Markov Chains as Tools for Jazz Improvisation Analysis

David M. Franz

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Joel A. Nachlas, Chairman
Brian M. Kleiner
Chip McNeill

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(ABSTRACT)

This thesis describes an exploratory application of a statistical analysis and modeling technique (Markov chains) for the modeling of jazz improvisation with the intended subobjective of providing increased insight into an improviser's style and creativity through the postulation of quantitative measures of style and creativity based on the constructed Markovian analysis techniques.

Using Visual Basic programming language, Markov chains of orders one to three are created using transcriptions of improvised solos by John Coltrane in his song *Giant Steps*. Still considered as statistical data, the Markov chains are examined and information is extracted from them through the development of several statistical tools for musical analysis. Two general categories of tools for analysis are developed: Subtraction matrices and graphical comparisons of distributions. Using these tools and the raw Markov chain data for musical analysis, quantitative measures for creativity and style are postulated. These measures are based on previously developed models and definitions of creativity and style taken from the literature. The information acquired from the implementation of the analysis tools is applied to the models in order to provide a theoretical basis for the development of the quantitative measures and a framework for the interpretation of the information. Guilford's Structure of Intellect model is used for developing creativity measures and Heen's model of the constructs of style analysis is used for determining measures of style.

Overall, this research found that Markov chains provide distinct and useful information for musical analysis in the domain of jazz improvisation. Many examples of Markov chains are enumerated and tools for analysis are developed that implement the Markov chains. It is then explained how Markov chains and the tools for their analysis can be interpreted to determine quantitative measures of creativity and style. Finally, this thesis presents conclusions on Markov chain portrayals, new analysis tools and procedures, quantitative measures of creativity and style, and, in sum, that Markovian modeling is in fact a reasonable and useful modeling approach for this application.

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Table of Contents

List of Figures

List of Tables

Chapter 1 : Introduction and Problem Description

1.1 Introduction

To the average listener, jazz improvisation may often appear to consist of random note selection over a given chordal structure. When analyzed relative to a deeper understanding of music, this apparently random note selection begins to take shape into definable, and at times even predictable, note choices. In fact, jazz improvisers implement rules, patterns, and other structures that govern their note selection which are all demonstrations of the style and creativity of the artist.

Since the beginning of jazz as an art form, extensive qualitative musical analysis of jazz improvisation has been performed. However, mathematical investigations of a statistical nature regarding the analysis of improvisation are rare. The objective of this thesis is to explore an application of a statistical analysis and modeling technique (Markov chains) for the modeling of jazz improvisation with the intended subobjective of postulating quantitative measures of style and creativity based on the constructed Markovian analysis techniques that can provide increased insight into an improviser's style and creativity.

1.2 Problem Description

The main purpose of this research is to determine if Markov chains can be used as tools for the analysis of jazz improvisation. It is hypothesized that Markov chains are useful tools for modeling improvisation and that a statistical analysis of constructed Markov chains can reveal underlying probabilities and patterns within a jazz improviser's style that may not be apparent through other forms of analysis. The legitimacy of using Markov chains to indicate improvisational movement (that is, note choice) is examined. Markov chains are created from data files coded from data sets of jazz improvisation. The data sets consist of pitches and rests and are aggregated to form the transition matrices of the Markov chains (section 1.4 Data Sets provides further explanation of this). Data sets consisting of John Coltrane solos in his song *Giant Steps* are examined as an example of this methodology. Analysis of the constructed Markov chains may provide new insight into John Coltrane's improvisation during *Giant Steps.* In addition, the Markov chains may provide possible determinants of his style and creativity and allow for the postulation of potential quantitative measures of style and creativity.

1.3 Markov Chains

Jazz solos can be viewed as a stream of notes, or using mathematical terminology, as a sequence of events. A Markov chain is a mathematical model used to represent the tendency of one event to follow another event, or even to follow an entire sequence of events. Markov chains are comprised of probabilities that reflect the dependence of one or more events on previous events. Each note in a jazz solo may be considered to be dependent on the previous note or notes and the complete improvised melody can be regarded as a chained series of intervallic transitions (i.e., transitions from one scale degree, or pitch within a scale, to another) which take place unidirectionally in time (Tirro, 1988). Hence, a jazz solo can be examined as a stochastic process and Markov chains can be formed to analyze the probabilities of particular note selections for any improvised melody.

Due to the fact that *Giant Steps* is played at an extremely fast tempo with many quick chord changes, Markov chains with orders of one through three are used. This is because Markov chains of order three can model all possible 4-note phrases and patterns that John Coltrane tended to play in one scale over one chord in the song that provides the data.

It is understood that using orders of one to three is not applicable to all songs. Some songs may require the use of higher order Markov chains to ensure the development of a more accurate model for analysis. However, a truncation point of three is best used for this research due to the chordal structure and tempo of *Giant Steps*. Also, this truncation point should provide sufficient generalizability for future applications of this methodology. In addition, orders larger than three are not considered because they are quite large, rather cumbersome to work with, and, although possibly useful for music composition purposes, they are not deemed necessary for this new approach to musical analysis.

1.4 Data Sets

To develop the ideas and propositions for this thesis, the selection of a musician and a piece of music to provide the data is necessary. The data chosen for this analysis are in the form of transcribed tenor saxophone solos performed by John Coltrane on his song *Giant Steps* (White, 1997). Here, a transcription refers to every note played in an improvised solo written out in musical notation. There are nine released takes (and transcriptions) of this song - this includes the originally released versions of *Giant Steps* and *Giant Steps*

(Alternate Version), as well as seven other alternate takes and incomplete takes (Atlantic R2 71984). This equates to ninety-six runs through the sixteen-bar chord structure which forms *Giant Steps* (The Real Book). Each note from each solo is coded 1) by actual note name and 2) by intervallic relationship (e.g., minor second, major seventh, etc.) to the appropriate scale played over each chord and by rhythmic value. That is, each note name and each note (coded as an interval of its parent scale) is entered as a data point to develop the Markov chain probability matrices.

There are several reasons for using only one song by one artist as data for this research. 1) As Graham Collier has stated, "Recordings of jazz performances give the illusion of permanence but, in almost all cases, recordings are simply one performance, a frozen moment in time, and care should be taken that they are not unthinkingly regarded as the definitive performance of a particular piece or the *ne plus ultra* of the player's style" (1975, p. x.). In this particular case, there is an unusually large amount of data for this song; there are two versions of the song and nine total recorded takes of *Giant Steps*. An analysis of most other songs would be limited to only one take of one version (i.e., one data set) of the song. 2) As the first implementation of Markov chain modeling in this capacity, this research is limited to the study of note (or pitch) selection as the primary variable being investigated. Thus, other variables such as rhythm, timbre, and other sound quality variables are not studied. Due to its fast tempo and unique chordal structure, *Giant Steps* is an especially useful song for only analyzing pitch because John Coltrane plays strings of eighth notes almost the entire way through his solos. This results in the other variables (such as rhythm and sound quality) being fairly constant throughout the solos and thus allows the research to focus on one variable (note selection) without largely compromising John Coltrane's true improvisational style on this song. 3) John Coltrane's style transformed from his earlier years to his later years as witnessed in his many recordings. The data for this song is taken from two recording sessions (the first was on March 26, 1959 and the second was on May 5, 1959). This modeling technique can be used to capture and model John Coltrane's style at a brief period of time during his musical career. 4) Other artists are not considered in this research because a comparison of individual improvisational style and level of creativity is not within the scope of this thesis.

1.5 Research Questions

The following **research questions** are answered regarding the methodologies developed in this thesis.

1) To what extent can Markovian modeling be applied to jazz improvisation?
2) What is the best method to model improvisation and portray the statistical data using Markov chains (regarding order, state definitions, etc.)
3) How should the Markov chains be manipulated so that the most information can be gleaned from them?
4) How can Markov chains be used to develop quantitative measures of style and creativity in the domain of jazz improvisation?

The Markovian modeling and analysis of the data sets is used to develop pitch statistics comparing four and eight-note patterns, scale intervals used in particular chord types, and different notes played over similar chord types. Statistics are generated based on these questions:

1) How often is a particular pattern of notes used?
2) How many different patterns, formulas, etc. are used over a chord in the song?
3) How much and how often is the pitch varied in a solo (a vertical analysis of the solo)?
4) How much and how often are the rhythmic phrases varied (a horizontal analysis)?
5) Are different patterns, scales, etc. used in similar types of chords?

The results found from these statistical questions are used to provide support in the answering of the aforementioned research questions.

Chapter 2 : Literature Review

2.1 Markov Chains

Markov chains have been used for many applications, and have been previously implemented in the realm of music. However, Markov chains have not been used for musical analysis.

2.1.1 Markov Chains

Andrei Andreevich Markov first introduced his mathematical model of dependence, now known as Markov chains, in 1907 (Howard, 1971). A Markov chain is a mathematical model used to represent the tendency of one event to follow another event, or even to follow an entire sequence of events. Markov chains are matrices comprised of probabilities that reflect the dependence of one or more events on previous events. Markov first applied his modeling technique to determine tendencies found in Russian spelling. Since then, Markov chains have been used as a modeling technique for a wide variety of applications ranging from weather systems (Ross, 1972) to baseball games (Bukiet, Harold, and Palacios, 1997).

2.1.2 Markov Chains Applied to Music

Hiller and Isaacson (1957) were the first to implement Markov chains in a musical application. They developed a computer program that used Markov chains to compose a string quartet comprised of four movements entitled the *Illiac Suite*. Hiller then collaborated with Baker in 1963 to create a second computer music composition entitled *Computer Cantata*, which was developed using Baker's pioneering computer program MUSICOMP (Music Simulator Interpreter for COMpositional Procedures).

Around the same time period, Meyer and Xenakis (1971) realized that Markov chains could reasonably represent musical events. In his book *Formalized Music*, Xenakis described musical events in terms of three components: frequency, duration, and intensity. These three components were combined in the form of a vector and then were used as the states in Markov chains. In congruence with Xenakis, Jones (1981) suggested the use of vectors to

describe notes (e.g., note = {pitch, duration, amplitude, instrument}) for the purposes of eliciting more complex musical behavior from a Markov chain. In addition, Polansky, Rosenboom, and Burk (1987) proposed the use of hierarchical Markov chains to generate different levels of musical organization (e.g., a high level chain to define the key or tempo, an intermediate level chain to select a phrase of notes, and a low level chain to determine the specific pitches) (Roads, 1996).

Since this initial work using Markov chains for compositional purposes, many others have contributed to this line of research including Ames & Domino (1992), North (1989), Tirro (1988), and Dodge & Jerse (1985) and Koenig (1970). A commercial computer program (namely, "M and Jam Factory") is even available that implements Markov chains for music composition and allows for real-time interactive control of the Markov chains themselves (Zicarelli, 1987). More recent research connecting music and Markov chains involves the implementation of improved computing techniques in order to enable real-time Markov chain computation, thus allowing accurate real-time playback of Markovian music. Lyon (1995) has suggested using stochastic Petri nets to achieve this because the Petri net approach removes all zero elements from a Markov chain. Essentially, Petri nets improve the efficiency of the computing algorithms when simultaneously composing and playing back Markovian-generated music.

All of the aforementioned research deals with the compositional aspects and uses of Markov chains. That is, all of this research was focused on creating musical **output** using Markov chains. However, "analysis is a neglected issue in algorithmic composition," (Roads, 1996, p. 906). As opposed to composition, analysis is concerned with music that has already been made. For Markovian analyses, this previously made music is the **input** for the Markov chains. There is no existing literature on the specific uses of Markov chains as tools for musical analysis.

2.1.3 Criticism of the Use of Markov Chains Applied to Music

There has been some criticism of using Markov chains in a musical setting. The use of Markov chains (or any stochastic method) for composition inherently implies the reliance on essentially random note selection in many instances. When this occurs, the output may or may not be favorable to the human ear. Levitt (1993) claimed that this reliance on randomness tends to obscure rather than disclose the underlying foundations and practices of music generation. To this, Moorer (1993) stated that the Markov methods used today are not complete enough by themselves to compose high quality music consistently.

Essentially, this criticism is directed at using Markov chains to create music—that is, to use Markov chains as the input for music composition. The criticism is not pointed at the usage of Markov chains when modeling music that has already been created -- that is, to use Markov chains as a tool for the analysis of an output that has been previously composed. In other words, this criticism does not apply to the usage of Markov chains for musical analysis.

2.2 Jazz Improvisation Analysis

The general analysis of jazz improvisation is mainly qualitative in nature. Several quantitative analysis techniques are cited, yet none are similar to the proposed methodology of this thesis. Following that, specific literature on John Coltrane the artist and his song Giant Steps illustrates the present knowledge on the particular data used in this thesis.

2.2.1 General Jazz Improvisation Analysis

Improvisation in music has been defined as the "simultaneous conception and production of sound in performance" (Dean, 1989, p. ix). For the purposes of this research regarding the analysis of improvisation, qualitative analysis refers to the assessment of the perceived sound that an improviser achieves and quantitative analysis refers to the assessment of the particular notes that the improviser plays.

Jazz improvisation can be generally analyzed in several different ways. Much of jazz analysis consists of qualitative assessments of an improviser's style (which may include such individual variables as: phrasing, tone, general feeling, experience, speed, emotion, and influences). Other qualitative assessments can be made of the particular musical style (with a similar list of variables) in which an improviser composes and performs. These two types of analysis can be found in many publications (books, biographies, interviews, magazines and journal articles) (Gridley, 1997; Cole, 1976; Kofsky, 1970; Simpkins, 1989; Nisenson, 1993; Carno, 1959, etc.).

Jazz improvisation analysis can take the form of quantitative assessments as well. As a beginning point for quantitative analysis, many authors have identified specific patterns, formulae, and motives that certain improvisers use during the course of a solo (Coker, 1970; Reeves, 1995; Baker, 1980). A pattern consists of multiple notes played together that may be transposed into any scale and used in many musical situations. A formula

refers to a short group of notes that are periodically played at certain points of an improvised phrase. Essentially, formulas are a means of negotiating particular chords, chord progressions, or cadences, regardless of the situation. A motive refers to a varied group of notes that is utilized as a compositional development. Motives differ from formulae in that they are not usually associated with any particular chord, chord progression, or cadence (Porter, 1983).

Transcriptions of improvised solos provide the visual outlay of the actual notes played by the improviser and supply the data for the quantitative analyses of patterns, formulae and motives. Transcriptions of many songs are available commercially and are usually the source data for extended explorations involving statistical and mathematical analysis of music.

Musical analysis has been performed using statistical software on a computer. An example of this is the research accomplished by Williams (1982) regarding themes and motives found in Bebop music. Williams developed a computer-aided analytical procedure that involves pattern matching (of specific characteristics), sorting (according to a predefined scale), and calculating (various statistical performance measures). This procedure is used to analyze the melodic style of musical themes found within and between a number of Bebop tunes.

Jazz analysis has also been studied from a mathematical viewpoint. For example, Cohen (1991) has developed a method of expressing jazz harmony in an algebraic context. Through a series of mathematical proofs, Cohen has delineated specific algebraic sets to represent scales, chords, intervals, etc. These isomorphisms are then shown to be useful for analysis purposes in a number of musical examples, primarily regarding the organization of chords in a song.

2.2.2 Analysis of John Coltrane and *Giant Steps*

Many of the qualitative variables (e.g., phrasing, tone, etc.) and quantitative variables (patterns, etc.) mentioned above can be directly or indirectly attributed to an improvisers influences. John Coltrane had a deep, dark, full-bodied tone that may be linked to the influences of Coleman Hawkins, Hershel Evans, and Chu Berry. He had an extremely large range - three whole octaves above the lowest note obtainable on a tenor sax (concert A-flat). His sound was just as clear, full, and unforced at the topmost notes as it was

down at the bottom (Carno, 1959). The intricate phrasing that Coltrane used in his solos may be attributed to influences from Charlie Parker, Johnny Hodges, and Lester Young, as well as Coleman Hawkins and others. The general feeling that Coltrane portrays in his soloing style has been likened most to that of Lester Young and Dexter Gordon. Coltrane himself has also cited Sonny Stitt, Sonny Rollins and Stan Getz as personal favorites. However, Gridley (1997) states that a frequent problem in determining the origin of a player's style is that, when a player names a particular favorite, it is not necessarily the same style that the player copies or even absorbs. "So even if we know a player's likes, we never know for sure whether a player sounds like another player because he copied the other, he has absorbed the same influences used by the other, or he has coincidentally arrived at a similar approach" (Gridley, 1997, p. 227). Thus, analysis of improvisational style with respect to a player's influences leaves much to be desired.

Coltrane's pre-1960's soloing style displayed an infatuation with chord changes and harmonic complexity. Often in his solos, Coltrane would attempt to acknowledge every note in every chord and every scale which might be compatible with a song. He played so fast that notes seemed to cascade from his horn in an unending stream, spawning the term "sheets of sound." Playing with great emotion, Coltrane chose each note he played carefully to fit a melodic idea or to become a critical component of a sweeping run. Because of the technical nature inherent in his soloing style, some listeners likened his style to hearing practice exercises or even just scales. However, transcriptions of Coltrane's improvisation reveal that his "fast runs deviate significantly from the sequence of notes that constitute most scales. And when you listen carefully, you discover that even Coltrane's most scale-like and exercise-like moments have an elusive construction that distinguishes them from practice room routines" (Gridley, 1997, p. 229-230). Hence, an in-depth analysis may find quantitative support for this observation.

John Coltrane's infatuation with chord progressions culminated with his song *Giant Steps*. In this song, the chords move quite frequently and few notes are held in common from one chord to the next. Because of this, there is little time for improvisers to develop melodic ideas on a single chord. To this day, this song is considered a test piece for improvisers (Gridley, 1997; Porter, 1983).

The chart for *Giant Steps* consists of a sixteen-measure chord progression that alternates root movement in thirds with ii-V-I progressions (see figure below). All ii-V motions lead to B, G, or E^b which articulates the augmented chord B-G-E^b. Because the key changes every other measure, Coltrane implemented patterns and formulas that could be transposed to fit each chord. One basic pattern that Coltrane used often in *Giant Steps* involves the

first, second, third, and fifth degree of each key. He played this ascending pattern or the reverse of it while descending from fifth to first scale degree. This particular pattern is labeled "pentatonic" even though there are normally four notes used in each pattern (Porter, 1983). Some other downward (descending) patterns that Coltrane implements (listed as scale degrees) are 5-3-1, 8-5-3, 5-3-1-^{b}7, 8-5-3-1, 9-^{b}7-6-5, and 7-5-3-1. Other upward patterns that he uses include 1-3-5-7, 3-5-8-10, 3-5-7-9, and 5-8-10. Some patterns that move in both directions are 8-1-3-5, 10-5-8-10, 5-6-7-5 and 3-1-2-3. There are numerous other patterns, variations, inversions and arpeggios as well. In addition, there are instances in which Coltrane uses the bebop 7th scale or even plays scales during his solo in *Giant Steps*. He also uses several chord alterations including the ^{b}9th and the augmented 5th over the dominant chord in bar 5 of the chart (Reeves, 1995; Coker, 1970; Cohen 1991).

The chord chart for *Giant Steps* follows. (The Real Book)

Bmaj7 D7 / / / /	Gmaj7 Bb7 / / / /	Ebmaj7 / / / /	A-7 D7 / / / /
Gmaj7 Bb7 / / / /	Ebmaj7 Gb7 / / / /	Bmaj7 / / / /	F-7 Bb7 / / / /
Ebmaj7 / / / /	A-7 D7 / / / /	Gmaj7 / / / /	Db-7 Gb7 / / / /
Bmaj7 / / / /	F-7 Bb7 / / / /	Ebmaj7 / / / /	Db-7 Gb7 / / / /

Regarding rhythm on his solos in *Giant Steps*, John Coltrane primarily played "swung" eighth notes (i.e., notated eighth notes, or duplets, played in a triplet feel with the second note in the duplet accented). There are many phrases composed entirely of continuous eighth notes with an occasional eighth note triplet used for variety. Coltrane also created rhythmic variety by beginning phrases on off-beats, such as after an eighth rest on the first beat of a measure (Porter, 1983).

2.3 Style and Creativity in Improvisation

From the literature review, there are neither adequate definitions, models nor measures of style and creativity in the jazz domain. The Markovian modeling approach may be an initial procedure in developing operational and quantitative measures of these facets of jazz improvisation.

2.3.1 Determination and Assessment of Style and Creativity

Musicologist Leonard Meyer (1989) has defined style as the "replication or patterning, whether in human behavior or in the artifacts of human behavior, that results from a series of choices made within some set of constraints" (p. 3). Unfortunately, this definition, as well as most other definitions of style, are so vague that they are essentially useless. In concordance, Cope (1991) has stated that "empirical definitions of style seem not to exist" (p. 27). In fact, the concept of style may be too broad to classify because of the large diversity of style and definitions of style that exist and have existed throughout the history of music.

Yet, it is possible to describe musical style in terms of a model. In much of the literature regarding the cognitive psychology of music, style is considered to be function of a person's own mental representation of music. Models of this type of theoretical representation have been made, the most well-known and widely-accepted being Lerdahl and Jackendoff's (1983) generative theory of tonal music (hereafter, GTTM). Essentially, the GTTM describes the hierarchical patterns, relationships, and dependencies implicit in the perception and mental representation of music. However, there is a large body of research that supports the proposition that people trained in music construct different cognitive representations of music than those not trained in music (Bamberger and Brofsky, 1988; Handel, 1989; Duke, 1994; Debellis, 1995; and many others) [There are

many theories, models and discussions in the literature on music and cognition that, unfortunately, cannot be covered here because they are beyond the scope of this thesis.]

Connected to the theories of music cognition, there has been a plethora of approaches to musical style analysis applied to the classical (traditional) music genre. Besides numerous ad hoc approaches, some examples of this include: Schenkerian Analysis, Forte's set theory, the semiotic approaches of Ruwet and Nattiez, and the systems of such theorists as Riemann, Reti, Keller and LaRue. (Debellis, 1995) [Surveys of these analytical systems can be found in Bent (1987) and Cook (1987).] However, like the theories and models of music cognition, "classical music analysis provides a static model of structure, but... [gives] little insight into musical *style*" (Cope, 1989, p. 28).

Thus, the utilization of a more explicit description of musical style is useful in most cases to simplify the procedures involved in the analysis of style. A more functional description characterizes musical style as a list of elements or attributes (e.g., rhythm, feel, sound, etc.) that are combined in some unique fashion (Winter, 1992). Following that description, the term 'style analysis' can be defined as the "identifications and investigation of all dimensions and features of musical selections, including harmony, rhythm, melody, timbre, and form and their combined affects" (Heen, 1981, p. 1). Heen presents a framework of style constructs (or dimensions and features) that may be a good starting point for style analysis (see Appendix C for Heen's model).

The definition and analysis of creativity face similar dilemmas to that of defining and analyzing style. General definitions of creativity provide no useful information. In addition, there are many models of creativity that, for the most part, consist of simply a list of components, factors, properties, or variables used to describe the phenomenon of creativity. Some examples of these are listed in the two paragraphs below.

Jackson and Messick (1965) have proposed four properties of creative products: unusualness (novelty), appropriateness, transformation, and condensation (Jackson and Messick, 1965; Dacey, 1989; Brown, 1989; Glover, Ronning, and Reynolds, 1989). Eysenck (1994) has suggested a possible set of cognitive variables (including intelligence, knowledge, technical skills, and special talents), personality variables (including politico-religious factors, cultural factors, socioeconomic factors, and educational factors), and environmental variables (including internal motivation, confidence, non-conformity, and an inherent creativity trait) that are likely to interact in a multiplicative fashion to produce creative products and achievements. The properties and variables mentioned in the lists above appear to be beneficial for evaluating creativity in a general sense but they do not

seem to be specific enough to be applicable to jazz improvisation. However, the following model appears to be better suited for the analysis of creativity in jazz improvisation.

Based on Guilford's (1967) structure-of-intellect (SOI) model, Glover (1980) delineated four components of creative behavior: "fluency (the number of ideas a person produces), flexibility (the number of different kinds of ideas a person develops), elaboration (the extent to which a person fills out his or her ideas), and originality (the uncommonness or statistical infrequency of a person's ideas)" (p. 11). Yet, Glover believes that the extent to which, for example, a piece of music possesses these characteristics cannot be determined directly, nor can it be compared directly to another creative work of art or science. "In other words, although the factors necessary for creativity can be specified, the exact creativity of any particular work can not be measured" (p.11). Glover argues that only relative assessments of creativity can be made mainly because the judgment of creativity is based on subjective individual and societal opinions.

A number of tests for general creativity exist including the Unusual Uses, Consequences B, Thematic Apperception, and Word Rearrangement test to name a few (Eysenck, 1994). These general creativity tests have yet to demonstrate their predictive value (Hopkins, Stanley, and Hopkins, 1990). In fact, their predictive validity tends to be low and many creativity tests do not correlate highly with each other (Hoepfner, 1967; Anastasi, 1988; Thorndike, 1963b). According to Barron and Harrington (1981), it is evident that creativity is *domain specific.*

As one defining aspect of creativity, divergent thinking - the ability to produce multiple solutions to a given problem - is assumed to result from expert skill, thereby suggesting that it may function as a domain-specific skill (e.g., skill in jazz improvisation) (Guilford, 1967; Gustafson and Mumford, 1997). Building on this idea, Jay and Perkins (1997) have suggested that expertise "is not merely an extensive bank of content knowledge but also a more highly organized set of...schemata that allow for rapid, recognition-like orientation to the 'deep structure' of a problem" (p. 10). An example of this could be the expertise with which John Coltrane navigates through the difficult chord changes developed in *Giant Steps*. In contrast to Glover's beliefs mentioned above, it seems that by delimiting the analysis of creativity to specific domains, the development of creativity measures might become easier. However, there are very few domain-specific measures of creativity.

Thus, there is a void in the literature regarding style and creativity, especially in the area of jazz improvisation (Sawyer, 1992). Although much has been written on the social factors, personalities, events and recordings of jazz, little has been written on the style analysis of jazz. The level of knowledge about jazz does not equal that of other musical genres, leading to an "absence of problem solving methods for style analysis within the jazz literature" (Heen, 1981, p.2). Similar conclusions arise concerning creativity. The variables pertaining to creativity have not been operationally defined for domain-specific tasks such as jazz improvisation and tests of creativity do not have any specific correlation with measurements of creativity in jazz improvisation. To make matters more convoluted, the method by which a person creates something could be considered part of their style. For example, the way that John Coltrane creates his solo in Giant Steps is a manifestation of his personal style. Therefore, creativity and style, in some respects, may be quite interrelated, and thus may represent an all-encompassing cognitive style, or a holistic way of thinking (Gustafson and Mumford, 1997).

Fortunately, some progress in style analysis has been made using statistics and computers. Bowles (1970, p. 19) wrote that the use of statistics and computers should result in "a more systematic and objective approach to the analysis of musical style, or content. The computer forces more rigor on the workdays of the scholar, at the same time providing the means for larger and thus more reliable data sampling... computerized content analysis will lead slowly to a more satisfactory answer as to what *style* really is, at least in its quantitative sense." In accord with Bowles, Cope (1991) has stated that, for any musical work that can be represented as pitches and durations in computer code, the style of that work can be statistically analyzed and/or replicated. Substantial statistical style analysis has only been feasible for the past few years due to the increased memory size and improvements in calculation speed of modern computers.

