THE EFFECTS OF POLYPHONIC INTERACTIVE MUSIC SYSTEMS ON DETERMINING HARMONIC FUNCTIONS

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Abstract

The ability to determine chords and progressions used in popular music is a valuable skill for musicians and part of musicianship. A music educator should be able to listen to the popular songs familiar to students and quickly and easily determine the chords and progressions being used in this music in order to convey information to the students about how the piece was composed and how it may be performed. Though some view this skill as being important, it is not assessed on teacher certification examinations, and the NASM (2010) accreditation mandate for addressing these particular skills in undergraduate and graduate ear-training (aural skills) courses is unclear at best.

Musicians who have learned music informally may be more adept at this skill, likely out of the necessity to learn new music without the assistance of reading standard music notation. Mastery of this skill, however, could have more to do with the frequency that individuals perform with a polyphonic instrument as opposed to performers who play primarily monophonic instruments. When compared to musicians who have mastered a polyphonic instrument such as guitar or piano, musicians lacking experience performing on a polyphonic instrument may also lack an understanding of the concept of a three-note sonority functioning in a way specified by the key. In order to determine chords and chord progressions, experience performing harmony, hearing how it functions, and doing so with fluency is necessary.

For players of monophonic instruments such as the trumpet or voice, the traditional approach for supplementing the lack of experience playing a polyphonic instrument is to give them piano lessons. However, without mastery of performance skills on this instrument, the fluency necessary to afford experiences in which the performer

can be performing harmony *while* hearing how it functions can be difficult. One solution can be the implementation of interactive musical instruments and environments that provide a way of performing harmony with controls that are more accessible in terms of immediate use than traditional instruments. Technology-based musical instruments are easily obtainable to individuals via digital mediums and allow an immediacy by which an individual can compose and perform even without formal music training (Manzo, 2007; Pask, 2007; Wel, 2011).

The present study observed the effects of activities involving polyphonic interactive music systems on participants' ability to determine chords and progressions. I observed the ways that post-test scores changed after using the software, and noted the extent to which subjects were able to determine chord progressions better or worse with the aid of this interactive software system versus a traditional polyphonic instrument. An increased ability to do so could yield important implications for individuals looking to easily perform chords for pedagogical reasons, such as practicing the determination of chords and chord progressions, but who lack mastery performing a polyphonic instrument; an interactive system could provide an alternative to traditional instruments. The open-source software developed and used for this study can be easily changed to allow musical events to be triggered using any sort of control mechanism including sensors, buttons, and more. This software, with its limited number of labeled controls, can be expanded to function as a prototype for future research. A supplemental website, vjmanzo.com/dissertation, has been created for this research project.

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CHAPTER 1

REVIEW OF THE LITERATURE

Determining Chord Progressions in Popular Music

Music perception requires that listeners make sense of presented musical material within the context of their prior musical experiences, but even experienced musicians may not immediately identify the quality of harmonic sonorities or their context within a key (West, Howell & Cross, 1985). The ability to determine chords, progressions, and their key contexts is a valuable skill for musicians and music educators and, as such, should be taught using effective and efficient strategies. These strategies might derive from processes pertaining to the intelligent handling of popular music in the classroom. Green (2008) outlined a performance strategy hinged on listening to music that is culturally familiar and learning to play the music informally "by ear" in the same way that many popular musicians have learned to perform (Green, 2002). In this "informal" strategy, music educators function as facilitators for student-directed learning, assisting with more complicated levels of musicianship when needed as opposed to the more traditional teaching scenario. Green described the ways in which students were able to learn to play instruments by listening to music and figuring out the notes and chords without teacher intervention, imitating the ways in which many popular musicians have learned to play music. In this strategy, teachers assisted students with conceptualizing aspects of form, harmony, and other musical concepts as the students' experiences with music caused them to ask questions about these concepts.

Though the activities in Green's study were successful in allowing students to learn to play in this informal style, listening to music and determining chords and progressions can be a difficult task for music educators and students alike. In order for Green's pedagogy to be best utilized in practical applications, the educator facilitating the student-directed learning must be proficient in aural discriminating used in determining chords and chord progressions by ear.

Ensuring that an educator is adept at this skill is also difficult. The Praxis teacher certification exam in music (ETS, 2010) administered by the Educational Testing Service, or ETS, must be passed in order for an individual to receive music teaching certification credentials in most U.S. states. While the test has a listening section which addresses musical characteristics of style including harmony, it is difficult to determine if the results of the listening questions asked on the Praxis accurately reflect the proficiency by which an educator can identify chords and progressions in popular songs within the context of a classroom situation as described by Green. The burden of ensuring that music educators possess these skills is left to the degree-granting institution.

The National Associations of Schools of Music, or NASM, handbook (2012) provides criteria for music courses as part of the accreditation process for colleges and universities. These criteria present standards for traditional ear-training (aural skills) courses. While they focus on ensuring that skills are conveyed, they allow flexibility in how the content is presented, resulting in the likelihood that the methods and approaches vary greatly among universities.

Curricular objectives regarding the individual ear-training skills being taught may vary from school to school and course to course; one teacher may emphasize intervallic relationships or harmony in isolation while another may emphasize harmonic direction in the context of the standard repertoire of Western art music. It would seem that mastery of the skills necessary to determine chords and progressions in popular music could vary from learner to learner. It is difficult to assess the extent to which a music education major possesses this skill apart from other ear-training skills assessed within the ear-training courses.

Instrument Background as a Factor in Determining Chord Progressions

I examined (2011a) a possible association between musicians' polyphonic or monophonic instrument background prior to college and their ability to determine chords and chord progressions. Since undergraduate content musicianship skills require some study of keyboard harmony by all music majors (NASM, 2010), the study focused on the instrument types of music majors prior to college study. I surveyed 94 undergraduate and graduate music majors at a mid-sized state university in the northeast United States who had completed at least two semesters of ear-training courses and were familiar with popular music. Participant responses were divided into two groups based on their experience playing monophonic or polyphonic instruments prior to college study. The criteria for the "polyphonic group" required participants to have had at least 3 years of experience playing a polyphonic instrument. Additionally, participants needed to have considered their level of proficiency with that instrument as being at the intermediate level or greater prior to college study. All other participants who had only played monophonic instruments prior to college study were placed in the "monophonic group."

In this self-report study, participants were asked a number of self-assessment questions regarding their skills in determining chord progressions in popular music and a possible association between the two groups was examined. A statistically significant difference (Fisher's Exact Test) between the abilities of both groups was found.

When asked to rate their ability to determine “by ear” the chords to harmonize a primarily diatonic melody, the polyphonic group had a higher percentage of respondents rating their ability as “Strong, and Very Strong”, 34.38%, and 10.94% respectively, compared to the monophonic group of which 10% and 3.3% of the members rated their ability as “Strong, and Very Strong”. The monophonic group had a larger percentage of respondents rate their ability as “Moderate” than the polyphonic group, 43.33% compared to 28.13% by the polyphonic group. A larger percentage of monophonic group members rated their ability as “Weak”; 40% compared to 21.88% by polyphonic group members. Percentages for rating their ability as “Very Weak” were similar: 3.33% and 4.69% for the monophonic and polyphonic groups respectively.

Instrument background aside, the response percentages of all participants, when asked to rate their skills in determining the chord progression being used in a typical popular song on the radio, were 4.26% "Very Weak", 24.47% “Weak”, 30.85% "Moderate", 26.6% "Strong", and 13.83% "Very strong". One could argue that the percentages in the “Very Weak”, “Weak”, and “Moderate” categories are high for music majors.

Obviously, not all music majors come from a polyphonic instrumental background. Although keyboard harmony courses are required in undergraduate degrees, it is probable that it is the rare instance in which the degree-granting institution, as a matter of course, fosters or develops the skills used in determining chords or chord progressions in popular music with the assistance of the student’s primary instrument, be it polyphonic or monophonic, or a secondary keyboard instrument. Based on the results of the previous study, one might conclude that musicians with a background in a monophonic instrument may have less opportunity to practice listening to music on the radio and determining the chords and progressions simply because of the monophonic limitation of their instrument. Since guitarists, keyboardists, and other players whose primary instrument is polyphonic deal with playing harmony on a regular and consistent basis, they may be more accustomed to hearing chords and progressions while they are performing them, and possibly have had more experience determining chords and chord progressions using their instrument as an aid in the manner described above than monophonic players, even those who also play some keyboard or guitar as a secondary instrument.

Perceptual Organization of Harmony

Understanding the functions of diatonic harmony (e.g., *tonic*, *subdominant*, *dominant*, etc.) and being able to determine chords and chord progressions must be paired with discussion concerning the understanding of melody. Mursell stated "…a sequence of tones constitutes a melody when it is apprehended in terms of a unified and single response" (1937, p. 104). Just as with harmony, the act of apprehending a pitch sequence and fitting it into some mental construct, either consciously or unconsciously, is a psychological phenomenon.

Much can be said about the role of culture in shaping listener expectations of melodic ideas. From an early age, listeners experience melodies and build mental frameworks of expectation for melodies (Dowling & Harwood, 1986). These *melodic schemata* develop through immersion in the music of one's own culture. A melody that seems foreign to the listener's culture, and thus lacks melodic expectations, as a result, lessens the possibility that a listener will respond to it as a melody (Meyer, 1967). Regardless of formal music learning experiences such as school music experiences, musical knowledge of melody as well as other musical elements are learned implicitly through experiencing music and forming listener expectations (Carterette & Kendall, 1989).

In a recent study by Demorest, Morrison, Beken, and Jungbluth (2008), 150 participants from the United States and Turkey were asked to listen to culturally familiar and unfamiliar music and then perform a series of memory tests regarding the musical material. All participants performed better at tasks that involved music of their native culture. This research suggests that cognitive schemata for musical information are derived from culture.

Enculturation is not the only determinant in understanding melody. Compositional elements such as melodic contour, rhythmic structure, and pitch placement all become factors of a Gestalt (Lipscomb, 1996; Terhardt, 1987). Yet, as Radocy and Boyle (2003, p. 213) state, “Ultimately, only the perceiver can judge whether a tonal sequence functions as a melody; If it does, it *is* a melody.” West, Howell, and Cross’s (1985) findings regarding cognitive musical structures suggest that past experiences with music as well as a number of extramusical or historical aspects in the music may be factors in the listener’s ability to perceive said structures.

According to a study of 120 undergraduates by Cuddy, Cohen, and Mewhort (1981) in which participants were asked to rate the tonality of melodies in such terms as “completeness” or “jarring”, both musicians and non-musicians rated the sequences consistently when chromaticism was introduced. Additional experiments by Cuddy

(1982) suggest that people tend to have an easier time remembering melodies that conform to the diatonic idioms of Western tonal music such as folk melodies or the melodies used in popular music.

The compositional manipulation of these expectancies, not just in melody, but also harmony, and the resulting tension or "thrills" experienced by the listener have been discussed in great detail in studies of music perception and emotion (Sloboda, 1991; Watterman, 1996). It is the structural efficacies in composition and the relationship to the perceived proclivity of harmony that have contributed much to the discussion of "musical grammars" (Sloboda, 1985) in the sense of Chomsky's work in linguistics syntax (1957, 1965, 1968).

Harmony refers to, in general terms, the simultaneous, or "vertical", pitch structures in music as opposed to melodic, and linear, or "horizontal", structures. It can be simplified to be thought of in terms of two textures: *polyphonic* in which two or more melodies are sounded simultaneously, and homophonic in which a single melody is supported by some harmonic accompaniment, often tertian. Like melody, perceiving harmony is also considered to be strongly linked to enculturation (Farnsworth, 1969; Lundin, 1967). Such findings are consistent with Demorest's findings referenced earlier.

Structurally, diatonic harmony has more to offer listeners in terms of implied tonality than melody alone due to nature of redundancy in scale degrees that suggest one tonal center over another as per studies in information theory (Broadbent, 1958; Meyer, 1956, 1967, 2001). From these tonal centers, harmonic structures and their harmonic progression are understood in terms of their tendency to move toward or away from tonal centers. Each harmonic structure, one for each diatonic scale degree, then serves a harmonic function strengthening this tendency in the expectation of the listener. In tonal music, there is a notion of finality as harmonic structures come to rest at the tonic chord. The perceived psychological relationships of chords in several contexts have been identified by Krumhansl, Bharucha, and Castellano (1982).

Structures of perception, as they relate to determining chord progressions, are more than hearing chord qualities, but rather hearing context of chord sonorities within a key. The discrimination of notes as belonging to a diatonic pitch set is a construct of perception and, naturally, a subset of aural skills training. The ways in which listeners establish harmonic contexts as “keys” have been long observed by researchers.

Research experiments by Butler (1989, 1990a, 1990b) suggest that a listener’s establishment of a tonic is based on the occurrence of “rare intervals”. The presence of a minor second interval or a tritone, in a tonal context, can only exist in a limited number of diatonic key scenarios and thus aid in established a sense of tonic. For example, the tritone interval C and F# if heard in a musical passage only occurs naturally, that is, without chromatic inflections, in the keys of G major, and enharmonically in C# major (B# and F#). Butler’s research suggests that listeners chose the tonal center for musical excerpts in his experiments based on the presence of rare intervals within the excerpt. As he explains: “The dominant-tonic succession that these temporal arrangements of rare intervals represent are characteristic to harmonic cadences in tonal music, and are seldom encountered in atonal music” (p. 9).

Krumhansl’s (1979, 1990) research and theory of “tonal hierarchies” stems from research experiments in which subjects were asked to rate the relationships between pitches presented in diatonic and non-diatonic contexts. Participants perceived similarities among diatonic tertian harmony when presented in diatonic keys, and rated the greatest perceived similarity among the tonic triad. Two studies by Cuddy (1991) support Krumhansl's theory of tonal hierarchies.

It should be noted that, with regard to timbre, in experiments of the perceptual organization of tonal hierarchies, researchers have employed timbre models that avoid perception complications associated with pitch height. These models attempt to confound attributes of pitch height in harmony such as voice leading and inversion leaving only pure harmony for the participant to hear and thereby make judgments (Deutsch & Boulanger, 1984). Early studies in perceptual organization of harmony (Deutsch, Moore, and Dolson, 1984; Krumhansel, Bharucha, and Kessler, 1982; Krumhansl and Kessler, 1982) implemented similar models to confound pitch height through a technique based on the so-called Shepard Tones named after Roger Shepard (1964) and often added some form of equal loudness contour such as Fletcher-Munson (Fletcher & Munson, 1933) and Robinson-Dadson contours (Robinson & Dadson, 1956).

According to Krumhansl (1990), research suggests that "…internal representation of tonal and harmonic relations is acquired through experience"; that there are "strong interdependencies between the three levels of musical structure: tones, chords, and keys…" (p. 211) and that empirical studies support this view. Radocy and Boyle stated: "…there is at least a tacit acceptance that, just as for melodic perception, experienced listeners develop internalized cognitive structures or schematas of musical keys, key relationships, and functions of chords within keys" (2003, p. 217). If the conceptualization of these cognitive structures is acquired and developed through experience, then musicians whose primary instrument is incapable of producing harmony could have a deficit in this skill, or will be slower to develop such skills compared to others whose primary instrument is capable of producing harmony. Furthermore, if measures are not taken, either through assessment standards mandated by accreditation services, teacher certification exams, or degree-granting educational institutions, to ensure that opportunities for the experiences are afforded developing musicians, music educators could enter the profession without the skills necessary to determine chords and chord progressions. Without these skills, a teacher's ability to identify chord sonorities in the context of keys is severely limited. If self-directed music activities like those described by Green (2008) are to take place in which students recognize musical material to some degree and perform it, the teacher would likely not be able to facilitate a discussion explaining what is happening harmonically and structurally within the music.

Popular music can be somewhat ubiquitous and unavoidable, pervading public places, workplaces, and social settings (Sloboda, 2005). Among popular music's qualities which are, for some, cultural familiarity and seemingly broad appeal, which Green (2008) identifies as being factors that could encourage mass participation in classroom settings, the simplicity of form and phrase, almost strict adherence to diatonicism, and repetitive nature of some popular music can be ideal repertoire for acquiring and developing experience hearing harmonic functions.

Experimental research in information theory describes aspects of redundancy (Broadbent, 1958; Meyer, 1956, 1967, 2001; Watson, 1973) within a message as a factor in perception. Research suggests that the more information contained in a message without redundancy of elements within the message, the greater the variability of ascertaining meaning or response from the message.

Meyer (1967) argues that redundancy in a musical message depends upon how closely the musical material provides structural redundancy (i.e. repeated formal sections, pitch sets (scales), and harmonic sonorities) and the experiences of the listener with regard to encountering these structures, a type of cultural redundancy. Thus, perceptual redundancy is a combination of both structural redundancy and cultural redundancy within the musical message.

Finding art music in the standard repertoire that presents musical traits, such as repetitive chord patterns, simple phrases and melodies, the presence of rare intervals, structural redundancy as per information theory, and an overall adherence to a single key, in the manner that these traits are encountered in popular music can be difficult because composers of art music tend to strive for and achieve a higher degree of sophistication in treatment of musical elements including harmony, form, and development. If music is deemed by the listener to be culturally familiar, as per cultural redundancy, and somewhat learnable, it could be used to afford an experience determining chords and chord progressions easier than even simple art music repertoire that is culturally unfamiliar, and certainly more so than other music, popular or art, that is more sophisticated. The simple, singable diatonic melodies used in much popular music strengthen the tonality of the harmonic accompaniment that supports it as melodic pitch structure is one determinant of tonality (Taylor 1976).

Serafine (1983) conducted experiments that provided evidence that hierarchical structures of musical material are more than theoretical constructs, but, instead, legitimate cognitive processes. In these experiments, non-musicians listened to musical examples of a short piece followed by two reductions of the same piece, one of which was “wrong”.

Subjects were able to identify the correct reduction over the wrong reduction only when the mistakes were present at the *foreground* level (i.e., in a musical part that is prominently featured such as a melody in a high register as opposed to inner harmony). Hearing beyond the foreground level, research suggests, is a skill that requires training.

Harmonic analysis within these layered structures has been discussed by many composers and theorists including Schenker (1979). Similarly, an analysis of popular music in order to determine chords and chord progressions can be thought of in terms of placing elements of the music into layers. Solos, drum beats, and melodic lines with their prominent rhythmic and pitch profile are typically perceived as part of the foreground level, while arrhythmic keyboard pads and guitars, that often contain the most diatonic pitch redundancy in terms of harmonic content, are typically perceived as part of the background. Again, hearing through the foreground to the background, and thus the harmony, is a learned skill, and could come easier to musicians with increased experiences performing harmony. Moreover, trained musicians who have not had sufficient experiences perceiving harmony beyond the foreground could have more difficulty identifying harmony in other levels than musicians who have had these experiences.

Interactive and Adaptive Music Systems and Instruments

Advances in technology have led to where what once took months of mastery on a traditional acoustic instrument, such as playing each triad in all keys, can now be accomplished with immediacy through the use of some accessible electronic musical instrument. It is this type of technology that could afford musicians who feel they lack the skills in determining chords and chord progressions greater opportunities to practice the skill and experience the harmonic result through performance. Where a primarily monophonic instrumentalist would have to spend months learning a new secondary polyphonic instrument to serve as a tool for improving their ear-training skills in this way, an electronic instrument can provide users with options to easily play diatonic chords with the press of a button, for example. This would allow them to focus more of their attention on the skills needed to determine chords and progressions and play them back in real-time and less on the idiosyncrasies associated with performing on a non-primary instrument that they are largely unfamiliar with and requires more time to learn.

Many method books begin students with learning to play monophonic material; learning a new instrument can be difficult and playing harmony takes even more time. For seasoned musicians who already understand concepts of music and are simply looking for an instrument that produces polyphony without a steep learning curve in order to assist in determining chords and progressions, this type of technology can be one solution.

