers in the music laboratory at the School of Music were updated to work correctly with Mona Listen, in order to facilitate easy access to the Web-based learning module from the computer laboratory by students at the School of Music.

During the two-week data collection period, participants retained complete control of the time and place to access the WBMI. Mona Listen was also “smart” enough to detect if software requirements were met before allowing login. Participants at a computer that lacked the necessary plug-in would be prompted to download and install the Flash plug-in before they were allowed to proceed to the primary learning area.

Participants

Participants for the study were first year music majors at a Research I university in the southeastern region of the United States. Permission to collect data from human participants was obtained from the Institutional Review Board at the host institution prior to the commencement of the study (see Appendix A). A total of 78 first year students, comprised of 34 males and 44 females above 18 years old, enrolled in the Music Theory I (MUSI 1110) class where pitch discrimination was a major instructional component.

All participants were music majors who were accepted into the music class of 2007 based on their musical performance in an audition-selection test. Although students from other programs in the university were allowed to take classes as non-majors with the School of Music, the MUSI 1110 class was only open to music majors. Non-majors were not expected to become musicians upon graduation, and therefore were not given the rigorous training required for music majors. Apart from music theory, music majors also had to undertake the study of a particular acoustic instrument, including voice, throughout their undergraduate programs of study.

The online ear-training tasks were assigned as a two-week long class assignment. Two ear-training Web sites, namely Mona Listen [http://monalisten.csloh.com], and Big Ears [http://www.ossmsnn.com/bigears/] were chosen by the investigator and were subsequently reviewed and approved by the course instructor as the online learning resources during the data collection period. Students of the MUSI 1110 class could choose either Mona Listen or Big Ears as Web-based pitch discrimination training. Those who completed all relevant exercises in any of the WBMIs would receive full marks for two weekly assignments. As reference, an entire semester's weekly assignments made up just 10% of a student's overall grade. This arrangement served the students well by rendering the online learning tasks as authentic classroom assignments, and at the same time, providing an opportunity for the instructors and students to try out WBMI for ear training.

Recruitment took place during class time whereby the investigator was invited to speak to the first year college music majors about the research study. Students consenting to participate in the study were asked to register as users of Mona Listen. Those who did not register with Mona Listen had to complete Big Ears as their weekly assignment. Because Big Ears did not have user-tracking ability, the instructors suggested that Big Ears users keep a "pen-and-paper" access log as proof of completion of the module. Mona Listen users were tracked automatically upon login. All 78 students in the MUSI 1110 class registered with Mona Listen; however, only 73 of them actually made use of the learning materials. Five students were considered to have withdrawn from the study — one registrant was removed due to late registration, and four others never made use of the WBMI at all.

The investigator sent out a welcome email to each participant detailing the participant's login password, as well as the duration and the deadline of the online course. The combination of student ID and login password thus allowed the participants to access Mona Listen for ear training at anytime, from anywhere via the Web. While the intended duration of the online course was just 14 days, the data collection period had to be extended to 16 days to preserve the ecological integrity of the study due to a small number of students who could not meet the deadline because of poor time management.

While there was a maximum limit on how many days participants were allowed to complete the online course, there was no minimum limit. Because of the unstructured nature of online courses, participants were allowed to make their own choices concerning their own pace of learning in completing the online lessons. Out of the 73 participants, a total of 65 music freshmen from the MUSI 1110 class completed all aspects of Mona Listen and received full marks for two weekly class assignments.

Development of Research Materials: The Making of Mona Listen

Progress tracking of the first year music students' online usage of Mona Listen was an important requirement for the learning modules, without which there would be no data for analysis. Before they could be tracked as human subjects, the students had to be informed of the tracking process for ethical reasons. Additionally, there needed to be a formalized *registration* and *exit* process that would take the music students through the entire study.

The user registration process for Mona Listen was expedited through a series of Web pages created to channel potential participants through the entire process (see Appendix B). These registration pages [http://monalisten.csloh.com/signup/] outlined the background of the research study, explained the need for participation consent, provided users with an alternative WBMI named Big Ears should they be choose not to participate in the study, and finally, solicited participants' demographic information. The participants' unique university-wide ID was used as login ID to Mona Listen.

A welcome email was sent out to every participant within 24 hours of registration. A pseudonym, *Mona* (as in Mona Lisa), was chosen to be the sender of the welcome email. This was done deliberately to provide the participants with: (a) an online persona with whom they could relate, (b) a mental connection to the site name Mona Listen and the corresponding Web address, http://monalisten.csloh.com, and (c) a personal touch to the research and learning environment. The following is the content of the email sent to participants from *Mona*.

> *Hi,*
>
> *Welcome to Mona Listen. It's great to have you signup and I hope you will have a good time learning.*
>
> *Do not hesitate to let [investigator] know if you experience any problems, including difficulty with logins. He can be reached at [telephone number] or [email address].*
>
> *You will, of course, need a pair of headphones or computer speakers ready to do the ear training properly, and about 30-minutes of uninterrupted time for each tutorial/quiz.*
>
> *Oh, I work best with a recent version of Internet Explorer and the latest Flash plug-in… (You have heard all that before, right?)*
>
> *You can visit my learning studio anytime at: http://monalisten.csloh.com/ and here's your password: [password]*
>
> *You will need to complete the entire course by midnight [day] [last date of study].*
>
> *Have fun, and I will meet you soon…*
>
> *Mona*

Any subsequent emails from the investigator were likewise communicated to the participants as if from *Mona*. Throughout the online module, participants would further encounter *Mona*, both as a background image and as the *virtual instructor* who provided the learners with feedback. Depending on the students' achievement scores in the online tutorials and quizzes, *Mona* would give appropriate comments, provide words of encouragement, or direct the students to retake the quiz or to move on to the next assignment (refer to Appendix C, No. 3, for a sample screenshot of Mona's feedback).

Melodic Interval Sampling Process

All of the melodic intervals needed for the study were first entered into GVox's Encore 4.5 as two separate music sheets, one containing the 20 test items used in the pretest and posttest (see Appendix D), and the other, the entire library of melodic intervals used in the tutorials, amounting to a collection of 192 melodic intervals. The MIDI information from the Encore file was then imported into Propellerhead's Reason 2.5 for the generation of sampled instrument sounds. The quality of the WAV files resembled those from a live recording because the sounds used in the generator were sampled from real instruments. The Acoustic Grand (piano) and Acoustic Guitar were the two instrument-sound banks chosen from Reason, and used to generate melodic intervals sound files for this study. All sound files employed in Mona Listen were in equal temperament tuning at the International Concert Pitch of A = 440 Hz. Because participants of the study were music majors and players of acoustic instruments, they would be most comfortable and familiar with instrument sounds in the modern tuning.

Melodic intervals in piano and guitar sound were first recorded as 16-bit WAV files at 44,100 kHz. The WAV files were normalized at –16 dB using SoundForge 6.5 for "equal loudness" and then spliced into individual melodic intervals. The two sets of melodic intervals (piano and guitar) were then transform-coded in Macromedia Flash as low (28 kbps), medium (32 kbps), and high (48 kbps) quality MP3 files. Because college students would probably not have access to audiophile equipment at computer laboratories, libraries, and dormitories, the fidelity of the sampled sounds heard over standard headphones and computer speakers was considered to be an important issue in this study.

External Validation of Sound Quality

Two musical experts, a practicing musician and a college music professor, were engaged to rank the audio test-samples as Acceptable or Not Acceptable in a "blind" condition, using only standard headphones or computer speakers. The outcome of the hearing test showed that 28 kbps samples were "too soft" and low in fidelity, thus not acceptable for ear training. Both 32 kbps and 48 kbps samples were of production quality and were found acceptable and virtually indistinguishable when listened to using standard computer speakers and headphones. Therefore, 32 kbps was preferred over 48 kbps because it offered similar fidelity with smaller file size and was thus adopted as the standard for sound sampling in the final study.

For each of the twelve chromatic keys, two octaves of ascending and descending melodic intervals were sampled, comprising perfect fifths, perfect fourths, major sixths, and minor thirds. A total of 304 melodic intervals were sampled for the final study, which consisted of 48 melodic intervals, in guitar and piano sounds for each of the four intervals, plus the 20 test items used in the pretest and posttest. Table 4 shows all of the notes sampled for the key of C. The other eleven chromatic keys were sampled accordingly.

Table 4

Melodic Intervals Sampled for the Key of C

Melodic Intervals	*Octave 1 (Ascending)*	*Octave 2 (Ascending)*	*Octave 2 (Descending)*	*Octave 1 (Descending)*
Perfect Fifth	$C_4 – G_4$	$C_5 – G_5$	$G_5 – C_5$	$G_4 – C_4$
Perfect Fourth	$C_4 – F_4$	$C_5 – F_5$	$F_5 – C_5$	$F_4 – C_4$
Major Sixth	$C_4 – A_5$	$C_5 – A_6$	$A_6 – C_5$	$A_5 – C_4$
Minor Third	$C_4 – E^b{}_4$	$C_5 – E^b{}_5$	$E^b{}_5 – C_5$	$E^b{}_4 – C_4$

Note. C_4 = middle C

Strengthening Participants' Audiation With Running Intervals

A melody, or "song without word," comprised of all 48 pairs of melodic intervals was conceptualized by the investigator as a means to facilitate continuous listening for the training of pitch discrimination. A *running interval* for a named melodic interval would include two octaves of the said interval in both ascending and descending manner for all twelve chromatic keys, beginning with the key of C and ending in the key of F, progressing through the Cycle-of-Fifths: C-G-D-A-E-B-F#-C#-G#-D#-A#-E#/F (see Figure 7). A total of four running intervals were thus composed, one each for the four melodic intervals covered in the study: P5, P4, M6 and m3. Participants were encouraged to listen to the running intervals as many times as possible and to hum or sing along in solfege as they listened in order to strengthen their audiation.

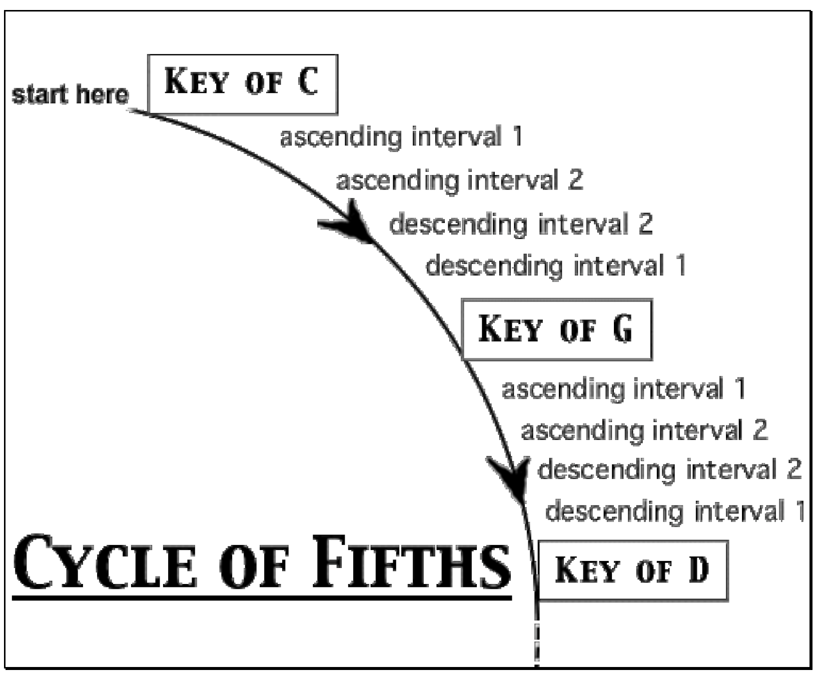

Figure 7. Construction of Running Interval Using Cycle of Fifths

Instructional Development Model

The Web-based training module Mona Listen was really a potpourri of Flash animation, programming scripts, and a scripted online database. As dictated in all good instructional design processes, the analysis of learning content and design of instruction should take place before any development work or coding of instruction. (Readers who might be interested in the investigator's reflection on the instructional development process are referred to Appendix F.) Several sessions of brainstorming and storyboarding occurred before the idea of using a pedagogic agent was finalized. The investigator stumbled upon the idea of using Mona Lisa as the center figure for the application while browsing a promotional pamphlet.

Once the idea of using Mona Lisa was confirmed, the investigator searched for a snapshot of the painting, prepared the graphics for digitization in the Flash animation, and began doodling. This was followed by searching for an appropriate piece of title music with enough energy to accompany the splash "movie" and to set the tone for the research study. After the initial splash movie was finalized, next came the "storyboarding" process, in which the "flow of information" was storyboarded so that users were properly channeled to the relevant Web pages. This information flow design process also included the interface design for the "Portal," the login process, chunking of messages from Mona and content material for each learning module. Only after all of this preparatory work did coding begin.

Macromedia Flash made use of a programming script called ActionScript to "drive" the Flash application. ActionScript is a subset of the ECMAScript language, from which came JAVA and the PHP Hypertext Processor (PHP). Although the investigator had taken one college-level introductory programming class using JAVA language, he had no knowledge of ActionScript, PHP, and MySQL prior to the conceptualization of the study. An entire summer semester was thus devoted to learning the scripting languages and online database through self-study books purchased from several online bookstores.

Once the Flash application, which consisted of several modules, became operational, the modules were posted onto the hosting Website for *usability testing*. Several persons, including the investigator's 11-year old daughter, were enlisted at this time to "play with" the modules and comment on their usability. Based on users' feedback, several modifications were made to make the application flow better. After that, the Flash application was finally connected to the online database for *beta testing.* Participants of beta testing were not included in the pilot testing, and once again, modifications were made where necessary.