Gabura (1965), LaRue (1967) and Forte (1967) were some of the first to analyze classical music styles with computers. For example, LaRue found low pattern redundancy rates in the music of Joseph Haydn and Gabura discovered that Haydn's harmonies move faster than those employed by Beethoven and Mozart. More recently, Levitt (1984), Ames (1992), Cope (1991) and Kirschen (1989) have developed computer programs primarily used for the composition of music that attempt to imitate particular musical styles. For example, Kirschen's Music Creator software can develop new songs based on the combinations of several different styles of music such as that of Bach and a contemporary

rock-n-roll group. A relevant example to this research is Fry's "Flavors Band" program (1984), which has been used for creating computer improvisations on John Coltrane's *Giant Steps.* The problem with Fry's program is that it implements its own "rules" of improvisation and does not model John Coltrane's particular soloing style.

In sum, a review of the literature indicates that there are neither models nor analysis techniques of style and creativity that effectively measure jazz improvisation. Granted, style and creativity may be judged differently in reference to the level of musical knowledge or the biases of the listener. However, "without a group of peers to evaluate and confirm [style and creativity], it is impossible to differentiate what is creative from what is statistically improbable or bizarre" and what is an element of a person's style from what is not (Csikszentmihalyi, 1988-a, p.235). Thus, there is a need for research in the area concerning the qualitative and quantitative assessment of style and creativity in jazz improvisation.

2.3.2 Measures of Style and Creativity

The question remains: Can style and/or creativity be quantified so that measurement of them is possible? Musical analysis has yielded some qualitative assessments of style including phrasing, tone, general feeling, experience, emotion, and the improviser's influences. Quantitative measures, especially in the domain of jazz music, are lacking though. By defining particular patterns that improvisers use, researchers have begun the work towards developing quantitative measures of style in jazz.

A similar discovery was made regarding creativity. Qualitative measures prevail, and quantitative measures are scarce. Almost all of the measurement systems for creativity found in the literature attempt to define general measures of creativity that can be applied across multiple disciplines. For instance, the measurement systems try to encompass innovations in art and music together with innovations in science and mathematics to produce all-inclusive measures of creativity. This leads to abstract measures that rarely provide any solid quantitative data within one domain of creative contribution.

In general, the literature has revealed many questions regarding the statistical analysis of style and creativity in jazz improvisation, yet no answers or proposed methodologies for answering the questions have been provided. In addition, domain specific measures concerning jazz improvisation have not been developed nor have methods for quantitative comparison of style and creativity. Thus, there is a need for research in the development of a measurement system for creativity and style in jazz improvisation. Domain specific quantitative measurement systems for style and creativity may benefit other fields where these attributes are studied. Used not only for the arts, these measurement systems may be applied to business, engineering and other fields as a new assessment tools for use by the management systems engineer or business consultant.

Chapter 3 : Methodology

Before developing and analyzing any Markov chains, several assumptions are necessary to facilitate the modeling approach. These assumptions delimit the scope of this thesis and simplify the modeling techniques used in the subsequent chapter. Following the assumptions, the selection of music (*Giant Steps*) is discussed regarding the reasons it was chosen as the data for this application. The software developed for the creation of the Markov chains is then discussed. Finally, an explanation of the procedure for the specific modeling and analysis approach used is given.

3.1 Assumptions

Assumption 1. It is assumed in this research that only monophonic musical instruments (e.g., saxophone, trumpet, etc.) are to be modeled using Markov chains. This means that, at any point in time, the system modeled by Markov chains can only occupy one state (i.e., have only one pitch value). This model is not intended to be generalized to include analysis of improvisation from polyphonic instruments (e.g., piano, guitar, etc.).

Assumption 2. In the analysis, pitch is the only variable modeled with the Markov chains. Thus, other variables of sound quality (including timbre, dynamics, etc.) are not analyzed. Regarding rhythmic values, only eighth notes are used. All phrases that do not consist entirely of eighth notes in the data sets are transformed into all eighth note phrases retaining as many of the pitch values as possible. For example, an eighth note triplet of three different pitches is transformed into two eighth notes retaining the pitches used in the first and third notes found in the triplet. When sixteenth notes appear in the solos, a singular eighth note replaces a pair of sixteenth notes with the eighth note taking on the pitch of the first note of the sixteenth note pair. The same logic is applied to thirty-second notes for which an eighth note replaces four notes and takes on the pitch of the first note. In addition, grace notes are not represented in this analysis. Rests that are valued at eighth note length or longer are transformed into all eighth note rests. For example, a half note rest is equal to four eighth note rests. Similar logic is applied to notes held longer than an eighth note. For example, a quarter note is modeled as an eighth note followed by a eighth rest.

This assumption is used because it simplifies the modeling process and is argued to be valid because the majority of phrases found in the solos of John Coltrane on *Giant Steps* consist of eighth notes. Table 3.1 below displays this observation.

Methodology for creating Table 3.1: Giant Steps is in common time (4 / 4), consists of 16 measures, and thus has 128 distinct eighth note beats (16 measures * 4 quarter notes per measure * 2 eighth notes per quarter note). Each 16 measure solo is broken down into 32 half-measures and each half-measure consists of a 4-note phrase. Only 4-note phrases with all eighth notes are counted in the "All 8th notes played". If even one grace note, triplet, or note of greater or lesser value (in terms of time) is in a 4-note phrase, those phrases are not considered in the "All 8th notes played" term. The "Total possible" term is simply the "# of times thru changes" multiplied by 32. This represents the total number of all 8th note 4-note phrases possible in each take of the song.

Table 3.1 Calculations for the Percentage of 4-note Phrases with All Eighth Notes

Solo #	# times thru changes	All 8th notes played	Total possible	Percentage
1	13	364	416	87.5%
2	10	272	320	85.0%
3	12	329	384	85.7%
4	8	230	252	91.3%
5	2	57	64	89.1%
6	9	247	288	85.8%
7	13	358	416	86.1%
8	13	368	416	88.5%
9	16	467	512	91.2%
GS	42	1199	1344	89.2%
GSAV	54	1493	1724	86.6%
Total	96	2692	3068	**87.7%**

The chart above shows that 4-note phrases of exclusively eighth notes makes up **87.7%** of the data analyzed. Because this percentage is so high, it is argued that the "all eighth notes"

assumption involved in this modeling technique is reasonable for this particular data set. It should be noted that other data sets may not have this high of a percentage. Thus, this assumption of using all eighth notes may not be generalizable to all data sets of improvised jazz solos.

Assumption 3. There is also an assumption related to the transcriptions used as the data sets for this research. "It is inevitable that the prejudices of the transcriber and the kinds of analysis being attempted will to some degree be reflected in the transcriptions, and so in turn bias the interpretation." (Dean, 1992, p. 198) While acknowledging the possible prejudices of the transcriber and the biases inherent in his interpretation, the assumption is maintained that Andrew White's transcriptions are accurate.

Assumption 4. Another assumption that is made concerns the different versions of *Giant Steps*. John Coltrane played the two versions, *Giant Steps* and *Giant Steps (Alternate Version)*, at different tempos. *Giant Steps* was recorded at a tempo of 276 beats per minute, whereas *Giant Steps (Alternate Version)* was recorded at a tempo of 253 beats per minute. Despite this difference in tempo, the solos from both of these versions of *Giant Steps* are assumed to be part of the same data set and are used together in the development of the Markov chains.

3.2 Music Selection (Data)

To develop the ideas and propositions for this thesis, the selection of a musician and a piece of music to provide the data is necessary. As stated in Section 1.4 entitled "Data Sets", transcriptions of improvised solos from John Coltrane on his song *Giant Steps* are the basic data used to develop the Markov chains in the subsequent chapter. These data sets are chosen primarily because of their highly homogeneous rhythmic nature (See Assumption 2 above) as well as the additional reasons stated in Section 1.4.

A listing of the data sets is shown below in Table 3.2. There are nine studio takes of the song *Giant Steps* recorded by John Coltrane. Transcriptions of the solos Coltrane played were purchased from Andrew's Musical Enterprises, Inc.

Table 3.2. Data Sets Used for Analysis

Solo #	Transcription #	Description	Disc / Track #
1	86	Giant Steps - Original Version	2 / 7
2	278	Giant Steps (Alternate Version)	1 / 9
3	545	GSAV Take #1 - incomplete	7 / 1
4	546	GSAV Take #3 - incomplete	7 / 3
5	547	GSAV Take #4 - incomplete	7 / 4
6	548	GSAV Take #5 - alternate	7 / 5
7	549	GSAV Take #7 - incomplete	7 / 7
8	556	GS Take #3 - incomplete	7 / 21
9	557	GS Take #6 - alternate	7 / 22

Notes:

1) The Transcription # refers to Andrew White's transcription numbering system
2) GSAV = Giant Steps (Alternate Version)
3) The Disc and Track Numbers refer to those found in *The Heavyweight Champion : The Complete Atlantic Recordings*. (Atlantic R2 71984)

The chord structure of *Giant Steps* (based on the song chart displayed in Section 2.2.2) is shown in Table 3.4 below. A count and examination of the chords used in the song is used to identify similarities and to enable comparisons to be made later in the Markovian analysis.

Table 3.3. Chord Delineation in *Giant Steps*

Chord Name	Chord Type	Beats where chord occurs in song
A-7	minor 7	25 - 28
A-7	minor 7	73 - 76
Bb7	Dominant	13 - 16
Bb7	Dominant	37 - 40
Bb7	Dominant	61 - 64
Bb7	Dominant	109 - 112
Bmaj7	Major 7	1 - 4
Bmaj7	Major 7	49 - 52
Bmaj7	Major 7	53 - 56
Bmaj7	Major 7	97 - 100
Bmaj7	Major 7	101 - 104
Db-7	minor 7	89 - 92
Db-7	minor 7	121 - 124
D7	Dominant	5 - 8
D7	Dominant	29 - 32
D7	Dominant	77 - 80
Ebmaj7	Major 7	17 - 20
Ebmaj7	Major 7	21 - 24
Ebmaj7	Major 7	41 - 44
Ebmaj7	Major 7	65 - 68
Ebmaj7	Major 7	69 - 72
Ebmaj7	Major 7	113 - 116
Ebmaj7	Major 7	117 - 120
F-7	minor 7	57 - 60
F-7	minor 7	105 - 108
Gb7	Dominant	45 - 48
Gb7	Dominant	93 - 96
Gb7	Dominant	125 - 128
Gmaj7	Major 7	9 - 12
Gmaj7	Major 7	33 - 36
Gmaj7	Major 7	81 - 84
Gmaj7	Major 7	85 - 88

Notes:

1) The 16 measure form of Giant Steps is broken down into 128 eighth-note beats. The "Beats where chord occurs in song" represent the four eighth-note beats corresponding to each chord in the song. In this song, chords are repeated at different times in the 16 measure form. The above chart simply groups similar chords together to display the occurrences of each chord type.

2) Sometimes, a chord is played for eight beats (one full measure). In the above chart, these chords are split into two in order to retain the consistency of the analysis.

This examination of the chords used in the song shows that only three different chord types are employed: Major 7th, minor 7th and Dominant chords. Knowing this, comparisons can be made across different chords of the same chord type.

3.3 Software

Transcriptions of the solos in *Giant Steps* (the data sets) are entered as data into a spreadsheet in Microsoft Excel. A portion of the spreadsheet of this data is shown below. The balance of the data is contained in Appendix A. [Note: In Table 3.4, **GS1*** is solo #1 in Table 3.2 and D7-5, D7-6, D7-7 and D7-8 in Table 3.4 collectively make up the half-measure entitled "D7 (5 to 8)".]

Table 3.4. Example Excel Spreadsheet Containing Note Name Data

	Bmaj7				D7				Gmaj7			
		B				D7				G		
	B - 1	**B - 2**	**B - 3**	**B - 4**	**D7 - 5**	**D7 - 6**	**D7 - 7**	**D7 - 8**	**G - 9**	**G - 10**	**G - 11**	**G - 12**
GS1*	Ab2	F2	Db2	Bb1	E2	F#2	G#2	B2	A2	E2	C#2	G1
2	E3	7	7	7	E3	7	7	D#3	C#3	E2	A2	C#3
3	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
4	7	Ab1	Db2	F2	E2	F#2	G#2	B2	A2	E2	C#2	A1
5	E3	7	7	7	E3	7	7	D#3	C#3	E2	A2	C#3
6	Bb2	Ab2	F2	Db2	E2	F#2	G#2	B2	A2	E2	C#2	A1
7	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
8	C3	7	7	Ab2	D#3	D3	7	B2	7	D3	C#3	E2
9	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	E2	7	A2	C#3
10	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	7	7	7
11	7	7	D#3	7	E3	7	7	C#3	7	D3	C#3	A2
12	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
13	7	E2	Ab2	Db3	E2	F#2	G#2	B2	A2	E2	C#2	A1
GS2*	Ab2	Db3	7	7	E2	G#2	7	7	C#2	E2	7	7
2	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
3	C3	Eb3	C3	D3	7	B2	G#2	E2	A2	B2	C#3	E3
4	7	Db2	F2	Ab2	E2	F#2	G#2	E2	A2	E2	C#2	A1
5	F2	Ab2	Db3	7	E2	G#2	C#3	7	E2	A2	C#3	E3
6	F2	Ab2	7	7	E2	D2	C#2	B1	A1	B1	C#2	E2
7	Db3	E3	Db3	E3	7	D3	B2	E3	C#3	A2	B2	C#3
8	C3	7	C3	7	Ab2	7	7	E2	G#2	E2	7	E2
9	F2	Ab2	Db3	7	E2	G#2	B2	D3	C#3	E2	A2	C#3
10	E3	7	7	7	D3	7	7	C#3	C#3E2	E2	A2	C#3
GS3*	Ab2	Db3	Ab2	E2	7	E2	C#2	E2	C#2	A1	B1	C#2
2	Db3	D3	E3	C#3	D3	7	7	B2	C#3	A2	C#3	C#3
3	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
4	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1
5	7	Ab2	7	Ab2	Db3	F2	G#2	B2	B2	F#2	G#2	B2
6	F2	Ab2	Db3	E2	7	G#2	B2	D3	C#3	7	7	7
7	C3	Eb3	C3	Ab2	C#3	D3	B2	A2	G#2	7	7	7
8	C3	Eb3	C3	Ab2	C#3	E3	B2	D2	C#3	E2	A2	C#3
9	Ab2	F2	Db2	Bb1	E2	F#2	G#2	B2	A2	E2	C#2	A1
10	Db3	Eb3	Db3	D3	7	B2	G#2	E2	A2	B2	C#3	A2
11	Ab2	F2	Db2	Ab1	E2	F#2	G#2	B2	A2	E2	C#2	A1
12	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1

The data in the spreadsheet are then used to create the Markov chains. The flowchart on page 24 below gives the elementary logic required to create a first order Markov chain

using the spreadsheet data (like that found in Table 3.4). This logic is the basis for the code developed in Visual Basic within Microsoft Excel that is used to create Markov chains from the data in the spreadsheets. Based on the logic of the flowchart for first order Markov chains, chains of order two and three are constructed as well. [Note: The "Replace" function is used in Excel to change the note names into numbers (shown in Table 3.5 below), which improves the overall run-time efficiency of the code.]

Table 3.5. Replacement of Note Names with Corresponding Numbers for Use in the Visual Basic Code

7 = Rest = 0	C2 = 12	C3 = 24
C#1 = 1	C#2 = 13	C#3 = 25
Db1 = 1	Db2 = 13	Db3 = 25
D1 = 2	D2 = 14	D3 = 26
*D#1 = 3	D#2 = 15	D#3 = 27
Eb1 = 3	Eb2 = 15	Eb3 = 27
E1 = 4	E2 = 16	E3 = 28
F1 = 5	F2 = 17	F3 = 29
F#1 = 6	F#2 = 18	*F#3 = 30
Gb1 = 6	Gb2 = 18	*Gb3 = 30
G1 = 7	G2 = 19	G3 = 31
G#1 = 8	G#2 = 20	*G#3 = 32
Ab1 = 8	Ab2 = 20	Ab3 = 32
A1 = 9	A2 = 21	A3 = 33
*A#1 = 10	A#2 = 22	
Bb1 = 10	Bb2 = 22	
B1 = 11	B2 = 23	

Notes:

1) * indicates that these note names never occurred in any of the transcriptions. Thus, the number "30" is not found in any data set. In addition, C#1 and A3 are the lower and upper extremes (respectively) to John Coltrane's range of improvised notes in all solos examined here.

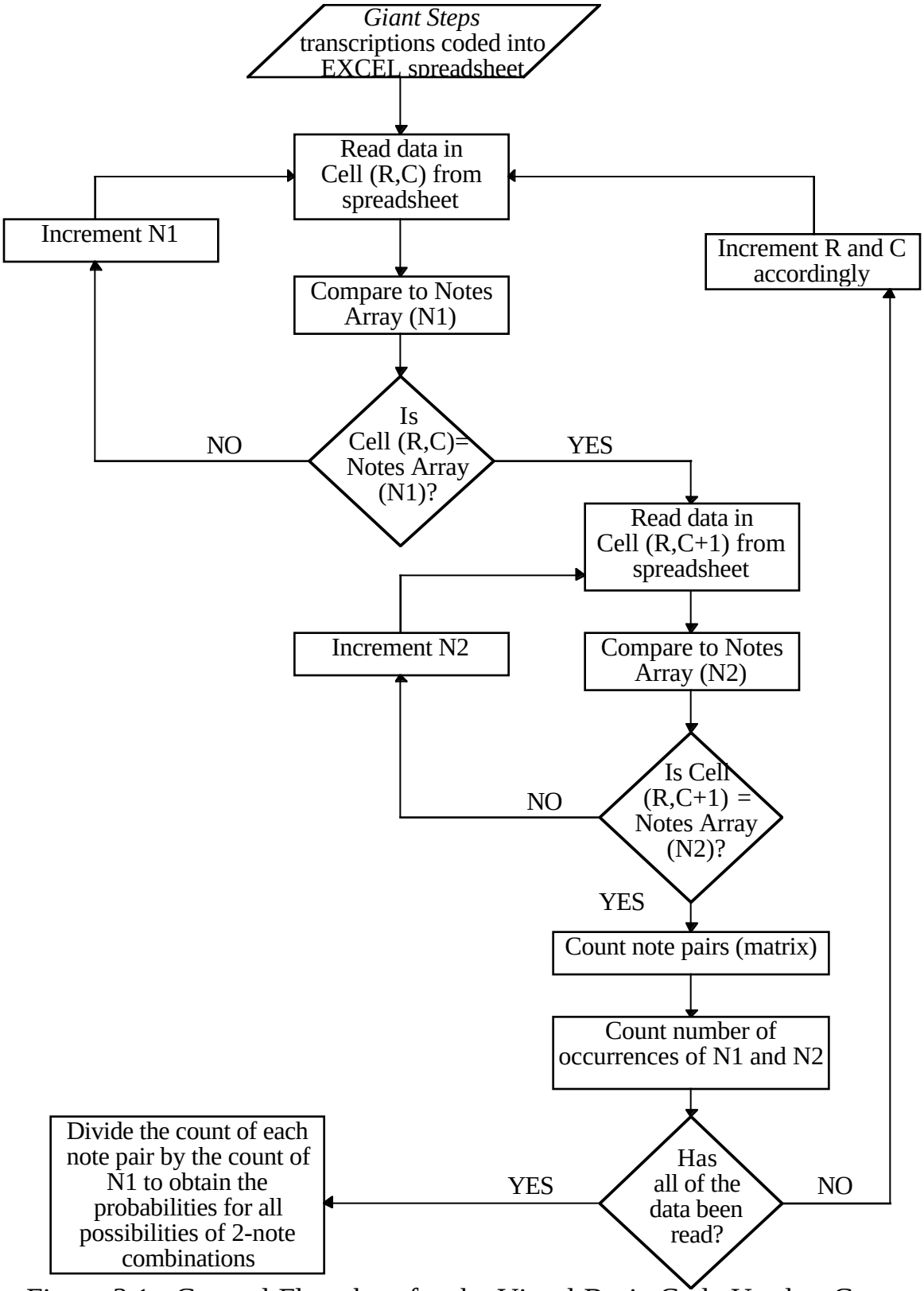

Figure 3.1. General Flowchart for the Visual Basic Code Used to Generate Markov Chains

3.4 Procedure

The procedure for this research can be considered a general methodology for analysis because the logic it follows can be applied to other pieces of music (data sets) that are based on jazz improvisation. Granted that each piece of music may have a different form, chord structure, tempo, musician, improvisational style, etc., and thus may require different preliminary assumptions, a similar procedure to the one described below for developing the Markov chain models and the tools for analysis can yield analogous results for other data sets. In addition, this procedure uses unchanging hard data and thus the conclusions made from the analysis are objective, reliable, and systematic in the fact that the analysis can be entirely reproduced by another researcher if desired.

Implementing the assumptions stated in Section 3.1, the data sets demonstrated in Section 3.2, and the Microsoft Excel Visual Basic software discussed in Section 3.3, Markov chains are created with orders of one to three. First order Markov chains represent the transitions from one note to the next note. Second order Markov chains model the transitions from a two-note pair to another note. Third order Markov chains represent the transitions from a three-note phrase to the next note and enable the enumeration of all possible 4-note patterns.

First, second and third order Markov chains are developed for:

1) all 32 half-measures of the song. Every half-measure has 96 4-note patterns associated with it (because there are 96 runs through the song).

2) all measures that contain only one chord (e.g., the Ebmaj7 chord in the third measure of the song). These chains include 96 8-note patterns in their creation.

3) all of the aggregated data for a single chord. For example: The A-7 chord occurs twice within the song -- at beats 25 to 28 and again at beats 73 to 76. Both sets of 96 4-note patterns associated with these chord occurrences are aggregated to make Markov chains that, in this case, include 192 4-note patterns. NOTE: Each of these Markov chains are explained individually using three different portrayal methods when they are displayed in Section 4.1 below.

Still considered as statistical data, the Markov chains are examined and information is extracted from them through the development of several statistical tools for musical

analysis. There are two general categories of tools for analysis developed here: Subtraction matrices and graphical comparisons of distributions. Subtraction matrices display the differences between two different Markov chains. When the Markov chains of two similar chords are analyzed using this subtraction matrix, the differences between the notes played over each chord becomes apparent. The second analysis tool implemented is a graphical comparison of the distribution of notes played (or states occupied) over particular chords. Many different versions of this tool are explored and explained in detail in Section 4.2 below.

Finally, through the use of these tools for musical analysis and the raw Markov chain data, quantitative measures for creativity and style are postulated. These measures are based on previously developed models and definitions of creativity and style taken from the literature. The information acquired from the implementation of the analysis tools is applied to the models in order to provide a theoretical basis for the development of the quantitative measures and a framework for the interpretation of the information. Guilford's Structure of Intellect model is used for developing creativity measures and Heen's model of the constructs of style analysis is used for determining measures of style.

Chapter 4 : Results and Discussion

Overall, this research found that Markov chains provide distinct and useful information for musical analysis. In the following discussion, many examples of Markov chains are presented. After enumerating the different examples in section 4.1, tools for analysis are developed in the following section that implement these Markov chains. The third section explains how Markov chains and the tools for their analysis can be interpreted to determine quantitative measures of creativity and style.

To anticipate the actual creation of Markov chains, a preliminary analysis of the data that can be used to show the applicability of Markovian modeling techniques is the sorting of the data sets by 4-note patterns. Based on the spreadsheet data set (found in Appendix A), Table 4.1 below demonstrates sorted pattern data that is an example of how John Coltrane played the same 4-note pattern at numerous different instances during his improvisation. In the example below, John Coltrane played the 4-note pattern "Rest - B1 - D2 - A2" fifteen out of ninety-six times over the chord A-7 occurring at beats 25 to 28. Other patterns like "A2 - F#2 - D2 - B1" were played less frequently. In the following section, Markov chains are shown to be useful in that they can model the usage frequencies of these observed patterns and tendencies found in jazz improvisation.

Table 4.1. An Example of Sorted 4-note Pattern Data for the A-7 Chord Occurring at Beats 25 to 28

7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	**B 1**	**D 2**	**A 2**
7	B2	7	A2
7	C#2	D2	A2
7	D2	7	7
7	D2	F#2	A2
7	E2	7	C#3
A2	7	7	F#2
A2	7	7	F#2
A2	7	7	F#2
A2	7	7	F#2
A2	7	7	F#2
A2	7	7	F#2
A2	7	A2	C#3
A 2	**F # 2**	**A 2**	**F # 2**
A 2	**F # 2**	**A 2**	**F # 2**
A 2	**F # 2**	**A 2**	**F # 2**
A 2	**F # 2**	**A 2**	**F # 2**
A 2	**F # 2**	**A 2**	**F # 2**
A 2	**F # 2**	**A 2**	**F # 2**
A2	F#2	D2	B1
A2	F#2	D2	B1
A2	F#2	D2	B1
A2	F#2	D2	B1
A2	F#2	D2	B1
A2	F#2	E2	D2
B1	D2	F#2	C#3
B1	D2	F#2	A2
B1	D2	F#2	A2

4.1 Markov Chains

As described in the procedure in Section 3.4 above, first, second and third order Markov chains are developed for all 32 half-measures. Every half-measure has 96 4-note patterns associated with it (because there are 96 runs through the song). Examples of these first, second and third order Markov chains are depicted in Table 4.2, Table 4.3 and Table 4.4 (respectively). These particular chains are portrayed with specific note names (ex. "Ab2") as the names for the states.

Table 4.2. Example of a First Order Markov Chain for the Chord A-7 Occurring at Beats 25-28 (with Note Names)

	Rest	D1	Ab1	A1	B1	Db2	D2	E2	F2	Gb2	G2	Ab2	A2	Bb2	B2	C3	Db3	D3	Eb3	E3	Total
Rest	0.52	0	0	0	0.1	0.01	0.02	0.01	0	0.08	0	0	0.07	0	0.03	0.02	0.05	0.03	0.03	0.01	87
D1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
B1	0	0.07	0.07	0.14	0	0.07	0.64	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Db2	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0	2
D2	0.04	0	0	0	0.2	0	0	0	0	0.36	0	0	0.36	0	0.04	0	0	0	0	0	25
E2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
F2	0.5	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	2
Gb2	0.1	0	0	0	0.02	0	0.34	0	0	0	0	0	0.46	0.05	0	0	0.02	0	0	0	41
G2	0	0	0	0	0	0	0	0	0.33	0.33	0	0	0.33	0	0	0	0	0	0	0	3
A2	0.26	0	0	0	0	0	0	0	0.03	0.45	0.03	0.16	0	0	0	0.03	0.03	0	0	0	31
Bb2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
B2	0.05	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0	0.05	20
C3	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0.5	4
Db3	0.13	0	0	0	0	0	0.03	0	0	0	0	0	0.13	0.03	0.17	0	0	0.33	0	0.17	30
D3	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0.91	0	0	0	0	0	11
E3	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	10
F3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

The top row represents the next state to be occupied and the left-most column represents the current state. The right-most column displays the total number of occurrences of the state in the left-most column (same row). For example, in Table 4.2 above, a "Rest" occurs 87 times as a state that is occupied before moving into another state. The value "0.52" found in the upper left corner of the matrix means that 52% of the time a "Rest" will follow a "Rest". In other words, of the 87 times that a "Rest" occurs as one of the first three notes in a 4-note phrase, 45 out of 87 times (52%) a "Rest" is followed by another "Rest." [Note: The summation of all probabilities across one row equals "1".]

In the cases of the second and third order Markov chains, the top row represents the next note to be played and the left-most columns represent the current state (consisting of multiple notes).