Adaptive Instruments

Some individuals cannot play traditional acoustic musical instruments, but, instead, play “adapted” or “adaptive” instruments designed for accessibility. Adaptive instruments can provide ease of use and accessibility for disabled and special needs populations. The instruments themselves are commonly created for a specific purpose, such as to play chords or percussive sounds, with a specific individual or group in mind with which the instrument will help overcome some limitation, perhaps physical or mental, on the part of the performer. Adaptive instruments can be acoustic or electronic in design and Crowe (2004) has reviewed the literature of electronic adaptive instruments used to assist in music making. Recent advances in technology have helped many new adaptive instrument projects to form including Skoog (Schogler, 2010), AUMI (Pask, 2007), My Breath My Music Foundation (Wel, 2011), and EAMIR (Manzo, 2007).

Software to aid in music instruction is also a fairly recent advancement, yet wealth of information exists in the literature documenting the use and characteristics of technology-assisted instruction (Rudolph et al., 2005; Sheldon, 1999; Watson, 2005). An abundance of technology, however, does not always ensure that is being used effectively by educators. The pedagogical frameworks TPACK (Koehler & Mishra, 2008), for example, attempts to describe the type of knowledge where a teacher uses knowledge of technology to facilitate knowledge in another content knowledge area, such as music, and conveys information using knowledge of pedagogy.

An excerpt from a recent practitioner’s journal for educators provides further insight:

> Today, there are software applications for just about everything, but to what extent do we allow music software to dictate how we teach musical concepts? After installing a software application, it's normal to look at the program and ask ‘what does it do,’ ‘how can I perform with this,’ and ‘how can I make a demonstration or instructional activity out of this for my class?’ There's certainly nothing wrong with this, but you may already have some musical ideas in mind and are looking for a way to express them using the efficiency and interactivity of technology. However, existing software may not be able to address the particular concepts you want to address from the angle you prefer.
>
> Imagine teaching harmony with the aid of a specialized program that showed common tones between the chords and scales, or a program that used the first seven number keys to play the seven diatonic chords of a key. Imagine composing a piece of music with a program that showed how chord functions tend to resolve in a given key.
>
> Software developers typically design a program’s layout to be accessible and intuitive, but in doing so, they are bound to show certain biases toward the visibility of what are considered the more common features. In an instructional setting, if the feature that is going to help the instructor explain concepts of rhythm or harmony is somewhat buried in

> the program's menus, he or she may be less inclined to teach those musical concepts right away because there is too much requisite knowledge of the software involved just to get to the desired menu. Instructors would have to teach a number of software concepts just to get to the place where they could teach the musical concept they wanted to address in the first place. It's not the software company's fault; after all, they don't know what and how you teach. However, it's a common case of technology dictating the instruction instead of instruction dictating the use of technology.
>
> This problem is not unique to technology. Even the conventions of traditional notation using staff paper can dictate how we're going to teach; if we don't enjoy counting notes on ledger lines, we just stick to writing notes on the staff. In the same way, it's just as easy for software to confine us. If we want to teach some musical concept in an interactive way using the efficiency of technology but can't find the technology to support it, the notion of an interesting approach to teaching the concept likely gets dropped.
>
> At the same time, teaching with technology can be seen as trendy and gimmicky. Suppose you decide to use a program that plays diatonic chords in a key by using the buttons of a videogame controller. The activity in a classroom setting can be fun, but at the same time, it can be pretty pointless if the program doesn't address some musical concept and the activity isn't accompanied by solid teaching. However, if these things are in place, the student is then able to accomplish some musical task using a controller that is easy to use—and probably more familiar than that one-octave xylophone he's hated using all year. It's easy to worship technology because of its 'ooh wow' factor, especially in a classroom setting. However, after the novelty of the technology wears off, we're still music educators first and technologists second. A good interactive system should allow a user to do musical things with efficiency, greater control, and clarity; it should not just exist for the sake of having technology in the classroom. (Manzo 2011b)

Through added features, controls, interface schemes, and more, the use of technological adaptive instruments can potentially be more difficult than the use of acoustic instruments despite the nature of adaptive instruments. In instruction, the function of the technology could receive the emphasis over the objective.

Interactive Music Systems

An interactive music system is a hardware or software configuration that allows an individual to accomplish a musical task, typically in real-time, through some interaction. The accessible design of such systems could allow them to be used in novel ways to allow individuals to compose and perform with greater ease than traditional instruments. An excerpt from the book *Max/MSP/Jitter for Music* on the subject of designing interactive music systems (Manzo, 2011c, p. 17) describes the role of interactive music systems in general with these implications in mind:

> Though commonly associated with composition and performance, the tasks associated with interactive music systems can include analysis, instruction, assessment, rehearsal, research, therapy, synthesis, and more. These systems typically have some set of controls, hardware or software, such as switches, keys, buttons, and sensors by which musical elements like harmony, rhythm, dynamics, and timbre can be manipulated in real-time through user interaction."
>
> Electronic musical instruments can then be thought of in terms of as controls for some musical elements. A variable is something that changes. A control is something that changes a variable. In music, there are many variables, such as pitch, dynamics, and timbre that change as a result of the instrument's control device, also known as a control interface.
>
> The control interface for a violin is typically a bow. Without buttons, knobs, or sensors, the bow is capable of controlling numerous variables within a single, simple, interface. For example, if you angle the bow differently as it hits the strings, the timbre will change; apply more pressure and the dynamics will change.
>
> The Buchla 200e, for example, is a modular synthesizer also capable of controlling numerous musical variables. In fact, the Buchla is capable of creating more diverse timbres than the violin. However, controlling musical variables on the Buchla, with the control interface of knobs, buttons, and patch cables, involves more gestures than the violinist and the bow.
>
> For the intent of performance, some control interfaces are more accessible than others for real-time use. With a computer, you can arguably achieve any sound imaginable if you tweak the right numbers and press the right buttons. It is a well-designed control interface, however, that allows a performer to readily control musical variables in a less cumbersome way than clicking on menu items from pull-down lists and checking boxes.
>
> Throughout history, people have created new musical instruments, and the instruments created generally reflect the technological resources available at the time. Early primitive instruments had few moving parts, if any. The Industrial Revolution made way for the modern piano to evolve using steel and iron. In the Information Age, it stands to reason that newly created instruments may largely involve computers and electronics.

> New Interfaces for Musical Expression (D'Alessandro, 2001), or NIME, is an international conference in which researchers and musicians share their knowledge of new instruments and interface design. Session topics include controllers for performers of any skill level as well as the pedagogical implications of using these controllers.
>
> Tod Machover, known for many great technological contributions to music including the Hyperinstruments group (Machover, et al., 1986), shared an interesting thought: "Traditional instruments are hard to play. It takes a long time to [acquire] physical skills which aren't necessarily the essential qualities of making music. It takes years just to get good tone quality on a violin or to play in tune. If we could find a way to allow people to spend the same amount of concentration and effort on listening and thinking and evaluating the difference between things and thinking about how to communicate musical ideas to somebody else, how to make music with somebody else, it would be a great advantage. Not only would the general level of musical creativity go up, but you'd have a much more aware, educated, sensitive, listening, and participatory public." (Oteri, 1999).

With practice, an individual can control most variables of an instrument well and at very fast speeds. However, the initial performance accessibility of an instrument or control interface has definite implications for its use by individuals as a musical instrument—in particular, those individuals who lack formal musical training and those who have physical or mental impairments.

In computer science, the term "mapping" is used to describe the correspondence of one set of data with another set. The potential mappings of musical variables to software controls has been the subject of recent experimental research (Couturier, Kessous, & Verfaille, 2002; Goudeseune, 2002; Levitin, McAdams, & Adams, 2002). Hunt and Wanderly (2002) conducted studies in which participants performed music making tasks using four control interfaces exemplifying two mapping types: one-to-one and many-to-one. One-to-one mapping types allow single musical variables to be controlled by a single controls mechanism of an interactive system. A many-to-one map allows numerous musical variables to be controlled by a single controls mechanism in an interactive system; more similar to the example of a violin bow controlling numerous musical variables as described earlier. In this research, the interfaces with many-to-one mappings were more engaging for subjects during the musical activities, yet both types of interfaces allowed subjects to perform the required tasks.

There is a paucity of literature comparing interactive systems and control interfaces to traditional musical instruments. As Hunt and Wanderly explain, the paradigm of instrument design up until just recently has been focused primarily on principals of acoustics. Design concepts that inhibit string vibration or airflow in ways that compromise musical variables such as timbral qualities and dynamic range in undesirable ways were and are concerns for makers of acoustic instruments. With electronic instruments, the mapping of musical variables to control can be similar to traditional instruments or completely unrelated. In this way, instrument designers can pursue concepts that allow for novel idiomatic writing and performance without the acoustical concerns of sound reproduction.

Learning to identify chord progressions with the assistance of a traditional polyphonic musical instrument requires some level of proficiency with that instrument, so that focus on the part of the participant is placed on hearing the chord progression and the harmonic flow as they are playing and not on the actual task of playing the progression. If asked to play a I V vi IV chord progression on a polyphonic instrument for the purpose of hearing what a I V vi IV progression sounds like, a musician who is unfamiliar with a polyphonic instrument like guitar or piano, might focus most of their attention on ensuring that they are playing the chords correctly and miss the purpose of the activity altogether: hearing what a I V vi IV progression sounds like. Using an accessible software instrument that allows a user to press, for example, a single labeled number key to play back the corresponding harmonic function could remove some of the need for attention to performance issues that one might encounter while performing a traditional acoustic polyphonic instrument. For educators, asking a student to play a I V vi IV progression would then require the student to press the four number keys on their computer keyboard labeled *1,5,6,* and *4*. In theory, there could be less instructional emphasis placed on teaching physical technique, tone production, and other factors since these variables are controlled by the computer software. The task of playing the chord progression by using a software instrument like this could allow users to focus attention on hearing the chord progression while they are playing it.

Separating the physical act of performing from the cognitive function of hearing harmony is important to educators because it allows *musicing* (Elliott, 1995) to occur by students without making them wait until they have learned the performance skills of a traditional instrument in order to play chords. In this way, playing chords and, conceivably, being able to compose and perform with them can occur much sooner with an electronic instrument than with traditional acoustic instruments. This allows a platform by which educators can help students make sense of the harmony of which they now have adept control.

It is important then to separate instruction in performance (i.e., instruction in the techniques of performing a musical instrument such as posture, chord shapes, and finger patterns) and instruction in musicality (i.e., instruction in theoretical constructs like harmony, melody, and timing). If the instructional objective of an educator is to teach a rhythmic pattern to a student for the purpose of performing it back, such a task can likely be accomplished with any instrument including just the voice. The instrument best suited for the task is the one that provides the most transparency for the student in terms of enabling them to conceptualize the rhythmic pattern and physically demonstrate the rhythmic pattern with the fewest external factors not directly related to the conceptualization of the rhythm, but to the demonstration of the rhythm (e.g. proper fingerings, not holding the strings against the fret hard enough to produce the proper pitch, etc.). In this way, an electronic instrument that, for example, would allow students to tap two distinct percussive sounds by simply tapping their fingers on a table would seem a much more transparent instrument to perform than a drum pad where stick grip and other factors become additional layers between the student and the task of demonstrating the rhythm. By minimizing the number of layers between the student and the task, the concept of the rhythm can be isolated to some extent and understood apart from the context of it being performed on a particular instrument. Though the performance skills associated with the electronic instrument might not be transferrable to other instruments, they did not require much time in order to learn them, and they served the purpose of facilitating the acquisition of the rhythmic concept. Conversely, it is entirely possible to spend a great deal of time learning a traditional instrument, also gaining non-transferrable skills, simply to facilitate the same acquisition.

Similarly, separating the cognitive functions of creating and performing music from the physical actions involved, at least to some degree, can allow individuals to develop an understanding about music using a musical instrument that is accessible to them. This is particularly important for users of adaptive instruments.

Interactive Music System Design and Implementations

The Manhattanville Music Curriculum Project (Thomas, 1970), or MMCP, was a teaching strategy aimed toward student-centered instruction. It aimed to reach students through activities that were artistically relevant, personally relevant, and socially relevant to the students. MMCP was similar in some ways to Lucy Green's (2008) research on informal music learning in that it addressed these spheres of relevance. Green's project, however, was primarily an alternate way of instructing students who were already part of the school music program whereas the MMCP additionally attempted to serve as a way to appeal to students with declining interest in school music programs.

Interactive music systems designed to allow accessibility in composition and performance could be a viable mechanism to achieving the objectives of MMCP by combining these systems with the informal music learning activities described by Green. The creation of a number of software systems specifically tailored to each student can be used to provide student-centered instruction in a self-directed learning environment where teachers serve as facilitators for the acquisition of musical skills to allow composition and performance of music that is artistically, personally, and socially relevant to the students.

Design Idiom

Interactive music systems are commonly used to produce some type of algorithmic composition. Rowe (1993) has identified and defined three methods of algorithmic composition: generative, sequenced, and transformative.

Generative methods use sets of rules to produce musical output from the stored fundamental material. Sequenced techniques use prerecorded music fragments in response to some real-time input. Some aspects of these fragments may be varied in performance, such as tempo playback, dynamic shape, slight rhythmic variations, etc. Transformative methods take some existing musical material and apply transformation to it to produce variants. According to the technique, these variants may or may not be recognizably related to the original. For transformative algorithms, the source material is complete musical input.

Graphical programming languages such as Max/MSP/Jitter developed by Cycling ’74 can be used to allow individuals to develop interactive systems in a visual environment different from traditional text-based programming languages (Manzo, Halper & Halper, 2011). Max/MSP/Jitter in particular is a popular programming language for use in creative works by composers, artists, and other multimedia designers given its vast set of programming objects that deal directly with audio and video. Through such an environment, individuals can create low-cost, easy to implement, and limitlessly customizable applications for specific purposes to facilitate their pedagogical objectives. The language has been used to allow composers, performers, educators, researchers, therapists and more to design customized software that is specific to their needs instead of relying on the availability and features of commercial software (Manzo, 2006; 2007).

I conducted a study (Manzo, 2010) of computer-assisted self-directed composition and performance activities for high school non-music students. In this study, the software was developed to allow students without formal music training to compose and perform original music while acquiring or strengthening knowledge of musical concepts like harmony, rhythm, and timbre. In essence, the computer managed much of the theoretical framework for producing music in terms of harmonic functions related to the selected tonal center, timbres, tempo, rhythms, chord voicings, dynamics and more, while allowing the user to assume the role of a composer/performer, easily causing musical events to sound with the freedom to dictate musical changes to the computer.

The resultant data suggested that participants did many of the same things a traditional composer would do while composing, including exploration of multiple diatonic tonal centers, conceptualization of some formal organization of pitch material, paying attention to themes and development in musical time, and experimentation with timbre and harmonic texture. The participants expressed that they gained some understanding of traditional musical vocabulary such as timbre, tempo, and harmony, by using the labeled controls within the software that changed these musical variables in real-time, allowing them to hear the results instantly. The self-directed composition activity did not involve any direct teacher instruction, yet yielded compositions that were both interesting to the students and harmonically sophisticated. Similar systems used with the guidance of a teacher could help facilitate discussion about music concepts as students encounter them in their own compositions. The data also suggested that students' perceptions about their school music program, in which these participants were not involved, changed for the positive and that they would want to be involved in the school music program if they knew that technology like this was commonly in use.

The Interactive Music Technology Curriculum Project (Manzo & Dammers, 2010), or IMTCP, was a study based on the similar concept of using interactive music systems designed in an accessible way in order to teach musical objectives. The project endeavored to teach musical concepts to non-traditional music students and students who were not involved in their school's music program through the use of software-based musical instruments. The participants were middle-school and high school students participating in a week-long summer camp who were presented with basic information about diatonic chord functions, chord progressions, harmonic ear-training, and harmonic direction tendencies, and activities that attempted to make use of this knowledge to compose original music. The primary musical instrument/interface used was a standard, unmodified ASCII computer keyboard that allowed the students to play diatonic chord functions by pressing the number keys 1 - 8.

A major aim of IMTCP was not only the impartation of musical skills in composition and performance, which included determining chord progressions in popular music by ear as well as discussions of harmonic function, form, and phrase structure, but also the use of simple accessible software systems written for specific pedagogical purposes to facilitate the instruction objectives established in our curriculum. These same teaching strategies and software systems could be used with trained musicians, as opposed to non-music students, who have a desire to increase their ability to determine chords and progressions in popular music. Such training could provide musicians with a self-directed approach to developing their skills using tools that are polyphonic, accessible, and allow for the performance of popular music.

Since note-reading was not a prerequisite for IMTCP, chord sheets were used that showed the diatonic chord functions for each section of the song as numbers placed above a beat pattern as shown in Figure 1. The first line of lyrics for each musical section was also provided as a reference while playing.

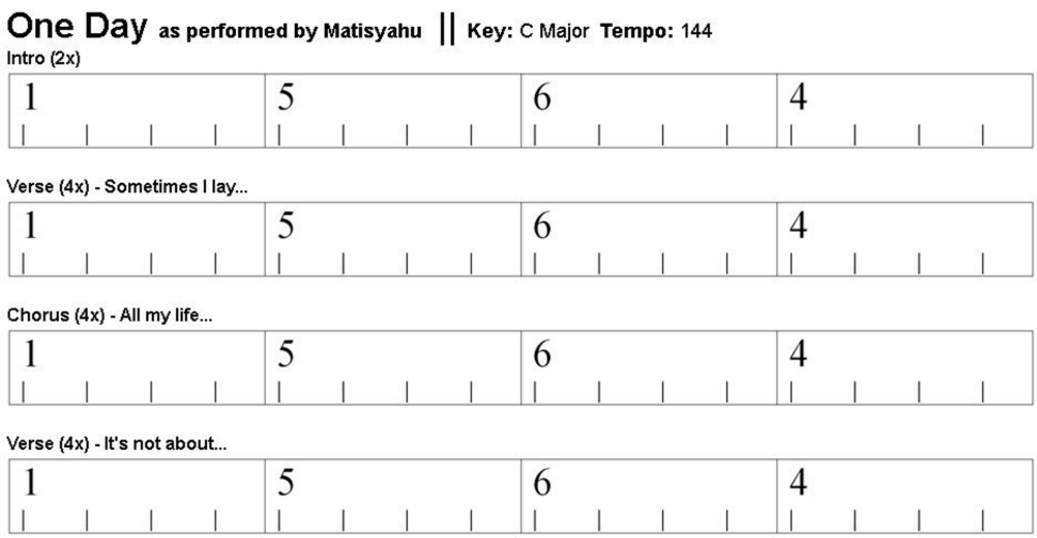

Figure 1. A chord sheet example in the IMTCP approach

These sheets provide the basic information necessary to play using the software used in the project: chord functions as numbers and a basic beat chart to play those chords. A participant would read the number “1” above the first beat, and press the corresponding number key on their computer keyboard (for example, the “1” key would yield a C major chord in the key of C major). The participant would then count the remaining beats in the measure and then play the next chord, “5”, by pressing the number key “5”. The software would trigger the appropriate chord function in the correct key for each song. Additional information such as key and tempo were provided for the facilitators.

In the present study, I continued to explore the objectives of IMTCP and sought to determine, to some degree, the extent a software instrument like the one described above can assist individuals determining chord-contexts within popular music the way that a traditional polyphonic instrument can. Additionally, I asked in what ways a software instrument compares to a traditional polyphonic instrument as a viable aid for assisting individuals in chord-determination activities.