The Pilot Study

After Mona Listen had been thoroughly tested, a pilot study was conducted in order to provide an opportunity to test the methods of data collection and to identify potential weaknesses in the overall design of the study. The pilot study also helped reveal issues not previously considered during the data collection process. Seven graduate students participated in the pilot study. Participants of the pilot study were similar to the participants of the final study in that they all had no prior experience of audiation, but wanted to improve their pitch discrimination skills. It was believed that Mona Listen would have similar effects on this group of students. The outcome of the pilot study showed that both music majors and non-majors participants benefited from an improvement in posttest achievement scores. However, because the participants of the pilot study group were not training to become musicians, they were less motivated to complete the online learning modules. Some of the music non-majors also found the learning materials to be too demanding. Therefore, only music majors were recruited as participants for the final study.

The pilot study showed that students were less motivated to participate when the WBMI was perceived as extra work, which carried no credits in their courses. A decision was made to incorporate the study as part of regular weekly class assignments and to add a second, comparable online course as an alternative. However, turning the online course into a weekly assignment for every student raised the question of the study design. On one hand, a true experimental requires the participants to be divided randomly into experimental and control groups. On the other hand, should an experimental intervention prove to be effective within an educational setting, there may be an ethical issue related to the control group being precluded from receiving the intervention. Thus, the best approach was to conduct a quasi-experimental study using a repeated measure design where students could be included as participants of a study and at the same time serve as their own experimental control.

The pilot study also revealed several weaknesses in the research design, which then resulted in several adjustments. First, the demographics survey was modified to include extra information on the students' musical background and training, such as their experiences in playing instruments different from their primary instrument-of-study in the music program. This information would be helpful in determining if the students already had prior ear training or musical experience that might affect their ability in pitch discrimination. While a participant who had prior musical experience should not automatically be assumed to possess good pitch discrimination skills, it could explain why this participant may require less time to complete the online learning module. Another change was effected in the instrument names listed as the participants' primary instrument — the term *Piano* was changed to *Piano/Keyboard* to also include the keyboard players.

Second, the session ID used in keeping track of individual users could potentially constitute a security breach on computers with a slower, dialup Internet connection. Because the Web pages originally had a white background, it was very easy to see the session ID on the screen. The investigator feared that this might attract some mischievous students to hack the online module using the Session ID and alter the data associated with the session. As there was no way to prevent the session ID from being shown, a decision was made to change the background of the Web page into black color, in effect masking the session ID.

Third, based on participants' feedback, thirty quiz questions were too much for one sitting and users became fatigued. Twenty test items were found to be optimum for quizzes, tutorials, pretest, and posttest. Because every module contained 48 melodic intervals, a script was written to generate 20 randomly ordered questions from the item pool. This further increased the validity of the learning module because every set of questions would be different, even if participants revisited the module immediately.

Fourth, the assessments in Mona Listen were fine-tuned using suggestions obtained from expert reviews. A 30-second count-down timer was added to each quiz question to provide enough challenge for the participants when doing pitch discrimination and to reduce cheating with an external pitch making instrument. Pitch matching of intervals in CAI using the commonly available musical keyboards in the music laboratory was a well-known method of cheating among the undergraduate music students. The 20 test questions for both the pretest and posttest were balanced using an exact number of ascending and descending melodic intervals of P5, P4, M6, m3, and distracters comprised of melodic intervals not covered in the modules. Last but not least, because the sound of a tritone was very distinctive, the experts believed that it would give away the answer and not be a good distracter. The tritone has since been replaced by a Major Sixth as one of the four distracters used in the pretest and the posttest.

Data Collection Instrument

The study was conducted using a quasi-experimental approach with repeated measures so that all students from the MUSI 1110 class could be included as potential participants who, at the same time, served as their own experimental control. Mona Listen was developed with an online database, thus eliminating the need for record keeping using removable media such as floppy disks. The online database further provided instructors with the means of retrieving students' records at any computer with an Internet connection. The online database captured and kept track of all students' records, including achievement scores, demographic information, time of login and logout, time-of-access for individual modules, and self-reporting of test-score improvement from pretest to posttest. The combination of login ID and password was the only means of user verification for the online course. The verification process ensured that only consenting participants of the research study were allowed access into the content area of Mona Listen.

Participants of the research study ($N = 73$) were divided at random into two instrument-sequence groups: Piano-Guitar (PG) and Guitar-Piano (GP). The instrument sequence was assigned to each participant at the point of registration. Based on this design, it was not possible to obtain equal number of participants for the two groups.

Record keeping by the online database was an extremely important task for Mona Listen, because the correct instrument sound must be played according to the instrument sequence assigned to each participant. For instance, a participant from the PG group would hear the melodic intervals of P5, P4, P4/P5 tutorials in piano sound, and M6, m3, M6/m3 in guitar sound.

Table 5 shows how participants from each instrument-sequence group proceeded through the online learning module.

Table 5

Instrument Sequence

Learning Module	*Piano-Guitar Group*	*Guitar-Piano Group*
P5	Piano	Guitar
P4	Piano	Guitar
Mix45	Piano	Guitar
M6	Guitar	Piano
M3	Guitar	Piano
Mix36	Guitar	Piano

A counterbalance design was used in this study to control for any possible carryover effect. Logical exit points and chunking of learning modules by melodic intervals served as controls for fatigue effect. Participants were given a choice to continue or exit at the end of every learning module, each of which took an average of fifteen to twenty minutes to complete. Further, the test items were randomized to control for any practice effect.

External Validation of the Research Instrument

The external validity of Mona Listen and the data collection instrument were corroborated through expert review. The expert review group consisted of two practicing musicians, the MUSI 1110 course instructor, and five graduate assistants who were teaching the ear-training component of the MUSI 1110 course.

A duplicate Mona Listen Web site, called Mona_DEMO, was created to preserve the integrity of the research data. The two sites were identical for all practical purposes. Login passwords and IDs were issued to the experts to allow access into the Mona_DEMO site. All of the experts took part in the posttest and confirmed that the test questions were of comparable standard to the ones used in the MUSI 1110 class. They also affirmed that the sound sources of MP3 used in the learning modules were of very high fidelity. The outcome of the review was highly positive. Some of the comments from the experts are listed below:

- "This is a really well done ear training program. I very much like the fact that the exercise only included a small set of intervals; this allows the user to concentrate on learning each interval outside of the context of a scale or comparative environment."
- "The samples are of very high quality and easy to listen to."
- "In general, I believe the site is well-thought out, and attractive… I look forward to seeing additional modules."
- "I find the program very nice. Everything seems to work very smoothly."

One week after the closure of the online course, a pen-and-paper follow-up posttest was administered to all students of the MUSI 1110 music majors. The purpose of the follow-up posttest was to check for any noticeable differences between online testing using sample sounds and classroom testing using real instrument sounds, which in this case were provided by an acoustic upright piano. The follow-up posttest also served as an indicator of post-training retention of pitch discrimination skill.

About 15% of the participants voluntarily participated in several session of focus-group discussions, which were conducted immediately after the follow-up posttest. Feedback from these focus groups showed that participants generally found no difference between taking the posttest online via Mona Listen and taking the posttest in class with the instructor playing on the piano.

Data Collection Procedure

Data collection in this study was conducted entirely online. Users could login to the online learning module from any computer with Internet access and progress through the lesson in a self-paced manner. Except for the pretest, which the students needed to complete before gaining access to the actual lesson, all other tests and quizzes could be taken at any time at the participants' discretion. The following section describes how a typical participant might have progressed through Mona Listen.

(A) Splash Module

A "splash," or movie, showing Mona donning a pair of headphones was shown to the participants during their first logins. After the splash, users would click on a "proceed" button to progress through the "pages" of information. Prior to every learning module, namely P5, P4, M6, and m3, users were cautioned to set aside 30 minutes of uninterrupted time for learning. If they were unable to spare the 30 minutes, they were advised to logout and return to Mona Listen when they were able to do so. No assessment was given in the Splash module.

(B) Introduction Module

An Introduction module then briefly explained what audiation is, and reminded the user of the 14-day duration of the online course. The user then had to complete a pretest before being allowed access to the rest of the learning modules. Similarly, no assessment was given in the Introduction module.

(C) P5 Audiation Studio

After the pretest, users were ushered into the "P5 Audiation Studio," where they would familiarize themselves with the P5 running intervals. When the participants were ready, they would try the 20-item assessment designed to test for P5 audiation. Based on their achievement score, users might be advised by Mona to either (a) proceed to the next tutorial if they scored 85% and above, or (b) repeat the P5 tutorial and retake the quiz if they scored below 85%.

(D) Access Portal

Once the users completed the P5 tutorial, they would be given access to either the P4 audition studio or the Access Portal (Appendix C, No.4). The Access Portal provided users with a centralized gateway into all parts of the tutorials, namely, P5, P4, P5/P4, M6, m3, M6/m3, and posttest. Access to the pretest was purposely removed to prevent users from taking the pretest more than once. There was no assessment in the Access Portal.

(E) Other Audiation Studios

The participants were allowed up to 14 days to explore and learn from the other Audiation Studios, namely, P4, M6 and m3, using Mona Listen's Access Portal.

(F) Mixed Assessments

There were two mixed assessment modules in Mona Listen, namely, P4-P5 mixed, and M6-m3 mixed. Generally, participants would attempt the mixed assessment modules after they had completed the audiation processes for the individual intervals. There were 20 questions in each mixed assessment module.

(G) Posttest Module

Participants were given the opportunity to attempt the final assessment, which is the posttest, after they had completed all of the quizzes. The same 20 test items were used in the pretest and the posttest, but in a randomized order to minimize any practice effect. Once a participant completed the final assessment, he or she would be guided through a sign-off process, where Mona would remove the participant's password from the online database. The difference between pretest and posttest scores would denote the improvement made after pitch discrimination training with audiation.

Data Analysis Design

The main research question for this study was: "What are the effects of Web-based pitch discrimination training on achievement in melodic interval identification?" A total of 65 students (male = 30, female = 35) completed both the online pretest and posttest, and 62 of them (male = 29, female = 33) also completed the pen-and-paper follow-up posttest. The three students who missed the follow-up posttest were either absent for the day or were late for class and arrived only after the follow-up posttest had started.

The 65 first year college students who completed the online tests comprised of music majors specializing in brass ($N = 12$), guitar ($N = 2$), piano ($N = 11$), strings ($N = 7$), voice ($N = 9$), and woodwind ($N = 24$) instruments. Participants were randomly assigned to one of two groups for pitch discrimination training of melodic intervals at the point of online registration for the study. One group of participants ($N = 31$) received training for P5/P4 intervals recorded in piano sound, followed by M6/m3 in guitar sound; and a second, counterbalance, group ($N = 34$), received training with P5/P4 recorded in guitar sound, followed by M6/m3 in piano sound.

The online pretest and posttest were integral modules from the Web-based music instruction (WBMI) called Mona Listen. The pen-and-paper follow-up posttest was administered one week after the two-week long online course had concluded to check for transfer and retention of pitch discrimination skills. Classroom instructors conducted the follow-up posttest during a regular music class period.

All test items from the pitch discrimination tests were selected from a single item bank of 20 melodic intervals. The 20 pitch-discrimination test items consisted of melodic intervals of five interval classes (P5, P4, M6, m3, and distracters), two play orders (ascending or descending), and two instrument sounds (piano or guitar). Distracter intervals were extraneous simple melodic intervals other than P5, P4, M6, and m3. The 20 multiple-choice test items were randomly selected form the item-bank and presented to students taking the online pretest and posttest. Class instructors randomly selected 12 items from the item bank to be played using the acoustic piano in their classes as follow-up posttest. No melodic intervals in guitar sound were used in the follow-up posttest. Students within a single class received an identical follow-up posttest, although class-to-class variation occurred as a result of instructor selections. The 20 pitch discrimination test items were carefully counterbalanced to ensure validity (see Table 6).

Table 6

Melodic Intervals by Class, Order, and Instrument Sound

Interval Class	*Piano/ Ascending*	*Piano/ Descending*	*Guitar/ Ascending*	*Guitar/ Descending*	*Total Items*
Perfect 5th	1	1	1	1	4
Perfect 4th	1	1	1	1	4
Major 6th	1	1	1	1	4
Minor 3rd	1	1	1	1	4
Distracters	1	1	1	1	4
Total Test Items	4	4	4	4	20

The data collected from the instruments were examined using directional *t*-tests and multivariate analysis with repeated-measure design. Feedback from the post-treatment interviews and focus groups were reviewed to inform the test results, and conclusions, as well as identify directions for future research. The results of the data analysis were used to support or reject the following null hypotheses:

1. Web-based pitch discrimination training will have a negative or no significant effect on achievement in melodic interval discrimination.
2. Pitch discrimination training in different instrument sounds will have a negative or no significant effect on achievement in melodic interval discrimination.
3. The amount of time spent on-task will have a negative or no significant effect on achievement in melodic interval discrimination.

CHAPTER 4: RESULTS

Overview

The purpose of this study was to investigate the effects of pitch discrimination training on achievement in melodic intervals identification. This study employed a quasi-experimental repeated measure design to determine the effects of pitch discrimination training. No experimental control group was necessary because participants of this repeated measure study served as their own control.

A total of 3,344 data points, or observations, were obtained from the three achievement tests. Inter-item correlation of the observations was computed using Cronbach alpha (α). A reliability coefficient of .906 (maximum = 1.00) attested to the high inter-item correlation among test items.