Table 4.3. Example of a Second Order Markov Chain for the Chord A-7 Occurring at Beats 25-28 (with Note Names)

		Rest	D1	Ab1	A1	B1	Db2	D2	F2	Gb2	G2	Ab2	A2	B2	C3	Db3	D3	Eb3	E3	Total
Rest	Rest	0.61	0	0	0	0	0	0	0	0.16	0	0	0.06	0	0.06	0.03	0.03	0	0.03	31
Rest	B1	0	0.11	0	0	0	0.11	0.78	0	0	0	0	0	0	0	0	0	0	0	9
Rest	Db2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Rest	D2	0.5	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	2
Rest	E2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rest	B2	0.33	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	3
B1	D1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
B1	Db2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
B1	D2	0	0	0	0	0	0	0	0	0.11	0	0	0.89	0	0	0	0	0	0	9
Db2	D2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
D2	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
D2	B1	0	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
D2	Gb2	0	0	0	0	0	0	0	0	0	0	0	0.89	0	0	0.11	0	0	0	9
D2	B2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
E2	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	2
F2	G2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Gb2	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Gb2	B1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Gb2	D2	0	0	0	0	0.42	0	0	0	0.58	0	0	0	0	0	0	0	0	0	12
Gb2	A2	0.33	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	0	9
Gb2	Bb2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
G2	Gb2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
G2	A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
A2	Rest	0.63	0	0	0	0	0	0	0	0.25	0	0	0.13	0	0	0	0	0	0	8
A2	F2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
A2	Gb2	0	0	0	0	0	0	0.4	0	0	0	0	0.6	0	0	0	0	0	0	10
A2	G2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
A2	Db3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Bb2	Rest	0	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0.33	0	0	0	3
B2	Rest	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
B2	A2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5
B2	E3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C3	A2	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	2
C3	E3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Db3	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	4
Db3	D2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Db3	A2	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0.33	0	0	0	3
Db3	Bb2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Db3	B2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5
Db3	D3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10
Db3	E3	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	5
D3	B2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	10
E3	Rest	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0.22	0.33	0	9
E3	D3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
F3	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

In the third order Markov chain below (Table 4.4), 4-note patterns are quite visible. For example, John Coltrane played the three note phrase "Db3 - D3 - B2" 10 times with a probability of playing an "A2" equal to "1". This means that he played the 4-note pattern "Db3 - D3 - B2 - A2" 10 out of 96 times (10.4%) over that particular chord.

Table 4.4. Example of a Third Order Markov Chain for the Chord A-7 Occurring at Beats 25-28 (with Note Names)

			Rest	Ab1	A1	B1	D2	F2	Gb2	Ab2	A2	C3	Db3	D3	Eb3	E3	Total
Rest	Rest	Rest	0.75	0	0	0	0	0	0	0	0	0.13	0.13	0	0	0	8
Rest	B1	D1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Rest	B1	Db2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Rest	B1	D2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Rest	Db2	D2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Rest	D2	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rest	D2	Gb2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Rest	B2	Rest	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Rest	E2	Rest	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
B1	D2	Gb2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Gb2	Rest	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Gb2	B1	D2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Gb2	D2	B1	0	0.33	0.67	0	0	0	0	0	0	0	0	0	0	0	3
Gb2	D2	Gb2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Gb2	A2	Rest	0	0	0	0	0	0	0.67	0	0.33	0	0	0	0	0	3
Gb2	A2	Gb2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Gb2	Bb2	Rest	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
E2	Rest	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F2	G2	A2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
G2	Gb2	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
A2	Rest	Rest	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5
A2	Gb2	D2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
A2	Gb2	A2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
B2	E3	Rest	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
C3	A2	F2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C3	A2	G2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
C3	E3	Rest	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	2
Db3	Rest	Rest	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Db3	Rest	B2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Db3	D2	B2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Db3	A2	Gb2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Db3	A2	Db3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Db3	Bb2	Rest	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Db3	B2	A2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5
Db3	D3	B2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10
Db3	E3	Rest	0.25	0	0	0	0	0	0	0	0	0	0	0.5	0.25	0	4
Db3	E3	D3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
E3	Rest	Rest	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	2
F3	Rest	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	2

There are instances in Giant Steps when one chord occupies an entire measure. That is, one chord lasts for 8 eighth note beats. An example of this is the Ebmaj7 chord that occurs in the third measure of the song. First, second and third order Markov chains are made for these 8-note phrases as well. [These are too large to show in the body of this text, so they are included in Appendix B.]

The next Markov chains are defined using an intervallic relationship naming scheme for the states instead of using note names. Intervals are named according to assumed scales over the given chords: Major scales over major7 chords (Ionian), Dorian scales over minor7 chords, and Mixolydian scales over dominant chords. Comparing Markov chains that use note names as the names of the states can be difficult because, if two different chords are compared, the note names of one chord must be transposed to the other to see the comparison. By changing the naming scheme to interval names, comparisons between different chords can be made more easily because no transposition is necessary. The following table demonstrates how the scale degrees were labeled depending on the type of chord.

Table 4.5. Scale Degree Names of Major, Minor and Dominant Chords

Chromatic #	Major7	Minor7	Dominant
1	1	1	1
2	b9	b9	b9
3	2	2	2
4	#9	3	#9
5	3	b11	3
6	4	4	4
7	#11	#11	#11
8	5	5	5
9	#5	#5	#5
10	6	6	6
11	b7	7	7
12	7	#7	#7

In the first set of three Markov chains below (Tables 4.6 to 4.8), *relative* intervals are used to label the states. That is, states are labeled by intervals *relative* to the octave in which they appear. For example: A state labeled "2_5" stands for the fifth scale degree in the second

octave. The states in next three Markov chains (Tables 4.9 to 4.11) are labeled by *absolute* intervallic names. That is, the states do not carry the octave information, only the strict intervallic relationships. Specifically, all transitions out of 5ths are summed together and all transitions into 4ths from 5ths are summed, regardless of octave. For instance, John Coltrane played an "E2" to a "D2" as well as an "E3" to a "D3" over the same A-7 chord. In the *absolute* interval Markov chains, these two transitions are considered to be equivalent transitions and are added together. In all of the following six Markov chains, combined data from both occurrences of the A-7 chord are used. That is, 192 4-note phrases are analyzed in building these Markov chains. Differences between the two intervallic naming schemes are discussed below.

Table 4.6. Example of a First Order Markov Chain for Both A-7 Chords Combined Using ***Relative*** Intervallic Relationship Names

	Rest	1_4	1_6	1_#7	2_1	2_2	2_b11	2_4	2_5	2_#5	2_6	2_7	2_#7	3_1	3_b9	3_2	3_3	3_b11	3_4	3_#11	3_5	Total
Rest	0.6	0	0	0	0	0.11	0.01	0.02	0.01	0	0.05	0	0	0.07	0	0.03	0.02	0.03	0.02	0.02	0.01	151
1_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
2_1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_2	0	0.02	0.09	0.09	0.26	0	0.02	0.51	0	0	0	0	0	0	0	0	0	0	0	0	0	43
2_b11	0	0	0	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0	0	0	0	3
2_4	0.03	0	0	0	0.02	0.37	0	0	0.02	0	0.22	0	0	0.32	0	0.03	0	0	0	0	0	65
2_5	0.6	0	0	0	0	0	0	0.2	0	0	0	0	0	0.2	0	0	0	0	0	0	0	5
2_#5	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	2
2_6	0.09	0	0	0	0	0.05	0	0.5	0.01	0	0	0	0	0.31	0.02	0.01	0	0.01	0	0	0	88
2_7	0	0	0	0	0	0	0	0	0	0.33	0.33	0	0	0.33	0	0	0	0	0	0	0	3
3_1	0.19	0	0	0	0	0	0	0	0	0.02	0.49	0.02	0.22	0	0	0	0.02	0.05	0	0	0	59
3_b9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
3_2	0.05	0	0	0	0	0	0	0.03	0	0	0	0	0	0.89	0	0	0	0	0	0	0.03	38
3_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0.6	5
3_b11	0.18	0	0	0	0	0	0	0.03	0	0	0	0	0	0.15	0.01	0.19	0	0	0.24	0	0.19	67
3_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0.89	0	0	0	0	0	18
3_5	0.91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0	22
3_#5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

One general observation that can be made regarding these first and second order Markov chains is a trend seen in the note choices that John Coltrane makes. Demonstrated above in Table 4.6 and below in Table 4.7, the probabilities form a diagonal from the upper left corner down to the lower right corner. This indicates that he transitioned to notes that are in a similar range of the note that he just played. Hence, there are very few large intervallic jumps in John Coltrane's improvisation style. Physical limitations of the saxophone may influence this behavior.

Table 4.7. Example of a Second Order Markov Chain for Both A-7 Chords Combined Using ***Relative*** Intervallic Relationship Names

		Rest	1_4	1_6	1_#7	2_1	2_2	2_b11	2_4	2_5	2_#5	2_6	2_7	2_#7	3_1	3_2	3_3	3_b11	3_4	3_#11	3_5	Total
Rest	Rest	0.65	0	0	0	0	0	0.02	0.02	0	0	0.11	0	0	0.07	0.02	0.04	0.02	0.02	0	0.04	54
Rest	2_2	0	0.06	0	0	0	0	0.06	0.88	0	0	0	0	0	0	0	0	0	0	0	0	17
Rest	2_b11	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	2
Rest	2_4	0.5	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	2
Rest	2_5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rest	3_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Rest	3_2	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	4
Rest	3_5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_2	1_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
2_2	2_b11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
2_2	2_4	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0.86	0	0	0	0	0	0	22
2_b11	2_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
2_4	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	2
2_4	2_1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_4	2_2	0	0	0.21	0.21	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
2_4	2_5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
2_4	2_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0.93	0	0	0.07	0	0	0	14
2_4	3_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
2_4	3_2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
2_5	Rest	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	3
2_#5	2_7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
2_6	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
2_6	2_2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
2_6	2_4	0	0	0	0	0.03	0.67	0	0	0.03	0	0.28	0	0	0	0	0	0	0	0	0	36
2_6	2_5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
2_6	3_1	0.33	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	0	12
2_6	3_b9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2_6	3_2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_7	2_6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_7	3_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
3_1	Rest	0.64	0	0	0	0	0	0	0	0	0	0.18	0	0	0.18	0	0	0	0	0	0	11
3_1	2_#5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_1	2_6	0	0	0	0	0	0	0	0.59	0.05	0	0	0	0	0.36	0	0	0	0	0	0	22
3_1	2_7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
3_1	3_b11	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.5	2
3_b9	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0.33	0	0	0	3
3_2	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	2
3_2	2_4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_2	3_1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	13
3_2	3_5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_3	3_1	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	2
3_3	3_5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
3_b11	Rest	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0	12
3_b11	2_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
3_b11	3_1	0	0	0	0	0	0	0	0	0	0	0.89	0	0	0	0	0	0.11	0	0	0	9
3_b11	3_b9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_b11	3_2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	13
3_b11	3_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	16
3_b11	3_5	0.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0	12
3_4	3_1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
3_4	3_2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	16
3_5	Rest	0.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05	0.11	0.16	0	19
3_5	3_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
3_#5	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Table 4.8. Example of a Third Order Markov Chain for Both A-7 Chords Combined Using ***Relative*** Intervallic Relationship Names

			Rest	1_6	1_#7	2_1	2_2	2_4	2_5	2_#5	2_6	2_#7	3_1	3_2	3_3	3_b11	3_4	3_#11	3_5	Total
Rest	Rest	Rest	0.82	0	0	0	0	0	0	0	0	0	0	0	0.09	0.09	0	0	0	11
Rest	Rest	2_b11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Rest	Rest	3_5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rest	2_2	1_4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Rest	2_2	2_b11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Rest	2_2	2_4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	15
Rest	3_2	Rest	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Rest	2_b11	2_4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Rest	2_4	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rest	2_4	2_6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Rest	2_5	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
2_2	2_4	2_6	0	0	0	0	0	0	0	0	0	0	0.67	0	0	0.33	0	0	0	3
2_4	3_1	3_b11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2_5	Rest	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2_#5	2_7	3_1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
2_6	Rest	Rest	0.86	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0	7
2_6	2_2	2_4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
2_6	2_4	2_1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2_6	2_4	2_2	0	0.21	0.21	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	19
2_6	2_4	2_5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
2_6	2_4	2_6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	10
2_6	3_1	Rest	0.25	0	0	0	0	0	0	0	0.5	0	0.25	0	0	0	0	0	0	4
2_6	3_1	2_6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
2_6	3_2	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_b11	3_2	3_1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	13
2_6	3_b9	Rest	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
2_7	2_6	Rest	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_1	Rest	Rest	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6
3_1	Rest	3_1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
3_1	2_6	2_4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
3_1	2_6	2_5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
3_1	2_6	3_1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6
3_2	2_4	Rest	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
3_2	3_5	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
3_3	3_1	2_#5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3_3	3_1	2_7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
3_3	3_5	Rest	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.33	0	3
3_b11	Rest	Rest	0.44	0	0	0	0	0	0	0	0	0	0.44	0.11	0	0	0	0	0	9
3_b11	Rest	3_2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
3_b11	2_4	3_2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
3_b11	3_1	3_b11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
3_b11	3_1	2_6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	8
3_b11	3_b9	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
3_b11	3_4	3_2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	16
3_b11	3_5	Rest	0.64	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0.18	0.09	0	11
3_b11	3_5	3_4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
3_5	Rest	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0	0	4
3_5	3_4	3_1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
3_#5	Rest	Rest	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	2

Table 4.9. Example of a First Order Markov Chain for Both A-7 Chords Combined Using ***Absolute*** Intervallic Relationship Names

	Rest	1	b9	2	3	b11	4	#11	5	#5	6	7	#7	Total
Rest	0.6	0.07	0	0.15	0.02	0.04	0.04	0.02	0.02	0	0.05	0	0	151
1	0.18	0	0	0	0.02	0.05	0	0	0	0.02	0.5	0.02	0.22	60
b9	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2	0.02	0.56	0	0	0	0.01	0.3	0	0.01	0	0.05	0	0.05	81
3	0	0.4	0	0	0	0	0	0	0.6	0	0	0	0	5
b11	0.17	0.14	0.01	0.19	0	0	0.27	0	0.2	0	0.01	0	0	70
4	0.02	0.3	0	0.5	0	0	0	0	0.01	0	0.17	0	0	84
5	0.85	0.04	0	0	0	0	0.11	0	0	0	0	0	0	27
#5	0.75	0	0	0	0	0	0	0	0	0	0	0.25	0	4
6	0.09	0.31	0.02	0.06	0	0.01	0.5	0	0.01	0	0	0	0	88
7	0	0.33	0	0	0	0	0	0	0	0.33	0.33	0	0	3

This type of Markov chain provides an interesting portrayal of intervallic transition relationships which can be very useful for comparison purposes between chords. Because note names are replaced with intervallic names and the octave information is omitted, this matrix provides more general trends of the patternistic playing style of John Coltrane. Examples of second and third order Markov chains using absolute intervallic relationship names are displayed in Tables 4.10 and 4.11 below.

Table 4.10. Example of a Second Order Markov Chain for Both A-7 Chords Combined Using ***Absolute*** Intervallic Relationship Names

		Rest	1	2	3	b11	4	#11	5	#5	6	7	#7	Total
Rest	Rest	0.65	0.07	0.02	0.04	0.04	0.04	0	0.04	0	0.11	0	0	54
Rest	1	0	0	0	0	1	0	0	0	0	0	0	0	1
Rest	2	0.05	0.14	0	0	0.05	0.76	0	0	0	0	0	0	21
Rest	b11	0	0	0	0	0	0.5	0	0.5	0	0	0	0	2
Rest	4	0.5	0	0	0	0	0	0	0	0	0.5	0	0	2
Rest	5	1	0	0	0	0	0	0	0	0	0	0	0	2
1	Rest	0.64	0.18	0	0	0	0	0	0	0	0.18	0	0	11
1	b11	0	0.5	0	0	0	0	0	0.5	0	0	0	0	2
1	#5	1	0	0	0	0	0	0	0	0	0	0	0	1
1	6	0	0.36	0	0	0	0.59	0	0.05	0	0	0	0	22
1	7	0	0	0	0	0	0	0	0	1	0	0	0	1
b9	Rest	0	0.67	0	0	0.33	0	0	0	0	0	0	0	3
2	Rest	0.5	0.5	0	0	0	0	0	0	0	0	0	0	2
2	1	0	0	0	0	0	0	0	0	0	0	0	1	13
2	b11	0	0	0	0	0	0	0	0	0	1	0	0	1
2	4	0.04	0.83	0	0	0	0	0	0	0	0.13	0	0	24
2	5	1	0	0	0	0	0	0	0	0	0	0	0	1
3	1	0	0	0	0	0	0	0	0	0.5	0	0.5	0	2
3	5	1	0	0	0	0	0	0	0	0	0	0	0	3
b11	Rest	0.75	0	0.25	0	0	0	0	0	0	0	0	0	12
b11	1	0	0	0	0	0.11	0	0	0	0	0.89	0	0	9
b11	b9	1	0	0	0	0	0	0	0	0	0	0	0	1
b11	2	0	1	0	0	0	0	0	0	0	0	0	0	13
b11	4	0	0.05	0.95	0	0	0	0	0	0	0	0	0	19
b11	5	0.92	0	0	0	0	0.08	0	0	0	0	0	0	12
4	Rest	0.5	0.5	0	0	0	0	0	0	0	0	0	0	2
4	1	0	0	0	0	0.33	0	0	0	0	0.67	0	0	3
4	2	0	0.78	0	0	0	0	0	0	0	0.11	0	0.11	37
4	5	0	1	0	0	0	0	0	0	0	0	0	0	1
4	6	0	0.93	0	0	0.07	0	0	0	0	0	0	0	14
5	Rest	0.64	0	0	0.05	0.09	0.09	0.14	0	0	0	0	0	22
5	4	0	1	0	0	0	0	0	0	0	0	0	0	2
#5	Rest	1	0	0	0	0	0	0	0	0	0	0	0	2
#5	7	0	1	0	0	0	0	0	0	0	0	0	0	1
6	Rest	1	0	0	0	0	0	0	0	0	0	0	0	8
6	1	0.33	0	0	0	0	0	0	0	0	0.67	0	0	12
6	b9	1	0	0	0	0	0	0	0	0	0	0	0	2
6	2	0.2	0	0	0	0	0.8	0	0	0	0	0	0	5
6	4	0	0.03	0.67	0	0	0	0	0.03	0	0.28	0	0	36
6	5	0	0	0	0	0	1	0	0	0	0	0	0	1
7	1	0	0	0	1	0	0	0	0	0	0	0	0	1
7	6	1	0	0	0	0	0	0	0	0	0	0	0	1

Table 4.11. Example of a Third Order Markov Chain for Both A-7 Chords Combined Using ***Absolute*** Intervallic Relationship Names

			Rest	1	2	3	b11	4	#11	5	#5	6	#7	Total
Rest	Rest	Rest	0.82	0	0	0.09	0.09	0	0	0	0	0	0	11
Rest	Rest	b11	0	0	0	0	0	0	0	1	0	0	0	1
Rest	Rest	5	1	0	0	0	0	0	0	0	0	0	0	1
Rest	2	Rest	0	1	0	0	0	0	0	0	0	0	0	1
Rest	2	b11	0	0	0	0	0	0	0	0	0	1	0	1
Rest	2	4	0	1	0	0	0	0	0	0	0	0	0	16
Rest	b11	4	0	1	0	0	0	0	0	0	0	0	0	1
Rest	4	Rest	1	0	0	0	0	0	0	0	0	0	0	1
Rest	4	6	0	1	0	0	0	0	0	0	0	0	0	1
Rest	5	Rest	0	0	0	0	1	0	0	0	0	0	0	1
1	Rest	Rest	0	0	0	0	0	0	0	0	0	1	0	6
1	Rest	1	0	0	0	0	1	0	0	0	0	0	0	1
1	6	1	0	0	0	0	0	0	0	0	0	1	0	6
1	6	4	0	0	1	0	0	0	0	0	0	0	0	5
1	6	5	0	0	0	0	0	1	0	0	0	0	0	1
2	4	Rest	0	1	0	0	0	0	0	0	0	0	0	1
2	4	6	0	0.67	0	0	0.33	0	0	0	0	0	0	3
2	5	Rest	0	0	0	0	0	0	1	0	0	0	0	1
3	1	#5	1	0	0	0	0	0	0	0	0	0	0	1
3	1	7	0	0	0	0	0	0	0	0	1	0	0	1
3	5	Rest	0.33	0	0	0	0.33	0	0.33	0	0	0	0	3
b11	Rest	Rest	0.44	0.44	0.11	0	0	0	0	0	0	0	0	9
b11	Rest	2	0	1	0	0	0	0	0	0	0	0	0	3
b11	1	b11	0	1	0	0	0	0	0	0	0	0	0	1
b11	1	6	0	0	0	0	0	1	0	0	0	0	0	8
b11	b9	Rest	0	0	0	0	1	0	0	0	0	0	0	1
b11	2	1	0	0	0	0	0	0	0	0	0	0	1	13
b11	4	2	0	1	0	0	0	0	0	0	0	0	0	18
b11	5	Rest	0.64	0	0	0.09	0	0.18	0.09	0	0	0	0	11
b11	5	4	0	1	0	0	0	0	0	0	0	0	0	1
4	1	b11	0	0	0	0	0	0	0	1	0	0	0	1
5	Rest	Rest	0.67	0	0	0.17	0	0.17	0	0	0	0	0	6
5	4	1	0	0	0	0	0	0	0	0	0	1	0	1
#5	Rest	Rest	0.5	0	0	0	0	0	0	0.5	0	0	0	2
#5	7	1	0	0	0	1	0	0	0	0	0	0	0	1
6	Rest	Rest	0.86	0	0	0	0	0.14	0	0	0	0	0	7
6	1	Rest	0.25	0.25	0	0	0	0	0	0	0	0.5	0	4
6	1	6	0	1	0	0	0	0	0	0	0	0	0	2
6	2	Rest	1	0	0	0	0	0	0	0	0	0	0	1
6	2	4	0	1	0	0	0	0	0	0	0	0	0	4
6	b9	Rest	0	1	0	0	0	0	0	0	0	0	0	2
6	4	1	0	0	0	0	0	0	0	0	0	1	0	1
6	4	2	0	0.58	0	0	0	0	0	0	0	0.21	0.21	19
6	4	5	0	1	0	0	0	0	0	0	0	0	0	1
6	4	6	0	1	0	0	0	0	0	0	0	0	0	10
7	6	Rest	1	0	0	0	0	0	0	0	0	0	0	1

The Markov chain that provides the best portrayal of information depends on the output desired. For specific analysis of the actual notes that John Coltrane played during his improvisation over particular chords, the note-named Markov chains should be used. For general analysis purposes, the absolute interval Markov chains provide the best information portrayal technique because they aggregate the data into a very usable format. The relative interval Markov chains provide the same information as the note-named Markov chains, except that they rename the state space as intervals. This renaming allows for comparisons to be made across similar types of chords (e.g., all dominant chords) without having to transpose the note names. Comparisons of this type are performed in the following section entitled Examples of Analysis Tools.

4.2 Examples of Analysis Tools

The information found in the Markov chains created above can be analyzed in numerous ways. These analyses produce many interesting findings that may have been previously unknown without the implementation of this type of Markovian modeling. In this section, several analysis tools and information portrayal techniques are developed in order to present statistical findings that are used to develop a new methodology of quantitative analysis of jazz improvisation.

In the first two sets of analyses, combined chord data (that is, data pulled from all instances of a particular chord) are compared. For example, both occurrences of the A-7 half-measures are aggregated (as in Table 4.9). The chords A-7 and F-7 are compared and the chords D7 and Gb7 are compared. These two specific chord comparisons are made for two primary reasons that justify the comparison. First, each aggregated data set contains the same number of data points for each type of chord. Second, the chords under comparison occur in similar positions within the song structure.

Following these comparisons, analyses are performed on one particular occurrence of a chord (one half-measure of Ebmaj7) in contrast with aggregated data from all seven occurrences of the Ebmaj7 chord (see Table 3.3). Further analyses are performed on data aggregated according to chord type (e.g., all dominant chords are combined). Finally, comparisons and conclusions are made regarding the informational value contained in Markov chains of different orders.

Table 4.12 below demonstrates a simple analysis technique used to compare Markov chains. The matrix values for the first order Markov chain for F-7 are subtracted from the first order Markov chain for A-7. This displays some inherent differences between the note choices over similar types of chords. This analysis yields the following specific findings:

1) The 3rd is played infrequently in both of these chords.

2) The 7th is not played very often either.

3) The #7th is played frequently over the F-7 chord.

4) The b9 is never used in the F-7 chord and is used very rarely (probably as a passing tone) in the A-7 chord.

5) The #11 is used very rarely except as a passing tone to the 4th in F-7.

6) The #5 is played very rarely as well and acts as a passing tone.

Some of these findings are particularly interesting. That the 3rd and 7th are not visited very often suggests that John Coltrane may have played a different scale over these chords than the standard scale assumption of A Dorian and F Dorian. The large number of #7s played in the F-7 chord may occur because Coltrane anticipated the next chord (Bb7) in the song. The #7 of F Dorian is "E", which is the #11 of Bb7. However, the A-7 chord also leads to a dominant chord (D7) and the #7 is not played often in A-7. The passing tones of b9, #11 and #5 are not surprising to find and further help to determine what scales Coltrane uses over these chords. Other interesting findings include the fact that, over the A-7 chord, Coltrane played many more 2nds, 4ths and 6ths than over the F-7. These numbers are **bold** in the subtraction matrix. Coltrane also played less (rested more often) in the F-7 chord.

Table 4.12. Comparison of A-7 and F-7 Combined Chords - First Order Markov Chain

A-7	Rest	1	b9	2	3	b11	4	#11	5	#5	6	7	#7	Total
Rest	0.6	0.07	0	0.15	0.02	0.04	0.04	0.02	0.02	0	0.05	0	0	151
1	0.18	0	0	0	0.02	0.05	0	0	0	0.02	0.5	0.02	0.22	60
b9	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2	0.02	0.56	0	0	0	0.01	0.3	0	0.01	0	0.05	0	0.05	81
3	0	0.4	0	0	0	0	0	0	0.6	0	0	0	0	5
b11	0.17	0.14	0.01	0.19	0	0	0.27	0	0.2	0	0.01	0	0	70
4	0.02	0.3	0	0.5	0	0	0	0	0.01	0	0.17	0	0	84
5	0.85	0.04	0	0	0	0	0.11	0	0	0	0	0	0	27
#5	0.75	0	0	0	0	0	0	0	0	0	0	0.25	0	4
6	0.09	0.31	0.02	0.06	0	0.01	0.5	0	0.01	0	0	0	0	88
7	0	0.33	0	0	0	0	0	0	0	0.33	0.33	0	0	3
F-7	Rest	1		2	3	b11	4	#11	5	#5	6	7	#7	Total
Rest	0.69	0.02		0.01	0.01	0.03	0.01	0	0.07	0	0.13	0	0.04	190
1	0.08	0		0.21	0	0.03	0	0	0.02	0	0.46	0.03	0.16	61
2	0.09	0.66		0	0	0.2	0.03	0	0	0	0	0	0.03	35
3	0	0.33		0	0	0	0.33	0	0	0	0	0	0.33	3
b11	0.11	0.14		0.37	0	0.2	0.17	0	0	0	0	0	0	35
4	0.1	0		0.15	0	0.71	0	0	0.02	0.02	0	0	0	41
#11	0	0		0	0	0	1	0	0	0	0	0	0	24
5	0.16	0		0	0.05	0.02	0.03	0.41	0	0.02	0.03	0.05	0.22	58
#5	0	0		0	0	0	0.5	0	0	0	0	0.5	0	2
6	0.02	0		0.02	0	0	0.11	0	0.02	0	0	0	0.82	45
7	0.55	0.09		0	0	0	0.09	0	0	0.18	0	0	0.09	11
#7	0.31	0.51		0	0	0	0	0	0.01	0	0.15	0.01	0	71
F-7 subtracted from A-7														
	Rest	1		2	3	b11	4	#11	5	#5	6	7	#7	Total
Rest	-0.09	0.05	0	0.14	0.01	0.01	0.03	0.02	-0.05	0	-0.08	0	-0.04	**-39**
1	0.1	0	0	-0.21	0.02	0.02	0	0	-0.02	0.02	0.04	-0.02	0.05	-1
	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2	-0.06	-0.1	0	0	0	-0.19	0.27	0	0.01	0	0.05	0	0.02	**46**
3	0	0.07	0	0	0	0	-0.33	0	0.6	0	0	0	-0.33	2
b11	0.06	0	0.01	-0.19	0	-0.2	0.1	0	0.2	0	0.01	0	0	35
4	-0.07	0.3	0	**0.35**	0	-0.71	0	0	-0.01	-0.02	0.17	0	0	**43**
#11	0	0	0	0	0	0	-1	0	0	0	0	0	0	-24
5	0.7	0.04	0	0	-0.05	-0.02	0.08	-0.41	0	-0.02	-0.03	-0.05	-0.22	-31
#5	0.75	0	0	0	0	0	-0.5	0	0	0	0	-0.25	0	2
6	0.07	**0.31**	0.02	0.03	0	0.01	**0.39**	0	-0.01	0	0	0	-0.82	**43**
7	-0.55	0.24	0	0	0	0	-0.09	0	0	0.15	0.33	0	-0.09	-8
#7	-0.31	-0.51	0	0	0	0	0	0	-0.01	0	-0.15	-0.01	0	**-71**

Besides the exceptions mentioned above in the examination of Table 4.12, the distributions in Figure 4.1 below do resemble each other. This indicates that similar scales may be used over these similar chord types.