The purpose of this study was to examine the effects of activities involving polyphonic interactive music systems on participants' ability to determine chords and progressions. I observed the ways that post-test scores changed after using the software, and noted the extent to which subjects were able to determine chord progressions better or worse with the aid of this interactive software system than with a traditional polyphonic instrument. An increased ability to do so could yield important implications for individuals looking to easily perform chords for pedagogical reasons, such as practicing the determination of chords and chord progressions, but who lack mastery performing a polyphonic; an interactive system could provide an alternative to traditional instruments. Additionally, open-source software systems, like the one developed and used for this study, can be modified to allow musical events to be triggered using any sort of control mechanism suitable to different individuals including sensors, buttons, and more, and can be expanded to function as a prototype for future research.

CHAPTER 2

METHODOLOGY

Participants

The participants (*N* = 67) were undergraduate music majors at a mid-size university in the northeast United States. Over 450 music majors at the university received an e-mail asking potential subjects to click a link to take the qualifying questionnaire (see *Qualifying Survey Questions* in Appendix D). If the students clicked the link and completed the initial online qualifying questionnaire survey, they were accepted to be part of the study and were given the option to receive extra credit in their music theory or aural skills courses as an incentive. In order to obtain baseline data about the participants, this qualifying questionnaire was administered to gather information about the participants' musical background and experience prior to college study as well as their current studies. The results of these data were used to ensure that two homogeneous groups bearing no statistically significant difference with regard to primary instrument type, number of semesters studying theory and ear-training, and familiarity with popular music were formed for this study.

Questions 2 and 3 of the qualifying questionnaire addressed the participants' current primary instrument as well as their familiarity with other instruments prior to their college experience. At the college level, lack of experience with monophonic or polyphonic instruments is negated as an issue due to courses such as wind methods, brass methods, and keyboard harmony which all music majors complete. In terms of forming two even groups, the responses to these two questions were used to flag each participant as either a primarily *monophonic* or *polyphonic* player. Both the experimental and control groups were similar in terms of the number of participants with backgrounds as either primarily monophonic players or primarily polyphonic players.

In this study, a *polyphonic* player was identified as anyone who, according to the response in Question 3, had at least three years of experience playing a polyphonic instrument *and* ranked their ability as at least *intermediate* for any of the following instrument groups:

- Piano or another keyboard instrument (like organ)
- Guitar or another polyphonic string instrument (like harp)
- Pitched polyphonic percussion instrument (like marimba or xylophone)
- Other polyphonic instrument

A *monophonic* player was identified as anyone who did not qualify as a *polyphonic* player and, additionally, had at least three years of experience playing a monophonic instrument *and* ranked their ability as at least *intermediate* for any of the following instrument groups:

- Primarily monophonic string instrument (like violin, viola, cello, and bass, electric bass)
- Voice
- Woodwind instrument (like flute, bassoon, or clarinet)
- Brass instrument (like trumpet, trombone, or tuba)
- Non-pitched or pitched monophonic percussion instrument (like drums, cymbals, or timpani)
- Other monophonic instrument

Participants who did not fit these criteria were placed in one of the two groups according to their current primary instrument type as per their response to Question 2. Part of this screening was to examine experiences as a polyphonic instrumentalist prior to college. If a participant considers himself a monophonic player while an undergraduate because he primarily sings or plays trumpet, but he has had a few years of experience playing a polyphonic instrument, he was still placed in the polyphonic category given his exposure to working with a polyphonic instrument even though he now plays a monophonic instrument.

After completing the qualifying questionnaire, participants were randomly placed into two groups labeled *control* and *experimental* with 34 participants in the experimental group and 33 in the control group. Given the qualifying questionnaire responses for each member in the groups, the responses of the qualifying questionnaire were analyzed to ensure that there was no statistical significance between the two groups (see Appendix E for Group Formation) using Fisher's Exact test. This analysis was based on responses given to this qualifying questionnaire with the exception of Question 1, which asked for the participant's name and e-mail address and Question 9 which asked "Have you ever listened to any popular or rock music such as the music played on the radio?". Anyone who answered *No* to Question 9 was excluded from the study as a general familiarity with popular music was viewed as necessary for performing analytical tasks about conceptualizing harmonic relationship as previously discussed with regard to studies of enculturation and perception.

While the study could have potentially focused on the rate of change between pre/post-test scores with regard to any of the criteria in these questions, this musical background experience information was used to ensure that both the control group and the experimental group were similar in terms of the background experiences of the participants with no statistical difference. In order to help organize the data, the e-mail address responses of each participant, as per Question 1, were included as the first question in the qualifying survey as well as the pre- and post-test surveys.

After completing the qualifying questionnaire, participants were sent, via email, a schedule of activities to complete (see *List of Activities and Schedule* in Appendix A) on their own over the next six weeks as well as the link to complete the pre-test survey. Participants were asked to devote 1.5 – 2 hours of their time each week to the activities assigned to them and not to exceed or fall behind this time allotment. Participants were asked to log their starting and ending times throughout the week. Both the experimental and control groups completed the same activities but with different music instruments as an aid: the control group used a traditional polyphonic instrument, while the experimental group used a software-based interactive music system.

A pilot study of 5 students was conducted after IRB approval was granted and prior to the formal study's commencement. The pilot study confirmed that the technical components of this study (i.e. software, online surveys) were operational and that all of the questions and activity instructions were worded clearly for participants to understand. As a result of the pilot, special notes were included in emails regarding certain browser compatibility with the online surveys.

Equipment

The activities for the experimental group used custom interactive software (see Software Design in Appendix B) called *E006* that allows individuals to perform chord functions 1 – 8 in a selected key by pressing the number keys 1 – 8 on a standard cross-platform ASCII computer keyboard to trigger the corresponding diatonic chord functions for that key. The computer keyboard, though not sensitive to pressure, plays a chord when the user presses the number key, sustains the chord while the key is held, and releases the chord when the user releases the key. Further options for customization of timbre, chords, chord voicings, and more are described in *Software Design* in Appendix B.

The software displays a window with the week's activities listed as well as videos demonstrating how to use the software as shown in Figure 2. Each week, the participants saw the activities for that week presented to them within the software. A typical activity consisted of playing a four-chord progression using the software while reading from chord sheets modeled after the IMTCP approach. The software included digital MP3 recordings of popular songs (See Activity Songs in Appendix C) so that the participant was able to play the chords to the song using the software controls (number keys) and reading the chord function numbers from the chord sheets provided while the actual recording played as an accompaniment. Participants were given the option to be provided with high quality Sennheiser HD 280 headphones in lieu of using built-in computer speakers if they did not have access to suitable speakers or headphone.

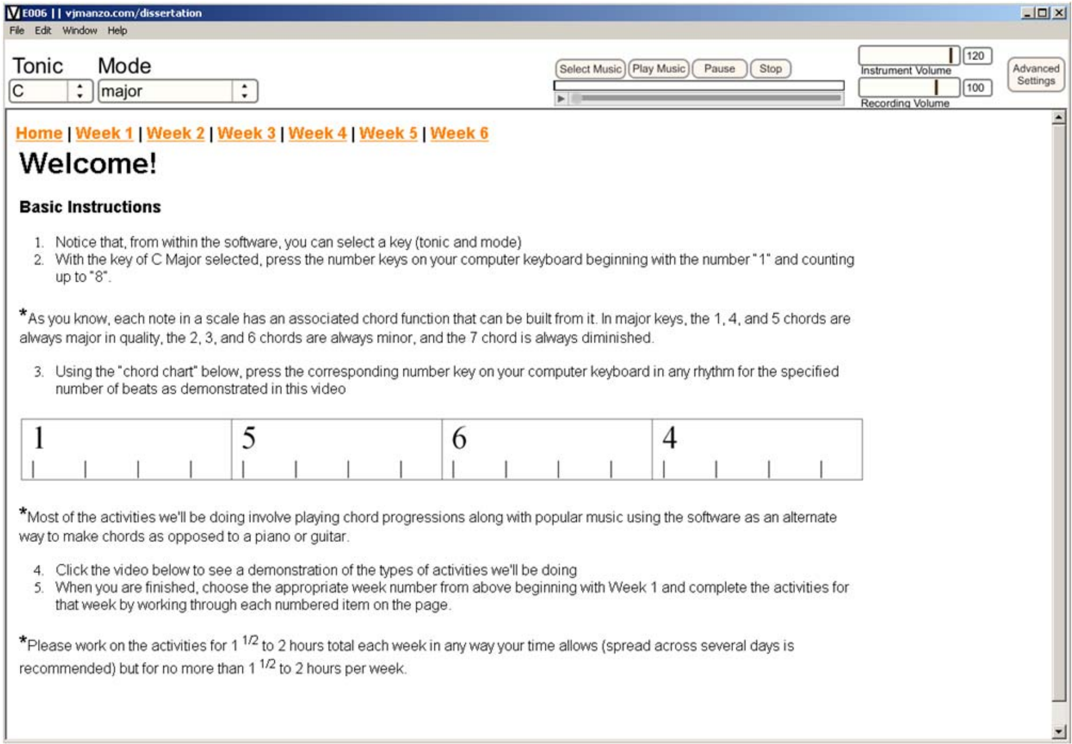

Figure 2. Software interface (PC version) displaying welcome screen and sample activity

The software automatically switched to the key of each selected song allowing participants to continue using the same seven controls (computer keys) despite varying key changes. Two songs used in this study contained modulations. Within the software, the “arrow up” key allows the performer to quickly modulate to the next key by pressing a single button. Pressing the “arrow down” key returns the performer to the original key.

Inversions can be played within the software by holding the SHIFT key down while pressing the number key. Additionally, pressing the "a" key can toggle the *auto-accompaniment* mode in which the tempo (in beats per minute) for each song being performed is applied to a playback style appropriate for that song. This allows the performer to focus even greater attention on the harmonic changes as the effort required to produce a rhythmic accompaniment is reduced. For some songs, the *auto-accompaniment* mode was enabled by default.

As previously mentioned, in experiments of the perceptual organization of tonal hierarchies (Deutsch, Moore, & Dolson, 1984; Krumhansel, Bharucha, & Kessler, 1982; Krumhansl & Kessler, 1982), researchers have employed timbre models that avoid perception complications associated with pitch height. However, given the nature of popular music and the skillset being observed, the timbre achieved through the employment of these techniques, whose only harmonics are multiples of the fundamental frequency at powers of two, do not resemble the timbres of traditional acoustic or electric instruments, let alone the instrumentation of a typical popular song recording. For this reason, timbres generated by the software have been selected that most closely resemble the instrumentation and style of the recordings being used.

Chord voicings and voiceleading within the software are fixed to a single preset voicing though the user has the option to manually change the chord voicings if desired. In a “real life” situation where someone was listening to a piece of music with the purpose of determining the chords, they would likely prioritize determining the correct chord and quality first and foremost. Determining the exact chord voicing used would likely be an afterthought and deals more with performance issues than analysis ones.

Activities - Experimental Group

For six weeks, the participants in the experimental group completed the activities presented from within the *E006* software. A typical activity consisted of playing a four chord progression using the software, and then playing that progression or similar ones using chord sheets, modeled after the IMTCP approach. The software included digital MP3 recordings of popular songs (See Activity Songs in Appendix C) so that the participant was able to play the chords to the song using the software controls (number keys) and reading the chord function numbers from the chord sheets provided while as the actual recording was playing as an accompaniment. The songs used were popular radio songs from the 1960s to 2011 in a variety of styles including rock, pop, R&B, and rap.

In additional analysis activities, participants were asked to listen to a song and, after being given the key and a blank chord sheet with the rhythmic profile, were asked to write down the chord progression using only the software (the control group used an acoustic instrument) as an aid. Additionally, "Name That Progression" activities were introduced where an audio excerpt from a song was played and the participant was asked to name the four-bar chord progression being used by ear without the aid of any instrument. This activity was similar to the one used in the pre/post-tests (See the complete List of Activities and Schedule in Appendix A).

Activities - Control Group

The control group participants were asked to complete the same activities as the experimental group without the aid of the software instrument using, instead, any polyphonic acoustic instrument of their choosing such as a piano or guitar. After groups were formed, participants in the control group received a link to the website *http://vjmanzo.com/dissertation/_c_group/* which hosted the similar activities used by the experimental group. Instead of having the option to press a number key on their computer keyboard to play a diatonic chord function, the instructions in these activities asked participants to play the chord progressions using an acoustic instrument such as piano or guitar. As with the experimental group activities, identical chord sheets and MP3s were provided to the participants for the purpose of performing songs with recorded accompaniment. Links to download the audio and print the sheet music were made available within the software so that participants did not have to be tethered to a computer in order to complete the activities. Control group participants were also given the option to be provided with high quality headphones in lieu of using built-in computer speakers.

Compositions

Within the activities for both groups, the chord progressions were displayed using Arabic numerals as opposed to Roman numerals for two reasons. First, number keys on the standard ASCII computer keyboard are Arabic numerals. Second, I considered it easier to discuss the harmonic functions of chords for all songs as being anchored around a major tonality, especially for somewhat ambiguous progressions whose tonality can be thought of in a major or natural minor context. All progressions were therefore presented to participants as being anchored around a major tonal center. For example, the progression emin C G D was thought of as a vi IV I V in the key of G major instead of a i VI III bVII in the key of emin. I viewed this as being easier to comprehend for those unfamiliar with the notion that such a progression can be thought of in multiple tonal contexts, on the major side or the minor side. Those already accustomed to the notion of considering harmonic functions in multiple contexts should find little difficulty with thinking in one tonality as opposed to two.

The simple phrases, often four or eight bars, used in these popular songs, arguably, lack context to distinguish between proclivities toward a minor tonality as opposed to a major one. Assistance in establishing a tonal center toward minor as opposed to major is not clearly implied by melodic factors given the lack of altered scale degrees (natural minor can be thought of as mode six of the major scale) as it is when the harmonic or melodic forms of the minor scale are used. In the aforementioned progression, given the use of the modal subtonic chord (bVII), commonly used in popular music as opposed to the leading tone seventh chord (vii^0), and the limited number of chords in the phrase pointed to one tonal center more than another, the progression will be thought of in the major key.

One goal of these activities was to develop an understanding of, for example, the function of the minor chord built at scale degree six in the context of a major key, not simply to distinguish between major, minor, and diminished chord qualities. For this reason, it serves us to think of all chords built on major scale degree six as “chord function 6” as opposed to the potential way it could be thought of as “chord function 1” in a minor modality *or* as “chord function 6” in a major modality. Uniformity of conceptualizing chord functions in a major key resolves this ambiguity and allows us to use the Arabic numerals instead of Roman numerals since it is then understood that a 1 5 6 4 progression is equivalent to a I V vi IV progression since we are in a major key and all 1, 4, and 5 chords are major in quality, all 2, 3, and 6 chords are minor and quality, and 7 chords are diminished in quality. No repertoire was used that involves non-diatonic chord tones or functions that include the dominant (V) chord in minor keys, secondary functions (V/V, etc.), borrowed chords, or other functions.

Some song activities presented in the first week were not in any strict progression, but were presented as introductory exercise songs to help familiarize the participant with the activities. As weeks progressed, different 4-bar progressions were used and combinations of progressions were introduced using only diatonic chord functions.

Although the software can be used to play chords with added notes beyond the triad, only triads voiced with doublings in a style typical of popular music were used.

In the majority of activities where the participant was asked to play along with an MP3 audio recording, songs requiring only root position chords were primarily used. The use of songs with inversions was limited, but was noted in the chord sheets provided to the participant. In cases where inversions were used, they occurred after the first week of activities and the inverted chords were first inversion V chords. The vii^0 chord did not appear in any of the songs selected for use in this study; it seems more common, in popular music, to use the V chord in first inversion as a substitute for the leading tone chord since they share the same bass note. The bVII (e.g. Bb major in the key of C Major) chord is used frequently in popular music, but was not used in this study since no chromatic chord functions were used.

Test instruments

This study employed a pre-test post-test design using online surveys as the testing instrument. Data were collected via online surveys and the responses by both groups to the pre-test and post-tests were compared. The rate of increase or decrease of the percentages was observed for all self-assessment questions in the pre/post-tests and analyzed using Fisher's Exact test. The rate of increase or decrease of the percentages for each of the five progression pairs was being observed for these listening questions in the pre/post-tests and analyzed using a T-test. Results follow in the *Results* section and full data are provided in Appendix E.

Pre-test

There was one single pre-test survey given to both the control and experimental groups (see *List of Pre/Post Questions* in Appendix D). The first four questions were self-assessment questions in which participants were asked to choose a response on a Likert-type scale. These questions asked participants to rate their current skills for activities related to aural skills and theory comprehension.

For both the pre-test and post-test surveys, there were 10 total listening questions, Questions 6 – 15, in which participants were asked to listen to an excerpt of a popular song that prominently featured the performance of a diatonic four chord pattern and select the appropriate chord progression used as displayed in numbers (e.g. 1 5 6 4) from a dropdown menu. For these 10 questions, five progressions appear twice as the correct response (see list of progressions as noted in Appendix C). The responses with matching progressions were paired for analysis; for example the correct answer to Questions 9 and 11 on the pre-test was the 1 5 6 4 progression, pair 4, as shown in Table 1 below. Table 1 also shows how the correct responses from the pre-test relate to the correct responses from the post-test.

Table 1.
Pre-test correct responses as they relate to post-test responses

Pre-test Correct Answers Questions 6 - 15	Post-test Correct Answers Questions 6 – 15
Question 6 – 1 4 6 5	Question 10 – 1 4 6 5
Question 7 – 6 4 1 5	Question 7 – 6 4 1 5
Question 8 – 1 6 5 4	Question 11 – 1 6 5 4
Question 9 – 1 5 6 4	Question 6 – 1 5 6 4
Question 10 – 1 4 6 5	Question 12 – 1 4 6 5
Question 11 – 1 5 6 4	Question 9 – 1 5 6 4
Question 12 – 6 4 1 5	Question 13 – 6 4 1 5
Question 13 – 1 6 4 5	Question 8 – 1 6 4 5
Question 14 – 1 6 5 4	Question 15 – 1 6 5 4
Question 15 – 1 6 4 5	Question 14 – 1 6 4 5
Response grouping pairs (for analysis) Pair 1 - 1 4 6 5, Pair 2 - 6 4 1 5, Pair 3 - 1 6 5 4, Pair 4 - 1 5 6 4, Pair 5 - 1 6 4 5	

The pre-test iterations of these questions were the same as the post-test questions with the exception that different audio examples were used on the post-test and that the correct responses to these questions were reordered. An attempt was made to match pre-test songs with post-test songs in terms of harmonic rhythm, tempo, and style. Beats per minute and key information for each song is provided in Appendix C. Some songs appearing on the pre-test were reused for the weekly activities, but no post-test songs were used in the weekly activities.

Post-test

At the completion of the sixth week of activities, participants were emailed the post-test questionnaire (see *Post-test Survey Questions* in Appendix D). There were two post-test surveys in total: one for each of the two groups. The questions on each of these surveys contained the same self-assessment questions asked on the pre-test and the same number of “quiz-style” listening questions, Questions 6 – 15, which, as noted earlier, used different audio examples and placed the correct responses in a different order than the pre-test survey.

Additional self-assessment questions, Questions 16 – 19, noted in Appendix E as “extension” questions, were included on the post-test that did not relate to the pre-test in any way; the responses by both groups to these questions were compared. Both the control and experimental group versions of these “extension” questions asked the participants to rate their experience completing the activities during the six-week period. Both versions of the extension questions were identical to each other with the exception of some modified wording in which the control group survey referenced the use of *a piano or other polyphonic instrument* while the experimental group referenced the use of *the software instrument*.