Statistically significant differences in this study were reported at the $\alpha = .05$ level. Although effect sizes in educational studies are more commonly reported as Cohen *d* values, the calculation requires two independent samples, namely an experimental (N_{exp}) and a control (N_{ctl}) group. Because studies using repeated measure design make use of only one group of participants ($N_{exp/ctl}$) in multiple times as the experimental and control group, this effectively render the Cohen *d* calculation erroneous. Effect size for repeated measure studies should be reported as Eta and partial Eta squared (η_p^2) values (Thalheimer & Cook, 2002). Partial Eta squared statistics of .01, .06, and .14 (or, 1%, 6%, and 14%) represent small, medium and large effect sizes, respectively (Green, Salkind, & Akey, 2000).

Research Findings

Research Question 1: What are the effects of Web-based pitch discrimination training on achievement in melodic interval discrimination?

The corresponding null and alternative hypotheses for research question 1 were as follows:

$H1_0$: Web-based pitch discrimination training will have a negative or no significant effect on achievement in melodic interval discrimination.

$H1_A$: Web-based pitch discrimination training will have a positive significant effect on achievement in melodic interval discrimination.

The effects of pitch discrimination training on achievement in melodic intervals identification can be understood as an interaction between independent and dependent variables, with the involvement of within-subject, and possibly, between-subject factors also. The review of relevant literature highlighted several music learning constructs that might be important for pitch discrimination training. The dependent variables of the study were pitch discrimination achievement scores of participants obtained from the online pretest, and posttest of Mona Listen. The independent variables of the study included the following factors:

1. ***Prior musical ability of the participants:*** whether learners possessed absolute or relative pitch, and if the inherent ability might have affected the pitch discriminating achievement
2. ***Prior instrument playing experience:*** whether students received any prior, formal training in instrument playing, and if the experience might have had any effect on pitch discrimination achievement

3. ***Prior music training received:*** whether participants received former musical training before entering college, and if this experience might have had any effect on pitch discrimination achievement
4. ***Class of the intervals:*** whether the pitch discrimination training might have had different effects on pitch discrimination achievement in identifying melodic interval by class, such as perfect fourths (P4), perfect fifths (P5), major sixths (M6), and minor thirds (m3)
5. ***Play order of the intervals:*** whether the pitch discrimination training might have had different effects on pitch discrimination achievement in identifying melodic intervals in ascending or descending order
6. ***Instrument sounds:*** whether the pitch discrimination training might have had different effects on pitch discrimination achievement in identifying melodic intervals recorded in piano or guitar sound.

On the whole, the main effect for TEST showed a statistically significant difference with very large effect size: F (2, 60) = 21.284, $p < .001$; effect size = 41.5%. A Bonferroni adjustment for multiple comparisons, using an α value of $0.05 \div 3 \approx 0.0167$, was applied to paired t-test analysis of achievement score means to better understand the effect of pitch discrimination training on achievement. The result of the t-test analysis is presented in Table 7.

Table 7

Paired Sampled *t*-Test Between Achievement Test Pairs

Contrasts	*Mean*	*Std. Dev.*	*95% Confidence Intervals of the Difference* *Lower*	*Upper*	*t-value*	*Sig.**	*Eta²*
Posttest – Pretest (N=65)	9.692	12.465	6.604	12.781	6.269	.000	.380
Follow-up – Pretest (N=62)	9.145	14.211	5.536	12.754	5.067	.000	.296
Follow-up – Posttest (N=62)	-.532	13.711	-4.014	2.950	-.306	.761	.002

Figure 8 is a plot of the achievement score means of participants from the pretest, posttest, and follow-up posttest. Pitch discrimination training produced a statistically significant difference with large effect size between (a) posttest – pretest [t (65) = 6.269; p < .001; effect size = 38.0%] and (b) follow-up posttest – pretest [t (62) = 5.067; p < .001; effect size = 29.6%]. Achievement score means between posttest and follow-up posttest were comparable with no statistically significant difference detected.

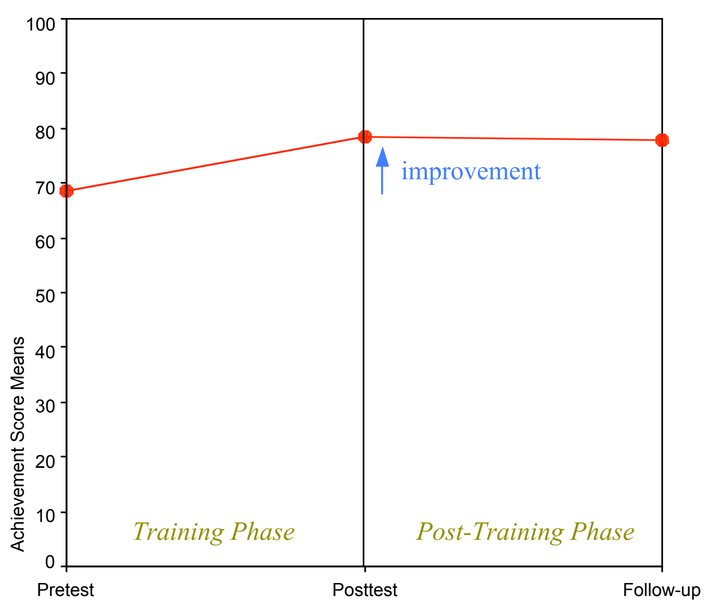

Figure 8. Pitch Discrimination Achievement Score Means by Tests

The interval between the pretest and the posttest denoted the *training phase,* during which pitch discrimination training occurred. The difference in achievement score means would therefore indicate the effect of pitch discrimination training. No further training was provided during the *post-training phase*, represented by the interval between posttest and follow-up posttest; therefore the difference in achievement scores would indicate the effect of retention. The degree of increase in achievement score means from pretest to posttest implies a substantial positive effect of the pitch discrimination training. The plateau from posttest to follow-up posttest indicates a high post-training retention of the pitch discrimination skills.

Pretreatment Differences

Tukey's Honestly Significant Differences (HSD) Test was useful in ascertaining if any variance existed among participants' pretest achievement score means, which would implicate pretreatment differences among participants in the following areas:

1. Pre-existing musical ability of participants in terms of absolute and relative pitch
2. Prior musical training experience in terms of instrument playing experience
3. Number of years of prior musical training experience.

There was no evidence to support that the participants' Pretest achievement scores differed significantly due to pre-existing conditions. Tukey's HSD confirmed that the participant make-up was rather homogeneous prior to using Mona Listen. Specifically, there was no statistically significant difference in:

1. Pre-existing musical ability of perfect/relative pitch [F (3, 65) = 1.984; p = .126]
2. Prior instrument experience with all participants as a group [F (1, 65) = .011; p = .915], or by the families of instrument [F (7, 65) = .702; p = .670], and
3. Prior musical training experience [F (1, 65) = .629; p = .431].

Perfect Pitch

Participants possessing *true* perfect pitch certainly would have performed better in pitch discrimination tasks than participants possessing relative pitch. Self-reporting of perfect pitch ability was used in this study, and participants were divided accordingly into the following groups:

- Group 0: Participants who were unable to *name* or *sing* at least one musical pitch accurately by ear
- Group 1: Participants able to *sing* at least one pitch accurately by ear
- Group 2: Participants able to *name* at least one musical pitch accurately by ear (Both Group 1 and 2 could be considered as having "relative pitch")
- Group 3: Participants who were able to name *most* musical pitches accurately by ear (this would be the quasi-absolute pitch)
- Group 4: Participants who claimed they possess perfect pitch *and* scored 95 to 100% on the pretest

There was no "true" perfect pitch among the participants, and thus Group 4 ($N = 0$) was eliminated. Analysis of pitch discrimination achievement scores by "perfect pitch" abilities (Group 0, 1, 2, and 3) did not reveal any statistically significant difference [F (6, 120) = 1.235; $p = .293$]. Table 8 presents the means, standard deviations, and standard errors of the achievement scores by the "perfect pitch" ability.

Table 8

Achievement Score Means by Perfect Pitch

Group	N	Pretest			Posttest		
		Mean	Std. Dev.	Std. Error	Mean	Std. Dev.	Std. Error
0	11	66.82	22.943	6.11	74.55	21.732	5.06
1	6	79.17	22.675	8.28	88.33	9.832	6.85
2	30	63.00	20.536	3.70	74.00	18.071	3.07
3	18	75.28	17.190	4.78	84.17	12.157	3.96
4	0	--	--	--	--	--	--
Total	65	68.54	20.743		78.23	17.285	

Instrument Playing Experience

Participants who have had prior instrument playing experience before college, for example from a high school band or school orchestra, could possibly perform better in pitch discrimination tasks than participants with no prior instrument experience. Additionally, string and guitar players might have better pitch discrimination skill through daily tuning of their instruments. Based on feedback from the online questionnaire, the 62 participants were divided into two groups: (a) 42 students with some formal training in instrument playing, and (b) 23 students with had no prior formal instrument experience. The 42 participants with formal instrument experience were further grouped according to the family of instruments they played: brass ($N = 5$), guitar ($N = 3$), percussion ($N = 4$), piano ($N = 6$), strings ($N = 7$), voice ($N = 8$), and woodwind ($N = 9$).

An analysis of pitch discrimination achievement score means using prior instrument experience [F (2, 59) = 2.218; p = .118] and types of instruments played [F (7, 57) = 1.638; p = .143] as between-subject factors were both not significant at the p = .05 level. Table 9 presents the means, standard deviations, and standard errors of the achievement score means by prior instrument experience according to families of instrument, sorted by Pretest score means.

Table 9

Achievement Score Means by Families of Instrument Played

Families of Instrument Played	*N*	*Pretest*			*Posttest*		
		Mean	*Std. Dev.*	*Std. Error*	*Mean*	*Std. Dev.*	*Std. Error*
Percussion	4	81.25	14.361	10.545	88.75	13.150	8.880
Guitar	3	80.00	5.000	12.176	83.33	12.583	10.253
String	7	72.14	19.334	7.971	78.57	23.042	6.712
Voice	8	70.63	23.820	8.456	81.25	15.755	6.279
Piano	6	65.00	24.083	8.610	83.33	12.910	7.250
Brass	5	61.00	26.077	9.431	76.00	22.749	7.942
Woodwind	9	60.00	20.917	7.030	76.67	15.000	5.920
Total	42	68.49	20.762		78.78	17.114	

Percussion (mostly xylophone) players were the top achievers in *both* the pretest and the posttest. The pretest score means for participants in the percussion, guitar, string, and voice categories were higher than that of the piano; further, guitar players had a very small standard deviation ($S.D._{pretest} = 5$, $S.D._{posttest} = 12.583$). Guitar and piano players shared the same achievement score means after pitch discrimination training.

Prior Music Training Experience

A homogeneity test using Tukey's HSD was carried out to verify that participants in the study were of similar standing in term of pitch discrimination achievement, regardless of the music training experience received prior to entering college. Participants were divided based on self-reported data as having received: (a) some (1 to 15) years of former training ($N = 42$), and

(b) no training (*N* = 23). Table 10 presents the means, standard deviations and standard errors of the achievement scores according to prior musical training experience.

Table 10

Achievement Scores by Prior Musical Training

		Pretest			*Posttest*		
Group	*N*	*Mean*	*Std. Dev.*	*Std. Error*	*Mean*	*Std. Dev.*	*Std. Error*
Musical training	42	67.02	20.750	3.21	79.88	16.135	2.67
No musical training	23	71.30	20.901	4.34	75.22	19.216	3.60
Total	65	68.54	20.743		78.23	17.285	

An analysis of pitch discrimination Pretest achievement score means using prior music training as a between-subject factor did not reveal any significant main effect [F (1, 63) = .002; p = .968]. However, a positive interaction with moderately large effect was detected in pitch discrimination training in relation to former music training experience [F (1, 63) = 8.555; p = .005; effect size = 12.0%]. Compared with participants without prior music training, participants with prior music training experience received a larger boost in pitch discrimination achievement from Pretest to Posttest. Figure 9 presents a plot of the difference in achievement score means between participants with and without prior music training experience.

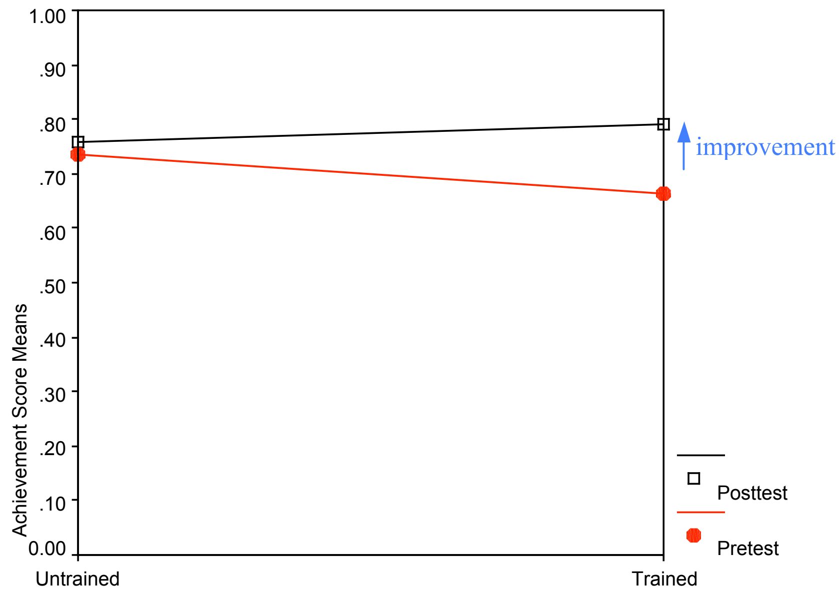

Figure 9. Improvement in Achievement by Prior Music Training Experience

Pitch discrimination training apparently had a stronger positive effect on college students with prior music training experience, resulting in an accelerated rate for pitch discrimination learning and higher achievement score means. Additional research studies would be necessary to fully investigate the extent of this interaction.