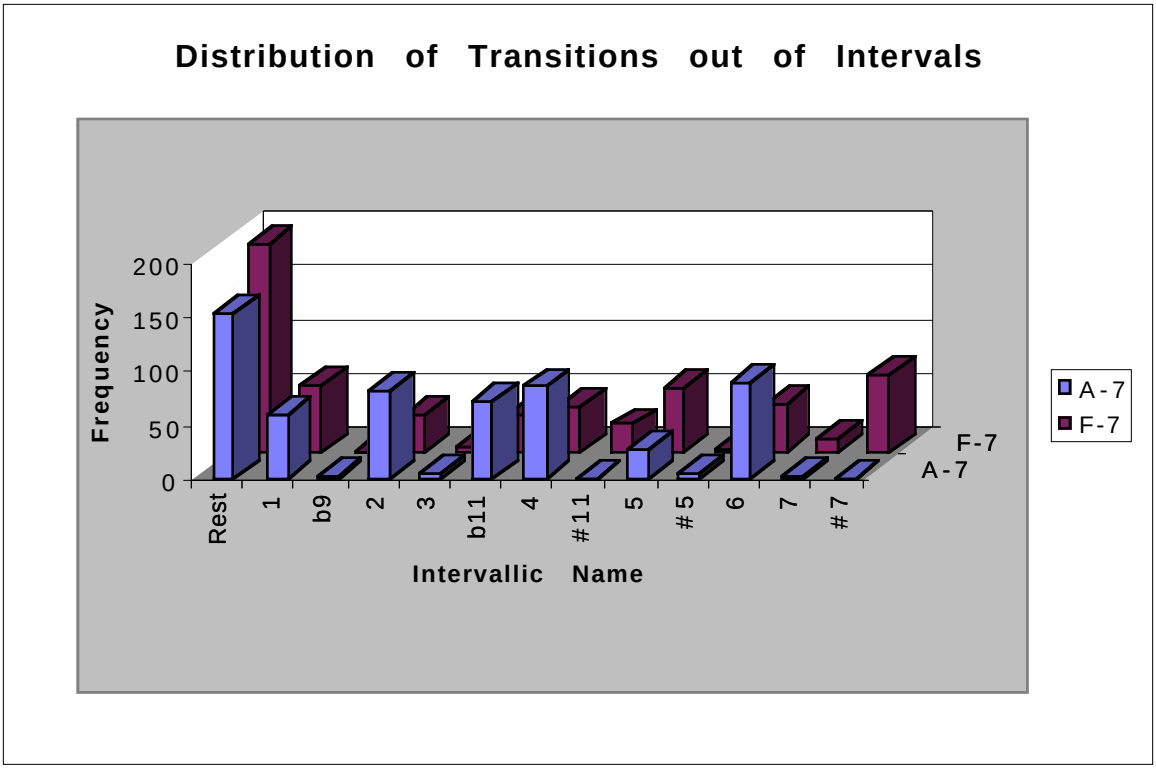

Figure 4.1. Comparison of the State Occupation Distribution of Particular Intervals for A-7 and F-7 Combined Chords

Similarly, the distributions in Figure 4.2 below are obviously quite alike. Yet, a striking difference can be seen in the number of transitions out of "1" to "2" for the F-7 in comparison to the A-7. Regarding Coltrane's patternistic style, this finding seems to indicate that Coltrane uses different intervallic patterns in F-7 that include more transitions from "1" to "2" than in A-7 chords.

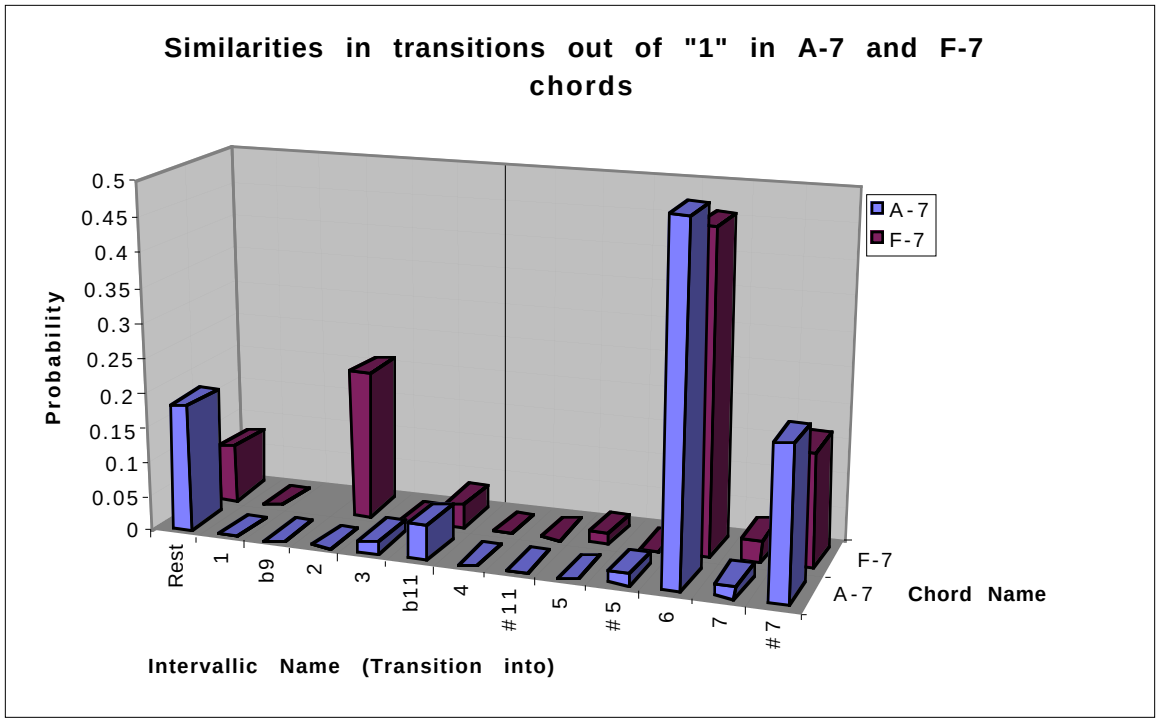

Figure 4.2. Demonstration of the Similarities in State Occupation of the First Scale Degree of the A-7 and F-7 Combined Chords

In the following two figures (Figures 4.3 and 4.4), Markov chains are represented in two different ways. The first representation uses *relative* probabilities. In this case, the probabilities in each row add to "1" and thus the probability for each state is relative only to its row of data in the Markov chain. The second representation is more meaningful in that it displays the *absolute* probabilities -- that is, the entire matrix of probabilities adds up to "1". In this case, the sum of all of the columns equals "1" and every state probability can be compared on an absolute basis against each other. This latter portrayal is better because it exhibits the proportional size of each probability in a manner that is easier to extract information from and is easier to understand.

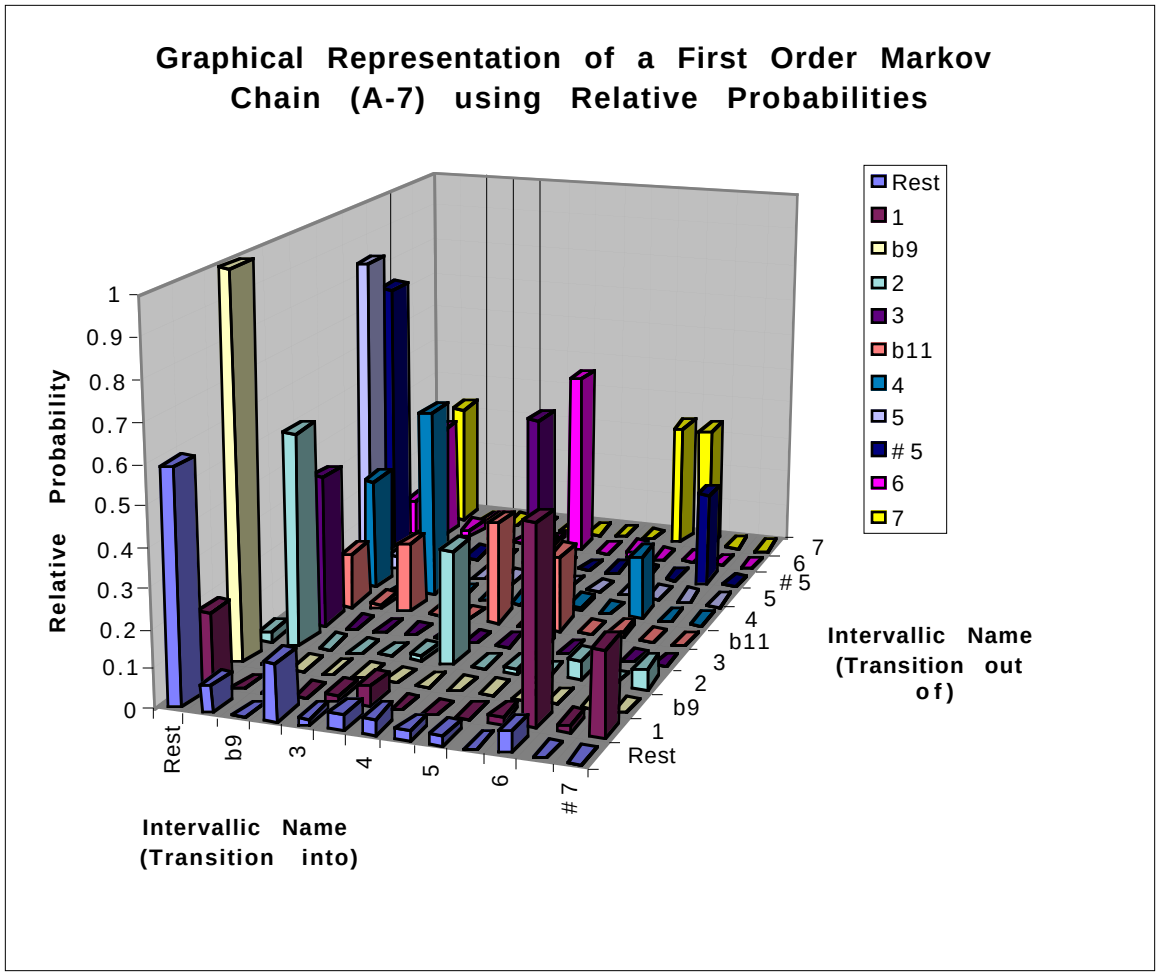

Figure 4.3. Graphical Representation of a First Order Markov Chain using the *relative* probabilities in the A-7 combined chord

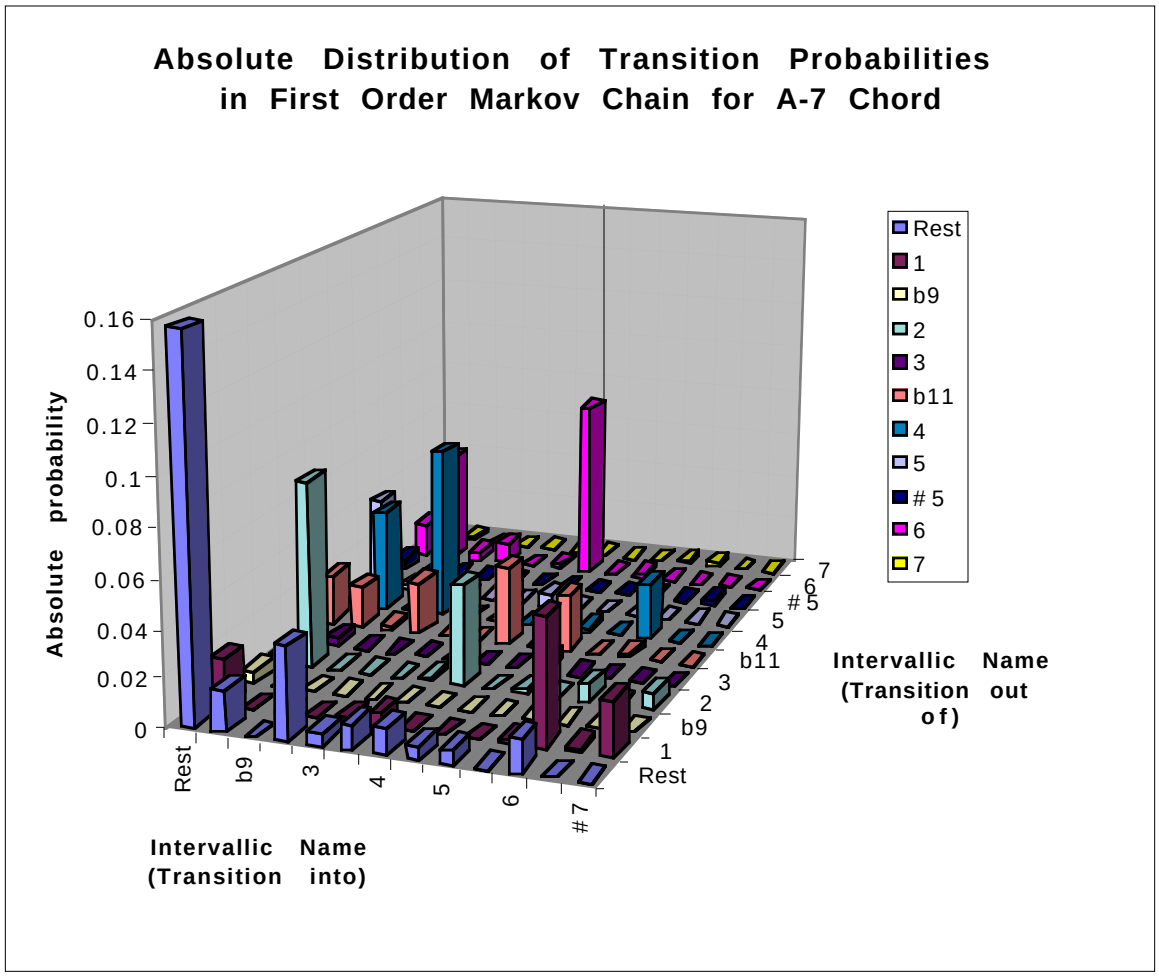

Figure 4.4. Graphical Representation of a First Order Markov Chain using the *absolute* probabilities in the A-7 combined chord

Similar to Table 4.12 (Comparison of A-7 and F-7 combined chords - First Order Markov Chain), Table 4.13 below displays some inherent differences between the note choices used over similar types of chords. The matrix values for the first and second order Markov chains of Gb7 are subtracted from the first and second order Markov chains of D7. This analysis yields the following specific findings:

1) The variety of note choices (states visited) is higher for the D7 chord as opposed to the Gb7 chord.

2) Rests are much more prevalent in the Gb7 Markov chain. This is probably due to the fact that one of the Gb7 chords is the last chord in the song and Coltrane had a habit of not playing through that chord in anticipation of playing on the next chord (which is the beginning of the song's chord structure).

3) Interestingly, the 7th is rarely occupied after another note here, however the 7th starts several 4-note patterns in the D7 chord. This can be seen in the Markov chain because it exists repeatedly (15 out of 288 times) as a first note but very little as a note to be occupied after a previous note.

4) The #11th is frequently visited in the D7 chord, yet never in the Gb7 chord. This can be observed in Figure 4. 5 below. A conclusion from this finding is that Coltrane uses a slightly different scale over the D7 chord as opposed to the Gb7 chord.

5) In both chords, the b9, the 4, and the #5 are not played that often and can be interpreted to be passing tones if they are played at all.

Table 4.13. Comparison of D7 and Gb7 Combined Chords - First Order Markov Chain

D7	Rest	1	b9	2	#9	3	4	#11	5	#5	6	7	#7	Total
Rest	0.54	0.04	0.03	0.12	0.01	0.06	0	0.05	0.01	0.01	0.09	0.01	0.04	181
1	0.37	0	0	0.19	0	0	0	0	0	0	0.19	0	0.26	27
b9	0.25	0.75	0	0	0	0	0	0	0	0	0	0	0	4
2	0.16	0.31	0.01	0.01	0.02	0.37	0	0.04	0.05	0	0.02	0	0.02	153
#9	0	0	0	0.75	0	0	0	0.25	0	0	0	0	0	16
3	0.01	0.07	0	0.3	0.01	0	0.01	0.57	0.01	0	0.01	0	0	96
#11	0.15	0.01	0	0.15	0.13	0.2	0	0	0.03	0	0.32	0	0.01	183
5	0.04	0	0	0	0	0.25	0	0	0	0	0.38	0	0.33	24
#5	0	0.5	0	0	0.5	0	0	0	0	0	0	0	0	2
6	0.19	0.06	0	0.11	0	0	0	0.51	0.03	0.01	0	0	0.09	80
7	0.13	0	0	0	0	0.13	0	0.73	0	0	0	0	0	15
#7	0.3	0.01	0	0.18	0.01	0	0	0	0.02	0	0.47	0	0	83
														864
Gb7	Rest	1	b9	2	#9	3			5	#5	6	7	#7	Total
Rest	0.66	0.02	0	0.16	0	0.04			0.01	0	0.06	0	0.04	482
1	0.05	0	0	0.31	0	0.51			0	0	0.09	0	0.04	78
b9	0.25	0	0	0	0.75	0			0	0	0	0	0	4
2	0.29	0.16	0	0	0	0.54			0	0	0	0	0.01	100
#9	0.5	0	0	0	0	0.25			0	0	0	0	0.25	4
3	0.74	0.04	0	0.18	0.01	0.01			0.02	0	0.01	0	0	108
5	0.75	0	0	0	0	0.13			0	0	0	0	0.13	8
#5	1	0	0	0	0	0			0	0	0	0	0	2
6	0.75	0.05	0	0.03	0	0.1			0.05	0	0.03	0	0	40
#7	0.5	0.03	0.08	0.03	0	0			0.03	0	0.34	0	0	38
														864
Gb7 subtracted from D7														
	Rest	1	b9	2	#9	3	4	#11	5	#5	6	7	#7	Total
Rest	-0.12	0.02	0.03	-0.04	0	0.01	0	0.05	0	0	0.03	0	0.01	**-301**
1	0.32	0	0	-0.12	0	-0.51	0	0	0	0	0.1	0	0.22	-51
b9	0	**0.75**	0	0	**-0.8**	0	0	0	0	0	0	0	0	0
2	-0.13	0.15	0.01	0.01	0.02	-0.17	0	0.04	0.05	0	0.02	0	0.01	53
#9	-0.5	0	0	0.75	0	-0.25	0	0.25	0	0	0	0	-0.25	12
3	**-0.7**	0.04	0	0.13	0	-0.01	0.01	0.57	-0.01	0	0	0	0	-12
#11	0.15	0.01	0	0.15	0.13	0.2	0	0	0.03	0	0.32	0	0.01	**183**
5	-0.71	0	0	0	0	0.13	0	0	0	0	0.38	0	0.21	16
#5	-1	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0
6	-0.56	0.01	0	0.09	0	-0.1	0	0.51	-0.03	0.01	-0.03	0	0.09	40
7	0.13	0	0	0	0	0.13	0	**0.73**	0	0	0	0	0	15
#7	-0.2	-0.01	-0.08	0.15	0.01	0	0	0	-0	0	0.13	0	0	45

Table 4.14. Comparison of D7 and Gb7 Combined Chords - Second Order Markov Chain

		Rest	1	b9	2	#9	3	4	#11	5	#5	6	#7	Total
Rest	Rest	-0.286	0.017	0.089	0.073	0.011	-0.022	0	0.047	-0.009	-0.021	0.038	0.061	-170
Rest	1	0.333	0	0	-0.333	0	0	0	0	0	0	0.333	-0.333	0
Rest	b9	-1	0	0	0	0	0	0	0	0	0	0	0	-1
Rest	2	0.206	0	0	0	0	-0.406	0	0	0	0	0	0.2	-31
Rest	3	-0.333	0	0	0.381	0	0	0	0.286	0	-0.333	0	0	4
Rest	#11	0	0	0	0.4	0	0	0	0	0	0	0.6	0	5
Rest	5	-1	0	0	0	0	0	0	0	0	0	0.5	0.5	1
Rest	#5	-1	0	0	0	0	0	0	0	0	0	0	0	-1
Rest	6	-0.2	0	0	0.1	0	-0.1	0	0.4	-0.2	0	0	0	0
Rest	7	0	0	0	0	0	1	0	0	0	0	0	0	1
Rest	#7	0.083	0	0	-0.111	0	0	0	0	0	-0.222	0.25	0	-5
1	Rest	-0.375	0	0	0	0	0	0	0	0	0.125	0.25	0	5
1	2	-0.13	0	0	0	0	-0.203	0	0	0	0	0.333	0	-20
1	3	-0.55	0	0	-0.375	-0.025	0	0	0	-0.05	0	0	0	-40
1	6	-0.857	0	0	0.25	0	-0.143	0	0.5	0.25	0	0	0	-3
1	#7	0.143	0	0	0	0	0	0	0	0	-1	0.857	0	6
b9	Rest	1	0	0	0	0	0	0	0	0	0	0	0	1
b9	1	0.333	0	0	0.667	0	0	0	0	0	0	0	0	3
b9	#9	-1	0	0	0	0	0	0	0	0	0	0	0	-2
2	Rest	-0.02	0.03	0	0	0	-0.04	0	0.05	0	0	0.05	-0.07	-5
2	1	0	0	0	0	0	0	0	0	0	0	0	0	4
2	b9	0	1	0	0	0	0	0	0	0	0	0	0	2
2	2	0	0	0	0	0	0	0	0	0	0	1	0	1
2	#9	0	0	0	0	0	0	0	1	0	0	0	0	2
2	3	-1	0	0	0	0	0	0.02	0.961	0	0	0.02	0	-2
2	#11	0.667	0	0	0	0	0	0	0	0	0	0.167	0.167	6
2	5	0	0	0	0	0	0	0	0	0	0	0	1	6
2	6	0.333	0.667	0	0	0	0	0	0	0	0	0	0	3
2	#7	-0.5	0	0	0.5	0	0	0	0	0	0	0	0	1
#9	2	0	1	0	0	0	0	0	0	0	0	0	0	12
#9	#11	0	0	0	0	0	0	0	0	0	0	1	0	1
#9	#7	0	0	-1	0	0	0	0	0	0	0	0	0	-1
3	Rest	0.862	0	0	-0.034	0	0	0	0	-0.034	-0.552	0	-0.241	-28
3	1	-0.5	0	0	0	0	0	0	0	0	0	0.5	0	5
3	2	-0.056	0.127	0	0	0	-0.111	0	0	0	0	0	0.04	7
3	#9	0	0	0	0	0	-1	0	0	0	0	0	0	-1
3	4	-1	0	0	0	0	0	0	0	0	0	0	0	-1
3	#11	0.02	0	0	0.04	0.06	0	0	0	0	0	0.88	0	50
3	5	0	0	0	0	0	0	0	0	0	0	0	1	1
#11	Rest	0.846	0	0	0.077	0	0	0	0	0	0	0.077	0	26
#11	1	1	0	0	0	0	0	0	0	0	0	0	0	1
#11	2	0.333	0.5	0	0	0.083	0.083	0	0	0	0	0	0	12
#11	#9	0	0	0	1	0	0	0	0	0	0	0	0	12
#11	3	0	0	0	0.958	0.042	0	0	0	0	0	0	0	24
#11	5	0	0	0	0	0	0	0	0	0	0	1	0	6
#11	6	0.286	0.143	0	0.5	0	0	0	0	0.071	0	0	0	14
#11	#7	1	0	0	0	0	0	0	0	0	0	0	0	2
5	Rest	0	0	0	0	0	0	0	0	0	0	0	0	-4
5	3	0	-0.667	0	0	0	0	0	0.667	0	0	0	0	5
5	6	0.111	0	0	0	0	0	0	0.111	0	0	0	0.778	9
5	#7	1	0	0	0	0	0	0	0	0	-1	0	0	0
#5	Rest	-0.5	0	0	-0.5	0	0	0	0	0	0	0	0	-2
#5	1	1	0	0	0	0	0	0	0	0	0	0	0	1
#5	#9	0	0	0	0	0	0	0	1	0	0	0	0	1
6	Rest	0.235	0	-0.04	-0.115	0	-0.08	0	0	0	0	0	0	-17
6	1	0	0	0	0	0	-1	0	0	0	0	0	0	-2
6	2	0	0	0	0	0.143	0.714	0	0	0.143	0	0	0	7
6	3	0	-0.75	0	-0.25	0	0	0	0	0	0	0	0	-4
6	#11	0.027	0	0	0.351	0.243	0.378	0	0	0	0	0	0	37
6	#5	0	0	0	0	1	0	0	0	0	0	0	0	1
6	6	-1	0	0	0	0	0	0	0	0	0	0	0	-1
7	Rest	1	0	0	0	0	0	0	0	0	0	0	0	2
7	3	0.5	0	0	0.5	0	0	0	0	0	0	0	0	2
7	#11	0	0.091	0	0.636	0	0.273	0	0	0	0	0	0	11
#7	Rest	0.15	0	0	0.033	0	-0.067	0	0	0.05	-0.4	0.25	-0.017	5
#7	1	0	0	0	-1	0	0	0	0	0	0	1	0	0
#7	b9	0	0	0	0	-1	0	0	0	0	0	0	0	-3
#7	2	0.286	0	0	0	0.071	0.143	0	0	0.429	0	0.071	0	14
#7	#9	0	0	0	0	0	0	0	1	0	0	0	0	1
#7	5	0	0	0	0	0	0.5	0	0	0	0	0.5	-1	1
#7	6	-0.7	0.03	0	-0.1	0	-0.2	0	0.97	0	0	0	0	23

Figure 4.5 below is the same type of chart found in Figure 4.1. It demonstrates the differences in the state occupancy distributions for the two chords. This graphically shows that #11s were played in D7 and not in Gb7 and that rests occurred much more frequently in Gb7 than in D7.