This qualifying questionnaire posed questions about the participants’ experiences with regard to determining chords and chord progressions in popular music, some self-assessment as to their ability to determine chords and chord progressions in popular music, and questions. Participants were given the option to be provided with Sennheiser HD 280 Pro headphones if they did not have them in lieu of using built-in computer speakers.

There were 10 listening questions of this nature for both the pretest and posttest (20 total) with two questions assessing the following five chord progressions: 1 5 6 4, 6 4

1 5, 1 6 5 4, 1 4 6 5, and 1 6 4 5. Using the same 10 songs on both tests would have allowed an opportunity for participants to study the excerpts and, thus, have an advantage during the latter test. For this reason, audio excerpts on both tests were similar to some degree with regard to tempo, meter, and harmonic rhythm. While the excerpts used may have been familiar to some participants, this would presumably have been more likely in terms of the melody than the harmony; that is, elements in the foreground as opposed to the background.

Excerpts in the pre/post tests were taken from a formal section of the song such as the chorus or verse (see *Pre-test/Post-test Songs* in Appendix C). No excerpts contained secondary functions or other chromaticisms though almost all songs contained diatonic non-chord tones such as suspensions and added diatonic tones beyond the triadic chord tones as this is common in homophonic music.

Excerpts of popular songs that have received national radio airplay were used in this study as opposed to newly created parodies that demonstrate the chord progressions to be identified. Using actual excerpts provided a “real world” context for the tasks as opposed to manufacturing examples that more clearly delineate or emphasize a chord progression. This would have likely introduced bias into the assessment and would have skewed the activities which also used actual popular music.

CHAPTER 3

RESULTS

Self-assessment

The four self-assessment questions from the pre-test also appear on the post-test. The responses to these questions were compared within both groups using Fisher's Exact test. While both groups may have had some improvement in their abilities from the pre-test to the post-test, there was no statistical difference found between the perceived rate of improvement responses in either the control or experimental group (see Appendix E for complete data analysis).

For self-assessment question 1, "Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio", the results shown in Figure 3 show no statistically significant differences (Experimental $p = 0.3341$; Control $p = 0.972$). The pie chart below shows percentage of responses for participants from each group for both the pre/post-test.

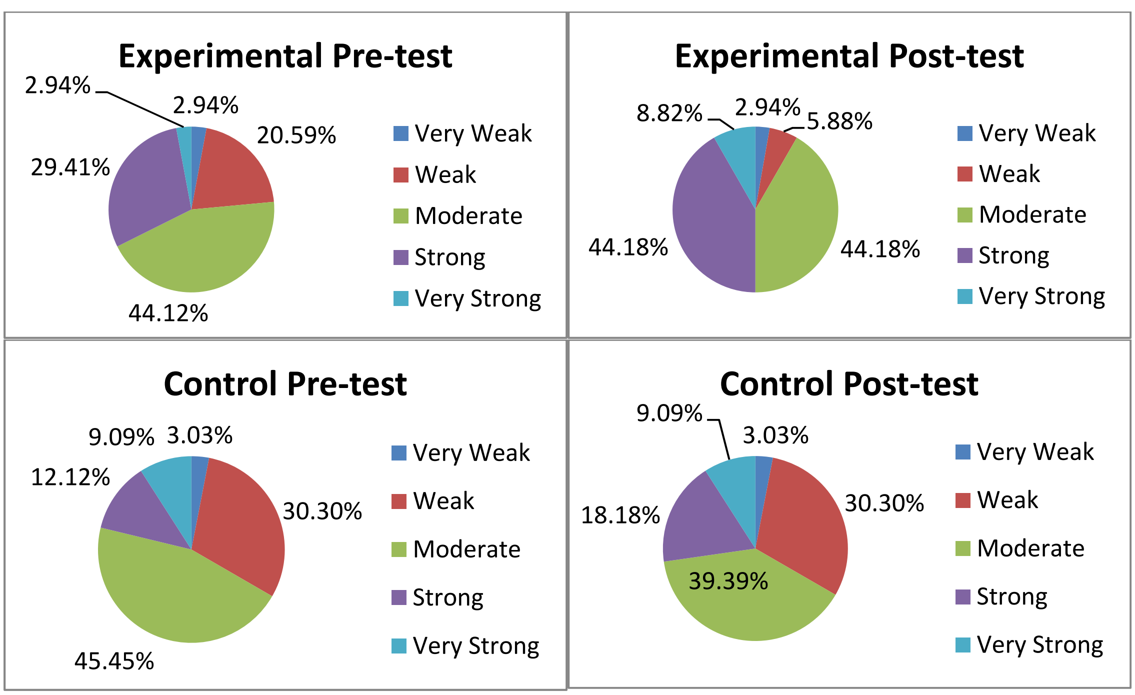

Figure 3. Self-assessment question 1 response: Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio

For self-assessment question 2, "Please rate your current overall skills in music theory", the results shown in Figure 4 show no statistically significant differences (Experiment $p = 0.89$; Control $p = 0.967$).

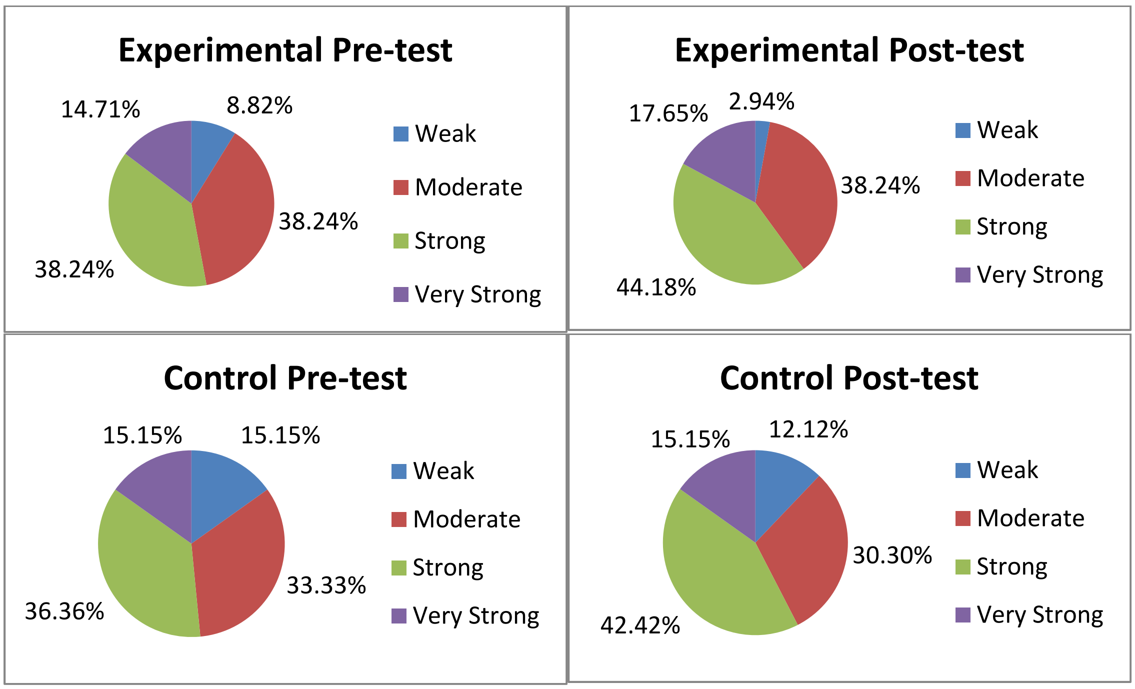

Figure 4. Self-assessment question 2 response: Please rate your current overall skills in music theory

For self-assessment question 3, "Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live", the results shown in Figure 5 show no statistically significant differences (Experimental $p = 0.535$; Control $p = 1.00$).

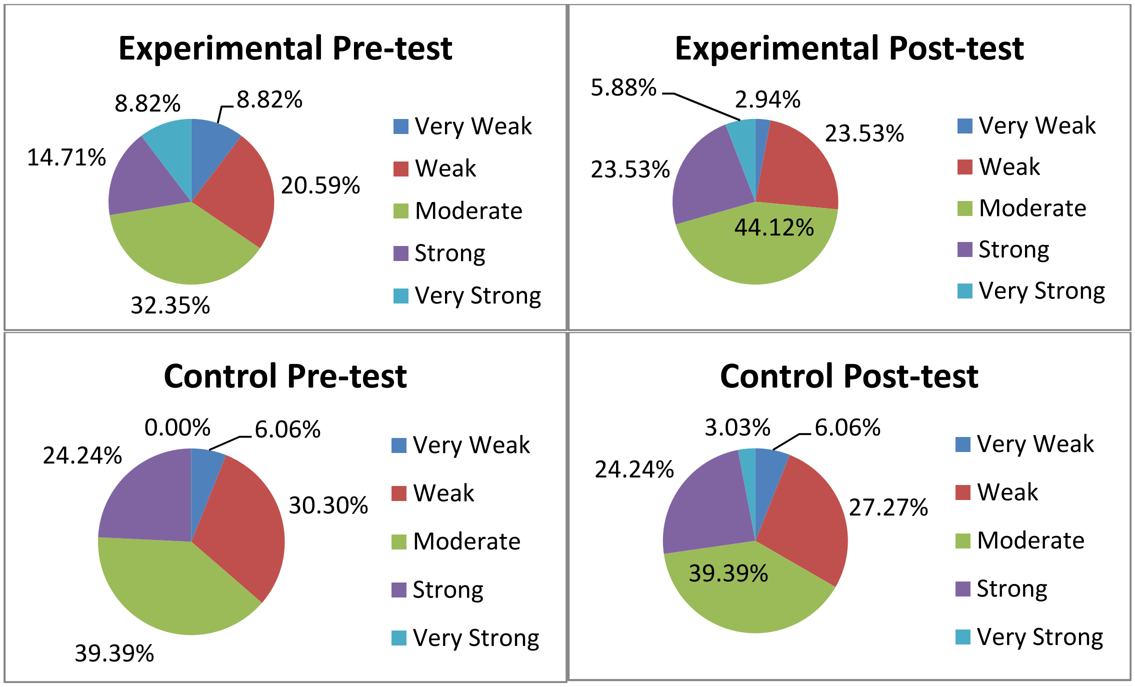

Figure 5. Self-assessment question 3 response: Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live

For self-assessment question 4, “Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live”, the results shown in Figure 6 show no statistically significant differences (Experimental $p = 0.501$; Control $p = 0.426$).

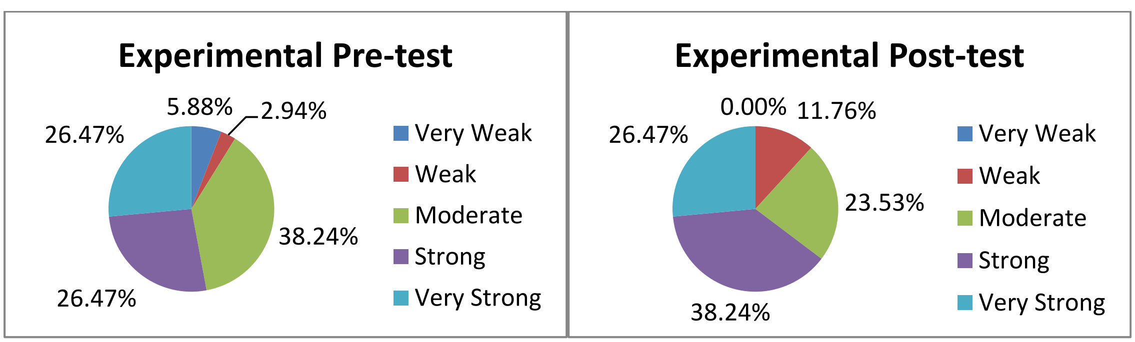

Figure 6. Self-assessment question 4 response: Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper

Figure 6, continued

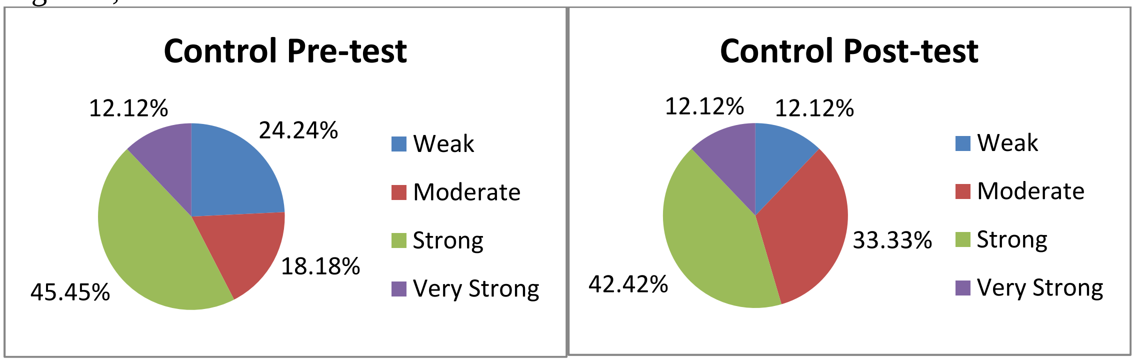

Figure 6. Self-assessment question 4 response: Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper

Listening questions

For both the pre-test and post-test surveys, there were ten total listening questions, Questions 6 – 15, in which five progressions appear twice as the correct response (see progressions noted in Appendix C).

In the experimental group, there were significant improvements for Pair 2, the 6 4 1 5, and Pair 4, the 1 5 6 4 progression. The correct responses to the questions in which the 6 4 1 5 progression was the correct answer improved 19% from pre-test to post-test as shown below in Table 2. The correct responses to the questions in which the 1 5 6 4 progression was the correct answer improved 15% from pre-test to post-test as shown below in Table 3. Improvement for the remaining question pairs answered by the experimental group had no statistically significant differences and overall among all 10 questions collectively, there was no significant improvement. There was no statistically significant improvement in the scores for any of the listening questions answered by the control group in pairs or collectively.

Table 2
Progression pair 2 (6 4 1 5) 19% improvement in experimental group

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	0.1912	0.3260	0.0559	-0.5000	1.0000
Mean	95%	CL Mean	Std Dev	95% CL	Std Dev
0.1912	0.0774	0.3049	0.3260	0.2630	0.4291
DF		t Value		Pr > |t|	
33		3.42		0.0017	

Table 3
Progression pair 4 (1 5 6 4) 15% improvement in experimental group

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	0.1471	0.3595	0.0617	-0.5000	0.5000
Mean	95%	CL Mean	Std Dev	95% CL	Std Dev
0.1471	0.0216	0.2725	0.3595	0.2900	0.4732
DF		t Value		Pr > |t|	
33		2.39		0.0230	

Post-test extension questions

Both post-test surveys had an additional four questions compared to the Pre-test survey, Questions 16 – 19. These four questions were identical to each other on both versions of the Post-test with the exception of some of the wording which referenced the use of a software instrument over a traditional instrument. The statistical test used is, in this case, testing whether there is an association between the groups and the extent of perceived improvement. The responses to Questions 16 – 18 from both post-test surveys were compared to each other and two of the three questions indicate that the control and experimental group have statistically significant differences in the perception of their improvement.

For extension question 1, “To what extent do you feel that your ability to determine chord progressions improved”, the results shown in Figure 7 show a statistically significant difference between both sets of scores ($p = 0.0346$) with mixed extents of improvement in both groups. For example, 58.82% participants in the experimental group reported a moderate extent of improvement while 30.30% of control group participants reported the same.

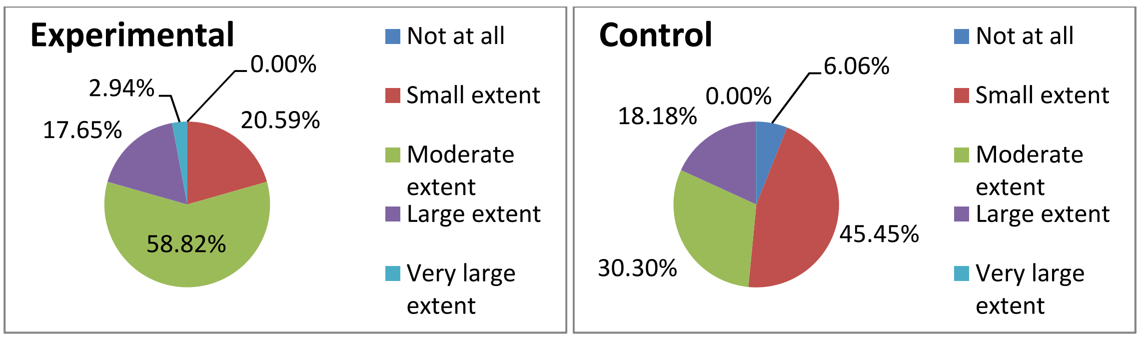

Figure 7. Extension question 1 response: To what extent do you feel that your ability to determine chord progressions improved?

For extension question 2, “To what extent do you feel that using the software instrument / an accompanying instrument (like piano) helped you determine chord progressions”, the results shown in Figure 8 show no statistical difference ($p = 0.5157$).

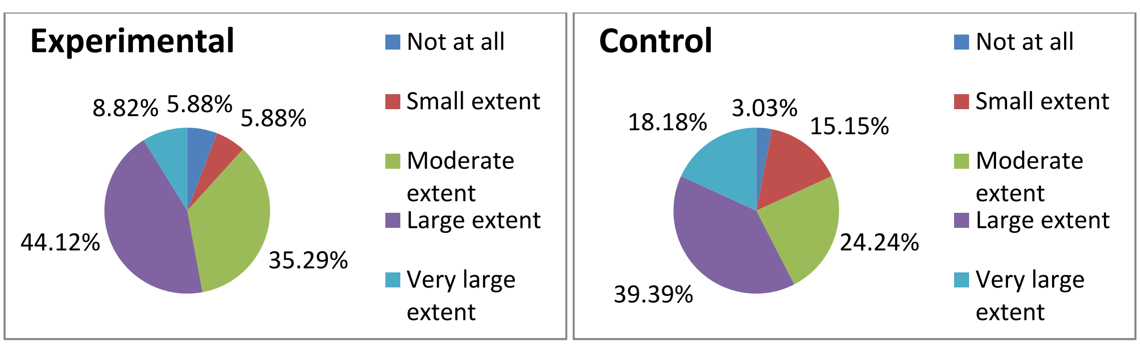

Figure 8. Extension question 2 response: To what extent do you feel that using the software instrument / an accompanying instrument (like piano) helped you determine chord progressions?

For extension question 3, “To what extent do you feel you would have been able to complete the same activities (determining chord progressions) to the same degree of success without the aid of the software / an accompanying instrument”, the results shown in Figure 9 show a statistically significant difference (p = 0.0249) with mixed extents of improvement in both groups. For example, a 21.21% of control group participants reported “Not at all” while 0% of experimental group participants reported the same.

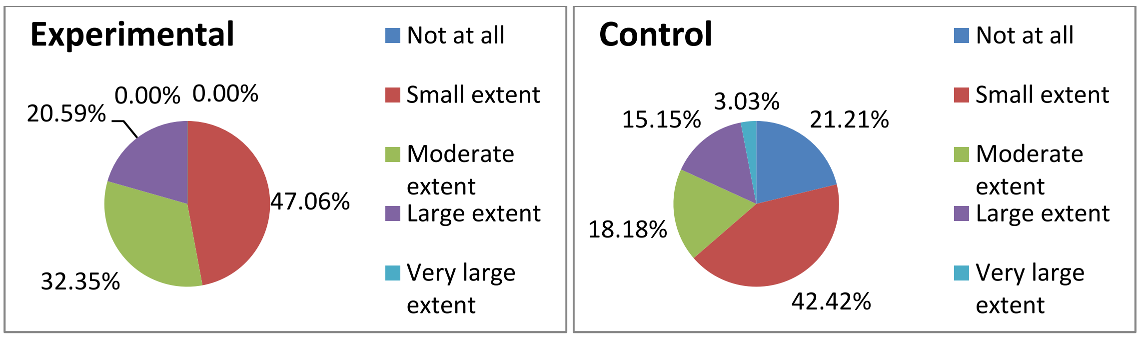

Figure 9. Extension question 3 response: To what extent do you feel you would have been able to complete the same activities (determining chord progressions) to the same degree of success without the aid of the software / an accompanying instrument?