Effects of Pitch Discrimination Training

The effect of pitch discrimination training was computed using repeated measure data analysis. Four within-subject factors were included in the analysis:

(1) Two levels of TESTS: pretest and posttest

(2) Five levels of INTERVALS: P5, P4, M6, m3, and distracters

(3) Two levels of play ORDERS: ascending (AS) and descending (DS)

(4) Two levels of instrument SOUNDS: piano (PN) and guitar (GT).

No between-subject factor was included. Table 11 presents the effects of training on pitch discrimination achievement, listed by the statistical significance, levels of interaction, and effect size, in that order.

Table 11

Effects of Training on Melodic Intervals Discrimination

Contrasts	*(df_1, df_2)*	*F values*	*Sig.*	*Partial Eta^2*
Intervals x orders x sounds	(4, 54)	10.454	.000*	.436
Intervals x orders	(4, 54)	40.224	.000*	.749
Intervals x sounds	(4, 54)	15.094	.000*	.528
Tests x orders	(1, 57)	8.624	.005*	.131
Orders x sounds	(1, 57)	7.721	.007*	.119
Tests x sounds	(1, 57)	4.488	.039*	.073
Intervals	(4, 54)	21.065	.000*	.609
Orders	(1, 57)	37.722	.000*	.398
Tests	(1, 57)	29.179	.000*	.339
Sounds	(1, 57)	.295	.589	.005
Tests x intervals	(4, 54)	1.204	.320	.082
Tests x orders x sounds	(1, 57)	3.539	.065	.058
Tests x intervals x sounds	(4, 54)	1.128	.353	.077
Tests x intervals x orders	(4, 54)	.114	.977	.008
Tests x intervals x orders x sounds	(4, 54)	1.205	.319	.082

Note. *: $p < .05$

No statistically significant differences were found in (a) sounds, (b) tests x intervals, (c) tests x orders x sounds, (d) tests x intervals x sounds, (e) tests x intervals x orders, and (f) tests x intervals x orders x sounds. From the rest of the constructs, which showed a statistically significant difference at $p = .05$ level, very large effect sizes (33.9% to 74.9%) were found in six constructs and medium to large effect sizes in three constructs (7.3% to 13.1%). Due to the presence of higher-order interaction effects, it became irrelevant to discuss individual main effects. Three statistically significant higher-order interaction effects will be discussed in greater details in the following sections:

1. Intervals x Orders x Sounds [$p < .001$; effect size = 43.6%],
2. Tests x Orders [$p < .01$; effect size = 13.1%], and
3. Tests x Sounds [$p < .05$; effect size = 7.3%].

Interval Class x Play Order x Instrument Sound

First year college students attained higher pitch discrimination achievement score means in the posttest than the pretest using Mona Listen for pitch discrimination training after a two-week pitch discrimination training period. Pitch discrimination training had a medium to large overall positive effect on achievement by intervals x orders x sounds. The three-way interaction suggested that instrument sounds play a significant role in affecting pitch discrimination achievement. Figure 10 and 11 presents the difference in achievement score means by interval class, play order, and instrument sounds, plotted for the pretest and posttest, respectively.

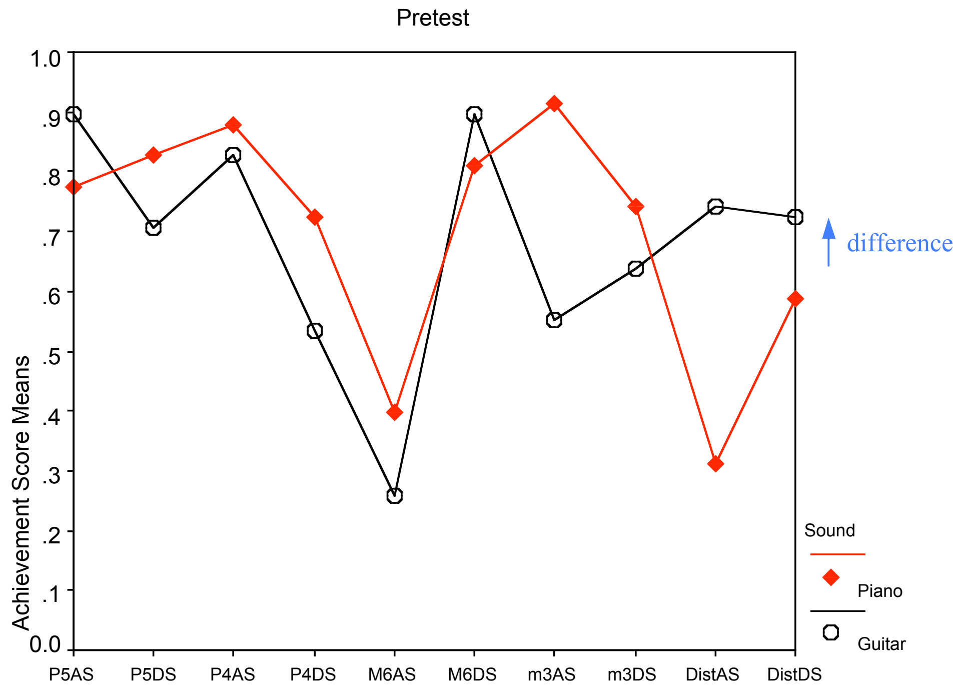

Figure 10. Pretest Achievement Difference by Instrument Sounds

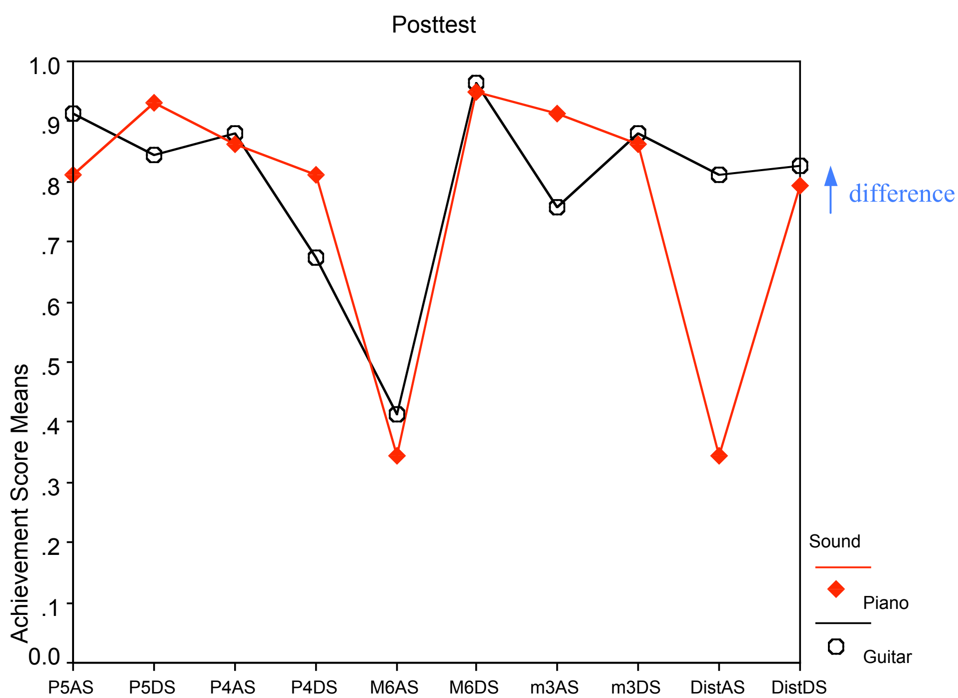

Figure 11. Posttest Achievement Difference by Instrument Sounds

Participants were more successful in discriminating melodic intervals recorded in piano sound than guitar sound, during the pretest, before using Mona Listen. After they were trained using the WBMI for two weeks, participants' discrimination ability for melodic intervals coded in guitar sound matched that for the piano sound. The general level of competency in pitch discrimination of melodic intervals also improved from Pretest to Posttest. Figure 12 shows the plot for improvement made in pitch discrimination achievement from the Pretest to the Posttest.

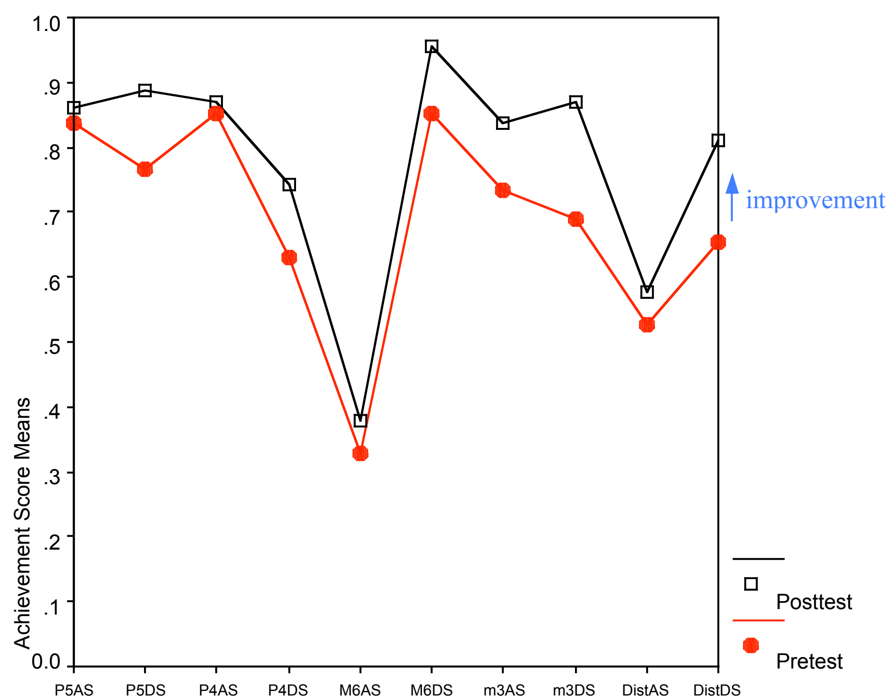

Figure 12. Improvement in Pitch Discrimination Achievement

Figure 12 shows that participants in this study made the least improvement in P5, P4, and M6 ascending intervals from the pretest to the posttest. Participants improved tremendously in discriminating descending intervals after pitch discrimination training. Examination of individual interval class showed a larger improvement in the discrimination of descending intervals than ascending ones; for example, P5DS means > P5AS means, and P4DS means > P4AS means. While differences in test score means of ascending intervals from the pretest to the posttest were generally small, the m3AS was the only ascending intervals with a large difference in test score means. The majority of the participants seemed to struggle with the M6AS interval. A closer examination of the data points revealed that participants mostly mistook the M6AS interval as P5AS.

Ascending Versus Descending Play Orders

Pitch discrimination training had a relatively small two-way interaction effect (effect size = 13.1%) on achievement by melodic intervals played in ascending or descending order. Figure 13 presents the plot for improvement in pitch discrimination achievement by the play orders of melodic intervals. Participants made a bigger improvement in discriminating descending intervals than ascending intervals after pitch discrimination training.

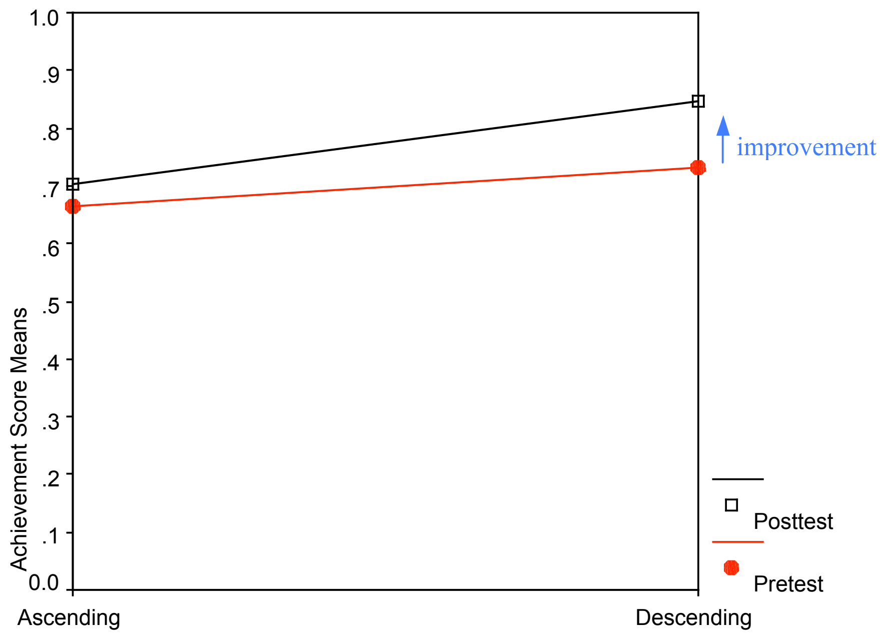

Figure 13. Improvement in Achievement by Play Orders of Melodic Intervals

Piano Versus Guitar Sounds

Pitch discrimination training had a two-way interaction effect (effect size = 7.3%) on achievement by melodic intervals recorded in different instrument sound. Participants who used Mona Listen for pitch discrimination training showed a statistically significant improvement in posttest achievement. While participants were more likely to answer correctly Pretest test items recorded in piano sound, the pitch discrimination training reversed the trend. During the Posttest, participants became more likely to answer correctly test items recorded in guitar sound. Figure 14 shows the plot for the effect of pitch discrimination training on achievement by melodic interval recorded in different instrument sounds.