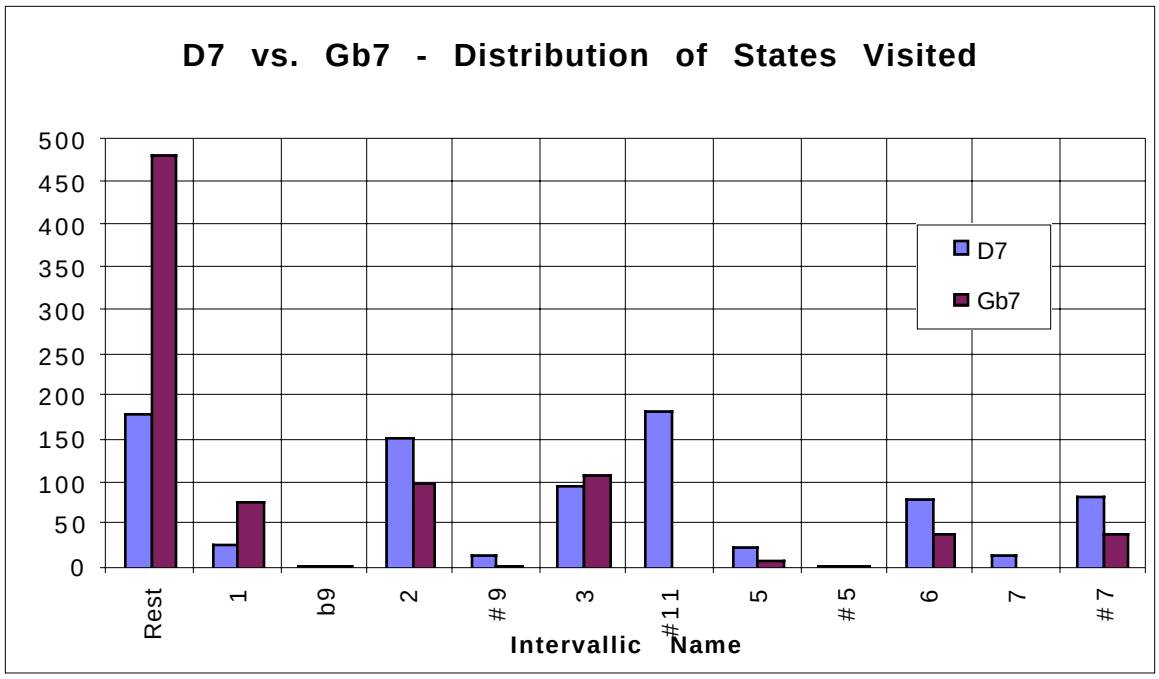

Figure 4.5. Comparison of the State Occupation Distribution of Particular Intervals for D7 and Gb7 Combined Chords

Figure 4.6 demonstrates John Coltrane's tendency to make transitions into scale tones that were in close proximity to note he was currently playing.

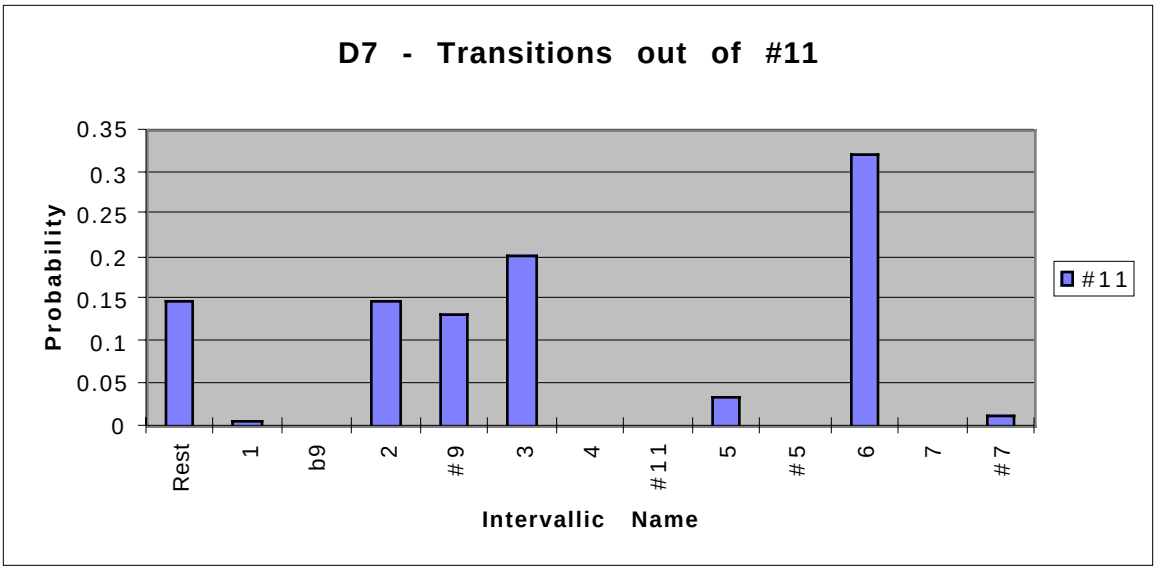

Figure 4.6. Distribution of the Next States Occupied After a #11 for the D7 Combined Chord

Figure 4.7 below demonstrates that, in the D7 chords, Coltrane tended to play either the 2nd or the #11th after playing the 3rd. These intervals are the closest notes to the 3rd in the scale used.

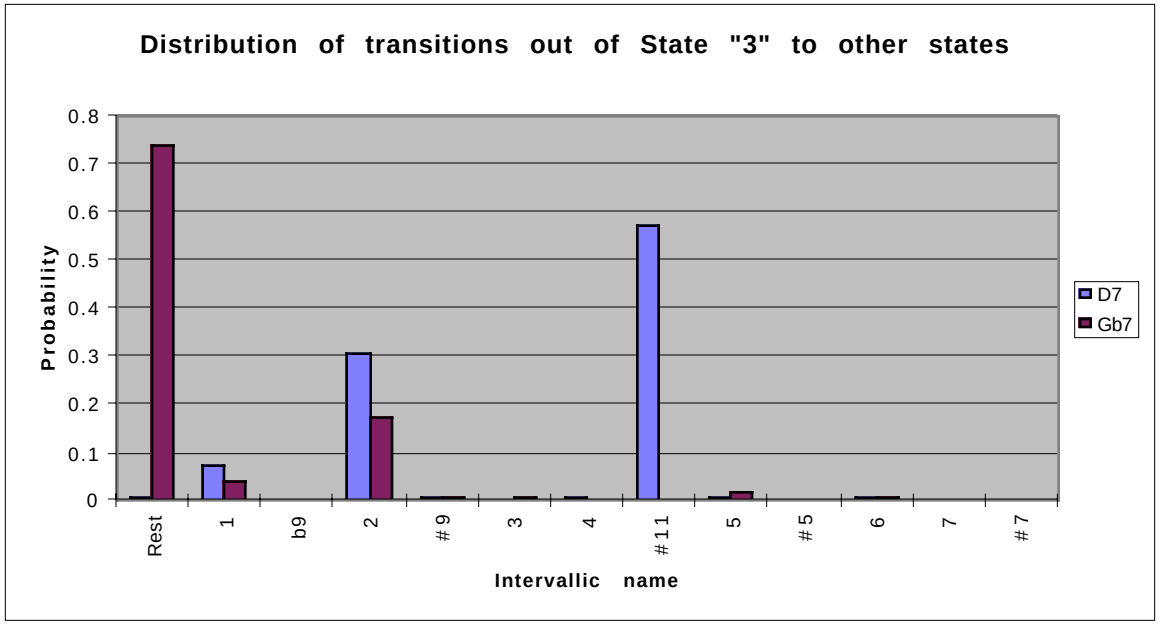

Figure 4.7. Comparison of the Distribution of the Next States Occupied After a 3rd for the D7 and Gb7 Combined Chords

The data below (Table 4.15) exhibits one particular Ebmaj7 chord occurrence to all seven Ebmaj7 chord occurrences in hopes that some relationships may be found. The following two figures provide more detail and, in fact, show the similarities of the part (one Ebmaj7 chord) to the whole (all seven Ebmaj7 chords).

Table 4.15. Comparison of One Ebmaj7 Chord to All Seven Ebmaj7 Chords Combined - First Order Markov Chain

ALL	Rest	1	b9	2	# 9	3	4	# 1 1	5	# 5	6	b7	7	Total
Rest	0.68	0.01	0.02	0.04	0	0.01	0.01	0.07	0.01	0.01	0.1	0.01	0.01	414
1	0	0	0.67	0	0	0	0	0	0.33	0	0	0	0	3
b9	0.09	0	0	0.09	0.01	0.56	0	0.01	0	0	0.01	0	0.24	181
2	0.2	0	0.19	0	0	0.48	0	0.05	0	0.01	0.04	0	0.02	382
# 9	0	0	0	0	0	0	0.33	0	0.33	0	0.33	0	0	3
3	0.14	0	0.07	0.28	0	0	0	0.49	0.01	0	0.01	0	0	292
4	0	0	0	0	0	0	0	0.33	0.67	0	0	0	0	3
# 1 1	0.11	0	0.07	0.21	0	0.15	0	0	0.04	0	0.39	0.01	0	365
5	0	0	0	0	0	0.03	0	0.66	0	0	0.21	0	0.11	38
# 5	0.4	0	0	0	0	0	0	0	0.2	0	0	0	0.4	5
6	0.22	0	0.03	0.04	0	0	0	0.26	0.11	0	0.01	0	0.33	233
b7	0	0	0.75	0	0	0	0	0	0.25	0	0	0	0	4
7	0.05	0	0.8	0.01	0	0.02	0	0.02	0	0	0.1	0	0	93
														2016
ONE	Rest		b9	2		3	4	# 1 1	5	# 5	6	b7	7	Total
Rest	0.79		0.01	0.01		0.01	0.01	0.09	0	0.01	0.01	0.01	0.01	67
b9	0.08		0	0.04		0.64	0	0	0	0	0	0	0.24	25
2	0.21		0.14	0		0.62	0	0.02	0	0	0	0	0	42
3	0.04		0.07	0.31		0.02	0	0.56	0	0	0	0	0	45
# 1 1	0.13		0	0.15		0.26	0	0	0.17	0	0.3	0	0	54
5	0		0	0		0	0	0.33	0	0	0.33	0	0.33	3
6	0.17		0	0.03		0	0	0.37	0.03	0	0	0.03	0.37	35
b7	0		1	0		0	0	0	0	0	0	0	0	1
7	0		0.81	0		0	0	0	0	0	0.19	0	0	16
														288

Figure 4.8 below indicates that the one Ebmaj7 chord analyzed is quite representative of all of the data for the Ebmaj7 chords. This may indicate that one scale is used over all seven Ebmaj7 chords.

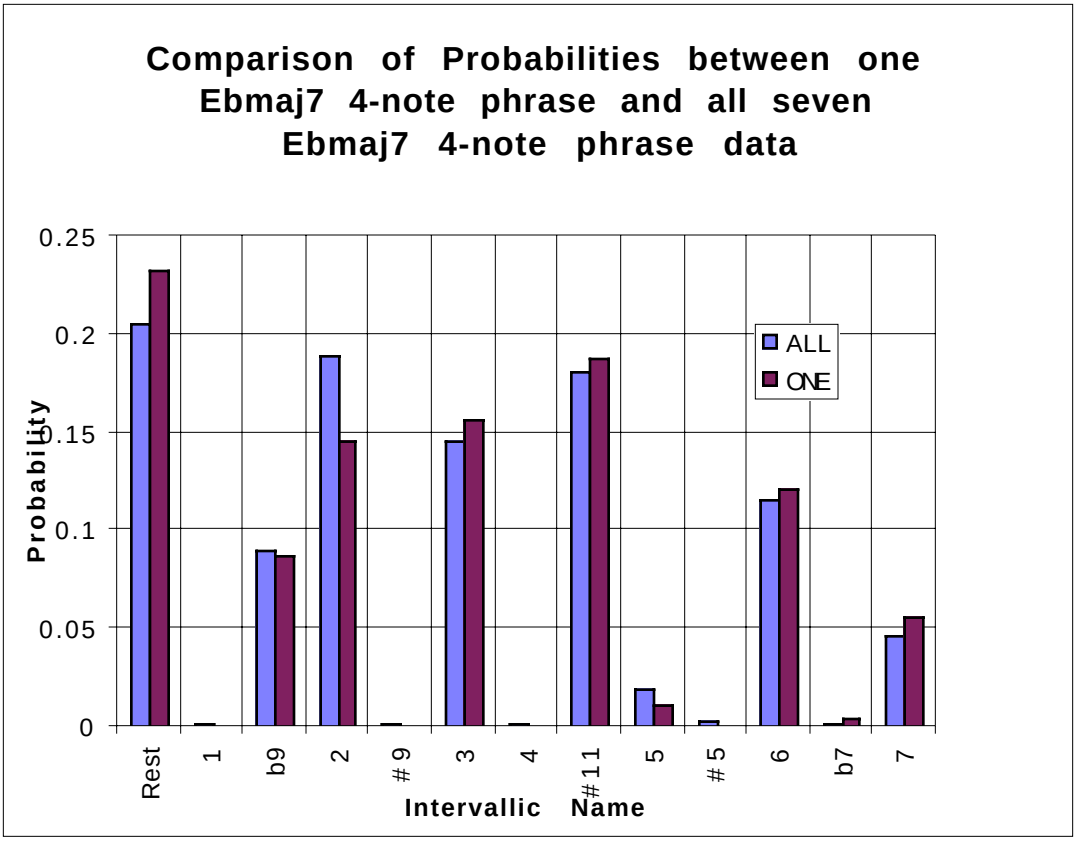

Figure 4.8. Comparison of the State Occupation Distribution of Particular Intervals for One Vs. All Ebmaj7 Combined Chords

Figure 4.9 below furthers the idea that Coltrane plays one distinct scale over all of the Ebmaj7 chords.

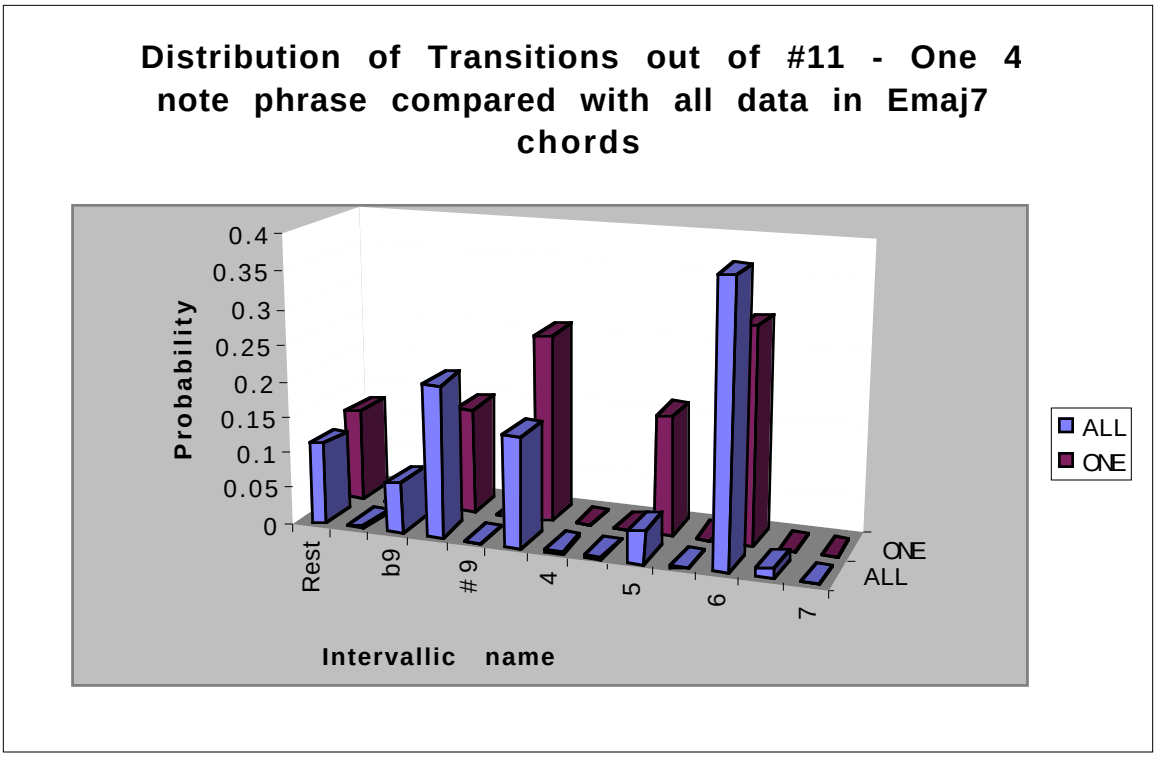

Figure 4.9. Comparison of the Distribution of the Next States Occupied After a #11 for One Vs. All Ebmaj7 Combined Chords

Aggregating the data according to chord type (e.g., all dominant chords combined) can lead to interesting results as well. The differences between interval usage is apparent from the chart below (Figure 4.10). This chart was made using the total probabilities of one-step transitions out of an interval.

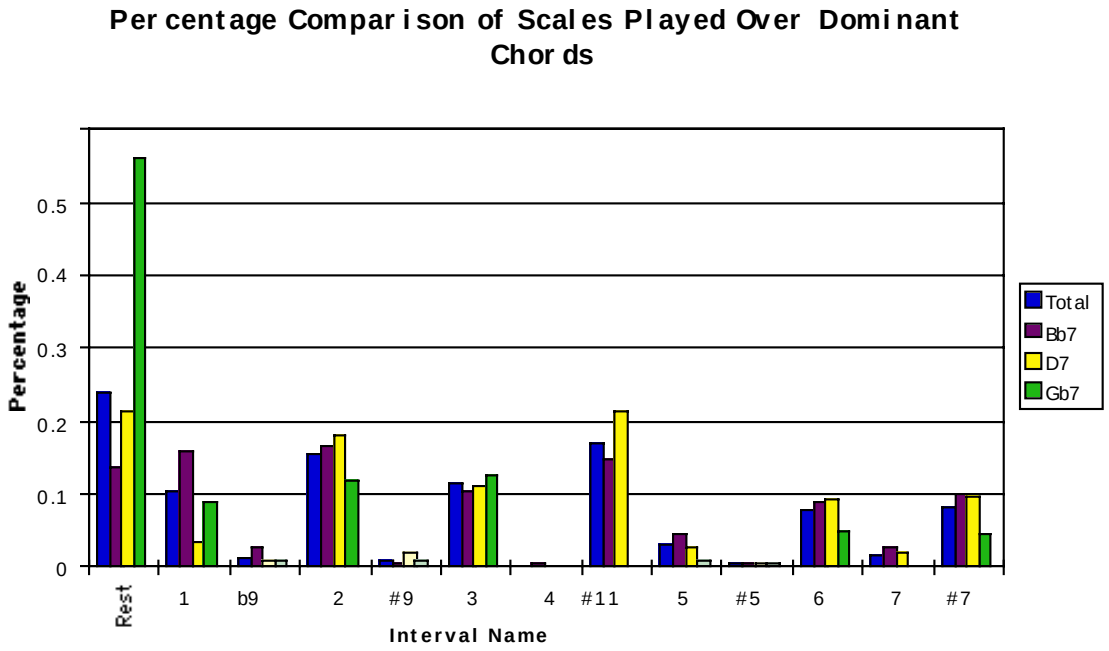

Figure 4.10. Interval Usage over Dominant Chords

Specific comparisons between third order Markov chains provide fascinating discoveries. In the following analysis, third order Markov chains from the chords D7 occurring at beats 5 to 8 (out of 128 total) and D7 occurring at beats 29 to 32 are compared. Although these chords are of the same type (dominant), the Markov chains make evident that the patterns played over these chords are surprisingly different. Between the thirty-two different 3-note phrases of the D7 (5 to 8) chord and the thirty-three different 3-note phrases of the D7 (29 to 32) chord, only **four** are exactly the same. Knowing that, it can be observed from the same data that only **four** 4-note patterns are exactly the same between the two chords. [Multiplied by the probabilities, there are five total occurrences the same pattern - see Table 4.18 below.] This results in a stunning realization: Out of 192 runs through these two similar chords (96 runs * 2 chords), John Coltrane only plays the same 4-note pattern five times! This number seems to be quite small. In addition to this, he plays the pattern "E2 -

F#2 - G#2 - B2" (shown in Table 4.16 below as "2 - 3 - #11 - 6") 42 out of 96 times in the D7 (5 to 8) chord (quite large), yet never once plays it over the D7 (29 to 32) chord.

Table 4.16. Third Order Markov Chain for the D7 (5 to 8) Chord

D7 - 5 to 8			Rest	1	b9	2	#11	5	6	#7	Total
Rest	1	6	0	0	0	1	0	0	0	0	1
Rest	1	#7	0	0	0	0	0	0	1	0	1
Rest	2	#7	0	0	0	1	0	0	0	0	1
Rest	3	#11	0	0	0	0	0	0	1	0	1
Rest	#11	6	0.333	0.333	0	0	0	0.333	0	0	3
Rest	6	#11	0	0	0	1	0	0	0	0	3
Rest	#7	6	0	1	0	0	0	0	0	0	1
1	Rest	Rest	0	0	0	0	0	0	0.5	0.5	2
1	2	3	0	0	0	0	1	0	0	0	2
1	2	6	1	0	0	0	0	0	0	0	1
b9	Rest	Rest	0	0	0	1	0	0	0	0	1
b9	1	Rest	0	0	0	0	0	0	1	0	1
2	Rest	Rest	0.286	0.143	0.429	0	0	0	0	0.143	7
2	Rest	#7	1	0	0	0	0	0	0	0	1
2	1	#7	0	0	0	0	0	0	1	0	5
2	b9	1	0	0	0	1	0	0	0	0	2
2	2	6	0	1	0	0	0	0	0	0	1
2	**3**	**#11**	**0**	**0**	**0**	**0.05**	**0**	**0**	**0.95**	**0**	**44**
2	#11	Rest	1	0	0	0	0	0	0	0	4
2	#11	6	0	1	0	0	0	0	0	0	1
2	#11	#7	1	0	0	0	0	0	0	0	1
2	#7	Rest	0	0	0	1	0	0	0	0	1
#11	Rest	Rest	0	0	0	1	0	0	0	0	2
#11	2	Rest	0	0	0	0	1	0	0	0	1
#11	3	2	0	1	0	0	0	0	0	0	1
#5	1	Rest	1	0	0	0	0	0	0	0	1
7	Rest	Rest	1	0	0	0	0	0	0	0	1
#7	Rest	#7	1	0	0	0	0	0	0	0	1
#7	1	6	0	0	0	0	0	1	0	0	1
#7	2	Rest	0	0	0	0	0	0	1	0	1
#7	2	6	0	1	0	0	0	0	0	0	1
#7	#9	#11	0	0	0	0	0	0	1	0	1

Table 4.17. Third Order Markov Chain for the D7 (29 to 32) Chord

D7 - 29 to 32			Rest	1	b9	2	# 9	3	4	# 1 1	6	# 7	Total
Rest	Rest	Rest	0.833	0	0	0	0	0	0	0	0	0.167	6
Rest	2	3	0	0	0	0	0	0	0.5	0.5	0	0	2
Rest	# 1 1	2	1	0	0	0	0	0	0	0	0	0	1
1	# 7	Rest	1	0	0	0	0	0	0	0	0	0	1
2	Rest	Rest	0	0.333	0.667	0	0	0	0	0	0	0	3
3	1	Rest	1	0	0	0	0	0	0	0	0	0	1
3	1	6	0	0	0	0	0	0	0	1	0	0	1
# 1 1	Rest	Rest	0.2	0	0	0.6	0	0.2	0	0	0	0	5
# 1 1	Rest	2	1	0	0	0	0	0	0	0	0	0	1
# 1 1	Rest	6	1	0	0	0	0	0	0	0	0	0	1
# 1 1	2	3	0	0	0	0	0	0	0	1	0	0	1
# 1 1	# 9	2	0	1	0	0	0	0	0	0	0	0	3
# 1 1	3	2	0	1	0	0	0	0	0	0	0	0	1 3
# 1 1	5	6	0	0	0	0	0	0	0	0	0	1	2
# 1 1	6	Rest	1	0	0	0	0	0	0	0	0	0	2
# 1 1	6	2	0	0	0	0	0.2	0.8	0	0	0	0	5
# 1 1	# 7	Rest	1	0	0	0	0	0	0	0	0	0	1
5	3	1	0	0	0	0	0	0	0	0	1	0	1
6	Rest	Rest	1	0	0	0	0	0	0	0	0	0	1
6	# 5	# 9	0	0	0	0	0	0	0	1	0	0	1
7	Rest	Rest	0	0	0	0	0	0	0	0	0	1	1
7	3	Rest	1	0	0	0	0	0	0	0	0	0	1
7	# 1 1	2	0	1	0	0	0	0	0	0	0	0	2
7	# 1 1	3	0	0	0	1	0	0	0	0	0	0	3
# 7	Rest	Rest	0	0	0	0.5	0	0	0	0.5	0	0	4
# 7	Rest	2	1	0	0	0	0	0	0	0	0	0	1
# 7	Rest	6	1	0	0	0	0	0	0	0	0	0	1
# 7	2	# 9	0	0	0	0	0	0	0	1	0	0	1
# 7	2	3	0	0	0	0	0	0	0	0.5	0.5	0	2
# 7	2	5	0	0	0	0	0	0	0	0	0	1	4
# 7	5	3	0	1	0	0	0	0	0	0	0	0	1
# 7	5	6	0	0	0	0	0	0	0	0	0	1	1
# 7	6	# 1 1	0	0	0	0.455	0.273	0.273	0	0	0	0	2 2

Table 4.18. Three and Four Note Patterns That Are Exactly the Same Between the D7 (5 to 8) Chord and the D7 (29 to 32) Chord

D7 - 5 to 8			Rest	1	b9	2	3	# 7	Total
2	Rest	Rest	0.286	0.143	0.429	0	0	0.143	7
# 1 1	Rest	Rest	0	0	0	1	0	0	2
# 1 1	3	2	0	1	0	0	0	0	1
7	Rest	Rest	1	0	0	0	0	0	1
D7 - 29 to 32			Rest	1	b9	2	3	# 7	Total
2	Rest	Rest	0	0.333	0.667	0	0	0	3
# 1 1	Rest	Rest	0.2	0	0	0.6	0.2	0	5
# 1 1	3	2	0	1	0	0	0	0	1 3
7	Rest	Rest	0	0	0	0	0	1	1

These differences found in the third order Markov chains are not readily apparent when simply analyzing the first order Markov chains associated with the chords. Some of these

differences may be anticipated by using charts produced from first order chains. Created from first order Markov chains, the chart below (Figure 4.11) displays the scale tones that Coltrane uses (as probabilities) in the two chords analyzed previously. This chart shows a more even distribution of scale tones used in the D7 (29 to 32) chord compared with the D7 (5 to 8) chord. However, these distributions are not that dissimilar to predict the outcome previously demonstrated by the third order Markov chains. Thus, using Markov chains of differing orders for musical analysis purposes is quite beneficial.