Question 19 was an open response question that need not be compared between the two groups (see Appendix E for responses). This question was optional and comments were mixed with some noting the technical ease or difficulties they encountered operating the software such as this response:

> I feel like the software didn't offer strategies for determining chord progressions and instead had the user repetitiously experiment with chord progressions hoping that the repetition would cause the progressions to stick in the users memory. I consistently felt as if I was guessing half the time though I will say I feel as if my ability to identify chord progressions in root position has improved. First inversion chords still confuse me because I rely on the bass line to determine chords and I often second guess my answers when there is a first inversion chord present since I still feel as if I am guessing. I would have liked more than 2 hours a week to work on these.

Others mentioned that they noticed an improvement in their abilities such as this comment from an experimental group participant: “So cool and greatly beneficial! I learned chords extremely fast because of this software. I feel it helped me more then me actually sitting in a classroom and learning this from a teacher."

Others noted the pedagogical implications of the activities: "I feel that this method would convey basic music theory much easier to the lay listener. Seems like it would be very useful for all scholastic levels. "

CHAPTER 4

DISCUSSION

The purpose of this study was to examine the effects of activities involving polyphonic interactive music systems on participants' ability to determine chords and progressions. The effects were observed using a pre-test/post-test design and the results were mixed.

Regarding the pre/post-test self-assessment questions, while both groups generally reported a perceived improvement in their abilities from the pre-test to the post-test, no statistical difference was found between the perceived rate of improvement responses for the control versus the experimental group. This is noteworthy because, although the questions themselves are subjective to the participant, the data suggests that there was no difference between the two groups in the perceived amount of improvement over the course of six weeks. An argument could be made that the software instrument was as viable as the traditional polyphonic instrument in its role as an aid for the activities as perceived by the participants.

Of importance to this study is the understanding that the self-assessment responses are the subjective opinions from the participants themselves. It is valuable to understand these points of view and compare them to the empirical results from the listening section in which their skills are assessed.

In designing the listening assessment portion of the surveys, I expected that the post-test scores for the experimental group would follow one of three conclusions: 1) the post-test scores would improve, 2) stay the same, or, 3) get worse. It was my assumption that the control group scores would improve as one would normally expect given these types of activities. Determining the degree of improvement, if any, was also important to me as I hoped that the scores of the experimental group would improve at least as much as the scores of the control group. This might suggest that a software-based instrument could be as viable in aiding in this activity as a traditional polyphonic instrument, bearing with it all of the benefits of a software-based instrument which include accessibility, portability, and other aspects described previously.

As the data show, results from the post-test for both groups primarily improved and there was no significant difference between the improvements within both groups overall. Additionally, the data suggest that the ability to recognize two of the progressions which, in my opinion, appear to occur more commonly in popular music, the vi IV I V and the I V vi IV, improved significantly in the experimental group but not in the control group.

Among the comments to Question 19 of the post-test survey, one of the ones I found to be most insightful came from a control group member:

> Because I'm not all that good at piano for a while I spent the time trying the [sic] get the chords (so basically I spent the time practicing technical things) which left me less time to really think about the sounds. I can hear chord changes now which is a HUGE improvement for me. I'd like to continue the exercises to see if I can better identify the chords with more practice. Right now I can hear the chords and the changes but I have trouble telling which chord it is.

This comment reinforces one of the core focuses of the study. Had this individual been able to use an instrument that was suited for the task and accessible, more attention could be placed on the cognitive operation and not on the physical mechanics of performance. It is this separation of physical actions from cognitive processes that seems to be addressed, at least to some degree, by the creation of software-based instruments.

Future research is needed to explore musical aspects not addressed in this study. There are obviously many more common chord progressions used in popular music that were not introduced or assessed. Similar activities using these progressions could yield conflicting or confirming results. Additionally, activities that address different non-diatonic harmony, modes, mode mixture, and chord inversions can be targeted with the same approach in the attempt to improve recognition. I am also interested in replicating this study with non-musicians. With the understanding that perceiving harmony on different levels is a learned skill as suggested by Serafine (1983), perhaps similar systems and activities can help musicians with the acquisition of this skill.

The notion of attempting to separate the physical actions involved in music making from the cognitive processes is worthy of more investigation. As technology continues to develop, the instrument as a physical “layer” between a cognitive process and the production of a related musical event may become more transparent. This layer will likely dissipate as the design of control mechanisms become more user-centered in terms of accessibility related to specific musical tasks as opposed to the traditional design of instruments being acoustically-centered; instrument design in terms of what will produce the best timbre and the loudest volume as opposed to physical gesture efficiency and accessibility.

I am reminded of an anecdote from my years as an undergraduate music education major when a fellow student was once advocating the role of turntables as performance instruments for students in K-12 music classrooms. I agreed that the idea was novel and interesting but held that turntables seemed to be inherently limited to only playing sonic materials derived from records with limited control over the ways that portions of the record could be manipulated. With finite ways, at that time, to produce raw musical materials, turntables seemed more like control mechanisms than musical instruments. Others in the class discouraged the use of turntables for different reasons, drawing a comparison to the many skills necessary to play the violin versus the skills necessary to spin and scratch a record thus raising an important question for me: does the ease of playability play a role in valuing the legitimacy of instruments?

Among other previously discussed issues of instrument design and accessibility, an electronic instrument can be much easier to play than a traditional instrument like the violin simply because the capacity for advancements in electronic instruments is far greater than that of traditional instruments. The open-architecture of technology-based instruments, particularly those that are primarily software-based with interchangeable hardware controls, can allow an individual to customize an instrument for any performer, performance environment, or performance application.

Even hybrid electro-acoustic instruments like the electric guitar have a greater capacity for advancements than traditional acoustic instruments simply because of their inclusion of technology. Changes to nearly every musical variable such as pitch, timbre, and dynamics can be expanded and enhanced to a greater degree than traditional acoustic instruments that possess no electronic technology.

Musical concepts are often introduced to beginning music students using instruments of simple design such as in the Orff approach. These Orff instruments are easy to play, in principle, much easier than a violin, but limited in terms of the number of musical variables one can control compared to other acoustic instruments such as the violin. However, as a result of electronic technology, accessibility in terms of ease of instrument playability does not need to be a determining factor in musical sophistication any longer.

If the design of a musical instrument, electronic or acoustic, can allow musical variables to be produced, manipulated, and controlled to some acceptable degree of sophistication, and the instruments potential to operate in this way is understood to some degree, then the control interface itself by which the instrument is operated is the primary remaining factor in evaluating the accessibility of the instrument and its potential for performance. Comparing the limits of traditional instruments to electronic ones, then, only reflects the shortcomings of traditional instrument design, not electronic instrument design which is seemingly without boundaries. Arguably, the more important comparison that can be made is with regard to the control mechanism of an instrument and those properties of the instrument that make performing certain musical operations more or less idiomatic than others.

Electronic musical instruments are used in abundance. The notion of triggering chords with a computer keyboard is no different than triggering a piano sample with a synthesizer. One aspect that is different, as noted earlier, is the control interface itself. It is common for musicians to visualize “shapes” on their instrument such as “chord shapes” or “scale pattern shapes”. Future research in the constructed mental shapes of musicians using electronic instruments while performing, particular those instruments with uncommon interface designs, is necessary. While these mental shapes are created by performers, they, perhaps, are more closely related to instrument design and the types of gestures that the instrument’s design dictates as being more or less idiomatic. Unlike a traditional instrument, the controls of an electronic instrument, like the one used in this study, can be configured in a variety of ways. This could potentially allow controls to emulate the positioning of other acoustic instruments similar to drum pads or guitar-type video game controllers, or, controls can be configured in unique patterns. Electronic instrument manufactures would then have the advantage of providing instruments in which performers can visualize shapes in a way similar to traditional instruments or in a completely unique way. The advantage of a software-based system is that the software does not need to know what the control mechanism is; it simply looks for some numbers to represent the state of a control parameter. The same software instrument can thus be mapped to numerous control mechanisms.

The six-week experiment window can be expanded to longer windows of study. It would also be useful to conduct similar experiments with non-musicians as the use of software instruments seem to have a growing interest with novice musicians and those who may have learned music informally.

As of the time of publication in 2012, links to this research have been made available at *http://www.vjmanzo.com/dissertation*. The software standalone apps are available for Mac and Windows, or as a Max for Live instrument from this site. The software is open-source and freely available for modification according the Creative Commons License Agreement. Additionally, the activities are available for preview online as well as example versions of the surveys used in this study. Links have also been provided to obtain all audio files used in the pre-test, post-test, and activities in a single collection through iTunes. The website *clicheprogressions.com* (Manzo, 2005), a free web resource that allows users to list and view popular songs that share common chord progressions by category and artist, has also been updated to include all examples used in this study.

The viability of software systems like *E006* could have considerable implications for music education. If software systems can be implemented in pedagogical situations where there is little difference in terms of their role in serving an instructional, compositional, or performance objective compared to traditional instruments, considerations like body-type, physical ability, accessibility, and so on, can, instead, become determinant factors regarding instrument use and design. Instrument creation can be designed to fit specific activities. These were possibilities that simply did not exist only a few short years ago, yet are now available through advances in technology.

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Appendix A - Activities

List of Activities and Schedule

The following appears in a window within the software interface: Activities for the control group are identical with the exception that references to the software are omitted and replaced with instructions to complete the activities with a traditional polyphonic instrument. Links and instructions to download the audio and print the chord sheets are provided these participants as well, so that they do not have to use a computer while completing activities.

Basic Instructions

Notice that, from within the software, you can select a key (tonic and mode). By default, the key of C Major selected

Press the number keys on your computer keyboard beginning with the number "1" and counting up to "8".

Hold the SHIFT key while pressing a number key to play a chord in 1st inversion.

As you know, each note in a scale has an associated chord function that can be built from it. In major keys, the 1, 4, and 5 chords are always major in quality, the 2, 3, and 6 chords are always minor, and the 7 chord is always diminished.

Using the "chord chart" below, press the corresponding number key on your computer keyboard in any rhythm for the specified number of beats as demonstrated in this video

1	5	6	4
| | | |	| | | |	| | | |	| | | |

Figure 10. Chord progression to be performed

Most of the activities we'll be doing involve playing chord progressions along with popular music using the software as an alternate way to play chords as opposed to a piano or guitar.

Click the video below to see a demonstration of the types of activities we'll be doing

Click a song title. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Listen to the song once without playing along by clicking the play button:

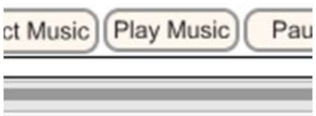

Figure 11. Screenshot of play button within the software

Practice playing the song without the music track. The chord sheet provides the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

When you are finished, choose the appropriate week number from above beginning with Week 1 and complete the activities for that week by working through each numbered item on the page.

Please work on weekly activities for a total of 1 1/2 to 2 hours each week in any way your schedule allows (spreading time across several days is recommended) but for no more or less than 1 $^{1/2}$ to 2 hours per week.

Week 1

Activity

Using the number keys, play a 1, 5, 6, 4 chord progression in the key of C Major for 24 bars noting, once again, that, in major keys, the 1, 4, and 5 chords are always major in quality while the 6 chord is always minor.

Figure 12. Chord progression to be performed

The songs below feature the "1 5 6 4" progression

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

Other Songs to Play: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Week 2

Activity

Using the number keys, play a 6, 4, 1, 5 chord progression in the key of C Major for 24 bars noting, once again, that, in major keys, the 1, 4, and 5 chords are always major in quality while the 6 chord is always minor.

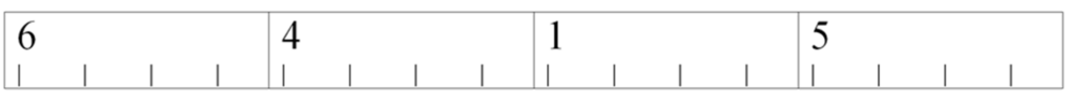

Figure 13. Chord progression to be performed

The songs below feature the "6 4 1 5" progression

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

Other Songs to Play: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Week 3

Activity

Using the number keys, play a 1, 4, 6, 5 chord progression noting, once again, that, in major keys, the 1, 4, and 5 chords are always major in quality while the 2 and 6 chords are always minor.

Figure 14. Chord progression to be performed

The songs below feature the "1 4 6 5" progression

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

NEW Assignment: Click the songs below and play along. Though the key and rhythmic profile are provided, chords and progressions for these songs are not, so use your ears and the software (**please** don't use any other instrument to help you) as an aid to help you determine the chord progression. **Tip:** If the progression doesn't sound familiar as a whole, it may be helpful to pick out the movement of the bass line first for each chord. Then, determine if each chord is major or minor in quality as this will help you reduce the number of "trial and error" choices. You can then use the software to "trial and error"-match chords for each measure of the progression.

As you determine the chords in a song, write down or type out the chords/progressions to create a chord sheet similar to those we’ve been working with.

After you have played along with the song several times and think you have the correct chords, click "show chord sheet" to reveal the chord progressions. Compare the sheet to the one you made.

Songs to Analyze: (See Activity Songs in Appendix C)

Other Songs to Play: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Week 4

Activity

Using the number keys, play a 1, 6, 5, 4 chord progression noting, once again, that, in major keys, the 1, 4, and 5 chords are always major in quality while the 2 and 6 chords are always minor.

Figure 15. Chord progression to be performed

The songs below feature the "1 6 5 4" progression

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

Assignment: Click the songs below and play along. Though the key and rhythmic profile are provided, chords and progressions for these songs are not, so use your ears and the software (**please** don't use any other instrument to help you) as an aid to help you determine the chord progression. **Tip:** If the progression doesn't sound familiar as a whole, it may be helpful to pick out the movement of the bass line first for each chord. Then, determine if each chord is major or minor in quality as this will help you reduce the number of "trial and error" choices. You can then use the software to "trial and error"-match chords for each measure of the progression.

As you determine the chords in a song, write down or type out the chords/progressions to create a chord sheet similar to those we’ve been working with.

After you have played along with the song several times and think you have the correct chords, click "show chord sheet" to reveal the chord progressions. Compare the sheet to the one you made.

Songs to Analyze: (See Activity Songs in Appendix C)

NEW Assignment: Listen to this audio excerpt below and, without using an instrument or other aid--just your ears--write down the chord progression.

Name that Progression: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Week 5

Activity

Using the number keys, play a 1, 6, 4, 5 chord progression noting, once again, that, in major keys, the 1, 4, and 5 chords are always major in quality while the 2 and 6 chords are always minor.

Figure 16. Chord progression to be performed

The songs below feature the "1 6 4 5" progression

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

Assignment: Click the songs below and play along. Though the key and rhythmic profile are provided, chords and progressions for these songs are not, so use your ears and the software (**please** don't use any other instrument to help you) as an aid to help you determine the chord progression. **Tip:** If the progression doesn't sound familiar as a whole, it may be helpful to pick out the movement of the bass line first for each chord. Then, determine if each chord is major or minor in quality as this will help you reduce the number of "trial and error" choices. You can then use the software to "trial and error"-match chords for each measure of the progression.

As you determine the chords in a song, write down or type out the chords/progressions to create a chord sheet similar to those we've been working with.

After you have played along with the song several times and think you have the correct chords, click "show chord sheet" to reveal the chord progressions. Compare the sheet to the one you made.

Songs to Analyze: (See Activity Songs in Appendix C)

Assignment: Listen to this audio excerpt below and, without using an instrument or other aid--just your ears--write down the chord progression.

Name that Progression: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Week 6

Activity

The songs below feature mixed progressions of chords.

Click a song title below. Notice that the software loads the chord sheet and selects the appropriate key and timbre.

Click the "Play" button (top right of window) to listen to the song once without playing along.

Practice playing the song without the music track using the chord sheets provided. The chord sheets provide the number of beats to play each chord number. You may take liberty with the rhythm you use, but stay within the number of beats within the bar.

Play along with the music by pressing the appropriate chord number along as the music plays. Additionally, you may press the "a" key to toggle on/off *auto-accompaniment* and the Spacebar to release chords/accompaniment.

If required by the song, the appropriate inversion type will switch automatically when the SHIFT key is pressed and a number key is pressed. Note: songs may use added notes beyond the root, 3rd, and 5th of the chord, but we'll be limiting our instrument to only play triads.

Using the software as an aid, press the appropriate number keys (1 - 7) within the software to play the chords along with the song as it plays.

Click on each of the other songs below and play the appropriate progression for each of these songs repeating the process if time allows.

Songs to Play: (See Activity Songs in Appendix C)

Assignment: Click the songs below and play along. Though the key and rhythmic profile are provided, chords and progressions for these songs are not, so use your ears and the software (**please** don't use any other instrument to help you) as an aid to help you determine the chord progression. **Tip:** If the progression doesn't sound familiar as a whole, it may be helpful to pick out the movement of the bass line first for each chord. Then, determine if each chord is major or minor in quality as this will help you reduce the number of "trial and error" choices. You can then use the software to "trial and error"-match chords for each measure of the progression.

As you determine the chords in a song, write down or type out the chords/progressions to create a chord sheet similar to those we’ve been working with.

After you have played along with the song several times and think you have the correct chords, click "show chord sheet" to reveal the chord progressions. Compare the sheet to the one you made.

Songs to Analyze: (See Activity Songs in Appendix C)

Assignment: Listen to this audio excerpt below and, without using an instrument or other aid--just your ears--write down the chord progression.

Name that Progression: (See Activity Songs in Appendix C)

Please work on this activity for 1 $^{1/2}$ to 2 hours total this week in any way your time allows (spread across several days is recommended) but for no more than 1 $^{1/2}$ to 2 hours per week.

Appendix B – Software

Software Design

This software was written in the programming language Max/MSP/Jitter. For information on developing similar applications, consult my book *Max/MSP/Jitter for Music* (Manzo, 2011c). To obtain a copy of the source code and project files used in this study, visit www.vjmanzo.org.

Basic Controls

- Use the number keys 1 - 8 to play diatonic chord functions in the selected key
- Hold the SHIFT key while pressing a number key (1-8) to play an inversion for that chord. Inversion types are set automatically for each song. See "playback_reportoire.txt" to modify.
- Press the "i" key to toggle between 1st & 2nd inversion chords when the SHIFT key is pressed along with a number key. Note: pressing the "I" key will enable third inversion chords if notes of 4 notes or more are used.
- Press the "arrow up" key to modulate within a song (key also set automatically for songs). Press the "arrow down" key to return to the original key.
- Press the "a" key to turn AutoAccompaniment mode on or off. It will also be automatically set for songs.
- Press the Spacebar to stop notes from sustaining and/or to stop AutoAccompaniment

Advanced Features

- Configure the MIDI Learn settings to your controller

- Configure the Controller Assignations settings to your playback needs for each control button
- Choose one of the following three playback modes:
    a. Chord Name Menu: allows controls to trigger chords simply by entering a chord name. The Chord Tones and Chord Voicings settings apply to this mode.
    b. Auto-Harmonizer: matches the note you’re playing against the diatonic and chromatic pitches associated with the selected key (Chord Tones menu) and autoharmonizes the chord. The Chord Tones and Chord Voicings settings apply to this mode.
    c. Keyboard Chord Maker: allows you to spell out chords exactly as you want them to sound.
- Storing Presets:
    a. -Choose preset number from dropdown menu.
    b. -Make changes to properties of a module
    c. -Click "store"
    d. -Click "write" to save presets to an XML file in the same folder as the program.
- The Velocity Sensitive toggle plays back chords with the same velocity received via the MIDI input or uses a fixed velocity number
- The Manual Sustain toggle allows chords to sustain forever or to be released when the MIDI controller sends a note-off message
- Auto-diatonic Harmonizing enables the Autoharmonizer mode and

disables all other chord playback modes (though it still uses the Chord Voicing and Chord Tone settings)

Adding Music

Due to copyright, the redistributable version of the E006 software does not include the studio MP3 recording used in this study. Instead, a temporary MP3 is used as a placeholder for each recording used in the study.