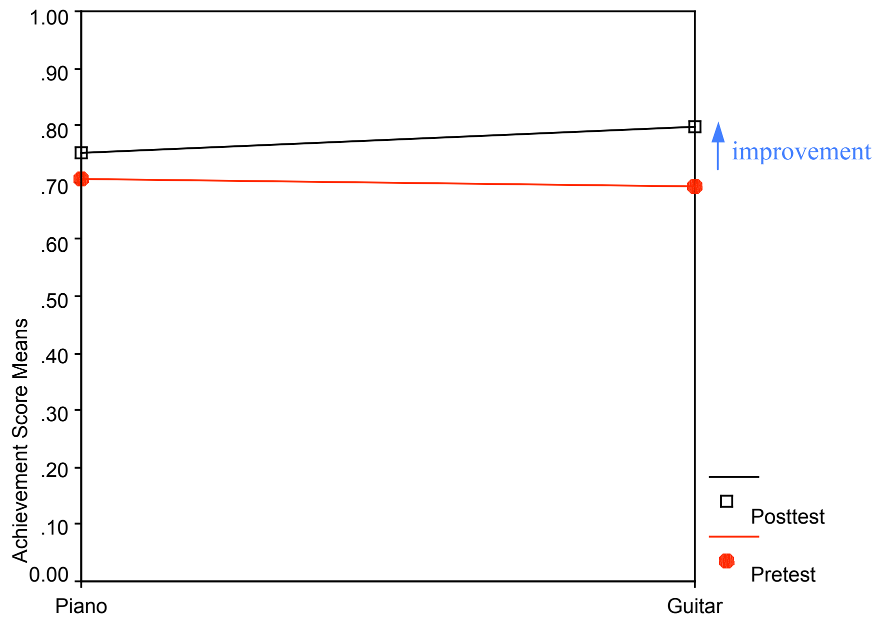

Figure 14. Improvement in Achievement by Instrument Sounds

Research Question 2: Do different instrument sound used in pitch discrimination training affect the achievement in melodic interval discrimination?

The corresponding null and alternative hypotheses for research question 2 were stated as follows:

$H2_0$: Pitch discrimination training in different instrument sounds will have a negative or no significant effect on achievement in melodic interval discrimination.

$H2_A$: Pitch discrimination training in different instrument sound will have a positive significant effect on achievement in melodic interval discrimination.

The review of literature suggested that a psychoacoustically purer tone was clearer and thus easier to identify than the fuzzy tones produced by some instruments, such as the piano. The effect of the instrument sounds could be inferred from participants' achievement score means. If participants' achievement score means in identifying melodic intervals coded in guitar sound were higher than those for piano sound, the psychoacoustically purer guitar sound could be said to be better for the purpose of pitch discrimination training.

A counterbalanced design was employed to control for carryover effects in pitch discrimination training using a particular instrument sound. Participants were randomly assigned to one of two "instrument sequence" groups, to be trained using (a) piano sound for P5/P4 and guitar sound for M6/m3 (hereafter, PN-GT), or (b) guitar sound for P5/P4 and piano sound for M6/m3 (hereafter, GT-PN), as shown in Table 12.

Table 12

Counterbalanced "Instrument Sequence" Grouping of Participants

Group	*P5 training*	*P4 training*	*Mix45 Quiz*	*M6 training*	*m3 training*	*Mix36 Quiz*
PN-GT	PN	PN	PN	GT	GT	GT
GT-PN	GT	GT	GT	PN	PN	PN

Pretest and Posttest pitch discrimination achievement score means of melodic intervals recorded in different instrument sounds (piano or guitar) were compared using paired sample *t*-tests. The significance level was reduced to $\alpha = .025$ using appropriate Bonferroni adjustment in order to control for the experimentwise error rate. Table 13 presents the results of the analyses.

Table 13

Paired Samples *t*-Tests of Contrasts by Piano/Guitar Sound

Contrasts	*N*	*Mean*	*Std. Dev.*	*95% Confidence Interval of the Difference*		*t-value*	*Sig.**	*Eta²*
				Lower	*Upper*			
Pos_GT - pre_GT	65	1.154	1.449	.795	1.513	6.418	.000	.392
pos_PN – pre_PN	65	.662	1.735	.232	1.091	3.075	.003	.129

Note. *: $p < .025$; pre: Pretest scores; pos: Posttest scores; PN: Piano; GT: Guitar

Melodic intervals recorded in guitar sound indicated a larger effect size [t (65) = 6.418; $p < .001$; effect size = 39.2%] than did melodic intervals in piano sound [t (65) = 3.075; $p < .005$; effect size = 12.9%] (see Table 13). The effect of pitch discrimination training using melodic intervals recorded in two different instrument sounds was computed using three within-subject factors:

1. Two levels of TESTS: pretest and posttest
2. Ten levels of INTERVALS and play ORDERS (AS and DS): P5AS, P5DS, P4AS, P4DS, M6AS, M6DS, m3AS, m3DS, distAS, distDS, and
3. Two-levels of instrument SOUNDS: Piano (PN) and guitar (GT).

No between-subject factor was included. A very large interaction effect was revealed between the contrasts Intervals of Sounds [F (9, 49) = 21.154; $p < .001$; effect size = 79.5%]. Due to the presence of higher-order interaction effect, it was no longer meaningful to discuss individual main effects. The variance between pretest and posttest achievement plots for all 10 intervals recorded in guitar sound suggested that melodic intervals coded in guitar sound had a greater effect than intervals coded in piano sound on pitch discrimination achievement. Figure 15 and 16 shows the difference in participants' achievement score means by instrument sounds, plotted for the Pretest and Posttest, respectively.

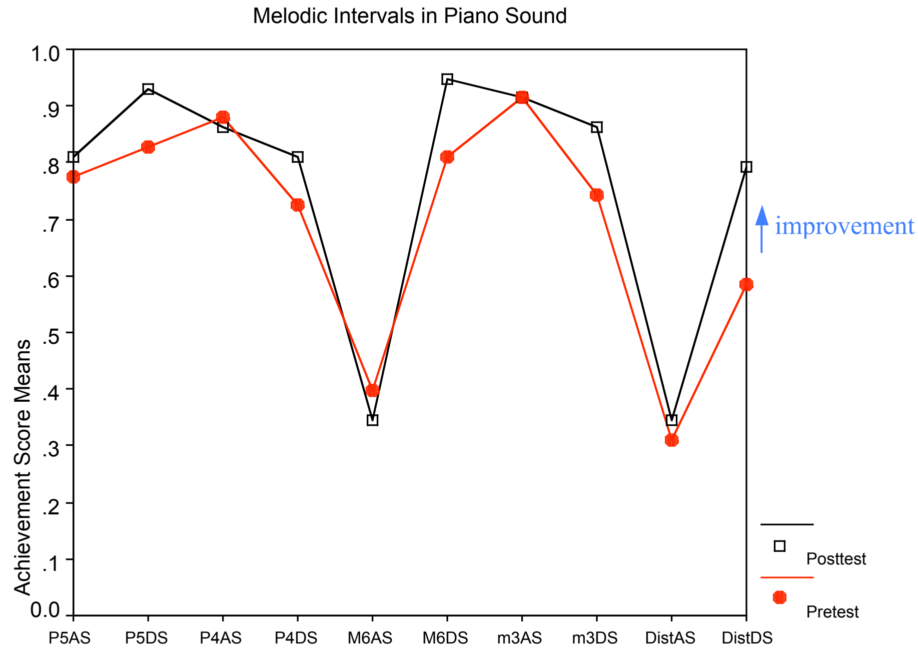

Figure 15. Improvement in Achievement from Pretest to Posttest (Piano Sound)

(DistAS: Distracter Ascending, DistDS: Distracter Descending)

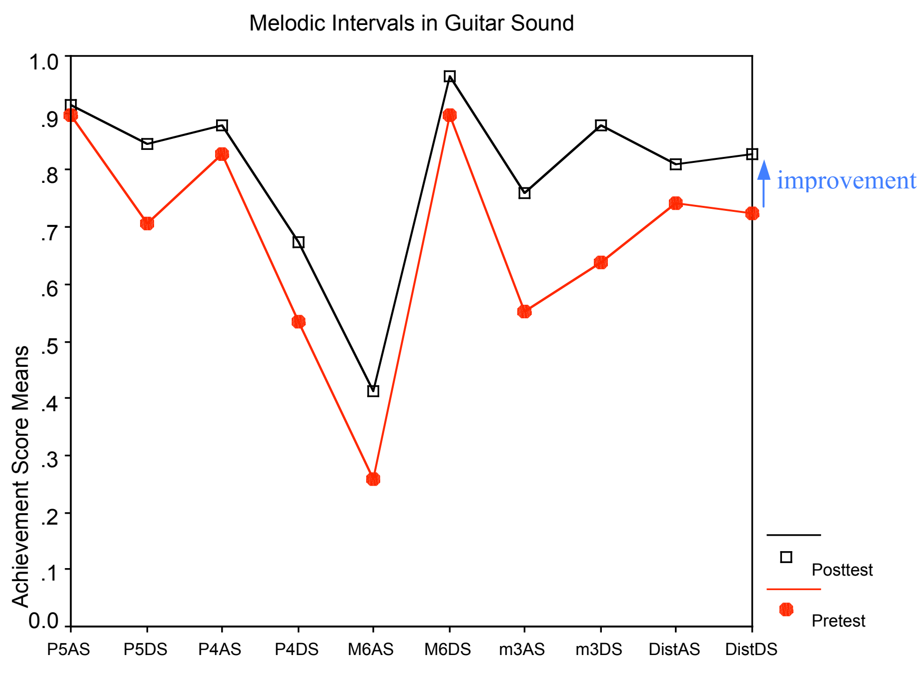

Figure 16. Improvement in Achievement from Pretest to Posttest (Guitar Sound)

The plot for guitar sound (Figure 16) shows a consistently larger increase in achievement score means than does the plot for piano sound (Figure 15). Participants seemed to have more trouble discriminating Distracter and M6 ascending intervals in piano sound and M6 ascending in guitar sound over all other intervals. Generally, participants were able to discriminate descending intervals better than ascending ones, with the pattern more prominently displayed in the plot for piano sound (Figure 10).

Participants' Posttest achievement score means were much higher than the Pretest achievement score means when tested using melodic intervals recorded in guitar sound as opposed to piano sound. The Pretest-Posttest achievement score means for melodic intervals recorded in piano sound were more closely aligned than melodic intervals recorded in guitar sound, meaning participants made larger improvements in achievement for intervals coded in guitar sound.

Research Question 3: Does the amount of time spent on-task in pitch discrimination training affect achievement in melodic interval discrimination?

$H3_0$: The amount of time spent on-task will have a negative or no significant effect on achievement in melodic interval discrimination.

$H3_A$: The amount of time spent on-task will have a positive significant effect on achievement in melodic interval discrimination.

An examination of participants' online usage patterns could offer new understanding of *how* pitch discrimination training affects achievement. Because the locus of control in online learning is primarily on the students, tracking of students' online usage patterns might provide the necessary clues to determine why some students attain higher achievement than others; for example, in an earlier study, Bauer (1994) analyzed participants' patterns of usage by the time of day. This study examined the effect of pitch discrimination training according to the amount of time participants spent in Web-based pitch discrimination training of melodic intervals identification.

While time logs of participants seemed like a good idea for estimating the amount of time students spent online, not all online and offline activities were relevant to pitch discrimination training. For instance, students might leave the computer, after login, to receive a pizza delivery, answer the door, or pick up a telephone call. The access time log showed that some participants eventually logoff several days later. Therefore, a better alternative was to instead calculate the amount of time students spent in training tasks, which included answering the practice tests and quizzes as part of the learning modules.

Number of Hours on Training

Because participants were advised to set aside a contiguous block of time for the practice quizzes, the time they spent on answering the quizzes was taken to be the *net training time* received . A timer was set up for each question to measure the amount of time lapsed from the moment participants clicked on the test item to listen to the melodic interval, up to the moment they clicked on the answer for that question. The time lapsed for all 20 questions for a practice quiz or test, when summed, would thus serve as the amount of *time spent on-task* for a particular module. The participants were divided into three groups according to the amount of time spent on task: (a) less than 1 hour, (b) 1-2 hours, and (c) more than 2 hours (up to a maximum of $3^1/_2$ hours).

Although the participants spent little time on pitch discrimination training within the two-week online course, this was another testimony to the affordances of technology-enhanced instruction, helping students to attain the same achievement as traditional instruction, but in a much shorter time frame (see Bowman, 1984; Taylor, 1982). Pretreatment analysis by net training time showed no statistically significant difference [F (2, 65) = 3.084; p = .053]. Tukey's HSD test showed all three groups to be fairly homogenous [p = .073] prior to receiving pitch discrimination training.