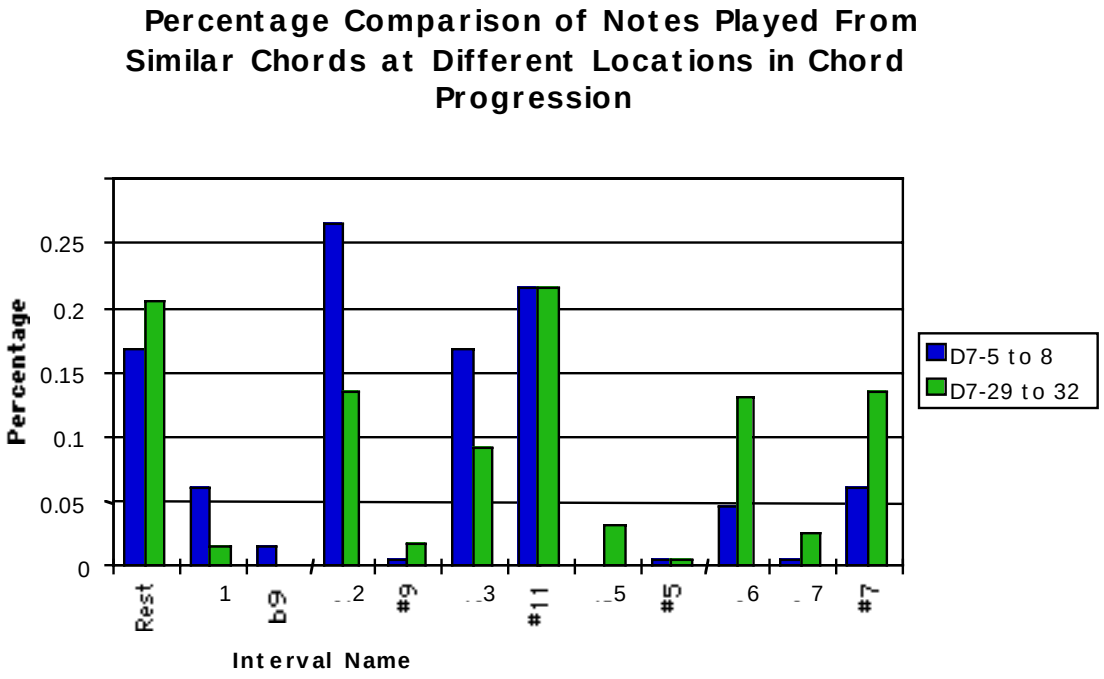

Figure 4.11. Scale Tones Used in D7 (5 to 8) vs. D7 (29 to 32)

4.3 Measures of Creativity and Style

The Markovian analysis approach demonstrated in the previous two sections of this chapter developed some interesting findings regarding the improvisational style and creativity of John Coltrane in *Giant Steps*. These specific findings may support the development of **generalizable** quantitative measures of style and creativity in jazz improvisation based on Markovian analysis.

From the literature review (Chapter 2), it is apparent that there is a dearth of quantitative measures regarding style and creativity, especially in the jazz improvisation domain. This is caused by two primary factors: 1) the lack of domain specific definitions of style and creativity and 2) the lack of quantitative measures in the domain of jazz improvisation. To address both of these factors, findings from the Markov chain analysis generated above are applied to two previously developed models, one for style analysis (Heen, 1981) and the other for the assessment of creativity (Guilford, 1967). Quantitative measures of style and creativity are then proposed within the context of the models.

"The goal of style analysis is to identify all of the elements and their manipulations because together they exhibit the salient and valid style characteristics, they identify general style trends, separate one period from another, and represent innovational or conventional works within a period." (Heen, p. 29) Thus, even though style analysis is a holistic assessment process, it must be broken down into measurable elements and characteristics. Heen (1981) developed a "Range of Factors for the Style Analysis Process" for the domain of jazz music. A portion of this list can be found in Appendix C. There are five general categories: Melody, Rhythm, Harmony, Timbre--Texture, and Form & Growth. As seen in Appendix C, Improvisation and Embellishments (in improvisation) fit under the category of Melody and are most related to this thesis. Under these two topics, there are four particular aspects that seem to lend themselves to quantitative analyses. They are a) Individual signatures, b) Types and placement of formulae, c) Vocabulary, and d) Decorative figures (embellishments vs. structural or improvisational features) including neighbor tones, escape tones, leading tones, vibrato, shakes, special sounds, glissandi, flutter, etc.

There is a linkage between the measurement of style and the measurement of creativity. Because improvisation is an instantaneous form of music creation, style and creativity are

fused together in the generation of jazz solos. Thus, the measures for each of them are quite interrelated and should be developed in that way. [In a review of the literature (Chapter 2 above), it is clear that Gustafson and Mumford (1997), in addition to others, support this proposal.] In the discussion on creativity below, four of the measurable aspects of style from the Range of Factors that Heen proposed above *(Individual signatures, Types and placement of formulae, Vocabulary, and Decorative figures)* are linked to similar components of creativity.

Regarding creativity, Guilford (1967) developed his Structure of Intellect (SOI) model containing four Components of Creative Behavior. Although this is a general model of creativity, the four components may be applied specifically to domain of jazz improvisation. The components of creative behavior that make up Guilford's model are listed and defined below:

Fluency = the number of ideas a person generates
Flexibility = the number of different kinds of ideas a person develops
Elaboration = the extent to which a person fills out his/her ideas
Originality = the uncommonness or statistical infrequency of a person's ideas

Quantitative measures from the Markovian modeling above fit particularly well into this model. Fluency (the number of ideas a person generates) may be measured as the number of different patterns played over the same chord (how large is his *Vocabulary* of patterns?). That is, if John Coltrane played the same pattern many times over one chord, it could be considered less creative (i.e., less "fluent"). This trend is apparent in some chords (e.g., D7 - 5 to 8), but not in others. Thus, over some chords, he was more fluent. This measure could be used to compare different players creativity levels on the same piece of music.

Flexibility (the number of different kinds of ideas a person develops) may be measured as the variability of patterns used between similar chord types (ex. all D7 chords). This is a creativity measure that is contained within one song (and can address the *Types and placement of formulae* in a song). An example of this measure is found in the instance when Coltrane implements different scales and patterns over similar chord types (as in the case of D7 chords compared with Gb7 chords). Instances of this different scale usage are

illustrated in the subtraction matrix (Table 4.13) and in Figure 4.5 (Comparison of the Distribution of Transitions out of Particular Intervals for D7 and Gb7 combined chords).

Elaboration (the extent to which a person fills out his/her ideas) is similar to fluency in the jazz domain. This component may be considered a measurement of "variety", or use of *Decorative figures*. Specific measures could include the number (or "variety") of different states visited in the Markov chains, the number of passing tones used, etc. One measure could be the calculation of how often Coltrane deviates from a scale to add “color” by using passing tones. A specific example of this could be the number of different states transitioned into from one particular note (Figures 4.6, 4.7 and 4.9). For example, if Coltrane visits only five different tones in a scale over one chord, but visits eight different tones in a scale over another chord, that demonstrates greater variety in his improvisation over the second chord.

Originality (the uncommonness or statistical infrequency of a person’s ideas) may be measured as the frequency (or rather, infrequency) of particular patterns played by Coltrane. This can be observed simply by inspecting the probabilities in the Markov chains. There are many transitional probabilities that are less than 0.005 (which are only played once), and are thus statistically infrequent. This may not be true for other improvisers, and consequently can be considered as a measure of an *Individual signature*. [Note: Care must be taken in developing this measure because statistical infrequency may not indicate skillful improvisation, but rather may point to poor note choices that were never repeated. Thus, notes chosen from "acceptable" jazz scales may be a criteria for this measure of style and creativity.]

Markovian analysis is beneficial in creating the statistics that can be used in developing and evaluating these measures of style and creativity. With further progress in the refinement of these measures, other pieces of jazz music and other improvisers can be compared quantitatively and the validity of these proposed measures can be increased. Therefore, the development of these particular quantitative measures may help to make the assessment of creativity and style in the domain of jazz improvisation more concrete resulting in future analyses that are more informative and beneficial.

Chapter 5 : Conclusions

This chapter presents conclusions on Markov chain portrayals, new analysis tools and procedures, quantitative measures of creativity and style, and, in sum, whether Markovian modeling is a reasonable and useful modeling approach for this application. In addition, this chapter provides ideas for future research based on the research conducted in this thesis.

5.1 Conclusions

The multi-disciplinary nature of this research lends itself to many questions of differing origins. Many of the initial questions asked in section 3.2 (General Analysis Performed) are concerned with the validity of Markovian modeling in this domain and with the specific statistical measures that Markov chains could provide. The other primary research questions are concerned with the quantitative measurement of style and creativity.

Markov Chain Modeling

It is true that Markov chains are not necessary for all of the analyses that were performed for this research. Some of the simple ratios and counted data that were examined could have been calculated without using Markov chains. However, Markov chains provide a robust and easily understood method of modeling and portraying data that render some new analysis techniques for jazz improvisation possible.

From this research, it is found that the Markov chains that are developed can identify how often and when a particular pattern of notes is used. They can model all of the different patterns played for any number of takes of a song and can be used as comparison tools for scale tone analyses. Markov chains can demonstrate how much and how often the pitch is varied in a solo and whether different patterns are played over similar chord types. Additionally, chains of differing order provide unique information and can be used cooperatively to exhibit different statistical facets of jazz improvisation. In general, they can be used for identifying stylistic similarities and differences as well as for developing quantitative measures of style and creativity. Because all of these factors are evident, Markov chain modeling is a valid and useful technique for modeling and analyzing jazz improvisation.

It is debatable as to which portrayal method is best for these Markov chains. Interval names (both relative and absolute) and note names provide distinct information and can be used together for a more thorough investigation of style and creativity.

Because this research is based on hard, unchanging data, the analyses performed in this thesis can be reproduced systematically to obtain the same results. Thus, this modeling and analysis approach is reliable and consistent.

Style and Creativity

In much of the literature, researchers on style and creativity in the jazz domain have made qualitative generalizations and then used the phrase, "an in-depth analysis may find quantitative proof of this observation." The methodology presented in this thesis provides that desired analysis technique. By integrating and implementing pre-existing theories and models of style and creativity, operational definitions and corresponding measures of style and creativity can be developed. Markov chains can be created and used for the quantitative measurement of these historically qualitatively-analyzed aspects of music, however the validity of these quantitative measures has yet to be tested.

Even though all of the actual results (Markov chains, figures, tables, etc.) from the analysis of *Giant Steps* are specific to that piece of music, the framework of questioning and analysis techniques presented in this thesis are general enough so that they may be applied to other pieces of music.

5.2 Future Research

There are many opportunities for further research based on the work completed in this thesis. Specifically, further analysis could be performed that examines whether combined chord data represents a better model of what John Coltrane plays vs. specific instance chord data (i.e., all D7 chords combined vs. D7 - 5 to 8). In addition, a comparison of data between *Giant Steps* vs. *Giant Steps (Alternate Version)* could be considered. This may yield some interesting stylistic and creative results due to the differing tempos at which each version was recorded. Comparisons across different (but similar) pieces of music may prove beneficial as a test for the usefulness of this modeling and analysis approach. For instance, examining the differences between *Giant Steps* and *26 - 2* may provide further insights into John Coltrane's style and creativity. In addition, other improvisers

could be modeled and compared using the exact same Visual Basic code that is developed in this thesis.

Although the techniques developed here are used for the purposes of jazz improvisation analysis, the Markov chains generated could be implemented for music composition. By examining the chains, one could create the "perfect" or "most bizarre" or "most creative" solo in the style of John Coltrane by linking particular 4-note phrases together. Ultimately, real-time alternative solos to *Giant Steps* in Coltrane's style could be generated and played through a computer or printed out and used as sight reading test material for jazz improvisation students.

In a further development, there also may be legal applications for the code and analysis techniques in the arena of music copyrighting. Ultimately, a piece of music could be evaluated to see if it is too similar to another person's music.

This research is a starting point for the quantitative measurement of style and creativity. More research should be conducted in this domain which may ultimately result in a comprehensive quantitative measurement approach to assessing style and creativity in the domain of jazz improvisation. Specifically, statistical comparisons between other pieces of music and other artists would help in producing more robust and valid measures. Also, the modeling approach and measurement tools developed here may be applied to other areas of study outside of jazz improvisation and even outside of music in general.

In conclusion, the value of this thesis lies in the design of the data collection, portrayal and analysis methodology. The transference of the data into more useful information through the development of valid quantitative measure of style and creativity is the next step required in the development of this research.

REFERENCES

Ames, C. and Domino, M. Cybernetic Composer: An Overview. In M. Balaban, K. Ebcioglu and O. Laske (Ed.), *Understanding Music with AI*. Cambridge, Massachusetts: AAAI Press, 1992.

Anastasi, A. Psychological Testing (6th Ed.). New York: Macmillan, 1988.

Baker, David. *The Jazz Style of John Coltrane: A Musical and Historical Perspective*. Lebanon, Indiana: Studio 224, 1980.

Bamberger, J. and Brofsky, H. *The Art of Listening: Developing Musical Perception (5th Ed*.). New York: Harper and Row, 1988.

Barron, F. and Harrington, D. M. Creativity, intelligence, and personality. *Annual Review of Psychology*, 32, 439-76, 1981.

Bent, Ian. *Analysis*. New York: Norton, 1987.

Boden, Margaret A. Creativity and Computers. *Cybernetics and Systems: An International Journal*, Vol. 26, 1995.

Bowles, Edmund. "Musicke's Handmaiden: Or Technology in the Service of the Arts." In H. Lincoln (Ed.) *The Computer and Music*. Ithaca, New York: Cornell University Press, 1970.

Brown, Robert T. Creativity - what are we to measure? (Chapter 1). In J. Glover, R. Ronning, and C. Reynolds (Eds.) *Handbook of Creativity*. New York: Plenum Press, 1989.

Budd, Malcolm. "Understanding Music." In *Proceedings of the Aristotelian Society Supplementary Volume*, 59, p. 233-248, 1985.

Bukiet, B., Harold, E. R., & Palacios, J. L. A Markov Chain Approach to Baseball. *Operations Research*, Vol. 45, No. 1, 14-23, 1997.

Carno, Zita. "The Style of John Coltrane." *Jazz Review*, November, 1959, pp. 13-17.

Cohen, Jonathan. *Algebraic Jazz Harmony*. Unpublished manuscript, 1991.

Coker, J., Casale, J., Campbell, G., & Greene, J. *Patterns for Jazz*. Lebanon, Indiana: Studio P/R, Inc., 1970.

Cole, Bill. *John Coltrane*. New York: Schirmer Books, 1976.

Coltrane, John. *Giant Steps*. John Coltrane: Giant Steps (Atlantic SD 1668), Atlantic Recording Company, 1960.

Coltrane, John. *The Heavyweight Champion : The Complete Atlantic Recordings* (Atlantic R2 71984), Atlantic Recording Company, 1995.

Cook, Nicolas. *A Guide to Musical Analysis*. New York: George Braziller, 1987.

Cope, David. *Computers and Musical Style*. The Computer Music and Digital Audio Series. Madison, WI: A-R Editions, Inc., 1991.

Csikszentmihalyi, M. Society, culture, and person: A systems view of creativity. In R. J. Sternberg (Ed.) *The Nature of Creativity: Contemporary Psychological Perspectives*. New York: Cambridge University Press, (1988-a).

Dacey, John S. *Fundamental of Creative Thinking*. Lexington, Massachusetts: D. C. Heath and Company, 1989.

Dean, Roger T. *Creative Improvisation*. Philadelphia: Open University Press, 1989.

Dean, Roger T. *New Structures in Jazz and Improvised Music Since 1960*. Philadelphia: Open University Press, 1992.

Debellis, Mark. *Music and Conceptualization.* New York: Cambridge University Press, 1995.

Dodge, Charles and Jerse, Thomas A. *Computer Music: Synthesis, Composition and Performance*. New York: Schirmer Books, 1985.

Duke, R.A. When Tempo Changes Rhythm: The Effect of Tempo on Nonmusicians' Perception of Rhythm. *Journal of Research in Music Education,* 42 (1), 27-35, 1994.

Eysenck, Hans J. The Measurement of Creativity (Chapter 8). In M. Boden (Ed.) *Dimensions of Creativity*. Cambridge, Massachusetts: The MIT Press, 1994.

Forte, Allen. "Computer-Implemented Analysis of Musical Structure." In G. Lefkoff (Ed.) *Papers from the West Virginia Conference on Computer Applications in Music*.Morgantown, WV: West Virginia University Library, 1967.

Fry, Christopher. Flavors Band: A Language for Specifying Musical Style. In S. Schwanauer and D. Levitt (Eds.) *Machine Models of Music.* Cambridge, Massachusetts:The MIT Press, 1993.

Gabura, A. James. "Computer Analysis of Musical Style." In *ACM Proceedings of the 20th National Conference*. New York: Association for Computing Machinery, 1965.

Glover, John A. *Becoming a More Creative Person*. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1980.

Glover, John A., Ronning, Royce R., and Reynolds, Cecil R. (Eds.) *Handbook of Creativity*. New York: Plenum Press, 1989.

Gridley, Mark C. *Jazz Styles*. (Sixth Ed.) Upper Saddle River, NJ: Prentice Hall, 1997.

Guilford, J. P. *The Nature of Human Intelligence*. New York: McGraw-Hill, 1967.

Gustafson, Sigrid B. and Mumford, Michael D. *An Integrative Model of Creativity*. Unpublished Manuscript, 1997.

Handel, S. *Listening: An Introduction to the Perception of Auditory Events.* Cambridge, Massachusetts: The MIT Press, 1989.

Heen, Carol L. *Procedures For Style Analysis of Jazz: A Beginning Approach*. Ph. D. dissertation., Department of Music, University of Minnesota, Minneapolis, Minnesota, 1981.

Hiller, Lejaren A. and Baker, Robert A. "*Computer Cantata*: A Study in Compositional Method". *Perspectives of New Music*, 3(1):62-90, 1964.

Hiller, Lejaren A. and Isaacson, L. M. *Experimental Music-Composition with an Electronic Computer*. New York: McGraw-Hill, 1959.

Hocevar, Dennis and Bachelor, Patricia. A Taxonomy and Critique of Measurements Used in the Study of Creativity (Chapter 3). In J. Glover, R. Ronning, and C. Reynolds (Eds.) *Handbook of Creativity*. New York: Plenum Press, 1989.

Hoepfner, J. Review of the Torrance Tests of Creative Thinking. *Journal of Educational Measurement*, 4, 191-192, 1967.

Hofstadter, Douglas R. *Godel, Escher, Bach: An Eternal Golden Braid.* New York: Vintage Books, 1979.

Hopkins, K. D., Stanley, J. C., and Hopkins, B. R. *Educational and PsychologicalMeasurement and Evaluation (7th Ed).* Englewood Cliffs, New Jersey: Prentice Hall, 1990.

Howard, Ronald A. *Dynamic Probabilistic Systems (Vol. 1: Markov Models).* New York: Wiley & Sons, 1971.

Jackson, P. W. and Messick, S. The person, the product, and the response: Conceptual problems in the assessment of creativity. *Journal of Personality,* 33 (3), p. 309-329, 1965.

Jay, E. S. and Perkins, D. N. Creativity's compass: A review of problem finding. In M. A. Runco (Ed.) *Creativity Research Handbook.* Cresskill, New Jersey: Hampton, 1997.

Jones, Kevin. Compositional Applications of Stochastic Processes. *Computer Music Journal*, Vol. 5, No. 2, 1981.

Kirschen, Yaakov. Music Creator. Ver. 1.0. Walnut, California: JFY, Inc., 1989.

Koenig, Gottfried M. "PROJECT2: A Programme for Musical Composition". *Electronic Music Reports*, 1(3):1-161, 1970.

Kofsky, Frank. *Black Nationalism and the Revolution in Music*. New York: Pathfinder Press, 1970.

LaRue, Jan. "Two Problems in Music Analysis: The Computer Lends a Hand." In E. Bowles (Ed.) *Computers in Humanistic Research: Readings and Perspectives*. Englewood Cliffs, New Jersey: Prentice-Hall, 1967.

Lerdahl, Fred and Jackendoff, Ray. *A Generative Theory of Tonal Music*. Cambridge, Mass: The MIT Press, 1983.

Levitt, David A. A Representation for Musical Dialects. In S. Schwanauer and D. Levitt (Ed.) *Machine Models of Music*. Cambridge, Massachusetts: The MIT Press, 1993.

Longuet-Higgins, H. C. The Perception of Melodies. In S. Schwanauer and D. Levitt (Ed.) *Machine Models of Music*. Cambridge, Massachusetts: The MIT Press, 1993.

Lorrain, Denis. A Panoply of Stochastic 'Cannons'. In C. Roads (Ed.) *The Music Machine*. Cambridge, Massachusetts: The MIT Press, 1993.

Lyon, Douglas. Using Stochastic Petri Nets for Real-Time Nth-order Stochastic Composition. *Computer Music Journal*, Vol. 19, No. 4, 1995.

Madura, Patrice D. An Exploratory Investigation of the Assessment of Vocal Jazz Improvisation. *Psychology of Music*, 23, p. 48-62, 1995.

Maxwell, H. John. An Expert System for Harmonizing Analysis of Tonal Music. In M. Balaban, K. Ebcioglu and O. Laske (Ed.), *Understanding Music with AI*. Cambridge, Massachusetts: AAAI Press, 1992.

Moorer, James A. Music and Computer Composition. In S. Schwanauer and D. Levitt (Ed.) *Machine Models of Music*. Cambridge, Massachusetts: The MIT Press, 1993.

Nisenson, Eric. *Ascension: John Coltrane and His Quest*. New York: St. Martin's Press, 1993.

North, Tom. *Extended Exploration of Markov Chains as a Generative Scheme for Automated Composition*. Ph. D. dissertation, Department of Music, University of California, San Diego, CA, 1989.

Piirto, Jane. *Understanding Those Who Create*. Dayton, Ohio: Ohio Psychology Press, 1992.

Polansky, L., Rosenboom, D., and Burk, P. HMSL: Overview (Version 3.1) and notes on intelligent instrument design. In J. Beauchamp (Ed.), *Proceedings of the 1987 International Computer Music Conference*. San Francisco: International Computer Music Association, 1987.

Porter, Lewis R. *John Coltrane's Music of 1960 Through 1967: Jazz Improvisation as Composition*. Ph. D. dissertation., Department of Music, Brandeis University, Waltham, Massachusetts, 1983.

The Real Book. A collection of standard jazz charts.

Reeves, Scott D. *Creative Jazz Improvisation* (2nd Ed.). Englewood Cliffs, NJ: Prentice Hall, 1995.

Roads, Curtis. *The Computer Music Tutorial*. Cambridge, Mass: The MIT Press, 1996.

Ross, Sheldon M. *Introduction to Probability Models* (5th Ed.). New York: Academic Press, Inc., 1993.

Sabatella, Marc. *A Jazz Improvisation Primer*. www.outsideshore.com/primer/primer/. 1997.

Sawyer, Keith. Improvisational Creativity: An Analysis of Jazz Performance. *Creativity Research Journal*, 5(3): 253-263, 1992.

Stanton, Kenneth. *Introduction to Jazz Theory*. Boston, Mass: Crescendo Publishing Company, 1976.

Stanton, Kenneth. *Jazz Theory*. New York: Taplinger Publishing Company, 1982.

Stewart, William J. MARCA: Markov Chain Analyzer, A Software Package for Markov Modeling. In W. Stewart (Ed.) *Numerical Solutions to Markov Chains*. New York: Marcel Dekker, Inc., 1991.

Thorndike, R. L. Some methodological issues in the study of creativity. In *Proceedings of the 1962 Invitational Conference on Testing Problems*. Princeton, New Jersey: Educational Testing Service, 1963b.

Tirro, Frank. Melody and the Markoff-Chain Model: A Gregorian Hymn Repertory. In E. Narmour and R. Solie (Ed.) *Explorations in Music, the Arts, and Ideas : Essays in Honor of Leonard B. Meyer*. Stuyvusant : Pendragon Press, 1988.

White, Andrew N. III. Andrew's Music Catalogue. Washington, D.C.: Andrew's Musical Enterprises. [Source for the transcriptions of Giant Steps.]

Williams, James K. 1982. *Themes Composed by Jazz Musicians of the Bebop Era: A Study of Harmony, Rhythm and Melody (Volumes I and II).* Ph. D. dissertation., Department of Music, Indiana University, Bloomington, Indiana.

Winter, Robert. *Music for Our Time*. Belmont, California: Wadsworth, 1992.

Xenakis, Iannis. *Formalized Music*. Bloomington: Indiana University Press, 1971.

Zicarelli, David. M and Jam Factory. *Computer Music Journal*, Vol. 11, No. 4, Winter 1987.

Appendix A - Data from all transcriptions

The following 11 pages display the hard data in spreadsheet format from the transcriptions of John Coltrane's improvisation in Giant Steps.