To replace a temporary MP3 with the actual recording:

1. Obtain the actual studio recording MP3 (CD, digital download, etc.). To purchase all audio used in this study through iTunes, visit *http://www.vjmanzo.com/dissertation/*
2. Open the *audio* folder within the E006 application’s *Support* folder (On a Mac – right click the application and select *Show Package Contents* to reveal the *Support* folder nested within the *Content* folder)
3. Rename the audio files you downloaded (Step 1) to the same name as the temporary MP3 in the "audio" folder (Note that you will have to convert other file formats such as “.aac” to “.mp3” or edit the "playback_reportoire.txt" as described below)
4. Copy the renamed MP3 to the "audio" folder replacing the temporary MP3

The activity chord sheets are essentially just web pages. The chord patterns are just image files and the text layout is an HTML file that can be modified with any text editor. The file "playback_reportoire.txt" in the E006 application folder obtains the page name from the webpages and loads a number of parameters into the software. This file can also be modified with any text editor. Refer to the legend on the first line of this file for specific information on what each value represents.

To add a song to the activities:

1. Open a webpage from the "pages" folder within the E006 application folder
2. Rename the page filename and its name within the <title> tags with an HTML or text editor
3. Open the playback_reportoire.txt file within the E006 application folder and copy one song line entirely to a new line.
4. Using the first line in this document as a legend, change the properties of the newly copied line to the properties of the song you're trying to add (webpage name, MP3 name, key, tempo, timbre, etc.).

Synthesis

The software is capable of using internal MIDI timbres synthesized through the default synthesis engine as per the user’s operating system or through a higher quality VST or host synth via virtual MIDI routing. A bank of Native Instruments Kontakt 7 sounds has been included with the standalone redistributable.

Appendix C - Music

Pre-test Songs

Clips were made of these songs isolating one section where the chord progression in question is clearly performed. An attempt was made to match pre-test songs with post-test songs in terms of harmonic rhythm and tempo. Songs denoted with an asterisk (*) were reused for the weekly activities. No post-test songs were used in the weekly activities. Songs appear below in the order they were presented on the pre-test. Each progression is expressed relative to the major key in the adjacent table cell.

Table 4
Pre-test songs

Title	**As performed by**	**Progression**	**Key**	**Tempo in BPM**
Magic*	B.O.B. (feat. Rivers Cuomo)	1 4 6 5	B	165
Numb	Linkin Park	6 4 1 5	A	112
Surrender	Cheap Trick	1 6 5 4	C	135
Here (In Your Arms)	HelloGoodbye	1 5 6 4	F	127
Dirty Little Secret	All American Rejects	1 4 6 5	Bb	143
I’m Yours	Jason Mraz	1 5 6 4	B	76
One of Us*	Joan Osborne	6 4 1 5	A	88
The Sign	Ace of Base	1 6 4 5	G	97
Two Princes*	Spin Doctors	1 6 5 4	D	104
Just Like a Pill*	Pink	1 6 4 5	A	102

Post-test Songs

Clips were made of these songs isolating one section where the chord progression in question is clearly performed. An attempt was made to match Pre-test songs with Post-test songs in terms of harmonic rhythm and tempo. Songs appear below in the order they were presented on the post-test. Each progression is expressed relative to the major key in the adjacent table cell.

Table 5
Post-test songs

Title	As performed by	Progression	Key	Tempo in BPM
Far Away	Nickelback	1 5 6 4	C#	132
Building a Mystery	Sarah McLachlan	6 4 1 5	D	82
Stay	Jackson Browne	1 6 4 5	G	102
Stop and Stare	OneRepublic	1 5 6 4	E	92
Best Thing I Never Had	Beyoncé	1 4 6 5	F#	99
You Learn	Alanis Morissette	1 6 5 4	G#	84
More Than a Feeling	Boston	1 4 6 5	G	110
Shark In the Water	V.V. Brown	6 4 1 5	E	99
Complicated	Avril Lavigne	1 6 4 5	F	78
I Remember	Stabbing Westward	1 6 5 4	D	75

Activity Songs

Inversions and modulations were noted where appropriate in the chord sheets provided. Songs denoted with superscript 1 ([1]) were edited for length from the original recording. Songs denoted with superscript 2 ([2]) were digitally tuned to the nearest equal-tempered key from the original recording. Additionally, some songs from the Pre-test were used in the activities. The progression listed in the table below for each song represents the primary progression emphasized pedagogically in the weekly activities. Though in some cases the single progression listed comprises the entire song, this is not what is intended to be conveyed by this category heading. In many cases, a single song was composed of several simple progressions providing repeated exposure to progressions previously encountered through the weekly activities. Each progression is expressed relative to the major key in the adjacent table cell.

Table 6
Activity songs

Title	**As performed by**	**Progression**	**Key**	**Tempo in BPM**
One Day	Matisyahu	1 5 6 4	C	144
Don’t Matter[2]	Akon	1 5 6 4	A	123
Glycerine	Bush	1 5 6 4	F	114
Good	Better than Ezra	1 5 6 4	G/A	109
When I Come Around	Green Day	1 5 6 4	F#	97
Any Way You Want	Journey	1 5 6 4	G	137
With or Without You	U2	1 5 6 4	D	118
Not Pretty Enough	Kasey Chambers	1 5 6 4	B	120
Keep Holding On	Avril Lavigne	1 5 6 4	G	106

Table 6, continued

Already Gone	Kelly Clarkson	1 5 6 4	A	74
The Edge of Glory	Lady Gaga	1 5 6 4	A	128
Swing Swing	All American Rejects	1 5 6 4	G	128
Apologize	OneRepublic	6 4 1 5	Eb	118
Replay	Iyaz	6 4 1 5	A	90
Run Away	Real McCoy	6 4 1 5	Db	132
If I Were a Boy	Beyoncé	6 4 1 5	F#	91
Save Tonight	Eagle-eye Cherry	6 4 1 5	C	120
Zombie	Cranberries	6 4 1 5	G	82
One of Us	Joan Osborne	6 4 1 5	A	88
Magic	B.O.B. (feat. Rivers Cuomo)	1 4 6 5	B	165
Escape	Enrique Iglesias	1 4 6 5	B	125
Good Life	One Republic	1 4 6 5	F#	95
Pretty Girls	Iyaz (feat. Travie McCoy)	1 4 6 5	Eb	77
She Drives Me Crazy	Fine Young Cannibals	1 4 6 5	D	108
That’s the Way It Is	Céline Dion	1 4 6 5	A	93
Cruel to Be Kind	Spacehog	1 6 5 4	C	132
Two Princes	Spin Doctors	1 6 5 4	D	104
Don’t Let Me Get Me	Pink	1 6 5 4	Eb	98
Purple Rain[1]	Prince	1 6 5 4	Bb	58
You’re a God	Vertical Horizon	1 6 5 4	Bb	97
Runaround Sue	Dion	1 6 4 5	D	80
Bleeding Love	Leona Lewis	1 6 4 5	F	104
D’yer Mak’er	Led Zeppelin	1 6 4 5	B	80

Table 6, continued

Somebody's Baby	Jackson Browne	1 6 4 5	D	116
Just Like a Pill	Pink	1 6 4 5	A	102
Stand By Me	John Lennon	1 6 4 5	A	106
Lovelier Than You	B.O.B.	1 6	G	78
Closer to Free	Bodeans	1 4 5 4	G	110
Dammit	Blink 182	1 5 6 4	C	110
Hear You Me	Jimmy Eat World	1 5 6 4	E	90
Hey, Soul Sister	Train	1 5 6 4	E	97
Every Rose Has Its Thorn	Poison	1 4	F#	70
All the Right Moves	OneRepublic	6 5 1 4 (2)	C	146
Machinehead	Bush	1 5 6 4	E	114
Kids	MGMT	6 4 1 5	Bb	122
Love Story	Taylor Swift	1 5 6 4	D/E	119
You Belong With Me	Taylor Swift	1 5 2 4	F#	130
Hit Me With Your Best Shot	Pat Benatar	1 4 6 5	E	127

Appendix D – Survey Questions

Qualifying Survey Questions

Table 7

Qualifying Survey Questions

Qualifying Survey Questions (Note: the layout of this survey online differed from what is shown below)

<table>
<tr><td colspan="10">Question 1. Please enter your name and e-mail address, so that we may notify you if you qualify for this study (information will not be used for any other purpose).</td></tr>
<tr><td colspan="10">Response:</td></tr>
<tr><td colspan="10">Name:</td></tr>
<tr><td colspan="10">Email address:</td></tr>
<tr><td colspan="10">Question 2. What is your primary instrument?</td></tr>
<tr><td colspan="10">Response:</td></tr>
<tr><td>Piano or another keyboard instrument (like organ)</td><td>Guitar or another polyphonic string instrument (like harp)</td><td>Primarily monophonic String instruments (like violin, viola, cello, bass, electric bass)</td><td>Voice</td><td>Woodwind instrument (like flute, bassoon, or clarinet)</td><td>Brass Instrument (like trumpet, trombone, or tuba)</td><td>Non-pitched or pitched-monophonic Percussion instrument (like drums, cymbals, or timpani)</td><td>Pitched polyphonic Percussion instrument (like marimba, xylophone,</td><td>Other monophonic instrument</td><td>Other polyphonic instrument</td></tr>
<tr><td colspan="10">Question 3. Prior to college study, what instrument(s) did you play and for how many years did you play it (them)? Please list the instrument on which you are most proficient first and rate your ability to perform on this instrument.</td></tr>
<tr><td colspan="10">Response:</td></tr>
<tr><td colspan="10">Primary Instrument</td></tr>
<tr><td colspan="6">Instrument Type or Family</td><td colspan="2"># of years played</td><td colspan="2">Ability</td></tr>
<tr><td colspan="6">Piano or another keyboard instrument (like organ)
Guitar or another polyphonic string instrument (like harp)
Primarily monophonic String instruments (like violin, viola, cello, bass, electric bass)
Voice
Woodwind instrument (like flute, bassoon, or clarinet)
Brass Instrument (like trumpet, trombone, or tuba)
Non-pitched or pitched-monophonic Percussion instrument (like drums, cymbals, or timpani)
Pitched polyphonic Percussion instrument (like marimba, xylophone,
Other monophonic instrument
Other polyphonic instrument</td><td colspan="2">less than 1
1
2
3
4
5 or more</td><td colspan="2">Very Weak
Weak
Intermediate
Strong
Very Strong</td></tr>
<tr><td colspan="10">Instrument 2</td></tr>
<tr><td colspan="10">Instrument Type or Family   # of years played   Ability</td></tr>
<tr><td colspan="10">Instrument 3</td></tr>
<tr><td colspan="10">Instrument Type or Family   # of years played   Ability</td></tr>
<tr><td colspan="10">Instrument 4</td></tr>
<tr><td colspan="10">Instrument Type or Family   # of years played   Ability</td></tr>
</table>

Table 7, continued

Question 4. At the university level, how many semesters of ear-training (aural skills) have you completed?				
Response:				
0 - 1semesters	2 – 3 semesters	4 or more semesters		
Question 5. At the university level, how many semesters of music theory have you completed?				
Response:				
0 - 1semesters	2 – 3 semesters	4 or more semesters		
Question 6. Compared to your peers, how would you rate your overall skills in ear-training (aural skills)?				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 7. Compared to your peers, how would you rate your overall skills in music theory?				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 8. How would you rate your ability to, by ear, determine the chord progression being used in a typical popular song on the radio?’ For example, could you determine: "The chorus of that Journey song is a "I V vi IV" progression repeated 4 times"				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 9. Have you ever listened to any popular or rock music such as the music played on the radio?				
Response:				
Yes	No			

Pre-test Survey Questions

Table 8

Pre-test Survey Questions

Pre-test Survey Questions (Note: the layout of this survey online differed from what is shown below)

Question 1. Please enter your name and e-mail address, so that we may notify you if you qualify for this study (information will not be used for solicitation).				
Response:				
Name:				
Email address:				
Question 2. Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio: *For example, could you determine: "The chorus of that Journey song is a "I V vi IV" progression repeated 4 times"*				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 3. Please rate your current overall skills in music theory:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 4. Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 5. Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Questions 6-15. Please listen to this audio example (below) and, by ear, select the closest matching chord progression from the choices below. Choose chord numbers assuming that each song is in a major key (e.g.: in C Major - 1 = C maj, 2 - dmin, 3 = emin, etc.). PLEASE - don't use any instrument or other aid to assist you in this.				
Response:				
1 4 2 5, 1 4 6 5, 1 5 6 4, 1 5 4 6, 1 6 4 5, 1 6 5 4, 6 4 1 5, 6 5 1 4, 2 5 1 6, 2 1 5 6, I don't know				

Post-test Survey Questions

Table 8

Post-test Survey Questions for Control Group

Post-test Survey Questions for Control Group (Note: the layout of this survey online differed from what is shown below)

Question 1. Please enter your name and e-mail address, so that we may notify you if you qualify for this study (information will not be used for solicitation).				
Response:				
Name:				
Email address:				
Question 2. Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio: *For example, could you determine: "The chorus of that Journey song is a "I V vi IV" progression repeated 4 times"*				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 3. Please rate your current overall skills in music theory:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 4. Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 5. Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Questions 6-15. Please listen to this audio example (below) and, by ear, select the closest matching chord progression from the choices below. Choose chord numbers assuming that each song is in a major key (e.g.: in C Major - 1 = C maj, 2 - dmin, 3 = emin, etc.). PLEASE - don't use any instrument or other aid to assist you in this.				
Response:				
1 4 2 5, 1 4 6 5, 1 5 6 4, 1 5 4 6, 1 6 4 5, 1 6 5 4, 6 4 1 5, 6 5 1 4, 2 5 1 6, 2 1 5 6, I don't know				
Question 16. To what extent do you feel that your ability to determine chord progressions improved?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 17. To what extent do you feel that using an accompanying instrument (like piano) helped you determine chord progressions?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 18. To what extent do you feel you would have been able to complete the same activities (determining chord progressions) to the same degree of success without the aid of an accompanying instrument?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 19. Please share any comments about the activities in this study.				
Response:				
Comments:				

Post-test Survey Questions for Experimental Group

Table 9

Post-test Survey Questions for Experimental Group
Post-test Survey Questions for Experimental Group (Note: the layout of this survey online differed from what is shown below)

Question 1. Please enter your name and e-mail address so that we may notify you if you qualify for this study (information will not be used for solicitation).				
Response:				
Name:				
Email address:				
Question 2. Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio: *For example, could you determine: "The chorus of that Journey song is a "I V vi IV" progression repeated 4 times"*				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 3. Please rate your current overall skills in music theory:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 4. Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Question 5. Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper:				
Response:				
Very Weak	Weak	Moderate	Strong	Very Strong
Questions 6-15. Please listen to this audio example (below) and, by ear, select the closest matching chord progression from the choices below. Choose chord numbers assuming that each song is in a major key (e.g.: in C Major - 1 = C maj, 2 - dmin, 3 = emin, etc.). PLEASE - don't use any instrument or other aid to assist you in this.				
Response:				
1 4 2 5, 1 4 6 5, 1 5 6 4, 1 5 4 6, 1 6 4 5, 1 6 5 4, 6 4 1 5, 6 5 1 4, 2 5 1 6, 2 1 5 6, I don't know				
Question 16. To what extent do you feel that your ability to determine chord progressions improved?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 17. To what extent do you feel that using the software instrument helped you determine chord progressions?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 18. To what extent do you feel you would have been able to complete the same activities (determining chord progressions) to the same degree of success without the aid of this software?				
Response:				
Not at all	Small Extent	Moderate Extent	Large Extent	Very Large Extent
Question 19. Please share any comments about interacting with the software.				
Response:				
Comments:				

Appendix E – Data

Self-assessment Question Analysis

Treat 1 – Experimental Group; Treat 2 – Control Group

Self-assessment Question 1: Please rate your current skills regarding your ability to, by ear, determine the chord progression being used in a typical popular song on the radio: *For example, could you determine: "The chorus of that Journey song is a "I V vi IV" progression repeated 4 times"*

There is no significant difference in control group, neither in experiment group.

```
------------------------------------------ Exp. Grp. ----------------------------------
              The FREQ Procedure
       AurAbi(PreAurAbi)     time
       Frequency   |
       Percent     |
       Row Pct     |
       Col Pct     |pos     |pre     |  Total
       ------------+--------+--------+
       Moderate    |     14 |     15 |     29
                   |  20.59 |  22.06 |  42.65
                   |  48.28 |  51.72 |
                   |  41.18 |  44.12 |
       ------------+--------+--------+
       Strong      |     14 |     10 |     24
                   |  20.59 |  14.71 |  35.29
                   |  58.33 |  41.67 |
                   |  41.18 |  29.41 |
       ------------+--------+--------+
       Very Strong |      3 |      1 |      4
                   |   4.41 |   1.47 |   5.88
                   |  75.00 |  25.00 |
                   |   8.82 |   2.94 |
       ------------+--------+--------+
       Very weak   |      1 |      1 |      2
                   |   1.47 |   1.47 |   2.94
                   |  50.00 |  50.00 |
                   |   2.94 |   2.94 |
       ------------+--------+--------+
       Weak        |      2 |      7 |      9
                   |   2.94 |  10.29 |  13.24
                   |  22.22 |  77.78 |
                   |   5.88 |  20.59 |
       ------------+--------+--------+
       Total             34       34       68
                      50.00    50.00   100.00
              The FREQ Procedure

       Statistics for Table of AurAbi by time

    Statistic                     DF       Value      Prob
    ------------------------------------------------------
    Chi-Square                     4      4.4789    0.3451
    Likelihood Ratio Chi-Square    4      4.6927    0.3203
    Mantel-Haenszel Chi-Square     1      1.1680    0.2798
    Phi Coefficient                       0.2566
    Contingency Coefficient               0.2486
    Cramer's V                            0.2566

            Fisher's Exact Test
        ----------------------------------
        Table Probability (P)       0.0015
        Pr <= P                     0.3341
              Sample Size = 68


------------------------------------------ Ctrl. Grp. ---------------------------------
              The FREQ Procedure

       AurAbi(PreAurAbi)     time
       Frequency   |
       Percent     |
```

```
Row Pct     |
Col Pct     |pos     |pre     | Total
------------+--------+--------+
Moderate    |     13 |     15 |     28
            |  19.70 |  22.73 |  42.42
            |  46.43 |  53.57 |
            |  39.39 |  45.45 |
------------+--------+--------+
Strong      |      6 |      4 |     10
            |   9.09 |   6.06 |  15.15
            |  60.00 |  40.00 |
            |  18.18 |  12.12 |
------------+--------+--------+
Very Strong |      3 |      3 |      6
            |   4.55 |   4.55 |   9.09
            |  50.00 |  50.00 |
            |   9.09 |   9.09 |
------------+--------+--------+
Very weak   |      1 |      1 |      2
            |   1.52 |   1.52 |   3.03
            |  50.00 |  50.00 |
            |   3.03 |   3.03 |
------------+--------+--------+
Weak        |     10 |     10 |     20
            |  15.15 |  15.15 |  30.30
            |  50.00 |  50.00 |
            |  30.30 |  30.30 |
------------+--------+--------+
Total             33       33       66
               50.00    50.00   100.00
          The FREQ Procedure
     Statistics for Table of AurAbi by time
Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     4      0.5429    0.9692
Likelihood Ratio Chi-Square    4      0.5457    0.9689
Mantel-Haenszel Chi-Square     1      0.0202    0.8871
Phi Coefficient                       0.0907
Contingency Coefficient               0.0903
Cramer's V                            0.0907

           Fisher's Exact Test
      ----------------------------------
      Table Probability (P)       0.0080
      Pr <= P                     0.9721
            Sample Size = 66
```