An analysis of the three achievement score means (Pretest, Posttest, and Follow-up Posttest) indicated a statistically significant main effect [F (2, 58) = 21.374; p < .001; effect size = 42.4%], as well as a significant interaction effect in achievement score means x hours spent on-task [F (4, 116) = 4.521; p = .02; effect size = 13.5%]. Because of the presence of a higher order interaction effect, a discussion of the main effects was not relevant. Figure 17 presents the plot of achievement score means by the number of hours participants spent on-task.

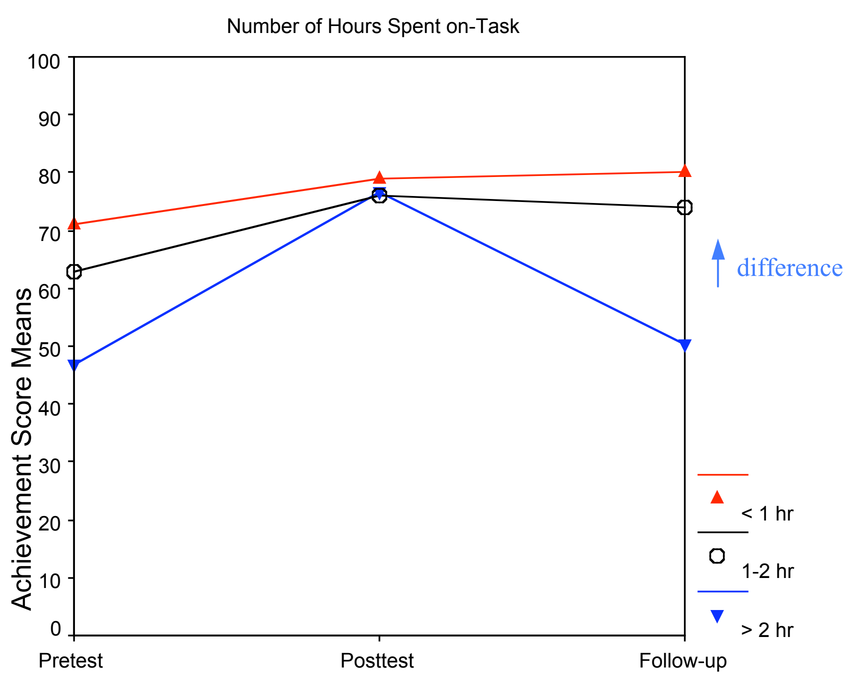

Figure 17. Differences in Achievement by Amount of Time Spent On-task

Although *net training time* in terms of "the number of hours spent" on-task was a useful way to measure how much time participants spent in training, other methods of measurement were considered. Because two participants could potentially accumulate the same *net training time* with two different time-on-task amounts due to different attempts at the same quiz, the total number of rounds participants attempted the quizzes was also analyzed as supportive evidence. For example, a participant who spent 30 seconds answering each of the 20 questions in one test could accumulate the same *net training time* with another participant who spent 15 seconds on each of the 20 questions in two tests.

Number of Rounds Attempted

Mona Listen contained a total of six practice quizzes for pitch discrimination training. Participants were divided into low, medium, and high quiz round, according to the number of rounds participants attempted the quizzes: (a) fewer than 10 times ($N = 15$), (b) 11 to 12 times ($N = 36$), and (c) more than 13 times ($N = 11$). A repeated measure analysis of achievement score means against Quiz Round revealed a statistically significant difference [F (2, 58) = 20.118; $p < .001$; effect size = 41.0%]. A post-hoc test using Tukey's HSD confirmed the presence of two subsets, namely: (a) low, and (b) medium and high. Figure 19 presents the plot of achievement score means by Quiz Round — the number of rounds participants attempted the quizzes and practice tests.

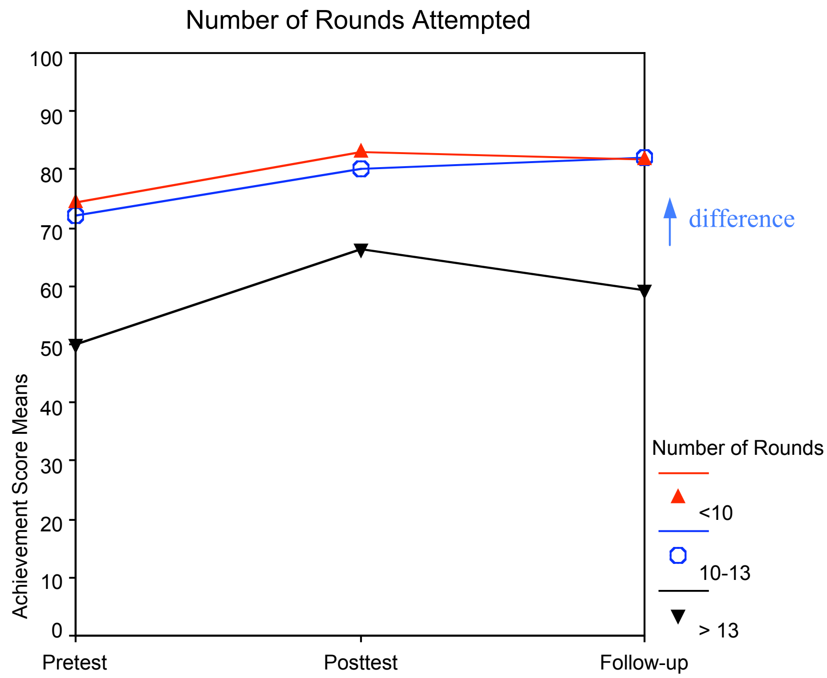

Figure 18. Differences in Achievement by Number of Rounds of Quizzes

The shapes of the plots for the amount of time spent on task and the number of rounds of quizzes were similar. The amount of time spent on learning was actually inversely proportionate to the participants' achievement in pitch discrimination. High-achievers, or participants who attained higher pretest scores, were able to improve their posttest score means significantly with less than an hour of pitch discrimination training. The rest of the participants were able to improve their achievement score means significantly also, but by spending more time: 1 to 2 hours for regular-achievers and more than 2 hours for low-achievers, respectively. The same could be said about the rounds of quizzes attempted: high-achievers attempted less than 10 rounds, regular-achievers attempted 11 to 12 rounds, and low-achievers attempted more than 13 rounds.

There was no statistically significant difference among achievement score means of the high-, regular-, and low-achievers when analyzed according to *net training time*. However, in the analysis by round of quizzes attempted, achievement score means of high-achievers were significantly better than those of the regular- and low-achievers.

Post-treatment, all three groups demonstrated some amount of retention in pitch discrimination ability. Although overall follow-up posttest and posttest score means showed no statistical significant difference (see Hypothesis 1), analysis by the amount of time spent on-task revealed that the low-achievers experienced the biggest decline in retention of pitch discrimination skills. There was no detectable statistical difference between the decline in pitch discrimination achievement from Posttest to Follow-up Posttest between high and regular achievers.

Posttest Feedback From Participants

Feedback was collected from the study's participants as part of the exit process. A total of 40 comments was received from 65 participants. The comments were subsequently organized into 11 broad categories:

1. **Sound Quality**. The majority of the participants commented about the high fidelity and realistic instrument sounds used in the training modules. Nevertheless, not all participants liked the sounds. Five participants commented that the sound quality was poor, distorted, and made pitch discrimination difficult. Specific comments from participants included:

   > *"I personally found the sounds used for this series of tests to be of horrible tone quality and made it incredibly difficult for me to even match pitch, much less hear intervals."*

"Some pitches sounded a little distorted making interval detection tricky."

"It would be nice if you had used an instrument that didn't have so many overtones when playing the intervals."

"I had trouble distinguishing some of the intervals because of the instrument that was used to play the sounds."

2. **Design Quality.** Many participants commented positively on the instructional design quality of the WBMI as "well-designed," "effective and easy to work with," and "user-friendly." Specific comments included:

   "This project is very well designed. I found the layout very easy to work with."

   "It has been an interesting learning experience. The format of Mona Listen was awesome."

3. **Emotive Description**. Participants of the study generally experienced positive feelings towards the WBMI, referring to the modules with adjectives such as "cool," "nice," "well," "good," and "great;" and emotive descriptors such as "like" and "enjoy". Specific comments included:

   "Mona Listen is a good program and I enjoyed using it."

   "I thought this was a good exercise because it definitely made it challenging."

   "This project is very well designed. I found the layout very easy to work with. The program was very good, nicely organized, and well written. The humor is also cute and appreciated."

4. **Helpful**. Participants found the pitch discrimination training to be "helpful," particularly in learning the descending melodic intervals:

"This was a very helpful program and I enjoyed it very much. It has positively supplemented my practicing of aural skills!"

"Mona really helped, even though I got a 70% on the Final Evaluation while I was doing the modules; it helped greatly."

"The intervals going down were really difficult for me, and I hadn't really practiced with those before. I liked the format!"

"My main difficulty was the descending intervals, and it certainly helped; and it only took minutes! Great! It did help."

5. **Preference for One Instrument**. Some participants expressed their preference for only one instrument sound to be used, stating:

   "The only thing that kind of confused me sometimes was the instrument sound used (guitar?). I guess I am just used to piano sounds from class."

   "It would have helped if all pitches were either played on piano or guitar--switching made it more difficult."

6. **Realizing Their Weaknesses**. The WBMI helped participants to recognize their learning weaknesses in specific intervals and play orders:

   "P4s and P5s are my weaknesses and this program helped me realize that."

   "I did well on most of the individual quizzes, just not so well when they were all mixed up together."

7. **Preference for Practice Mode**. Two modes of assessment were found in Mona Listen. In the *Practice mode*, each interval would be played twice, and the correct answers revealed if participants were wrong. In the *Test or Quiz mode*, each interval would only

be played once, and no answer was revealed. Participants seemed to prefer practice mode to test or quiz mode. Specific comments included:

> *"During the quiz I would have liked to have Mona repeat the pitches at least twice more."*
>
> *"Especially during the practice test it would be good to be able to play the interval again after the student has answered. That way the student will be able to hear the interval again and be able to learn from his or her mistakes."*

8. **Frustration in Ear Training Exercises**. Some participants expressed personal frustration in doing pitch discrimination exercises.

> *"I'm a relatively impatient person when it comes to practicing or doing anything that could possibly help train my ears. Besides being bad at audiation, this frustrated me more because practicing never seems to pay off in the long run."*
>
> *"It is the attention of actually listening that is the problem for me. I can generally discern the interval; I just have trouble paying attention to what is actually being played."*

9. **Comparison With Other Ear Training CAI.** Several participants compared the WBMI with the CAI program currently in use by the music department for pitch discrimination training, stating:

> *"This works well and I think that it should be used instead of MacGamut."*
>
> *"Compared to the horror stories I have heard about MacGamut, this is awesome."*
>
> *"The thing that stuck out in my mind is how appealing Mona Listen looks. While this won't help a person's ear training skills, a person will be more willing to shell*

out money for a program that is as sleek looking as yours, than MacGamut; which makes me wonder what the heck I spent $40 on."

10. **Suggestions for Improvement**. Several participants provided suggestions on improving the functionality of Mona Listen, such as adding more instrument sounds, including more melodic and harmonic intervals, and rhythmic exercises:

    "Use other synthesizer sounds too!"

    "It would help if the program went through all of the intervals."

    "I would like to use this system for the more difficult intervals as well as harmonic ones."

    "There needs [sic] *to be exercises with the intervals played harmonically as well as melodically. I would also like it if more intervals were covered. It could always be more in-depth, perhaps going into melodies and naming intervals or rhythms."*

Focus Groups Discussion

Post-treatment focus groups were conducted to solicit for additional feedback and to uncover any problems experienced during the pitch discrimination study and the follow-up posttest. Ten participants from all music theory classes attended the two focus group sessions ($N_1 = 4$, $N_2 = 6$). The following questions were asked of the attendees. The groups' responses are summarized below each question.

1. Comparing In-module Tests With the Real-life Test.

Most of the focus group attendees agreed that the instrument sounds used in Mona Listen compared well with the real acoustic instruments in terms of sound quality and authenticity (for example, you can actually hear the "fret" sound in melodic intervals played with a guitar sound).

Some attendees noted that the melodic intervals in the online tests sounded better than the "real" classroom test, perhaps because the sound was more spread out in the classrooms as compared to being confined in the headphones. Only one attendee commented that the piano sound in class was "fuzzier" than the piano sound used in Mona Listen; the rest said there was no difference between the piano sounds used in the class test and Mona Listen.

One major difference between online and classroom tests was the classroom condition that mandated students to maintain silence when taking a test. The majority of the attendees found this test condition for maintaining silence to be significantly different from the online test condition for Mona Listen. As part of the learning process for audiation, Mona Listen taught the participants to hum or sing along in solfege. The attendees commented that the humming and singing in solfege was very helpful to them in learning audiation, and in identifying melodic intervals. The classroom test condition was deemed too restrictive in comparison to Mona Listen.

2. Distraction or Interference During Class Test.

There was no discernable interference during the follow-up posttest that was conducted in class. Although follow-up posttests were also being conducted in neighboring classes, there was no interference because the classrooms were soundproofed. Additionally, instructors staggered the test so that no two classes were doing the follow-up test at the same time.

3. **Comparing Sampled Sound and MIDI-based Sound in Ear Training.**

Although most of the attendees had not used a MIDI based ear-training application before, those who did commented that the instrument sounds used in Mona Listen were either similar or better in quality than sounds generated by MIDI synthesis.

A few of the attendees commented that the classroom pitch discrimination test using acoustic piano sound was more difficult than the tests used in Mona Listen because of the harmonics produced by the acoustic piano. Other attendees who were less sensitive to the piano harmonics did not find any differences between the sounds of a live acoustic instrument and the sampled instruments used in Mona Listen.