GIANT STEPS	B				D7				G				Bb7			
GS1*		**B**				**D 7**				**G**				**Bb7**		
1	Ab2	F2	Db2	Bb1	E2	F#2	G#2	B2	A2	E2	C#2	G1	D2	Bb1	Ab1	G1
2	E3	7	7	7	E3	7	7	D#3	C#3	E2	A2	C#3	C3	B2	Bb2	D3
3	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
4	7	Ab1	Db2	F2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
5	E3	7	7	7	E3	7	7	D#3	C#3	E2	A2	C#3	C3	B2	Bb2	D3
6	Bb2	Ab2	F2	Db2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
7	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
8	C3	7	7	Ab2	D#3	D3	7	B2	7	D3	C#3	E2	A2	C#3	C3	B2
9	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	E2	7	A2	C#3	Bb2	7	7	D3
10	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	7	7	7	C3	E3	7	D3
11	7	7	D#3	7	E3	7	7	C#3	7	D3	C#3	A2	B2	D3	C3	7
12	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
13	7	E2	Ab2	Db3	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
GS2*		**B**				**D 7**				**G**				**Bb7**		
1	Ab2	Db3	7	7	E2	G#2	7	7	C#2	E2	7	7	Bb1	D2	7	7
2	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
3	C3	Eb3	C3	D3	7	B2	G#2	E2	A2	B2	C#3	E3	Bb2	D3	C3	Bb2
4	7	Db2	F2	Ab2	E2	F#2	G#2	E2	A2	E2	C#2	A1	D2	Bb1	A1	G1
5	F2	Ab2	Db3	7	E2	G#2	C#3	7	E2	A2	C#3	E3	Bb2	D3	7	C3
6	F2	Ab2	7	7	E2	D2	C#2	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
7	Db3	E3	Db3	E3	7	D3	B2	E3	C#3	A2	B2	C#3	C3	B2	Bb2	D3
8	C3	7	C3	7	Ab2	7	7	E2	G#2	E2	7	E2	7	C2	7	A1
9	F2	Ab2	Db3	7	E2	G#2	B2	D3	C#3	E2	A2	C#3	Bb2	D3	C3	Bb2
10	E3	7	7	7	D3	7	7	C#3	C#3	E2	A2	C#3	Bb2	D2	7	D2
GS3*		**B**				**D 7**				**G**				**Bb7**		
1	Ab2	Db3	Ab2	E2	7	E2	C#2	E2	C#2	A1	B1	C#2	C2	B1	Bb1	D2
2	Db3	D3	E3	C#3	D3	7	7	B2	C#3	A2	C#3	C#3	C3	B2	Bb2	D3
3	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	B1	A1	G1
4	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
5	7	Ab2	7	Ab2	Db3	F2	G#2	B2	B2	F#2	G#2	B2	A2	E2	C2	Bb1
6	F2	Ab2	Db3	E2	7	G#2	B2	D3	C#3	7	7	7	C3	B2	Bb2	D3
7	C3	Eb3	C3	Ab2	C#3	D3	B2	A2	G#2	7	7	7	A2	B2	C#3	D3
8	C3	Eb3	C3	Ab2	C#3	E3	B2	D2	C#3	E2	A2	C#3	C3	B2	Bb2	D3
9	Ab2	F2	Db2	Bb1	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
10	Db3	Eb3	Db3	D3	7	B2	G#2	E2	A2	B2	C#3	A2	C3	G#2	E2	C2
11	Ab2	F2	Db2	Ab1	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
12	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	A2	F2	E2	D2
GS4*		**B**				**D 7**				**G**				**Bb7**		
1	Ab2	F2	7	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
2	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
3	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
4	Db3	E3	Db3	D3	7	B2	G#2	E2	A2	B2	C#3	E3	C3	B2	Bb2	D3
5	7	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	Ab2	G2	F2	E2	D2	C2	Bb1
6	C3	Ab2	Bb2	C3	G#2	E2	7	G#2	E2	C#2	7	E2	E2	7	C2	7
7	7	Db2	F2	Ab2	D2	E2	F#2	G#2	A2	B2	C#3	E3	Bb2	D3	C3	Bb2
8	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
GS5*		**B**				**D 7**				**G**				**Bb7**		
1	F2	Ab2	7	7	E2	G#2	7	7	E2	G2	7	7	E2	7	7	7
2	F2	Ab2	Db2	E2	7	G#2	B2	7	7	7	E2	C#3	Bb2	D3	7	C3

GS6*		**B**				**D7**				**G**				**Bb7**		
1	7	F2	Ab2	C3	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	E2	F2	7
2	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	B2	C#3	E3	Bb2	D3	C3	Bb2
3	7	Db2	F2	Ab2	D2	E2	F#2	G#2	B2	A2	E2	C#2	C2	D2	E2	F2
4	C3	Eb3	C2	7	C3	7	7	7	C3	7	Ab2	C3	Ab2	E2	7	7
5	Ab2	7	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
6	F2	Ab2	Db3	B2	7	G#2	B2	A2	7	E2	C#2	A1	D2	F2	E2	D2
7	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	A2	C2	D2
8	7	Db1	F1	B1	E1	F#1	G#1	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
9	F2	Ab2	F2	E2	7	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
GS7*		**B**				**D7**				**G**				**Bb7**		
1	Ab2	Db2	7	7	E2	G#2	7	7	C#2	E2	7	7	Bb1	D2	7	7
2	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
3	Ab2	Db3	Ab2	F2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
4	7	Db2	F2	Ab2	E2	F#2	G#2	B2	E2	G2	Bb2	D3	C3	7	7	7
5	7	Db2	F2	Ab2	E2	F#2	G#2	E2	A2	E2	C#2	A1	D2	Bb1	A1	G1
6	Db3	D#3	E3	7	E3	7	7	D3	C#3	E2	A2	C#3	Bb2	D3	C3	Bb2
7	F2	Ab2	F2	E2	7	D2	C#2	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
8	F2	Ab2	7	7	E2	G#2	7	7	C#2	E2	7	7	Bb1	D2	7	7
9	Db3	E2	A2	Db3	Bb2	D2	7	7	7	7	7	C3	C3	7	7	Bb2
10	7	Ab2	7	C#3	G#2	7	7	E2	B2	C3	7	7	7	C3	A2	E2
11	C3	Eb3	7	Db3	D3	E3	B2	7	7	D3	C#3	E2	A2	C3	7	7
12	F2	Eb2	Db2	A1	E2	D2	C#2	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
13	7	F2	Ab2	Db3	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
GS8*		**B**				**D7**				**G**				**Bb7**		
1	Ab2	F2	7	Ab2	E2	C#2	7	E2	C#2	A1	Bb1	C#2	B1	Bb1	A1	D2
2	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	G1	C2
3	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	7	7	7	7	7	7	C3
4	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
5	E3	7	C#3	E3	7	C#3	B2	D3	C#3	E2	A2	C#3	C3	B2	Bb2	D3
6	Db2	Eb2	F2	Ab2	E2	Eb2	D2	E2	C#2	F#1	A1	C#2	Bb1	C2	D2	E2
7	Eb3	C3	7	7	E3	7	7	Eb3	C#3	E2	A2	C#3	Bb2	D3	C3	Bb2
8	Ab2	F2	Eb2	Db2	E2	D2	C#2	B1	A1	B1	C#2	Eb2	Bb1	C2	D2	E2
9	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
10	E3	7	7	D#3	D#3	7	7	E3	E3	C#3	7	E3	E3	7	7	E3
11	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	E3	Bb2	7	7
12	Ab2	7	7	7	E2	D2	C#2	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
13	Eb3	7	C3	D#3	C#3	7	C#3	7	7	7	C#3	E2	A2	C3	B2	D3
GS9*		**B**				**D7**				**G**				**Bb7**		
1	7	Db2	Eb2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
2	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
3	Db2	Eb2	F2	Ab2	E2	Eb2	D2	E2	C#2	A1	Bb1	C#2	C2	B1	Bb1	D2
4	7	C#3	E3	7	E3	7	7	7	E3	7	7	Eb3	C3	B2	Bb2	D3
5	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	Bb1	A1	G1
6	Db3	Eb3	7	Db3	E3	E3	B2	D3	C#3	E2	A2	C#3	C3	B2	Bb2	D3
7	C3	Db3	Eb3	E3	C#3	E3	7	B2	C#3	E2	A2	C#3	C3	B2	Bb2	D3
8	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	E2	F2	G2
9	7	Db2	F2	Ab2	E2	F#2	G#2	B2	E2	A2	C#3	E3	Bb2	D3	C3	Bb2
10	Db2	Eb2	F2	Ab2	E2	D2	C#2	B1	A1	B1	C#2	E2	Bb1	C2	D2	E2
11	Db2	Eb2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	E2	F2	G2
12	F3	7	C3	7	E3	7	C#3	7	E3	7	C#3	7	C3	7	7	7
13	Db2	Eb2	F2	Ab2	Ab2	F#2	E2	D2	C#2	A1	C#2	E2	Bb1	C2	D2	E2
14	Ab2	7	7	E2	E2	7	7	7	E2	7	7	7	C2	7	7	7
15	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	F2	E2	D2
16	7	Db2	F2	Ab2	E2	F#2	G#2	B2	A2	E2	C#2	A1	D2	E2	F2	D2

Eb				Eb				A - 7				D7				G			
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	D2	B1	A1	G#1	F2	E2	D2	C#2	E2	A2	C#3
C3	A2	G2	F2	A2	F2	7	7	E3	7	7	C3	7	G#2	E2	7	7	E2	A2	C#3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	A#2	7	A2	C#3	E2	F#2	G#2	A2	B2	C#3	E3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	A2	7	A2	C#3	E2	F#2	B2	A2	B2	C#3	D3
C3	A2	G2	F2	A2	G2	7	F3	7	E2	7	C#3	B2	7	7	7	7	E2	A2	C#3
C2	D2	E2	G2	F2	G2	7	G#2	C#3	B2	A2	G#2	7	7	7	7	7	E2	A2	C#3
C2	A2	7	7	7	7	7	A2	A2	7	7	F#2	G#2	A2	B2	C#3	A2	7	C#3	A2
Bb2	D3	C3	A2	G2	F2	A2	C3	F#2	7	7	7	C#3	B2	G#2	F#2	E2	F#2	G#2	B2
C3	7	7	A2	G2	F2	7	7	7	B1	D2	A2	C#3	7	E2	7	A2	B2	C#3	D3
C3	Bb2	A2	G2	F2	G2	A2	C3	F3	7	7	7	E3	7	7	Eb3	C#3	E2	A2	C#3
7	7	7	E3	E3	7	7	D3	C3	A2	F2	7	E3	7	7	D3	C#3	E2	A2	C#3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	D2	F#2	A2	C#3	B2	G#2	F#2	E2	F#2	A2	C#3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	A2	7	F#2	C#3	E2	A2	C#3	A2	B2	C#3	E3
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
C2	7	7	A1	A2	F2	7	7	7	7	7	7	G#2	7	B2	7	A2	7	7	C#3
C2	A1	Bb1	C2	D2	E2	F2	G2	A2	F#2	A2	F#2	G#2	B2	E2	F#2	A2	B2	C#3	E3
A2	C3	A2	G2	F2	G2	A2	C3	F3	7	7	E3	D3	C#3	7	7	C#3	E2	A2	C#3
C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2	7	E2	F#2	G#2	A2	B2	C#3	E3
C3	7	7	A2	G2	7	7	F#2	A2	7	7	F#2	G#2	B2	E2	F#2	A2	B2	C#3	E3
F2	G2	7	C3	F3	A2	7	7	7	D2	7	7	C#3	B2	G#2	F#2	E2	A2	C#3	E3
C3	A2	G2	F2	A2	F2	E2	D2	F#2	A#2	7	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3
C2	7	7	7	7	7	7	7	A2	7	7	F#2	G#2	B2	E2	F#2	G#2	7	7	7
A2	F2	E2	D2	F2	7	7	7	C#3	A2	C#3	A2	C3	G#2	F#2	E2	A2	E2	A2	C#3
C3	7	A2	E2	G2	F2	7	7	7	7	7	7	C#3	B2	G#2	E2	A2	B2	C#3	E3
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
C2	A1	G1	F1	A1	7	7	C#2	B1	D2	F#2	C#3	C#3	7	7	E2	A2	C#3	7	7
C3	A2	G2	F2	A2	F2	7	7	7	B1	D2	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3
C2	D2	E2	G2	F2	G2	7	C3	C#3	E3	7	D3	C3	G#2	F#2	E2	7	E2	A2	C#3
C2	D2	E2	G2	F2	G2	7	A2	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
A1	C2	D2	E2	G2	F2	E2	7	F#2	D2	F#2	A2	C#3	E2	A2	C#3	A2	B2	C#3	E3
C3	A2	G2	F2	A2	F2	E2	D2	F#2	7	7	7	C#3	B2	G#2	F#2	E2	F#2	A2	C#3
C3	B2	Bb2	D2	C3	A2	G2	F2	A2	F#2	A2	F#2	G#2	B2	7	7	A2	B2	C#3	E3
C3	A2	G2	F2	A2	7	C3	F3	7	B2	7	A2	C#3	A2	B2	C#3	A2	E2	A2	B2
C2	D2	E2	G2	F2	G2	A2	C3	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
A2	E2	7	G2	F2	G2	A2	C3	C#3	A2	F#2	D2	G#2	B2	E2	F2	A2	7	7	7
C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2	G#2	7	7	E2	A2	B2	C#3	E3
C2	D2	E2	G2	F2	G2	A2	C#3	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	G#2	A2
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2	G#2	7	7	F#2	E2	C#2	7	7
C2	D2	E2	G2	F2	G2	7	C3	C#3	E3	D3	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
C2	D2	E2	G2	7	G2	F2	7	7	B1	D2	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3
C3	A2	G2	F2	A2	F2	E2	D2	F#2	D2	F#2	A2	C#3	B2	G#2	E2	A2	7	7	7
A2	C2	D2	E2	G2	F2	E2	D2	F#2	A2	7	F#2	C#3	B2	G#2	F#2	E2	A2	C#3	E3
C2	7	7	A1	C2	A1	7	7	7	7	7	7	C#3	B2	G#2	F#2	E2	F#2	G#2	B2
A2	F2	E2	G2	F2	G2	7	C3	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C3
C2	D2	E2	G2	F2	G2	7	A2	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	G#2	A2
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
E2	7	7	C2	E2	7	C2	7	7	7	7	7	7	7	7	7	7	E2	A2	C#3
A2	7	F2	A2	F2	7	7	7	7	B1	D2	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3

	Eb				**Eb**				**A - 7**				**D 7**				**G**		
F2	G2	E2	7	7	7	D2	E2	E2	7	7	7	7	7	7	7	7	E2	A2	C#3
A2	F2	E2	G2	F2	G2	A2	C3	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
G2	7	7	E2	F2	G2	A2	C3	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
7	7	7	G2	G2	7	7	E2	G2	F#2	7	7	F#2	D2	B1	G#1	E2	7	C#2	E2
C2	D2	E2	G2	F2	G2	A2	C3	C#3	D3	B2	A2	G#2	7	7	E2	A2	E2	7	7
C2	D2	E2	G2	F2	G2	A2	7	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
G2	7	7	F2	A2	F2	7	7	7	7	7	7	7	7	7	7	7	E2	A2	C#3
F2	G2	7	C3	E3	7	C3	7	E3	7	7	D3	C3	G#2	E2	D2	C#2	E2	A2	C#3
C2	D2	E2	G2	F2	G2	7	C#3	C#3	A#2	7	C#3	B2	A#2	F2	G#2	7	E2	A2	C#3
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
C2	7	7	A1	F2	A2	7	7	A2	7	7	F#2	G#2	C#3	7	7	E2	A2	C#3	E3
C2	D2	E2	G2	F2	G2	7	C#3	C#3	D2	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
C2	A1	Bb1	C2	D2	E2	F2	G2	A2	F#2	D2	B1	G#2	E2	F#2	G#2	B2	A2	G#2	A2
C3	7	7	Bb2	A2	E2	7	7	7	B1	D2	A2	C#3	B2	G#2	F2	E2	A2	C#3	E3
C2	D2	E2	G2	F2	G2	A2	C#3	C#3	A2	F#2	D2	G#2	7	7	E2	A2	B2	C#3	E3
A2	C3	E3	7	G3	7	7	7	7	7	7	7	7	7	7	7	7	E2	A2	C#3
F2	G2	A2	C3	E3	D3	C3	A2	C#3	E3	7	Eb3	C3	G#2	F#2	E2	A2	B2	C#3	E3
C2	7	7	A1	F2	A2	7	7	A2	7	7	F#2	G#2	B2	7	7	7	E2	A2	C#3
A2	F2	E2	G2	F2	G2	7	C3	C#3	E3	7	7	E3	7	7	Eb3	C#3	E2	A2	C#3
D#2	E2	G2	E2	F2	G2	7	A2	F#2	D2	B1	G#1	G#2	7	7	7	7	E2	A2	C#3
7	7	7	7	7	7	7	C3	C3	A2	G2	F2	A2	F#2	D2	B1	G#2	E2	A2	C#3
F2	G2	A2	C3	E3	D3	C3	A2	C#3	D3	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
C2	A1	Bb1	C2	D2	E2	F2	G2	A2	F#2	A2	F#2	G#2	B2	E2	F#2	A2	B2	C#3	E3
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
C2	A1	G1	F1	A1	C2	7	7	7	B1	D1	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3
A1	C2	D2	E2	G2	F2	E2	D2	F#2	D2	F#2	A2	C#3	B2	G#2	E2	A2	7	7	7
C3	7	7	A2	G2	G2	F2	7	C#3	7	7	A2	G#2	7	E2	7	7	E2	A2	C#3
C2	D2	E2	G2	F2	G2	A2	C3	C#3	E3	7	D3	C3	G#2	E2	D2	C#2	E2	A2	C#3
C3	A2	G2	F2	A2	7	7	7	7	B1	D2	A2	C#3	E2	A2	C#3	A2	B2	C#3	E3
F2	G2	A2	C3	F3	7	7	7	7	7	7	C#3	C#3	7	7	E2	A2	7	C#3	Bb2
A2	F2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2	7	E2	F#2	G2	A2	B2	C#3	D3
F2	7	7	7	7	7	7	7	B2	E3	7	Eb3	C#3	7	7	G#2	B2	G#2	A2	C#3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	A2	F#2	A2	C#3	E2	A2	C#3	E2	A2	C#3	D3
C3	7	7	A2	G2	F2	7	7	C3	E3	7	Eb3	C3	F#2	7	7	7	E2	A2	C#3
7	7	7	C3	7	7	A2	G2	F2	G2	A2	C3	C#3	A2	F#2	D2	G#2	A2	B2	C#3
F2	7	G2	A2	7	7	7	7	A2	F#2	A2	F#2	G#2	A2	B2	C#3	A2	B2	C#3	Eb3
C3	A2	G2	F2	A2	F2	E2	G2	7	D2	F#2	A2	C#3	E2	F2	G#2	B2	C#3	7	E3
	Eb				**Eb**				**A - 7**				**D 7**				**G**		
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	D2	B1	A1	G#1	F2	E2	D2	C#2	E2	A2	C#3
F1	G1	A1	Bb1	C2	D2	E2	G2	F#2	A2	F#2	A2	C#3	B2	G#2	F2	E2	F#2	G#2	B2
C2	A1	7	7	7	7	7	7	C#3	7	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
C3	A2	G2	F2	A2	F2	E2	G2	F#2	D2	F#2	A2	C#3	B2	G#2	F2	E2	F#2	G#2	B2
F1	7	7	A1	C2	F2	7	7	7	B1	D2	A2	C#3	B2	G#2	E2	A2	B2	C#3	E3
C3	A2	G2	F2	A2	7	7	7	C3	E3	7	C#3	C#3	7	7	G#2	B2	G#2	A2	B2
C3	A2	G2	F2	A2	F2	E2	D2	F#2	D2	F#2	A2	C#3	B2	G#2	F2	E2	F#2	G#2	B2
A2	G2	E2	D2	C2	D2	E2	G2	F#2	B1	D2	A2	C#3	B2	G#2	F2	E2	F#2	G#2	B2
A2	7	7	7	7	7	7	C#3	C#3	7	B2	A2	G#2	F#2	E2	D2	C#2	E2	A2	C#3
F2	G2	A2	C3	E3	D3	C3	C#3	C#3	7	7	A2	F#2	D2	7	7	7	C#3	B2	A2
A2	G2	E2	D2	C2	D2	E2	G2	F#2	D2	F#2	A2	C#3	B2	G#2	F2	E2	A2	C#3	D3
C3	7	7	B2	A2	F2	E2	G2	F#2	7	7	7	7	7	7	C#3	C#3	E2	A2	C#3
F2	G2	A2	C3	E3	7	7	7	7	C#2	D2	A2	C#3	B2	G#2	E2	A2	B2	C#3	E2
C2	7	7	7	7	7	7	7	7	B1	C#2	F#2	C#3	7	B2	7	B2	7	7	G#2
C2	A1	Bb1	C2	Db2	E2	F2	G2	A2	F#2	D2	B1	G#2	F2	E2	D2	C#2	D2	E2	F#2
G2	E2	D2	C2	7	7	7	7	7	7	7	C3	C3	7	7	C#3	C#3	7	7	A2

Bb7				Eb				Gb7				B				B			
	Bb7				**Eb**				**Gb7**				**B**				**B**		
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	C3	7	Bb2	Ab2	7	7	7	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Ab2	7	7	F2	Eb2	D2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	7	7
E2	G2	Bb2	D3	F2	G2	A2	7	7	7	7	7	Ab2	7	F2	Eb2	Db2	Eb2	F2	A2
E2	G2	Bb2	D3	F2	G2	A2	C3	F3	7	Eb3	Db3	C3	Bb2	Ab2	Gb2	F2	Eb2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Ab2	C3	Bb2	7	Ab2	C3	B2	Bb2	A2
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
C3	B2	Bb2	D3	C3	A2	G2	F2	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	Eb2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	7	7	7	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	F2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	F3	7	7	7	F3	7	Eb3	Db3	C3	Ab2	F2	Db2
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	7
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	Eb2	Db2	Bb1
	Bb7				**Eb**				**Gb7**				**B**				**B**		
E2	G2	7	Bb2	C3	7	7	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	7	Eb2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Db2	7	7	7
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Db2	Eb2	F2	Ab2
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	C3	Eb3	Eb3	7	7	C3	Ab2	F2	7	7
Bb2	D3	C3	Bb2	A2	F2	A2	C3	F3	Eb3	Bb2	Gb2	F2	7	7	Bb2	Eb2	D3	C3	7
Bb2	D3	C3	Bb2	A2	F2	Gb2	C3	F3	Eb3	C3	Bb2	Ab2	7	7	7	Eb3	Db3	C3	7
E2	7	7	C2	C2	7	7	A1	F1	7	7	Ab1	Ab1	7	Bb1	C2	Db2	Eb2	F2	Ab2
Bb2	D3	C3	Bb2	A2	F2	7	7	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2
Bb2	D3	C3	Bb2	A2	G2	F2	D2	F2	Eb2	C2	Ab1	Gb1	Ab1	Bb1	C2	Db2	Eb2	F2	Ab2
	Bb7				**Eb**				**Gb7**				**B**				**B**		
Bb2	D2	7	7	C3	7	7	A2	Gb2	Bb2	7	7	7	7	7	Ab2	Ab2	7	7	F2
Bb2	D3	C3	Bb2	A2	F2	C2	A1	Gb2	Eb2	Bb1	Ab1	F2	7	7	Eb2	7	Eb2	Db2	7
Bb2	D3	C3	Bb2	A2	F2	E2	D2	Gb2	Eb2	7	C3	F3	7	Eb3	C3	C3	7	7	Ab2
Bb2	D3	7	7	7	7	F2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	C3	7	7	7
Bb2	D3	C3	Bb2	A2	F2	E2	D2	Gb2	Eb2	C2	Ab1	F2	C2	F2	C2	Eb3	D3	C3	7
Bb2	D3	C3	Bb2	A2	F2	E2	D2	Gb2	Eb2	C2	Ab1	F2	7	7	7	7	C2	7	G2
Bb2	D3	C3	Bb2	A2	G2	F2	7	F2	7	7	Eb2	F2	7	Ab2	F2	7	7	7	7
Bb2	D3	C3	Bb2	A2	7	7	7	F3	Eb3	Bb2	Gb2	F2	7	Ab2	Eb3	Eb3	D3	C3	7
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	F3	Eb3	7	7	7	7	7	7	C3
Bb2	G2	E2	C2	F2	G2	A2	C3	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	7	7	7	7
Bb2	D3	7	7	7	7	Gb2	Bb2	Ab2	Gb2	F2	Eb2	F2	7	7	Eb2	F2	7	Ab2	C3
A2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	Bb7				**Eb**				**Gb7**				**B**				**B**		
E2	Bb1	7	D2	C2	7	7	7	F2	7	Bb1	7	C2	Eb2	7	C2	Ab1	7	7	7
Bb2	D3	C3	Bb2	A2	F2	E2	D2	Gb2	Eb2	C2	Ab2	F2	Db2	Eb2	F2	Ab2	C3	7	Bb2
Bb2	D3	7	C3	A2	7	7	F2	Gb2	Bb2	C3	F3	Eb3	7	7	C3	Ab2	F2	7	7
Bb2	Gb2	7	7	7	7	7	7	Ab2	F2	7	Ab2	F2	7	7	C2	Eb2	Db2	7	7
Bb2	D3	C3	Bb2	A2	F2	E2	D2	Gb2	Bb2	C3	F3	Eb3	Ab2	Bb2	Eb3	C3	Ab2	F2	Db2
Bb2	G2	E2	7	7	F2	7	7	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Db2	Eb2	F2	Ab2
G1	A1	Bb1	D2	C2	A1	G1	F1	Gb1	Bb1	C2	Eb2	Db2	Eb2	F2	Ab2	C3	7	7	7
A2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	Bb7				**Eb**				**Gb7**				**B**				**B**		
Bb2	D3	C3	Bb2	A2	F2	G2	Bb2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	7	Eb2	Db2	7
Bb2	D2	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Db2	Eb2	F2	Ab2

	Bb7				**Eb**				**Gb7**				**B**				**B**		
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2
Gb2	Bb2	7	D3	C3	A2	F2	C2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Db2	Eb2	F2	A2
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	Eb3	C3	7	Ab2	F2	7	7	7	7
A2	C2	D2	E2	F2	G2	A2	C3	Gb2	Bb2	C3	F3	7	F3	Eb3	C3	7	C3	Ab2	F2
7	Bb2	G2	E2	F2	7	7	A2	Gb2	7	7	Bb2	Ab2	7	7	F2	Eb2	7	7	7
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	F3	Eb3	Ab2	Bb2	Eb3	C3	Ab2	F2	Db2
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	Eb3	C3	7	Bb2	Ab2	7	Gb2	F2	7
E2	G2	Bb2	D3	C3	F2	7	C3	F3	Eb3	7	C3	C3	Bb2	7	Ab2	7	7	7	7
Bb2	D2	C3	Bb2	A2	F2	G2	C3	Gb2	Ab2	7	7	F2	7	7	Eb2	C2	E2	Db2	Ab2
	Bb7				**Eb**				**Gb7**				**B**				**B**		
Bb2	D3	7	C3	A2	7	7	7	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	7	7	7	7
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	F3	Eb3	7	C3	Ab2	Ab2	7	7	7
G2	E2	C2	Bb1	A1	C2	D2	E2	F2	G2	A2	C3	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2
Bb2	D3	C3	Bb2	A2	F2	E2	D2	F2	Eb2	C2	Ab1	Gb1	Ab1	Bb1	F2	7	F2	Eb2	Bb1
Bb2	D2	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	Ab2	Gb2	F2	Ab2	F2	Eb2	7	Eb2	Db2	Bb1
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	Eb3	C3	7	Bb2	Ab2	7	F2	Eb2	Db2
Bb2	D3	C3	Bb2	A2	F2	7	7	7	7	Gb2	Ab2	Gb2	F2	Ab2	F2	Eb2	Eb2	Db2	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	Ab2	Gb2	F2	Ab2	Bb2	C3	C3	7	7	7
Bb2	D3	C3	Bb2	A2	C3	E3	F3	7	Eb3	Bb2	Gb2	F2	7	7	7	C3	Eb3	7	Db3
E2	G2	Bb2	D3	C3	A2	G2	F2	Gb2	Bb2	C3	Eb3	C3	7	Ab2	F2	7	F2	Db2	Bb1
E2	Bb2	7	D3	C3	A2	G2	F2	Gb2	Bb2	C3	Eb3	C3	Ab2	Bb2	C3	Ab2	F2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	A2	Bb2	F2	Eb2	Db2	Ab1	C2	7	7	7
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Bb2	C3	Eb3	C3	7	Ab2	F2	7	7	7	7
	Bb7				**Eb**				**Gb7**				**B**				**B**		
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	7	7	C3	Ab2	F2	7	7
D3	7	Bb2	G2	A2	7	7	C3	Gb2	7	7	Bb2	Eb3	7	7	C3	Ab2	F2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	F2	7	7	Gb2	Ab2	Bb2	C3	C3	7	7	Bb2	Ab2	F2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	C3	Bb2	C3	Ab2	C3	B2	Bb2	A2
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Bb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	Gb2	Db2	Bb1
C2	B2	Bb2	D3	C3	A2	G2	F2	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
Bb2	D3	C3	Bb2	F2	G2	7	A2	Gb2	Ab2	7	F2	F2	7	7	Eb2	Db2	Ab1	7	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
E2	7	7	7	7	7	7	7	Eb3	7	7	7	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	F3	F3	7	Eb3	C3	Bb2	Ab2	7	7
C3	B2	Bb2	D3	C3	A2	G2	F2	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1
Bb2	D3	C3	A2	F2	7	7	Ab2	7	7	Bb2	Eb3	Eb3	7	7	C3	Ab2	F2	7	7
	Bb7				**Eb**				**Gb7**				**B**				**B**		
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	Eb3	C3	7	Bb2	Ab2	7	7	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	E2	Db2	Bb1
F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Eb3	7	7	7	Eb3	7	7	7	Eb3	7	C3	7
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb2	C3	Bb2	Ab2	F2	Eb2	Db2	Bb1
C3	B2	Bb2	D3	C3	A2	G2	F2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb2	C3	Bb2	Ab2
Bb2	7	7	7	7	7	7	C3	C3	7	7	A2	G2	A2	F2	7	7	7	7	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	7	7	F2	7	7	7	7	7	7	7
E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Ab2	7	7	F2	Eb2	Eb2	Db2	Bb1
7	7	7	7	E2	G2	Bb2	D3	F2	G2	A2	C3	Gb2	Bb2	C3	Eb3	7	7	7	7
E2	G2	Bb2	D3	F2	G2	A2	Eb3	D3	7	7	7	7	Eb3	7	Db3	C3	Ab2	F2	Db2
E2	G2	Bb2	D2	F2	G2	A2	C3	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	F2	Db2	Bb1
Bb2	D3	C3	Bb2	A2	F2	G2	A2	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	Eb2	Db2	Bb1
G2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
G#2	A2	B2	G#2	A2	7	7	7	7	7	7	7	7	7	7	7	C3	Eb3	7	7
C3	B2	Bb2	D3	C3	A2	G2	F2	Gb2	Ab2	Bb2	C3	Eb3	C3	Bb2	Ab2	F2	Eb2	Db2	Bb1