Self-assessment Question 2: Please rate your current overall skills in music theory: There is no significant difference in control group, neither in experiment group.

```
------------------------------------------- Exp. Grp. -----------------------------------
          The FREQ Procedure
        Table of TheAbi by time
TheAbi(PreTheAbi)     time

Frequency   |
Percent     |
Row Pct     |
Col Pct     |pos     |pre     | Total
------------+--------+--------+
Moderate    |     13 |     13 |     26
            |  19.12 |  19.12 |  38.24
            |  50.00 |  50.00 |
            |  38.24 |  38.24 |
------------+--------+--------+
Strong      |     14 |     13 |     27
            |  20.59 |  19.12 |  39.71
            |  51.85 |  48.15 |
            |  41.18 |  38.24 |
------------+--------+--------+
```

```
Very strong |      6 |      5 |     11
            |   8.82 |   7.35 |  16.18
            |  54.55 |  45.45 |
            |  17.65 |  14.71 |
------------+--------+--------+
Weak        |      1 |      3 |      4
            |   1.47 |   4.41 |   5.88
            |  25.00 |  75.00 |
            |   2.94 |   8.82 |
------------+--------+--------+
Total             34       34       68
               50.00    50.00   100.00
```

Statistics for Table of TheAbi by time

```
Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     3      1.1279    0.7703
Likelihood Ratio Chi-Square    3      1.1746    0.7591
Mantel-Haenszel Chi-Square     1      0.1696    0.6804
Phi Coefficient                       0.1288
Contingency Coefficient               0.1277
Cramer's V                            0.1288
```

The FREQ Procedure
Statistics for Table of TheAbi by time
Fisher's Exact Test

```
----------------------------------
Table Probability (P)       0.0135
Pr <= P                     0.8889
```

Sample Size = 68

--- Ctrl. Grp. ----------------------------------

The FREQ Procedure

Table of TheAbi by time

TheAbi(PreTheAbi) / Frequency / Percent / Row Pct / Col Pct	time: pos	pre	Total
Moderate	10	11	21
	15.15	16.67	31.82
	47.62	52.38	
	30.30	33.33	
Strong	14	12	26
	21.21	18.18	39.39
	53.85	46.15	
	42.42	36.36	
Very strong	5	5	10
	7.58	7.58	15.15
	50.00	50.00	
	15.15	15.15	
Weak	4	5	9
	6.06	7.58	13.64
	44.44	55.56	
	12.12	15.15	
Total	33	33	66
	50.00	50.00	100.00

Statistics for Table of TheAbi by time

Statistic	DF	Value	Prob
Chi-Square	3	0.3126	0.9576
Likelihood Ratio Chi-Square	3	0.3130	0.9576
Mantel-Haenszel Chi-Square	1	0.0149	0.9030
Phi Coefficient		0.0688	
Contingency Coefficient		0.0687	
Cramer's V		0.0688	

The FREQ Procedure

Statistics for Table of TheAbi by time

Fisher's Exact Test

Table Probability (P)	0.0150
Pr <= P	0.9677

Sample Size = 66

Self-assessment Question 3: Please rate your current skills regarding your ability to, on-the-spot (i.e. "by ear"), choose chords to harmonize a primarily diatonic melody being performed live:

There is no significant difference in control group, neither in experiment group

```
------------------------------------------ Exp. Grp. ----------------------------------

              The FREQ Procedure
          HarLivAbi(PreHarLivAbi)     time
          Frequency   |
          Percent     |
          Row Pct     |
          Col Pct     |pos     |pre     |  Total
          ------------+--------+--------+
          Moderate    |     15 |     11 |     26
                      |  22.06 |  16.18 |  38.24
                      |  57.69 |  42.31 |
                      |  44.12 |  32.35 |
          ------------+--------+--------+
          Strong      |      8 |      5 |     13
                      |  11.76 |   7.35 |  19.12
                      |  61.54 |  38.46 |
                      |  23.53 |  14.71 |
          ------------+--------+--------+
          Very strong |      2 |      3 |      5
                      |   2.94 |   4.41 |   7.35
                      |  40.00 |  60.00 |
                      |   5.88 |   8.82 |
          ------------+--------+--------+
          Very weak   |      1 |      3 |      4
                      |   1.47 |   4.41 |   5.88
                      |  25.00 |  75.00 |
                      |   2.94 |   8.82 |
          ------------+--------+--------+
          Weak        |      8 |     12 |     20
                      |  11.76 |  17.65 |  29.41
                      |  40.00 |  60.00 |
                      |  23.53 |  35.29 |
          ------------+--------+--------+
          Total            34       34       68
                        50.00    50.00   100.00
              The FREQ Procedure
         Statistics for Table of HarLivAbi by time
       Statistic                     DF       Value      Prob
       ------------------------------------------------------
       Chi-Square                     4      3.3077    0.5077
       Likelihood Ratio Chi-Square    4      3.3697    0.4980
       Mantel-Haenszel Chi-Square     1      2.2338    0.1350
       Phi Coefficient                       0.2206
       Contingency Coefficient               0.2154
       Cramer's V                            0.2206
              Fisher's Exact Test
           ----------------------------------
           Table Probability (P)      0.0018
           Pr <= P                    0.5351

              Sample Size = 68

------------------------------------------ Ctrl. Grp. ---------------------------------
              The FREQ Procedure
          HarLivAbi(PreHarLivAbi)     time
          Frequency   |
          Percent     |
          Row Pct     |
          Col Pct     |pos     |pre     |  Total
          ------------+--------+--------+
          Moderate    |     13 |     13 |     26
```

```
            |  19.70 |  19.70 |  39.39
            |  50.00 |  50.00 |
            |  39.39 |  39.39 |
------------+--------+--------+
Strong      |      8 |      8 |     16
            |  12.12 |  12.12 |  24.24
            |  50.00 |  50.00 |
            |  24.24 |  24.24 |
------------+--------+--------+
Very strong |      1 |      0 |      1
            |   1.52 |   0.00 |   1.52
            | 100.00 |   0.00 |
            |   3.03 |   0.00 |
------------+--------+--------+
Very weak   |      2 |      2 |      4
            |   3.03 |   3.03 |   6.06
            |  50.00 |  50.00 |
            |   6.06 |   6.06 |
------------+--------+--------+
Weak        |      9 |     10 |     19
            |  13.64 |  15.15 |  28.79
            |  47.37 |  52.63 |
            |  27.27 |  30.30 |
------------+--------+--------+
Total             33       33       66
               50.00    50.00   100.00
          The FREQ Procedure
  Statistics for Table of HarLivAbi by time

Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     4      1.0526    0.9017
Likelihood Ratio Chi-Square    4      1.4390    0.8374
Mantel-Haenszel Chi-Square     1      0.0208    0.8854
Phi Coefficient                       0.1263
Contingency Coefficient               0.1253
Cramer's V                            0.1263

 WARNING: 40% of the cells have expected counts less
          than 5. Chi-Square may not be a valid test.
               Fisher's Exact Test
          ----------------------------------
          Table Probability (P)       0.0103
          Pr <= P                     1.0000

                Sample Size = 66
```

Self-assessment Question 4: Please rate your current skills regarding your ability to choose chords to harmonize a primarily diatonic melody written on staff paper:

There is no significant difference in control group, neither in experiment group

```
------------------------------------------ Exp. Grp. ----------------------------------

                 The FREQ Procedure
              Table of HarPapAbi by time
         HarPapAbi(PreHarPapAbi)     time
         Frequency   |
         Percent     |
         Row Pct     |
         Col Pct     |pos     |pre     |  Total
         ------------+--------+--------+
         Moderate    |      8 |     13 |     21
                     |  11.76 |  19.12 |  30.88
                     |  38.10 |  61.90 |
                     |  23.53 |  38.24 |
         ------------+--------+--------+
         Strong      |     13 |      9 |     22
                     |  19.12 |  13.24 |  32.35
                     |  59.09 |  40.91 |
                     |  38.24 |  26.47 |
         ------------+--------+--------+
         Very strong |      9 |      9 |     18
                     |  13.24 |  13.24 |  26.47
                     |  50.00 |  50.00 |
                     |  26.47 |  26.47 |
         ------------+--------+--------+
         Very weak   |      0 |      1 |      1
                     |   0.00 |   1.47 |   1.47
                     |   0.00 | 100.00 |
                     |   0.00 |   2.94 |
         ------------+--------+--------+
         Weak        |      4 |      2 |      6
                     |   5.88 |   2.94 |   8.82
                     |  66.67 |  33.33 |
                     |  11.76 |   5.88 |
         ------------+--------+--------+
         Total             34       34       68
                        50.00    50.00   100.00
                 The FREQ Procedure
          Statistics for Table of HarPapAbi by time
       Statistic                     DF       Value      Prob
       ------------------------------------------------------
       Chi-Square                     4      3.5844    0.4652
       Likelihood Ratio Chi-Square    4      3.9992    0.4061
       Mantel-Haenszel Chi-Square     1      0.8605    0.3536
       Phi Coefficient                       0.2296
       Contingency Coefficient               0.2238
       Cramer's V                            0.2296
        WARNING: 40% of the cells have expected counts less
                 than 5. Chi-Square may not be a valid test.
                      Fisher's Exact Test
                 ----------------------------------
                 Table Probability (P)       0.0026
                 Pr <= P                     0.5009

                      Sample Size = 68

------------------------------------------ Ctrl. Grp. ---------------------------------
                 The FREQ Procedure
              Table of HarPapAbi by time
         HarPapAbi(PreHarPapAbi)     time
         Frequency   |
         Percent     |
```

```
Row Pct     |
Col Pct     |pos     |pre     |  Total
------------+--------+--------+
Moderate    |     11 |      6 |     17
            |  16.67 |   9.09 |  25.76
            |  64.71 |  35.29 |
            |  33.33 |  18.18 |
------------+--------+--------+
Strong      |     14 |     15 |     29
            |  21.21 |  22.73 |  43.94
            |  48.28 |  51.72 |
            |  42.42 |  45.45 |
------------+--------+--------+
Very strong |      4 |      4 |      8
            |   6.06 |   6.06 |  12.12
            |  50.00 |  50.00 |
            |  12.12 |  12.12 |
------------+--------+--------+
Weak        |      4 |      8 |     12
            |   6.06 |  12.12 |  18.18
            |  33.33 |  66.67 |
            |  12.12 |  24.24 |
------------+--------+--------+
Total             33       33       66
               50.00    50.00   100.00

   Statistics for Table of HarPapAbi by time
Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     3      2.8384    0.4172
Likelihood Ratio Chi-Square    3      2.8862    0.4095
Mantel-Haenszel Chi-Square     1      2.3917    0.1220
Phi Coefficient                       0.2074
Contingency Coefficient               0.2031
Cramer's V                            0.2074

 WARNING: 25% of the cells have expected counts less
          than 5. Chi-Square may not be a valid test.
               The FREQ Procedure

              Fisher's Exact Test
        ----------------------------------
        Table Probability (P)       0.0046
        Pr <= P                     0.4269

               Sample Size = 66
```

Listening Question Analysis
Compare pair 1-5 and overall 10 questions from pretest to posttest by treatment group;

Response grouping pairs (for analysis)

Pair 1 - 1 4 6 5, Pair 2 - 6 4 1 5 , Pair 3 - 1 6 5 4, Pair 4 - 1 5 6 4, Pair 5 - 1 6 4 5

In experiment group, there are significant improvement for pair 2 and pair 4 questions, increased by 19% and 15% respectively. In overall, among 10 questions, there is no significant improvement.

-------------------------- Exp. Grp. --

Difference: pp1 - p1

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	-0.0294	0.3881	0.0666	-1.0000	0.5000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
-0.0294	-0.1648	0.1060	0.3881	0.3130	0.5109

DF	t Value	Pr > |t|
33	-0.44	0.6615

Difference: pp2 - p2

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	0.1912	0.3260	0.0559	-0.5000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1912	0.0774	0.3049	0.3260	0.2630	0.4291

DF	t Value	Pr > |t|
33	3.42	0.0017

Difference: pp3 - p3

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	-0.1029	0.4732	0.0812	-1.0000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
-0.1029	-0.2681	0.0622	0.4732	0.3817	0.6229

DF	t Value	Pr > |t|
33	-1.27	0.2135

Difference: pp4 - p4

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	0.1471	0.3595	0.0617	-0.5000	0.5000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1471	0.0216	0.2725	0.3595	0.2900	0.4732

DF	t Value	Pr > |t|
33	2.39	0.0230

Difference: pp5 - p5

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	-0.0588	0.3644	0.0625	-1.0000	0.5000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
-0.0588	-0.1860	0.0683	0.3644	0.2939	0.4797

DF	t Value	Pr > |t|
33	-0.94	0.3534

Difference: meanpoq615 - meanq615

N	Mean	Std Dev	Std Err	Minimum	Maximum
34	0.0294	0.1586	0.0272	-0.4000	0.4000

Mean	95% CL Mean	Std Dev	95% CL Std Dev

0.0294	-0.0259	0.0848	0.1586	0.1280	0.2088

DF	t Value	Pr > |t|
33	1.08	0.2875

In control group, there is no significant difference for any of the 5 pairs or the overall rate in all 10 questions.

--- Ctrl. Grp. ----------------------------------

Difference: pp1 - p1

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.1212	0.4151	0.0723	-1.0000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1212	-0.0260	0.2684	0.4151	0.3339	0.5491

DF	t Value	Pr > |t|
32	1.68	0.1032

Difference: pp2 - p2

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.1061	0.4465	0.0777	-0.5000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.1061	-0.0523	0.2644	0.4465	0.3590	0.5905

DF	t Value	Pr > |t|
32	1.36	0.1819

Difference: pp3 - p3

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.0455	0.4737	0.0825	-1.0000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.0455	-0.1225	0.2134	0.4737	0.3810	0.6266

DF	t Value	Pr > |t|
32	0.55	0.5853

Difference: pp4 - p4

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.0455	0.3392	0.0590	-0.5000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.0455	-0.0748	0.1657	0.3392	0.2728	0.4487

DF	t Value	Pr > |t|
32	0.77	0.4471

Difference: pp5 - p5

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.0455	0.4737	0.0825	-1.0000	1.0000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.0455	-0.1225	0.2134	0.4737	0.3810	0.6266

DF	t Value	Pr > |t|
32	0.55	0.5853

Difference: meanpoq615 - meanq615

N	Mean	Std Dev	Std Err	Minimum	Maximum
33	0.0727	0.2541	0.0442	-0.5000	0.7000

Mean	95% CL Mean		Std Dev	95% CL Std Dev	
0.0727	-0.0174	0.1628	0.2541	0.2043	0.3360

DF	t Value	Pr > |t|
32	1.64	0.1099

Treat 1 – Experimental Group; Treat 2 – Control Group

Compare changes on 5 pairs and percentage over 10 questions between treatment groups; there is no significant difference among the changes between experiment and control group on 5 pairs and percentage over 10 questions.

The MEANS Procedure

treat	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
1	34	dp1	34	-0.0294118	0.3881029	-1.0000000	0.5000000
		dp2	34	0.1911765	0.3260114	-0.5000000	1.0000000
		dp3	34	-0.1029412	0.4732129	-1.0000000	1.0000000
		dp4	34	0.1470588	0.3594906	-0.5000000	0.5000000
		dp5	34	-0.0588235	0.3644154	-1.0000000	0.5000000
		dmeanall	34	0.0294118	0.1586485	-0.4000000	0.4000000
2	33	dp1	33	0.1212121	0.4151488	-1.0000000	1.0000000
		dp2	33	0.1060606	0.4464719	-0.5000000	1.0000000
		dp3	33	0.0454545	0.4737424	-1.0000000	1.0000000
		dp4	33	0.0454545	0.3392003	-0.5000000	1.0000000
		dp5	33	0.0454545	0.4737424	-1.0000000	1.0000000
		dmeanall	33	0.0727273	0.2540580	-0.5000000	0.7000000

The TTEST Procedure

Variable: dp1

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	-0.0294	0.3881	0.0666	-1.0000	0.5000
2	33	0.1212	0.4151	0.0723	-1.0000	1.0000
Diff (1-2)		-0.1506	0.4016	0.0981		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		-0.0294	-0.1648	0.1060	0.3881	0.3130	0.5109
2		0.1212	-0.0260	0.2684	0.4151	0.3339	0.5491
Diff (1-2)	Pooled	-0.1506	-0.3466	0.0454	0.4016	0.3429	0.4849
Diff (1-2)	Satterthwaite	-0.1506	-0.3469	0.0456			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	-1.53	0.1297
Satterthwaite	Unequal	64.388	-1.53	0.1302

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	32	33	1.14	0.7018

Variable: dp2

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	0.1912	0.3260	0.0559	-0.5000	1.0000
2	33	0.1061	0.4465	0.0777	-0.5000	1.0000
Diff (1-2)		0.0851	0.3900	0.0953		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		0.1912	0.0774	0.3049	0.3260	0.2630	0.4291
2		0.1061	-0.0523	0.2644	0.4465	0.3590	0.5905
Diff (1-2)	Pooled	0.0851	-0.1052	0.2754	0.3900	0.3330	0.4708
Diff (1-2)	Satterthwaite	0.0851	-0.1065	0.2767			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	0.89	0.3751
Satterthwaite	Unequal	58.498	0.89	0.3776

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	32	33	1.88	0.0769

Variable: dp3

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	-0.1029	0.4732	0.0812	-1.0000	1.0000
2	33	0.0455	0.4737	0.0825	-1.0000	1.0000
Diff (1-2)		-0.1484	0.4735	0.1157		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		-0.1029	-0.2681	0.0622	0.4732	0.3817	0.6229
2		0.0455	-0.1225	0.2134	0.4737	0.3810	0.6266
Diff (1-2)	Pooled	-0.1484	-0.3795	0.0827	0.4735	0.4042	0.5716
Diff (1-2)	Satterthwaite	-0.1484	-0.3795	0.0827			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	-1.28	0.2042
Satterthwaite	Unequal	64.936	-1.28	0.2042

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	32	33	1.00	0.9935

Variable: dp4

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	0.1471	0.3595	0.0617	-0.5000	0.5000
2	33	0.0455	0.3392	0.0590	-0.5000	1.0000
Diff (1-2)		0.1016	0.3496	0.0854		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		0.1471	0.0216	0.2725	0.3595	0.2900	0.4732
2		0.0455	-0.0748	0.1657	0.3392	0.2728	0.4487
Diff (1-2)	Pooled	0.1016	-0.0690	0.2722	0.3496	0.2985	0.4221
Diff (1-2)	Satterthwaite	0.1016	-0.0689	0.2721			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	1.19	0.2387
Satterthwaite	Unequal	64.95	1.19	0.2383

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	33	32	1.12	0.7439

Variable: dp5

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	-0.0588	0.3644	0.0625	-1.0000	0.5000
2	33	0.0455	0.4737	0.0825	-1.0000	1.0000
Diff (1-2)		-0.1043	0.4218	0.1031		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		-0.0588	-0.1860	0.0683	0.3644	0.2939	0.4797
2		0.0455	-0.1225	0.2134	0.4737	0.3810	0.6266