4. Biggest Benefit of Mona Listen.

Attendees generally agreed that Mona Listen allowed them to complete the online learning at their own pace and in their own time. Most of the attendees agreed that if students wished to have more practice with pitch discrimination, they could access the Web-based module anytime. Most of the attendees found the *running interval* concept implemented in Mona Listen helpful because they could play the running intervals many times.

Others liked Mona Listen because it is Web-based, eliminating the need to book a practice room just to conduct pitch discrimination training with a friend. Mona Listen allows them to access pitch discrimination practice at home or anywhere else that is convenient. Most attendees expressed their liking for a Web-based training module because they were free to move on to other commitments once they completed the assignment.

The majority of the attendees found the instant feedback of Mona Listen to be very helpful. One attendee commented that Mona Listen helped identify her weaknesses and allowed her a great deal more practice, particularly with the descending intervals. She suggested separating descending intervals from the ascending ones so that students can concentrate on one or the other. (Currently, Mona Listen plays the ascending and descending intervals in a counterbalanced manner to facilitate data analysis.)

One particular attendee remained after the focus group session to offer the following concluding remarks: "Mona Listen is a more entertaining way to do ear training, and as a result of that, I feel that I learned better. I enjoyed the interaction, even though it involves only mouse-clicks, for example, clicking on an icon to play or to listen to the intervals. I had just returned home from a jig and tried the ear training at 3:00 am in the morning. Even then, I still find Mona Listen to be very helpful, especially in helping me learn the descending intervals."

Summary of Results

Pitch discrimination through ear training is important for beginning college music students because the aural skill developed will allow them to better understand the musical pitches they hear and help them to become better musicians. Specifically, Web-based pitch discrimination training is effective and has a positive effect on pitch discrimination achievement. Melodic intervals recorded in guitar sound were found to be superior to melodic intervals recorded in piano sound for the purpose of pitch discrimination training. While spending time in training is worthwhile in raising achievement scores, a person's achievement in pitch discrimination cannot be easily predicted through the total amount of time spent on task.

Participants found Mona Listen to be well-designed, user-friendly, and good for pitch discrimination practice. Specifically, participants liked the WBMI because it helped them realize their weaknesses in certain melodic intervals and allowed them anytime access to the ear-training module to selectively work on these intervals. Participants were able to practice ear training on their own, rather than relying on friends to practice with them. They also found Mona Listen to be more visually attractive then the current ear training application used in the Department of Music.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

Conclusions

Research Finding 1

Findings of the study rejected the null hypothesis for Research Question 1 at the $p = .05$ level and thus accepted the alternative hypothesis: Web-based pitch discrimination has a positive effect on achievement in melodic interval discrimination.

Research Finding 2

Findings of the study rejected the null hypothesis for Research Question 2 at the $p = .05$ level and thus accepted the alternative hypothesis: Pitch discrimination training in different instrument sounds has a significant effect on achievement in melodic interval discrimination. Specifically, participants were more successful in identifying melodic intervals recorded in guitar sound than piano sound.

Research Finding 3

Findings of the study rejected the null hypothesis for Research Question 3 at the $p = .05$ level. Although findings showed the amount of time spent on-task to have a significant effect on achievement in melodic interval discrimination, closer examination revealed that the amount of time spent on-task was not a good predictor for achievement in melodic interval discrimination because other confounds exist.

Based on the overall findings from this study, first year college music students improved significantly on their achievement in melodic interval discrimination. Thus, technology-enhanced pitch discrimination training was indeed effective. Table 14 presents a summary of the research findings of this study.

Table 14

Summary of Research Findings

Research Question	**Findings**
1. "What are the effects of Web-based pitch discrimination training on achievement in melodic interval discrimination?"	Web-based pitch discrimination training had a positive effect on first year college music students' achievement in melodic interval identification.
	Additionally, students with prior music training experience were also found to learn melodic interval discrimination at a faster rate than did students without training.
2. "Do different instrument sounds used in pitch discrimination training affect the achievement in melodic interval discrimination?"	Pitch discrimination training of melodic intervals recorded in different instrument timbres had a differential effect on achievement in melodic intervals identification.
	Participants were found to be more successful in identifying melodic intervals recorded in guitar sound than in piano sound.
3. "Does the amount of time spent in pitch discrimination training affect achievement in melodic interval discrimination?"	The amount of time spent on-task had no significant effect on achievement in melodic interval discrimination.
	The amount of time spent on-task was not a good predictor of students' musical achievement as results suggest other confounds might be involved.

Discussion of Results

The increasingly ubiquitous Internet means Web-based learning is now a viable, even sought after, method of instruction. College music majors who seek supplemental ear training opportunity, music non-majors interested in basic ear training, and amateur musicians at large, would benefit from a Web-based training module for pitch discrimination.

Effects of Web-based Pitch Discrimination Training

Based on the findings of this study, Web-based pitch discrimination training can have an overall positive effect on first year college music students' achievement in melodic interval discrimination. The intervention produced an improvement in the students' achievement scores not only in terms of statistical significance, but also in terms of effect size.

While the review of literature suggested three possible factors that might affect music achievement, only prior music training experience was found to have a complementary, statistically significant, interaction with music training in this study. The other two factors, perfect pitch and prior instrument playing experience, showed no statistically significant difference. Perfect pitch, as an inherent ability, would be difficult to train for. Thus, a more logical approach to improve one's aural and pitch discrimination skill would be to begin musical training before the age of nine, where his or her musical aptitude hits a plateau (Gordon, 1967).

Musical instrument playing experience was apparently not a strong influence in melodic interval discrimination as compared with prior music training experience. The implication here is between practical knowledge, as in instrument playing, versus cognitive understanding, as in prior music training. One reason could be because music instrument playing would be related more with motor skills and less with the understanding of musical structure. Another possible explanation could be that high school band and orchestra instructors spend more time preparing the high school musicians for concerts than teaching them music structures or training them for pitch discrimination. Thus, even though high school musicians seeking entrance into college music programs were found to be adept enough in playing the required musical pieces for the admission auditions, they might still be lacking in other musical skills, including pitch discrimination of melodic intervals.

Music students with prior musical training achieved greater improvement in test scores from the pretest to the posttest than did students without prior music training. Prior musical training apparently laid a good foundation in these students in supporting and scaffolding their acquisition of pitch discrimination skills. Students with prior music training could be said to either achieve better test scores than those without training or learn pitch discrimination at a faster rate. The latter phenomenon would be somewhat akin to the "same achievement, shorter time" effect of CBI found in the literature (see page 47).

Players of instruments requiring regular tuning, including the voice majors, were found to discriminate musical pitches better than players of instruments that did not require tuning (see Table 10). However, in this study, it was the percussion players (primarily xylophonists) who achieved the highest score means in both the pretest and posttest. Further analysis of the psychoacoustic quality of the xylophone and other related instruments, such as the glockenspiel and marimba, might be of interest to other researchers.

Effects of Different Instrument Sounds

Pitch discrimination training using melodic intervals coded in guitar sound was found to have a greater positive effect than intervals coded in piano sound on the achievement of melodic intervals discrimination. First year college music students were able to discriminate melodic intervals coded in guitar sound better than coded in piano sound.

Based on the review of literature, pitch discrimination studies favored psychoacoustically purer sound, which means guitar sound would be superior to piano sound for the purpose of pitch discrimination training. However, pitch discrimination in the music classroom has been provided traditionally with the acoustic piano, an age-old practice that seemed to produce fine musicians. Do the findings in this study challenge the classroom best practice of using piano as the tool of pitch discrimination instruction?

The 88-key acoustic piano became the accepted classroom tool for music instruction because of its versatility in providing a large variety of music structures, including intervals, chords, and melodic and harmonic progressions. However, the psychoacoustically purer guitar sound and its higher impacts on pitch discrimination achievement, as shown in this study, imply that there is a difference between psychoacoustically difference timbres. Music educators might want to reconsider the music instrument to be used for pitch discrimination training in their classrooms.

As music making involves a large variety of timbres and not just one instrument, there remain great merits in providing a wide selection of timbres for music instruction. However, because the psychoacoustically purer guitar sounds apparently brought about an increase in students' achievement, it would appear that psychoacoustically purer sounds are easier to discriminate than "fuzzy" sounds. Does guitar therefore make a better choice than piano for pitch discrimination? Perhaps the psychoacoustically purer, or simpler, guitar sound should be reserved for students having difficulty with pitch discrimination. One practical approach is to reserve the piano and more "complex" instrument sounds only for students who have already attained an accepted level of pitch discrimination skills. This approach should help the less able students so that they are not overloaded cognitively with too much information as they begin learning the rudiments of pitch discrimination.

If psychoacoustic properties are indeed important in pitch discrimination, as suggested by the data in this study, then it follows that music educators will need to understand more about the psychoacoustics properties of instruments, and the complexity rankings of the timbres. Appropriate pitch discrimination instruction should include differential treatment, in which more complex and "difficult" instrument sounds are reserved only for students in an advanced standing.

Students should probably not be allowed the freedom to choose any timbre for ear training, as timbre with complex psychoacoustic properties could complicate their learning. Because instrument sounds are not neutral, music educators should refrain from choosing a commercial pitch discrimination application that allows students' to indiscriminately choose any instrument sounds of their liking for ear training.

Finally, music educators might want to reconsider pitch discrimination testing using acoustic piano in the classroom because the harmonic-rich sound could adversely affect achievement of the music students. Will the use of psychoacoustically complex piano sound therefore constitute unfair pitch discrimination testing? Such questions will need to be answered by the music educators, and no one else.

The analysis of achievement score means by melodic intervals showed that students were struggling with the M6 ascending and distracter ascending (see Figure 12 and 13). Upon closer inspection, the majority of the students who answered wrongly in the M6AS item had picked P5AS as the answer. Although P5 was at an equal sonic distance to P4 and M6, Mona Listen only paired the intervals by perfect intervals, as in P5 with P4; but not across perfect and major intervals, as in P5 with M6. Because participants were only trained to discriminate between P5 and P4 intervals in module 1 to 3, and not between P5 and M6, they could have been "under-trained" in discriminating between P5 and M6. Perhaps the inclusion of P5/M6, P4/M6, P5/m3, and P4/m3 were in order, although that would have increased the required length of the practice sessions by several fold.

Based on the findings and focus group interviews, one clear advantage of the training was the added practice students received in descending intervals, which led to higher achievement as compared to ascending ones. Although descending intervals are generally believed to be more difficult to discriminate than ascending intervals, according to common belief among music educators, this study showed that improvement is possible with appropriately designed training. Technology-based pitch discrimination training thus offered the clear advantage of anytime anywhere training by allowing students the convenience to repeatedly work on their weaknesses in order to raise their ability.

Effect of Time Spent on Task

Although the musicians' proficiency in musical skills has typically been attributed to the amount of time they spend on practicing instruments (Sloboda and Davidson, 1996), there were many conflicting reports in the literature. Some studies on the effect of increased training time on achievement were positive (e.g., Bauer, 1994; Davis, 2001; Hess, 1995), while others reported no significant difference (e.g., Fortney, 1993; Heritage, 1986; Hess, 1994). Based on the findings in this study, the investigator does not think the amount of time spent on task is a good predictor of musical achievement in melodic interval identification, due to the possible presence of confounding factors.

Consistent with Ozeas' (1991) findings, where participants from the "high-score" group outperformed the "low-score" group who spent more time training, the high-achievers in this study were found to attain higher posttest score means than regular- and low-achievers, despite *less* training time. Although low-achievers were able to increase their posttest achievement score through additional training involving more hours and more rounds of quizzes, they still could not surpass the posttest score means of high-achievers. However, in the case of net training time, there was no significant difference among posttest achievement score means for all participants involved.

Retention of pitch discrimination skill was depicted by the 7-day period between the posttest and the follow-up posttest. Figures 17 and 18 show that high-achievers and regular-achievers were both able to retain the pitch discrimination skills learned, much more than the low-achievers within the same time frame. Moreover, after training was withheld for 7 days, the low-achievers had nearly reverted to their original state.

Because environmental and instructional factors have been shown not to play a significant role in the development of aural skills (Heritage, 1986), researchers in the field believed there were other extraneous factors involved that would better account for the effect of computer-based music instruction than simply computing technology. Findings in this study seem to suggest a predetermined level of music ability as a possible factor. The nature of the underlying factors should be explored to verify if they might play an important role in affecting music training and if they might serve as better predictors for student achievement in music. Both Howard Gardner's (1999) musical intelligence and Edwin Gordon's (1997) concept of musical aptitude appear to be likely candidates for further inquiries.

Posttest Feedback

A special feature of Mona Listen was the incorporation of sampled instrument sounds of high fidelity for pitch discrimination training. The quality of the sound files was subjected to expert reviews, and both the experts and the majority of the participants attested to the high fidelity of the instrument sound used. Nevertheless, there were a few isolated cases where participants insisted that the sampled sounds were not only of "poor" quality, but also severely affected their judgment in pitch discrimination. Although the contradictions were thought to be mostly the result of hardware technical problems related to the computers, sound cards, or poor quality computer speakers, is it possible that these students have a very different set of standards concerning what constitutes "good" sounds as compared to the expert reviewers?

Even though participants performed did better with intervals coded in guitar sounds, several students complained about the "quality" of the guitar sounds because the sounds were peculiar to them. One reason could be that sampled guitar sounds invariably included a sonic component known as *onset transients*. Onset transients can be found as the initial fluctuations of any sound: for example, the moment a trumpeter tongues the notes, a violinist puts the bow on the strings or a guitarist places his fingers on the guitar frets. Onset transients are extremely important in identifying a sound source's spatial location and timbre and would render the sound unrecognizable if spliced from the recordings. However, the onset transients of the guitar samples in this case might have constituted a distraction to non-guitar players. For reference, electronically generated pure tones do not contain onset transients.

Post-treatment feedback showed that several students who expressed doubts concerning the value of training rushed through the online modules and found it difficult to concentrate when staring at the computer screen. A Web-based learning environment was probably not suitable for these participants. How would music educators convince and motivate similar students to undergo the pitch discrimination training they so need? Motivational issues remain a large obstacle to effective training.

Two participants offered suggestions to improve Mona Listen. One participant suggested auto-detection of participant's weaknesses in the intervals, somewhat akin to competency-based programmed instruction as suggested by Pembrook (1986). The other participant suggested color coding individual melodic intervals to facilitate rote memory, bringing to mind Paivio's Dual-Coding Theory (1986) and Mayer's multiple representation for multimedia learning (1999). While the suggestions sound very interesting and are certainly within the capability of current technology, would it add pedagogic value to pitch discrimination training or simply become a vehicle to raise test scores? Although students would probably do better in pitch discrimination using dual-coding materials in training and testing, real-life music listening remains primarily an audio experience without any visual cues.

Several attendees of the focus group commented that the classroom piano sound used during the follow-up posttest was somewhat distracting because of its harmonics. The phenomenon of harmonics is peculiar to acoustic pianos, and less so in guitar, because each note played on a piano is produced by a set of three vibrating strings, as contrasted to a single string for guitar. Sometimes, depending on the intensity of the vibrating piano strings, neighboring groups of strings start to vibrate as well, thus creating the "aural illusion" of simultaneous notes even when only one piano key was actually played. Further, the higher frequency harmonics might have been amplified by the four walls of the music classroom so as to become distracting to students seated in certain locations. Digital sound samples of acoustic piano did not exhibit this effect. Participants with very sensitive hearing might therefore perceive digital sound samples to be purer (and therefore, better) than real acoustic instrument sounds because digital sound samples are not colored by harmonics.

Unusually High Participation Rate

One unexpected observation in this study was the extremely high participation rate. Because participation was voluntary and participants were free to choose between the Big Ear site and the Mona Listen site, why did every student in the class signed up for Mona Listen? Findings showed that no one made use of the Big Ear site, and all 72 music students from the cohort intake signed up with Mona Listen. The four who dropped out from the Mona Listen study due to non-participation did not switch to Big Ear. What, then, is the difference between the two web sites that resulted in an extremely high participation rate in one but not the other?

Having discussed the observation with the course instructor and teaching assistants, the investigator believed auto-tracking of user progress was the determining factor. While students choosing the Big Ear site would have been required to keep a pen-and-paper access log, those choosing to participate in the Mona Listen study did not need to do so. Mona Listen was equipped with a user login process that would automatically track users by their login IDs and automatically generate a login report for the instructor. Hence, students did not need to “worry” about keeping a time log. This observation seemed to suggest a “pampered” lot of young people who were committed to doing what was most convenient. While a pen-and-paper access log was susceptible to inconsistency and fraud, with students falsely reporting on the number and length of time of logins, the fact that no one took advantage of the situation to “get out” of the situation of having to participate in a research study was a surprise to the researcher and the course instructors.

Targeted Versus Achieved Level of Competency

The large effect size and statistically significant differences (at the $\alpha = .05$ level) found in this study affirmed the effectiveness of the WBMI intervention. However, what practical level of pitch discrimination skill did the first year college music students in this study achieve? More specifically, did they achieve the level of mastery or competency expected of them?

Based on the achievement score of the expert reviewers, who unanimously scored 100% on the Posttest, a desired level of competency for melodic interval discrimination would appear to be around 90% (or 18 out of 20). However, Hofstetter (1979) and Pembrook (1986) report that students became frustrated with CBMI for ear training when an extremely high level of competency (more than 85%) was expected of them. Thus, it was notable that the participants in this study achieved such a high level of competency (around 78%) within the short time frame given. For comparison, a regular basic music theory class would devote up to two years, or four semesters, for pitch discrimination training.

Limitations of the Study

Because participants in the study were not randomly selected from the population, findings from this study might be localized and thus be limited in its generalizability. However, it should be applicable in as far as beginning music students are concerned. Additionally, self-reported demographics data collected can be a limiting factor in interpreting the actual influence of early-years music experience on participants' music achievement. These demographics data included the perfect pitch ability, prior instrument playing experience, and prior music training experience.

Other limitations of the study include all common limitations found in online or distance learning studies. The authenticity of online learning environments and participants' different learning paces was one limitation. Because the affordances of online training included self-paced and anytime anywhere learning, it became difficult to control when or how participants completed the online course.

On one hand, although technology could allow the posttest to be fixed on Day 14 of the data collection period, this approach would have created an unauthentic online course. On the other hand, allowing participants to complete the training at their own choosing might inadvertently subject the study to other time-related validity issues. Testing for perfect pitch is another consideration. Although testing for perfect pitch is possible, it would demand a face-to-face session with the students who were supposedly taking an online music course. Because perfect pitch was not a critical piece of information that might adversely affect the study, the face-to-face testing was not conducted. Other researchers could consider expanding the study to further investigate the effect of pitch discrimination within a clinical versus an authentic online learning environment including participants from different states and countries.

Finding an optimal duration for the course was another limitation. Because all courses would have a start and end date, students taking online courses must likewise comply with this restriction. Students with a very slow pace of learning might require more time than others and risk performing poorly under such circumstances. Students with poor discipline would also not perform well in an online course. Other uncontrolled limitations included procrastination, gradual loss of motivation, and determination. As with research studies dealing with computer and Internet technology, breakdown of computers, technical faults of sound cards, multiple user logins, missing data due to packet loss during Internet transfer, participants not following instructions, and improper logoffs were all possible limitations of this study.

Problems Encountered During Data Collection

Two problems were encountered during data collection. Because Mona Listen was an online instructional module, it was designed in such a way that participants could login to the online course from any computer with an Internet connection. Although the music computer laboratory was tested to work with Mona Listen before the study commenced, due to the high volume of student-users who made use of the computers for all kinds of learning tasks, it soon became impossible to ensure continuous functionality of the workstations. As one participant commented, “I tried five different computers in the music lab before finding one that would work. I could not hear any sound from the first four computers.” She had to test out several workstations by logging into Mona Listen to find one that would play back sound. This trial-and-error process led to several groups of extraneous data for the participant concerned. Hence, the investigator could no longer report on the total time spent by participants in the entire online course (using the login-logout timestamps), and instead, reported only the time spent by participants in taking online assessments. Participants using home computers for online access generally experience fewer problems than those using the computer laboratory. Other researchers with more resources and enough funding might consider providing preconfigured laptops to all students.

Bandwidth congestion of the Internet was the other problem that resulted in loss of data points. When the responses from participants were sent through the Web, bandwidth congestion sometimes resulted in the packet not arriving at the server. Under similar circumstances, a student who was using floppy disks in a CAI would have corrupted the entire disk and lost all data for the exercise, whereas in the case of this study with an online database, only one data point was lost. The computers they used in taking the online courses may have affected participants' achievement. The stability of the computer system, which is a hardware factor, and the compatibility of software installed, a software factor, must be taken into consideration by researchers. Unauthorized software, such as spyware, virus, and music (MP3) download agents, could further compromise the stability of the system.

The running interval could have constituted another limitation, although feedback gathered from the focus groups did not indicate this to be an issue for consideration. One expert reviewer (a teaching assistant) had suggested that the running intervals "went by too fast for a student to be able to sing them along." Because the running intervals were composed as "songs without word," it was intended that participants would listen to them for several rounds before attempting to hum or sing along in solfege. Some participants may have been too eager to sing along in solfege the first time they heard the running intervals and may have experienced frustration in so doing. Since singing in solfege was only a suggested activity, audiation could still occur with the participant listening but without humming along. A side effect could be the frustration experienced by participants, which could then reduce the overall perceived value of the WBMI. The possibility of this limitation was asked of the focus groups, and feedback from students did not indicate this to be an issue.

Recommendations

Future research should examine the effect of prior music training in greater detail to determine which aspects of prior training received were most important in providing the necessary scaffoldings. Longitudinal studies may be necessary to accurately quantify users' training experiences as self-reported data would become a potential limitation.

The effect of other instrument sounds should be researched to determine the best instrument of choice for pitch discrimination training. Ranking of instrument sounds by their psychoacoustic complexity may help to determine which instruments are most suited for pitch discrimination purposes. Promising instruments include instruments that were often described as being “pure” in tonal and sonic qualities; examples would include the oboe, the recorder, and the harpsichord. Future research may also examine the effect of melodic intervals recorded in percussive instruments, such as the xylophone, to ascertain why percussion players consistently performed better than guitar and piano players (see Table 10). Other researchers may be interested in comparing the effect of piano sounds with and without harmonics to ascertain the extent of influence of piano harmonics on pitch discrimination.

Expert reviewers of Mona Listen suggested expanding Mona Listen by adding new sections to teach musical notation after students complete the audiation training. Future expansion of Mona Listen to become a complete Web-based music instruction for pitch discrimination training could include: (a) all melodic intervals, (b) all harmonic intervals, (c) chords and inversions, and (d) dictation. Instrument sounds in multiple temperaments might be another consideration for future research among the music purists.

Future research may include mapping of the hierarchy of musical learning by intervals and play orders of the intervals. Some choirmasters claim success in teaching m2 and m7 before other intervals. Is there a “true” hierarchy of learning among the twelve intervals? Which intervals should be taught first, and which should be last? Does it even matter? Pitch discrimination training using different learning sequences of intervals in different play orders and different instrument sounds could also be examined.

While the inclusion of musical notation will make Mona Listen a more complete WBMI for freshmen theory curriculum, researchers must be careful to introduce inferential learning only after discrimination learning has been achieved (Gordon, 1967; Walter, 1989b). Audiation needs to be mastered first, before the introduction of notation.

Based on participants' feedback, the running intervals may be too long for listening comfort and sing-along purposes. One possible way of shortening the length of running intervals is to break them apart (chunking) according to the play order, ascending or descending. Because findings showed that pitch discrimination training had a positive effect according to the play order of the melodic intervals, making available an ascending and a descending running interval would allow users to more easily select a particular play order for focused training.

As for all repetitive drill-and-practice learning tasks, loss of motivation due to boredom could well affect pitch discrimination achievement. Because the running intervals were all recorded using the same key sequence (beginning with C, then F, then G, etc.), students may become bored after several rounds of listening to the same running intervals. Variety could be added to the listening through randomly playback of running intervals in different keys sequences, beginning in F or G instead of just C. However, the inclusions of more than one key sequence for the same running interval would certainly mean a much larger file size, which would further translate into longer download time in an online learning environment.

Other researchers could employ a variety of research methodologies to cross-examine how students learn pitch discrimination in an online environment. Large-scale research work, possibly involving longitudinal studies, would be necessary to fully explore the effects of musical intelligence and music aptitude on musical achievement. Factorial analysis of musical achievement may be useful in helping to uncover deeper underlying issues that affect a person's pitch discrimination ability.

Additionally, instructional gaming had been suggested (White, 2002) as an innovative means to relieve the boredom found in repetitive learning tasks such as ear training drills. Future research could incorporate instructional gaming as an alternative mode of delivery for pitch discrimination training.

Finally, as new technology such as mobile devices become more accessible, researchers should also consider pitch discrimination or music instruction in a mobile learning environment using wireless personal digital assistants as conduits for accessing online instructional materials for music learning. Researchers are interested in mobile devices, such as the PocketPC, because they can already play Flash documents and MP3 files, in addition to connecting to the Internet wirelessly. However, one should be aware that the Flash player in the PocketPC has tended to be one version behind the current offering and may lack certain features as compared to the Flash player for desktop and laptop computers. The Palm Pilot variety of mobile devices does not currently have the same capability as far as the PocketPC, and thus, is not suitable for Web-based learning purposes at this time.

Concluding Remarks

Since the 1970s, technology-enhanced pitch discrimination application had long been known to be an effective tool for pitch discrimination training. Compared to computer assisted instruction (CAI), Web-based pitch discrimination training further allows greater flexibility in the areas of accessibility, convenience, content delivery, individualized instruction, and self-paced learning. Additionally, many of the technical obstacles found in the early versions of computer-based music instruction have been overcome through advances in technology.

Although Web-based instruction has many advantages over the older computer-assisted instruction and is a vibrant growing trend in other subjects of study, there is currently a wide gap in the literature on the use and effects of innovative technology and Web-based music instruction at the college level. This study informed the literature by examining the effects of Web-based pitch discrimination training on college music students' achievement in melodic interval discrimination. Further, the Web-based training module used in this study employed realistic instrument sound to provide not only the musical context for music learning, but also to maximize the pedagogic values of ear training for music students aspiring to become professional instrumentalists.

The time has come for an update of pitch discrimination training using current available Internet-related technology. More important, new research is necessary for the re-evaluation and verification of pedagogic values of current classroom practices. As music educators seek to improve music pedagogy, researchers of instructional technology can help to innovate by carefully applying instructional design technology principles in the development of technology-enhanced music instruction. The collaborative research endeavors in Web-based music instruction will serve to benefit both academic fields and improve the field of music education.

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