Diff (1-2)	Pooled	-0.1043	-0.3101	0.1016	0.4218	0.3601	0.5092
Diff (1-2)	Satterthwaite	-0.1043	-0.3112	0.1027			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	-1.01	0.3154
Satterthwaite	Unequal	60.091	-1.01	0.3176

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	32	33	1.69	0.1390

The TTEST Procedure

Variable: dmeanall

treat	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	34	0.0294	0.1586	0.0272	-0.4000	0.4000
2	33	0.0727	0.2541	0.0442	-0.5000	0.7000
Diff (1-2)		-0.0433	0.2111	0.0516		

treat	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
1		0.0294	-0.0259	0.0848	0.1586	0.1280	0.2088
2		0.0727	-0.0174	0.1628	0.2541	0.2043	0.3360
Diff (1-2)	Pooled	-0.0433	-0.1463	0.0597	0.2111	0.1802	0.2548
Diff (1-2)	Satterthwaite	-0.0433	-0.1474	0.0608			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	65	-0.84	0.4041
Satterthwaite	Unequal	53.39	-0.83	0.4079

Equality of Variances

Method	Num DF	Den DF	F Value	Pr > F
Folded F	32	33	2.56	0.0087

Self-assessment Extension Question Analysis

Treat 1 – Experimental Group; Treat 2 – Control Group

Compare post-test extent between control and treatment groups; there is significant difference for ext 1 and ext 3 between the two groups

```
          Table of Ext1 by treat
Ext1(Ext1)     treat(treat)

Frequency      |
Percent        |
Row Pct        |
Col Pct        |      1|      2|  Total
---------------+--------+--------+
Large extent   |      6 |      6 |     12
               |   8.96 |   8.96 |  17.91
               |  50.00 |  50.00 |
               |  17.65 |  18.18 |
---------------+--------+--------+
Moderate extent |     20 |     10 |     30
               |  29.85 |  14.93 |  44.78
               |  66.67 |  33.33 |
               |  58.82 |  30.30 |
---------------+--------+--------+
Not at all     |      0 |      2 |      2
               |   0.00 |   2.99 |   2.99
               |   0.00 | 100.00 |
               |   0.00 |   6.06 |
---------------+--------+--------+
Small extent   |      7 |     15 |     22
               |  10.45 |  22.39 |  32.84
               |  31.82 |  68.18 |
               |  20.59 |  45.45 |
---------------+--------+--------+
Very Large exten |      1 |      0 |      1
t              |   1.49 |   0.00 |   1.49
               | 100.00 |   0.00 |
               |   2.94 |   0.00 |
---------------+--------+--------+
Total                34       33       67
                  50.75    49.25   100.00

           The FREQ Procedure

      Statistics for Table of Ext1 by treat

Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     4      9.2296    0.0556
Likelihood Ratio Chi-Square    4     10.5188    0.0325
Mantel-Haenszel Chi-Square     1      2.6314    0.1048
Phi Coefficient                       0.3712
Contingency Coefficient               0.3480
Cramer's V                            0.3712

 WARNING: 40% of the cells have expected counts less
        than 5. Chi-Square may not be a valid test.


          Fisher's Exact Test
      ----------------------------------
      Table Probability (P)    3.328E-04
      Pr <= P                     0.0346

           Sample Size = 67
           The FREQ Procedure
          Table of Ext2 by treat
```

```
Ext2(Ext2)     treat(treat)

Frequency       |
Percent         |
Row Pct         |
Col Pct         |       1|       2|  Total
----------------+--------+--------+
Large extent    |     15 |     13 |     28
                |  22.39 |  19.40 |  41.79
                |  53.57 |  46.43 |
                |  44.12 |  39.39 |
----------------+--------+--------+
Moderate extent |     12 |      8 |     20
                |  17.91 |  11.94 |  29.85
                |  60.00 |  40.00 |
                |  35.29 |  24.24 |
----------------+--------+--------+
Not at all      |      2 |      1 |      3
                |   2.99 |   1.49 |   4.48
                |  66.67 |  33.33 |
                |   5.88 |   3.03 |
----------------+--------+--------+
Small extent    |      2 |      5 |      7
                |   2.99 |   7.46 |  10.45
                |  28.57 |  71.43 |
                |   5.88 |  15.15 |
----------------+--------+--------+
Very Large exten |      3 |      6 |      9
t               |   4.48 |   8.96 |  13.43
                |  33.33 |  66.67 |
                |   8.82 |  18.18 |
----------------+--------+--------+
Total                 34       33       67
                   50.75    49.25   100.00

            The FREQ Procedure

     Statistics for Table of Ext2 by treat

Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     4      3.5478    0.4707
Likelihood Ratio Chi-Square    4      3.6210    0.4597
Mantel-Haenszel Chi-Square     1      1.9079    0.1672
Phi Coefficient                       0.2301
Contingency Coefficient               0.2243
Cramer's V                            0.2301

 WARNING: 60% of the cells have expected counts less
          than 5. Chi-Square may not be a valid test.


           Fisher's Exact Test
      ----------------------------------
      Table Probability (P)       0.0018
      Pr <= P                     0.5157

            Sample Size = 67
            The FREQ Procedure
           Table of Ext3 by treat

Ext3(Ext3)     treat(treat)

Frequency       |
Percent         |
Row Pct         |
Col Pct         |       1|       2|  Total
----------------+--------+--------+
Large extent    |      7 |      5 |     12
                |  10.45 |   7.46 |  17.91
```

```
            |  58.33 |  41.67 |
            |  20.59 |  15.15 |
-----------------+--------+--------+
Moderate extent  |     11 |      6 |     17
            |  16.42 |   8.96 |  25.37
            |  64.71 |  35.29 |
            |  32.35 |  18.18 |
-----------------+--------+--------+
Not at all       |      0 |      7 |      7
            |   0.00 |  10.45 |  10.45
            |   0.00 | 100.00 |
            |   0.00 |  21.21 |
-----------------+--------+--------+
Small extent     |     16 |     14 |     30
            |  23.88 |  20.90 |  44.78
            |  53.33 |  46.67 |
            |  47.06 |  42.42 |
-----------------+--------+--------+
Very Large exten |      0 |      1 |      1
t           |   0.00 |   1.49 |   1.49
            |   0.00 | 100.00 |
            |   0.00 |   3.03 |
-----------------+--------+--------+
Total                34       33       67
                  50.75    49.25   100.00

              The FREQ Procedure

       Statistics for Table of Ext3 by treat

Statistic                     DF       Value      Prob
------------------------------------------------------
Chi-Square                     4      9.9245    0.0417
Likelihood Ratio Chi-Square    4     13.0363    0.0111
Mantel-Haenszel Chi-Square     1      0.7919    0.3735
Phi Coefficient                       0.3849
Contingency Coefficient               0.3592
Cramer's V                            0.3849

 WARNING: 40% of the cells have expected counts less
        than 5. Chi-Square may not be a valid test.


             Fisher's Exact Test
        ----------------------------------
        Table Probability (P)    1.002E-04
        Pr <= P                     0.0249

              Sample Size = 67
```

Aggregated List of Comments

Optional Comments 10 Experiment 15 Control 25 Total

Experimental Group Comments:

- I feel that, along with the software, the weekly repetition and drilling was what I benefited from most.
- Had real difficulties load software to PC platform. Maybe the problem was me. Not at all familiar with 85% of the music. Maybe too old to be a good judge of the effectiveness of samples. I might have felt more comfortable using song of my vintage. I think this is a great idea for use in the classroom. Examples may need to be changed on a regular basis. Student hate old songs.
- While using the software, it was helpful. I still have trouble determining chords without using a piano (or the software).
- This software has helped me to play popular songs by ear so much easier! This software will help you get more gigs, which will then put money in your pocket, which will then have you spending money on equipment, which will then aid and rebuild our economy. E006 for president
- Software layout is uncluttered, fairly intuitive and easy to use. Extremely accessible.
- I feel like the software didn't offer strategies for determining chord progressions and instead had the user repetitiously experiment with chord progressions hoping that the repetition would cause the progressions to stick in the users memory. I consistently felt as if I was guessing half the time though I will say I feel as if my ability to identify chord progressions in root position has improved. First inversion chords still confuse me because I rely on the bass line to determine chords and I often second guess my answers when there is a first inversion chord present since I still feel as if I am guessing. I would have liked more than 2 hours a week to work on these.
- The only real problem I had with this software is that there was a slight delay between pressing the notes and hearing the chords, also the chords ended before the fourth beat of most of the songs. Over all the delay and premature end of the chords were only a bit of an annoyance and ultimately i do feel stronger about hearing chords after use of the program.
- I loved the music choices! Prof. Manzo, you've got a great taste in music! Thanks for letting me use your software!
- It was really helpful to play along and see the progressions at the same time. Then, I was able to make the connection to what chord I was hearing and see it at the same time.
- So cool and greatly beneficial! I learned chords extremely fast because of this software. I feel it helped me more then me actually sitting in a classroom and learning this from a teacher. Bravo Manzo!

Control Group Comments:

- Definitely the best (helped me) and most fun survey I've ever had to take! Awesome, man. Good luck with your dissertation!
- I feel that this method would convey basic music theory much easier to the lay listener. Seems like it would be very useful for all scholastic levels. I enjoyed this survey. Thank you and goodluck!
- because I'm not all that good at piano for awhile I spent the time trying the get the chords (so basically I spent the time practicing technical things) which left me less time to really think about the sounds. I can hear chord changes now which is a HUGE improvement for me. I'd like to continue the exercises to see if I can better identify the chords with more practice. Right now I can hear the chords and the changes but I have trouble telling which chord it is.

- I found my repeated inability to correctly identify the chord progression increasingly frustrating as I expected improvement, and I fear that may have gotten in the way of progressing. I had hoped to leave the study with an improved ability to identify these chord progressions, but instead I'm afraid I am now mostly more acutely aware of my lack of ability to do so. I'm sorry. :/
- I had a great time participating in this study and loved the selection of songs that you chose to figure out chord progressions for. It made the study interesting and practical to college students because we have all heard most of these songs before. My ability to notice chords on the spot has increased a huge amount since I started. I would never have known where to begin if I did not have the use of the piano helping me as well. Thank you so much, and I hope you receive your Ph.D!
- I appreciated the way that you laid out the chord numbers over the measures, like on a ruler dividing up the beats. It helped me time when the chords would change in the progression, seeing it visually like that.
- The more I did this the more I felt my skills weren't as advanced as I originally thought. It helped me to use the piano. I think I'm able to figure them out without the piano, but it takes me a lot more time.
- In the past my instrument experience was based on the violin and it was very difficult for me to convert that knowledge to the piano especially since I haven't played in over a decade
- I'm sorry I didn't complete this earlier in the week, it was a hectic week preparing for midterms.
- This was definitely an interesting study to participate in. Determining chord progressions of popular music is a skill that many musicians have and it was nice to see if I could do it as well.
- I really got a lot out of using this program. My ears are very thankful.
- I'm glad i took this opportunity, because i felt like i improved on listening than when i started, it was a great experiences and fun. ^^
- Some progressions were difficult to understand simply because of what was going on in the song besides the clear chords. Some were just hard to hear. But I do feel that this helped me to be more in tune to what happens in any kind of song and be able to hear things and apply what I already know about music theory.
- I thought this dissertation was great for theory students in college to gain some insight into the modern world of music since they primarily study classical and jazz chord progressions. Learning to play pop songs effortlessly with an instrument is an underrated skill that teachers will find valuable someday. This experiment was well put together and provided us surveyors with a good repertoire of pop songs as well as connecting our theory knowledge with a real life application we can use for teaching, performing, or inspiring creativity once learning that every pop song uses the same chord progression slightly varied.
- It made fun to listen to this kind of pop music. Pop music is so simple and so many songs are similiar to each other but they work and since we are used listening to this kind of music it was actually really easy to reveal the chorf progressions. I mean since we are all musicians we shouldn't have any troubles with such easy chords progressions and harmonies. Everything was quite predictable and obvious although I realized at the final survey that I made a mistake at the former survey by choosing two times "I don't know". because I was analysing it in minor although you asked us to see it all in major keys. My instinct just made me chosing the wrong selection. Kind of blue- eyed. Thanks anyway. It was fun to explore the music.

Group formation and analysis

Treat 1 – Experimental Group; Treat 2 – Control Group

Two treatment groups 1 and 2: 34 students are in treatment group 1; 33 students are in group 2. all variables do not have significant difference between the two treatment groups:

1. Number of semesters ear-training completed:

Frequency
Percent
Row Pct
Col Pct

Table of AuralSem by treat

AuralSem(AuralSem)	treat(treat) 1	2	Total
0 - 1	6	11	17
	8.96	16.42	25.37
	35.29	64.71	
	17.65	33.33	
2 - 3	15	13	28
	22.39	19.40	41.79
	53.57	46.43	
	44.12	39.39	
4 or more	13	9	22
	19.40	13.43	32.84
	59.09	40.91	
	38.24	27.27	
Total	34	33	67
	50.75	49.25	100.00

Statistics for Table of AuralSem by treat

Statistic	DF	Value	Prob
Chi-Square	2	2.3263	0.3125
Likelihood Ratio Chi-Square	2	2.3519	0.3085
Mantel-Haenszel Chi-Square	1	2.0320	0.1540
Phi Coefficient		0.1863	
Contingency Coefficient		0.1832	
Cramer's V		0.1863	

Fisher's Exact Test	
Table Probability (P)	0.0162
Pr <= P	0.3042

Sample Size = 67

2. Number of semesters of theory completed:

Frequency Percent Row Pct Col Pct			
Table of TheoSem by treat			
TheoSem(TheoSem)	**treat(treat)**		
	1	**2**	**Total**
0 - 1	6	8	14
	8.96	11.94	20.90
	42.86	57.14	
	17.65	24.24	
2 - 3	13	17	30
	19.40	25.37	44.78
	43.33	56.67	
	38.24	51.52	
4 or more	15	8	23
	22.39	11.94	34.33
	65.22	34.78	
	44.12	24.24	
Total	34	33	67
	50.75	49.25	100.00

Statistics for Table of TheoSem by treat

Statistic	DF	Value	Prob
Chi-Square	2	2.9352	0.2305
Likelihood Ratio Chi-Square	2	2.9713	0.2264
Mantel-Haenszel Chi-Square	1	2.1638	0.1413
Phi Coefficient		0.2093	
Contingency Coefficient		0.2049	
Cramer's V		0.2093	

Fisher's Exact Test	
Table Probability (P)	0.0124
Pr <= P	0.2570

Sample Size = 67

3. Overall skills in ear training:

Frequency Percent Row Pct			
Table of AuralSkill by treat			
AuralSkill(AuralSkill)	**treat(treat)**		
	1	**2**	**Total**

Col Pct				
	Moderate	14	15	29
		20.90	22.39	43.28
		48.28	51.72	
		41.18	45.45	
	Strong	13	8	21
		19.40	11.94	31.34
		61.90	38.10	
		38.24	24.24	
	Very Strong	3	3	6
		4.48	4.48	8.96
		50.00	50.00	
		8.82	9.09	
	Very Weak	0	1	1
		0.00	1.49	1.49
		0.00	100.00	
		0.00	3.03	
	Weak	4	6	10
		5.97	8.96	14.93
		40.00	60.00	
		11.76	18.18	
	Total	34	33	67
		50.75	49.25	100.00

Statistics for Table of AuralSkill by treat

Statistic	**DF**	**Value**	**Prob**
Chi-Square	4	2.6106	0.6249
Likelihood Ratio Chi-Square	4	3.0106	0.5561
Mantel-Haenszel Chi-Square	1	0.3924	0.5310
Phi Coefficient		0.1974	
Contingency Coefficient		0.1937	
Cramer's V		0.1974	
WARNING: 50% of the cells have expected counts less than 5. Chi-Square may not be a valid test.			

Fisher's Exact Test	
Table Probability (P)	0.0047
Pr <= P	0.6631

Sample Size = 82

4. Overall theory skills:

Frequency
Percent
Row Pct
Col Pct

Table of TheoSkill by treat

TheoSkill(TheoSkill)	treat(treat)		
	1	**2**	**Total**
Moderate	12	12	24
	17.91	17.91	35.82
	50.00	50.00	
	35.29	36.36	
Strong	7	9	16
	10.45	13.43	23.88
	43.75	56.25	
	20.59	27.27	
Very Strong	10	7	17
	14.93	10.45	25.37
	58.82	41.18	
	29.41	21.21	
Very Weak	0	1	1
	0.00	1.49	1.49
	0.00	100.00	
	0.00	3.03	
Weak	5	4	9
	7.46	5.97	13.43
	55.56	44.44	
	14.71	12.12	
Total	34	33	67
	50.75	49.25	100.00

Statistics for Table of TheoSkill by treat

Statistic	DF	Value	Prob
Chi-Square	4	1.8760	0.7585
Likelihood Ratio Chi-Square	4	2.2656	0.6870
Mantel-Haenszel Chi-Square	1	0.1118	0.7381
Phi Coefficient		0.1673	
Contingency Coefficient		0.1650	

Statistic	DF	Value	Prob
Cramer's V		0.1673	
WARNING: 40% of the cells have expected counts less than 5. Chi-Square may not be a valid test.			

Fisher's Exact Test	
Table Probability (P)	0.0053
Pr <= P	0.8521

5. Chord skill between treatment groups:

Frequency Percent Row Pct Col Pct

Table of ChordSkill by treat			
ChordSkill(ChordSkill)	treat(treat)		
	1	2	Total
Moderate	16	14	30
	23.88	20.90	44.78
	53.33	46.67	
	47.06	42.42	
Strong	7	6	13
	10.45	8.96	19.40
	53.85	46.15	
	20.59	18.18	
Very Strong	4	4	8
	5.97	5.97	11.94
	50.00	50.00	
	11.76	12.12	
Weak	7	9	16
	10.45	13.43	23.88
	43.75	56.25	
	20.59	27.27	
Total	34	33	67
	50.75	49.25	100.00

Statistics for Table of ChordSkill by treat

Statistic	DF	Value	Prob
Chi-Square	3	0.4454	0.9307
Likelihood Ratio Chi-Square	3	0.4462	0.9306
Mantel-Haenszel Chi-Square	1	0.3707	0.5426
Phi Coefficient		0.0815	

Statistic	DF	Value	Prob
Contingency Coefficient		0.0813	
Cramer's V		0.0815	
WARNING: 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.			

Fisher's Exact Test	
Table Probability (P)	0.0140
Pr <= P	0.9524

6. Player types between treatment groups:

Frequency
Percent
Row Pct
Col Pct

Table of type by treat

type(type)	treat(treat) 1	2	Total
mono	7	9	16
	10.45	13.43	23.88
	43.75	56.25	
	20.59	27.27	
poly	27	24	51
	40.30	35.82	76.12
	52.94	47.06	
	79.41	72.73	
Total	34	33	67
	50.75	49.25	100.00

Statistics for Table of type by treat

Statistic	DF	Value	Prob
Chi-Square	1	0.4116	0.5211
Likelihood Ratio Chi-Square	1	0.4123	0.5208
Continuity Adj. Chi-Square	1	0.1260	0.7226
Mantel-Haenszel Chi-Square	1	0.4055	0.5243
Phi Coefficient		-0.0784	
Contingency Coefficient		0.0781	
Cramer's V		-0.0784	

Fisher's Exact Test	
Cell (1,1) Frequency (F)	7
Left-sided Pr <= F	0.3615

Fisher's Exact Test	
Right-sided Pr >= F	0.8232
Table Probability (P)	0.1846
Two-sided Pr <= P	0.5763

Sample Size = 67