F-7				Bb7				Eb				Eb				A-7			
	F-7				**Bb7**				**Eb**				**Eb**				**A-7**		
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	G2	F#2	D2	B1	F#1
D2	E2	F2	D2	A2	G2	E2	D2	C2	7	7	Bb2	A2	F2	7	7	7	B1	D2	A2
7	7	7	7	Eb3	7	7	D3	C3	Bb2	A2	G2	F2	G2	7	C3	E3	7	7	7
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	G2	F#2	D2	B1	F#1
D2	E2	F2	G2	A2	G2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	D2	B2	D2	7	A2
G2	F2	E2	D2	C2	Bb1	A1	G1	F1	A1	Bb1	D2	E2	G2	C3	7	7	7	C#2	E2
D2	E2	F2	G2	A2	G2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	G2	F#2	D2	B1	G#1
A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2	G2	F2	A2	A2	7	7	7	7
D2	E2	F2	A2	G2	7	7	7	7	Bb2	A2	E2	G2	F2	E2	D2	F#2	B2	7	7
F2	G2	A2	G2	C3	Ab2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2
D#3	E3	D#3	C#3	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2	F#2	A2	7	7
C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3	F3	7	7	7	7	7	E3	7
D2	E2	F2	G2	A2	G2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	D2	F#2	7	7	7
	F-7				**Bb7**				**Eb**				**Eb**				**A-7**		
D2	E2	F2	C2	G#2	E2	C2	A1	A2	7	E2	G2	F2	A2	7	C3	C#3	B2	A2	G#2
7	7	7	A2	A2	7	7	7	A2	G2	E2	D2	C2	D2	E2	G2	F#2	D2	E2	A2
A2	G2	F2	D2	E2	F2	G2	A2	F2	G2	A2	C3	F3	C3	7	7	7	7	7	7
C3	Ab2	Bb2	Db3	G#2	E2	C2	G#1	A2	E2	G2	E2	F2	D2	7	7	7	7	7	7
7	7	7	E3	E3	7	7	D3	C3	A2	Bb2	G2	A2	G2	F2	C2	A2	F#2	D2	B1
7	7	7	E3	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	7	E3	7	7	7
7	7	7	E3	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	7	C3	C#3	E3	7	7
C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	A2	F#2	D2
A2	7	7	E2	G#2	C3	7	7	7	C2	D2	G2	F2	G2	A2	C3	C#3	7	7	7
C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	A2	F#2	D2
	F-7				**Bb7**				**Eb**				**Eb**				**A-7**		
C3	A2	F2	A2	G2	7	7	E2	G2	E2	G2	E2	F2	D2	7	B2	A2	7	A2	C#3
7	7	7	7	A2	A2	G2	F2	E2	D2	C2	Bb1	A2	C2	D2	E2	F#2	D2	B1	F#1
F2	7	7	7	7	C3	7	7	C3	E3	7	D3	C3	7	7	7	C#3	E3	7	7
7	7	7	C3	C3	7	7	7	C3	A2	E2	G2	F2	A2	7	C3	C#3	E3	7	7
C3	7	7	7	7	C3	7	7	C3	A2	G2	F2	A2	F2	D2	A2	C#3	7	7	7
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2	F2	A2	7	C#3	C#3	D3	B2	A2
7	7	7	C3	C3	7	7	B2	A2	F2	E2	G2	F2	B2	7	A2	C#3	E3	7	7
7	7	7	7	A3	7	7	G3	E3	C3	C3	7	C3	7	7	B1	D2	A2	C#3	E3
E3	7	7	7	C3	Bb2	A2	G2	F2	A2	7	C3	F3	7	C3	D3	C#3	7	7	A2
A2	A2	G2	F2	E2	D2	C2	A1	A2	7	F2	G2	G2	7	7	7	A2	F#2	D2	B1
7	7	7	7	C3	7	7	Bb2	A2	E2	7	7	F3	C3	7	7	7	B1	D2	A2
7	7	7	7	7	7	7	7	7	C3	7	7	C3	7	7	C#3	C#3	7	7	7
	F-7				**Bb7**				**Eb**				**Eb**				**A-7**		
7	7	7	7	A1	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2
Bb2	7	7	F2	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	7	C3	C#3	B2	A2	G#2
7	7	7	7	C3	7	E3	D3	C3	Bb2	A2	G2	F2	G2	7	C3	C#3	E3	7	7
D2	E2	F2	D2	G#2	E2	C2	Bb1	A1	C2	D2	E2	G2	F2	E2	D2	F#2	B1	D2	A2
C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	7	7	7	B1	D2	A2	A2	F#2	A2	F#2
A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2	F2	G2	A2	F2	A2	F#2	E2	D2
7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	G2	F2	B2	7	7	C#3	E3	7	7
7	7	7	7	7	7	7	7	7	A2	C3	E2	G2	7	F2	7	7	B1	D2	A2
	F-7				**Bb7**				**Eb**				**Eb**				**A-7**		
D2	E2	F2	D2	G#2	F2	C2	Bb1	A1	C2	D2	E2	G2	F2	E2	G2	F#2	D2	B1	F#1
C3	B2	Bb2	A2	G2	F2	E2	D2	C#2	Bb2	A2	E2	G2	F2	7	7	7	B1	D2	A2

	F - 7				**Bb7**				**Eb**				**Eb**				**A - 7**		
A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2	G2	F2	G2	F#2	F#2	7	7	D2
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	A2	E2	G2	F2	G2	A2	C#3	C#3	D3	B2	A2
7	G1	Bb1	A2	C3	G#2	E2	C2	A2	7	E2	G2	F2	G2	A2	C#3	C#3	D3	B2	A2
C3	E3	7	7	C3	Bb2	A2	G2	F2	G2	A2	C3	F3	7	7	7	7	B1	D2	A2
7	7	7	7	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	D3	B2	A2
C3	7	7	7	G#2	G#2	E2	7	A2	F2	7	7	7	7	7	7	C#3	7	7	B2
F2	7	7	D2	F2	D2	C2	Bb1	E2	F2	G2	A2	F2	G2	A2	C3	C#3	D3	B2	A2
7	7	7	E3	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3	E3	D3	A2	F#2
7	7	7	7	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2	B1	D2	F#2	A2
	F - 7				**Bb7**				**Eb**				**Eb**				**A - 7**		
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	G1	Bb1	C2	D2	E2	F2	G2	A2	F#2	D2	B1
C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	A2	F#2	D2
D2	Bb1	A1	G1	C2	A2	7	G2	F2	G2	A2	C3	F3	C3	7	7	7	B1	D2	A2
D2	Bb1	G1	F1	E2	7	7	C2	A2	E2	G2	F2	7	7	7	7	7	B1	D2	A2
D2	E2	F2	D2	G#2	E2	C2	Bb1	A2	C2	D2	E2	G2	F2	E2	D2	F#2	D2	F#2	A2
C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	D3	B2	A2
7	7	7	7	A2	G2	E2	C2	D#2	E2	G2	E2	F2	G2	A2	C3	C#3	D2	B2	A2
7	7	7	C3	C3	7	7	7	C3	A2	E2	G2	F2	G2	A2	C3	C#3	7	7	A2
C3	Bb2	A2	G2	F2	E2	D2	Db2	C2	Bb2	A2	E2	G2	F2	7	A2	F#2	D2	B1	G#1
D2	E2	F2	D2	G#2	E2	C2	A1	F2	E2	G2	E2	F2	G2	A2	C3	C#3	A2	F#2	D2
C3	7	7	A2	Bb2	Bb2	Ab2	E2	C2	A2	7	E2	G2	F2	7	7	7	B1	D2	A2
7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	D2	F2	7	7	D2	F#2	D2	B1	G#1
C3	Eb3	7	7	C3	Bb2	A2	G2	F2	G2	7	C3	F3	7	C3	7	E2	7	7	7
	F - 7				**Bb7**				**Eb**				**Eb**				**A - 7**		
7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	A2	F#2	D2
7	7	7	A2	A2	7	7	G2	E2	F2	G2	E2	F2	G2	A2	C3	F#2	D2	A1	F#1
D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	F2	G2	F2	E2	G2	F#2	7	7	7
G2	A2	Bb2	G2	C3	G#2	E2	C2	A2	F2	E2	G2	F2	G2	A2	C3	C#3	E3	7	C3
A2	Bb2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2	G2	E2	F2	D2	F#2	B1	D2	A2
D#2	F2	G2	E2	G#2	E2	C2	Bb1	A1	C2	D2	E2	G2	F2	E2	F#2	F#2	B1	D2	A2
7	7	7	7	A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2	F#2	D2	B1	A1
E2	F2	7	D2	G#2	E2	C2	Bb1	A1	C2	D2	E2	G2	F2	E2	D2	F#2	D2	F#2	A2
D2	E2	F2	G2	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	B2	C#3	B2	A2	G#2
C3	E3	7	D3	C3	Bb2	A2	G2	F2	E2	G2	E2	F2	G2	A2	C3	C#3	B2	A2	G#2
D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2
D2	E2	F2	G2	A2	G2	E2	D2	C2	A2	7	7	7	7	7	A2	A2	7	7	F#2
7	7	7	7	A2	Bb2	G2	E2	F2	G2	A2	C3	E3	D3	C3	A2	C#3	A2	F#2	D2
	F - 7				**Bb7**				**Eb**				**Eb**				**A - 7**		
7	7	7	A2	A2	7	7	G2	F2	C2	F2	G2	A2	G2	F2	C2	F#2	D2	B1	A1
G2	F2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	G2	F2	G2	A2	C3	C#3	7	7	7
D2	E2	F2	D2	A2	G2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	D2	F#2	D2	F#2	A2
Ab2	F2	7	7	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	F#2	D2	B1	A1
D2	E2	F2	D2	A2	7	7	7	7	A2	E2	G2	F2	G2	A2	C3	F#2	D2	B1	A1
F2	Eb2	Db2	Bb1	A2	7	7	7	7	A2	E2	G2	F2	G2	A2	C3	F#2	D2	B1	A1
7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	G2	F2	G2	7	A2	F#2	D2	B1	A1
F2	G2	A2	F2	G#2	E2	C2	Bb1	A1	C2	D2	E2	G2	F2	E2	D2	F#2	7	7	7
D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	7	B2	A2
C3	E3	7	D3	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	F#2	D2	B1	A1
C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3	F3	C3	7	7	C3	E3	7	7
D2	E2	F2	G2	A2	G2	E2	D2	C2	A1	Bb1	C2	Db2	E2	F2	G2	A2	F#2	A2	F#2
D2	E2	F2	G2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	F#2	D2	B1	A1
C3	E3	7	7	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3	F#2	D2	B1	A1
C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2	G2	F2	E2	D2	B1	D2	F#2	A2
D2	E2	F2	G2	A2	G2	E2	D2	C2	D2	E2	G2	F2	G2	A2	C3	C#3	B2	A2	G#2

D7				G				G				Db-7				Gb7			
	D7				**G**				**G**				**Db-7**				**Gb7**		
A1	F#1	G#1	F2	E2	D2	C#2	B1	A1	B1	C#2	E2	F2	Eb2	Db2	C2	7	Ab1	Bb1	C2
C#3	B2	G#2	F#2	E2	F#2	G#2	B2	A2	B2	C#3	C3	C3	Db3	7	7	7	7	7	7
E3	7	7	D#3	C#3	G#2	B2	G#2	A2	E2	C#2	A1	F2	Db2	C2	Ab1	Bb1	Ab1	Bb1	C2
A1	7	7	G#1	E2	7	E2	C#3	7	7	7	7	7	Eb2	Gb2	Eb3	C3	7	Eb3	7
C#3	7	A2	C#3	C#3	7	7	A2	C#3	E3	7	7	7	Eb2	Gb2	Db3	C3	Eb3	7	7
F#2	A2	C#3	7	C#3	7	7	G#2	B2	A2	7	7	7	Eb2	Gb2	Db3	C3	7	F3	7
E2	7	7	D2	C#2	E2	F#2	G#2	7	7	7	7	7	Eb2	Gb2	Db3	C3	7	Ab2	7
A2	F#2	G#2	B2	A2	E2	C#2	A1	E2	7	7	7	F2	7	Db2	Ab1	C2	7	7	Ab1
C#3	B2	G#2	F#2	E2	G#2	B2	B2	A2	E2	C#2	A1	7	7	7	7	F2	7	7	C2
7	F#2	E2	D2	C#2	E2	A2	B2	C#3	A2	B2	C#3	C3	7	7	7	Eb3	7	7	7
C#3	E3	7	D3	C#3	E2	G#2	B2	7	B2	A2	7	7	7	7	C3	C3	7	7	Ab2
E3	7	7	7	E3	7	C#3	G#2	7	G#2	F#2	7	Ab2	7	7	Gb2	Ab2	7	Gb2	F2
C#3	7	B2	7	B2	7	7	G#2	E2	C#2	7	7	7	7	B2	7	Bb2	7	Db3	7
	D7				**G**				**G**				**Db-7**				**Gb7**		
7	A2	B2	G#2	G#2	7	7	E2	F#2	C#2	7	7	7	Eb2	Gb2	Db3	Ab2	Bb2	C3	Eb3
C#3	B2	G#2	F#2	E2	F#2	G#2	B2	7	G#2	E2	C#2	Bb2	Eb2	Gb2	Db3	C3	7	7	7
C#3	B2	G#2	F#2	E2	F#2	G#2	B2	A2	B2	C#3	E3	Db3	7	7	Bb2	Gb2	Eb2	7	C3
C#3	B2	G#2	F#2	E2	F#2	G#2	B2	A2	B2	C#3	C#3	Bb2	7	7	Gb2	Ab2	7	F2	Eb2
G#2	A2	B2	C#3	A2	E2	F#2	G#2	B2	A2	G#2	F#2	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
7	C3	F#2	E2	E2	7	7	F#2	A2	7	7	7	7	Eb2	Gb2	Bb2	F3	7	Eb3	7
C3	G#2	E2	D2	C#2	7	7	G#2	A2	7	7	7	7	Eb2	Gb2	Db3	F3	Eb3	7	C3
G#2	7	7	7	7	B2	G#2	B2	A2	B2	7	Db3	Db3	7	7	Bb2	C3	Ab2	Bb2	C3
A2	B2	7	7	B2	7	7	G#2	E2	E2	C#2	A1	7	7	7	Bb2	C3	7	7	Bb2
G#2	B2	E2	A2	C#3	7	7	B2	G#2	E2	7	7	7	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
	D7				**G**				**G**				**Db-7**				**Gb7**		
B2	7	7	E2	B2	7	7	G#2	E2	C#2	7	7	7	Eb2	Bb2	C3	C3	7	7	7
A1	F#1	G#1	F2	E2	D2	C#2	B1	A1	B1	C#2	E2	F2	Eb2	Db2	C2	7	Ab1	Bb1	C2
C3	G#2	E2	7	7	C#2	7	7	B2	G#2	B2	Bb2	Bb2	7	7	Gb2	F2	Eb2	7	7
B2	7	7	E3	C#3	7	7	G#2	B2	A2	7	7	7	Bb2	Gb2	Db2	C3	7	F3	7
C#3	7	7	7	C#3	B2	G#2	F#2	E2	7	7	Bb2	Db3	Bb2	Db3	7	C3	7	7	Ab2
G#2	F#2	E2	D2	C#2	E2	G#2	B2	7	B2	G#2	E2	7	7	7	7	7	7	7	7
C3	G#2	E2	D2	C#2	D2	E2	F#2	G#2	A2	B2	7	Ab2	7	F2	Db2	7	D2	C2	Ab1
D3	7	7	7	D3	7	7	B2	C#3	E2	7	7	7	Eb2	Gb2	Db2	Ab2	Bb2	C3	Eb3
F#2	D2	7	B2	B2	7	7	G#2	E2	7	C#2	7	7	Db3	7	Bb2	Gb2	Eb2	7	C3
G#2	7	7	E2	E2	F#2	G#2	B2	7	B2	A2	7	7	7	Eb2	Bb2	C3	7	7	Bb2
G#2	7	B2	E3	E3	7	C#3	G#2	B2	7	A2	7	Eb2	Gb2	Bb2	C3	C3	7	F3	Ab3
B2	7	7	B2	B2	7	7	G#2	E2	C#2	Eb2	Bb2	C3	7	7	7	C3	7	7	Ab2
	D7				**G**				**G**				**Db-7**				**Gb7**		
7	F#2	G#2	7	G#2	7	7	F#2	E2	C#2	7	7	7	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
G#2	7	7	F#2	E2	C#2	7	7	7	7	7	7	7	7	7	C3	C3	7	7	Bb2
C3	G#2	E2	D2	C#2	E2	F#2	G#2	B2	A2	G2	E2	Bb2	7	7	Gb2	C3	7	7	Bb2
C#3	7	7	7	C#3	B2	G#2	F#2	E2	C#2	7	7	7	7	7	7	Eb2	Gb2	Bb2	Db3
G#2	B2	E2	F#2	B2	7	7	G#2	E2	C#2	7	7	7	Eb2	Gb2	Db3	C3	F3	7	Eb3
G#2	7	7	7	B2	A2	G#2	B2	A2	E2	C#2	A1	F2	Bb1	Db2	F2	C2	7	7	7
C3	G#2	E2	D2	C#2	E2	F#2	G#2	B2	7	7	7	7	7	Eb2	Bb2	C3	7	7	Bb2
C#3	7	B2	7	B2	7	7	G#2	E2	7	C#2	7	7	Eb2	G2	Db3	C3	7	7	Bb2
	D7				**G**				**G**				**Db-7**				**Gb7**		
A1	F#1	G#1	F2	E2	D2	C#2	B1	A1	B1	C2	E2	7	7	7	Bb2	Db2	7	C3	7
C#3	B2	G#2	F2	E2	7	7	F#2	G#2	F#2	7	7	7	7	7	Ab2	7	7	7	Gb2

	D 7				**G**				**G**				**D b - 7**				**Gb7**		
B1	G#1	7	E2	E2	7	7	7	7	7	7	7	7	Eb2	Gb2	Db2	C3	7	7	Ab2
G#2	7	7	F#2	E2	C#2	7	7	7	7	7	7	Eb2	Gb2	Bb2	Db3	C3	Eb3	C3	Bb2
G#2	F#2	E2	D2	C#2	E2	G#2	B2	7	B2	G#2	E2	F2	7	7	7	F2	7	Eb2	Db2
C#3	E3	7	7	C#3	7	7	B2	7	G#2	E2	C#2	Gb2	7	7	Db3	F3	Db3	F3	Eb3
G#2	F#2	E2	D2	C#2	G#1	7	B1	A1	B1	C#2	E2	F2	Eb2	Db2	C2	7	Ab1	Bb1	C2
C#3	7	B2	G#2	G#2	7	7	E2	7	C#2	7	7	7	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
G#2	F#2	E2	D2	C#2	E2	G#2	B2	7	B2	G2	E2	Bb2	Db3	Bb2	Gb2	Eb2	Eb2	C2	7
G#2	B2	7	E3	E3	C#3	7	7	B2	A2	Eb2	Gb2	Bb2	C3	7	7	C3	7	7	Bb2
C#3	B2	G#2	F2	E2	F#2	G#2	B2	A2	B2	C#3	D3	Bb2	Ab2	7	7	Ab2	7	7	Gb2
	D 7				**G**				**G**				**D b - 7**				**Gb7**		
G#2	7	7	F2	E2	A2	E2	D2	C#2	E2	7	7	7	7	Eb2	Bb2	C3	7	7	Bb2
G#2	7	7	E2	B2	G#2	E2	C#2	7	C#2	A1	7	7	7	Eb2	Bb2	C3	7	Eb2	C3
C#3	7	7	7	C#3	7	B2	G#2	7	G#2	E2	C#2	Gb2	Eb2	Gb2	Db2	C3	F3	7	F3
B2	G#2	F#2	F2	E2	E2	C#2	A1	B1	7	7	F#1	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
C#3	B2	G#2	F#2	E2	A2	7	7	7	7	7	7	7	7	7	Db3	C3	7	C3	7
G#2	7	7	7	B2	A2	G#2	B2	A2	E2	C#2	A1	F2	Db2	Bb1	Gb1	C2	7	7	Ab1
G#2	F#2	E2	D2	C#2	7	7	7	B1	A1	G#1	A1	F2	Eb2	Db2	C2	7	Ab1	Bb1	C2
F#2	D2	7	A#2	A#2	B2	7	G#2	E2	7	C#2	7	Db3	7	7	7	Db3	Bb2	Gb2	7
G#2	7	7	7	G#2	7	F#2	G#2	7	G#2	E2	C#2	F2	7	Db2	Bb1	C2	7	7	7
G#2	7	7	E2	B2	A2	7	7	7	7	7	7	7	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
C#3	B2	G#2	F#2	E2	F#2	G#2	B2	A2	E2	C#2	A1	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
7	G#1	E1	7	A1	B1	C#2	E2	7	B1	D2	F#2	Db3	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
C#3	7	7	E3	B2	7	7	A2	C#3	E3	7	7	7	Eb2	Gb2	Db2	C3	Ab3	7	7
	D 7				**G**				**G**				**D b - 7**				**Gb7**		
G#2	E2	F2	G#2	B2	A2	G#2	B2	A2	E2	C#2	A1	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
G#1	F2	E2	D2	C#2	E1	F#1	G#1	B1	A1	G1	B1	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
F#2	D2	B1	G#1	E2	D2	C#2	B1	A1	B1	C#2	E2	F2	Eb2	Db2	C2	7	Ab1	Bb1	C2
C3	G#2	D2	7	7	C#2	E2	B2	A2	7	Eb2	Eb2	Db3	F3	7	Eb3	C3	7	7	Eb3
C#3	E2	A2	C#3	C#3	7	7	A2	C#3	B2	7	7	7	Eb2	Gb2	Db3	C3	7	7	Bb2
C#3	7	7	B2	B2	7	7	G#2	E2	C#2	7	7	Db3	7	7	7	C3	7	7	7
G#1	F2	E2	D2	C#2	E1	A1	C#2	A1	B1	C#2	E2	Bb1	Db2	Eb2	Bb2	C3	7	7	7
C#3	E2	A2	C#3	B2	7	C#3	B2	7	7	7	7	7	7	7	Db3	Db3	7	C3	7
7	F#2	E2	D2	C#2	D2	E2	F#2	G#2	A2	B2	C3	Db3	7	Bb2	Gb2	Eb2	7	G2	C3
7	F#2	E2	D2	C#2	E1	A1	C#2	B1	7	7	7	7	Eb1	Gb1	Db2	C2	Ab1	Bb1	C2
7	F#2	E2	D2	C#2	E2	A2	C#3	7	7	7	7	7	Eb2	Gb2	Db3	C3	7	7	7
G#2	A2	B2	C#3	G#2	7	7	E2	G#2	F#2	7	Eb2	Gb2	C3	7	7	C3	7	C3	7
G#2	A2	B2	C#3	A2	G#2	F#2	F2	E2	D2	C#2	A1	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
	D 7				**G**				**G**				**D b - 7**				**Gb7**		
G#1	F2	E2	D2	C#2	E2	7	7	7	7	7	F2	F2	7	7	Db2	C2	7	7	Ab2
7	7	C#3	7	E3	7	7	C#3	G#2	7	F#2	7	Ab2	7	Gb2	F2	Ab2	7	Gb2	F2
C#3	E3	7	D3	C#3	E2	F#2	G#2	B2	A2	G2	F2	F2	7	7	Eb2	F2	7	Eb2	C2
G#1	F2	E2	D2	C#2	E1	F#1	G#1	B1	A1	G1	A1	F2	Db2	Bb1	Ab1	C2	Ab1	Bb1	C2
G#1	F1	E1	D1	C#1	7	7	7	7	7	Eb1	Bb1	C2	Ab1	Bb1	Db2	Eb2	Gb2	Bb2	Db3
G#1	7	7	7	7	C#3	7	G#2	B2	7	7	7	B2	Db3	7	Bb2	C3	7	7	C3
G#1	F2	E2	D2	C#2	D2	E2	F#2	G#2	A2	B2	C#3	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
C#3	7	B2	7	B2	7	7	G#2	E2	7	C#3	7	B2	7	7	C#3	C3	7	7	C3
G#2	F#2	E2	D2	C#2	E2	A2	C#3	7	C#3	B2	Eb2	Gb2	Db3	C3	7	C3	7	7	Bb2
G#1	F2	E2	D2	C#2	E2	A2	C#3	B2	7	7	7	7	Eb2	Gb2	Db3	C3	Ab2	Bb2	C3
E3	7	D3	7	D3	7	C#3	7	C#3	7	7	7	7	Eb3	7	7	Eb3	7	7	7
G#2	A2	B2	C#3	A2	E2	C#2	A1	E2	7	7	7	7	F2	Db2	C2	C2	Ab1	Bb1	C2
G#1	F2	E2	D2	C#2	E2	A2	C#3	7	7	7	7	7	Eb2	Gb2	Db3	C3	7	7	7
G#1	F1	E1	D1	C#1	D1	E1	F#1	G1	7	7	7	7	Eb1	Gb1	Db2	C2	Ab1	Bb1	C2
C#3	B2	G#2	F2	E2	F#2	G#2	B2	A2	B2	C#3	C3	C3	7	7	Ab2	Bb2	C3	7	Ab2
7	F#2	E2	C#2	7	7	7	7	7	7	Eb2	Bb2	C3	7	7	Ab2	Bb2	C3	7	Ab2

B				B				F-7				Bb7				Eb			
	B				**B**				**F - 7**				**Bb7**				**Eb**		
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	7	7	7	Bb2	A2	G2	E2	F2	G2	7	C3
C3	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2	D2	E2	F2	D2	A2	G2	E2	D2	C2	7	7	A2
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	Bb2	7	7	A2	G2	F2	E2	D2	C2	Bb1	A1	G1
Eb3	7	7	C3	Ab2	F2	7	E3	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Eb3	7	C3	Bb2	Ab2	F2	Db2	7	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Eb3	7	7	C3	Ab2	F2	7	7	7	E3	7	D3	C3	Bb2	A2	G2	F2	E2	G2	E2
Ab2	7	7	F2	Eb2	7	Db2	7	D2	E2	F2	D2	A2	G2	E2	D2	C2	F2	G2	A2
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	A2	Bb2	G2	C3	Ab2	E2	C2	A2	F2	E2	G2
C2	7	7	Ab1	Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb2	A2	E2
C3	7	7	Eb3	C3	Ab2	F2	Db2	D2	E2	F2	G2	A2	G2	E2	D2	C2	F2	A2	C3
Bb2	C3	Ab2	F2	7	F2	Db2	Bb1	D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	G2
F2	7	Ab2	7	Eb3	7	7	Db3	C3	7	7	7	C3	7	7	Bb2	A2	F2	E2	G2
C3	7	7	Ab2	F2	7	Db2	7	E3	7	7	D3	C3	7	7	Bb2	A2	G2	7	F2
	B				**B**				**F - 7**				**Bb7**				**Eb**		
C3	7	Bb2	Ab2	7	F2	Eb2	Db2	A2	G2	F2	D2	E2	F2	G2	A2	F2	G2	A2	C3
C3	7	7	Ab2	F2	Db2	7	7	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
C3	7	7	Ab2	G2	7	Db2	7	Eb3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Eb2	7	7	C2	F2	Ab2	7	7	A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	E2	F2
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	A1	C2	A1
Eb3	7	7	C3	Ab2	7	F2	7	C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
C3	7	7	Ab2	F2	F2	Eb2	7	D2	E2	F2	D2	A2	G2	E2	C2	F2	7	A2	C3
Db3	Eb3	C3	Ab2	7	F2	Db2	Bb1	C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2
Ab2	Bb2	Ab2	F2	7	Eb2	Db2	A1	D2	E2	F2	D2	A2	G2	E2	C2	A2	7	C3	C3
Db3	Eb3	7	D3	C3	Ab2	F2	Db2	C3	B2	Bb2	A2	G2	F2	E2	D2	A2	F2	E2	G2
	B				**B**				**F - 7**				**Bb7**				**Eb**		
C3	7	7	Ab2	F2	7	D2	7	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	A1	G1	F1
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	A1	G1	F1
7	Ab2	F2	C2	7	Eb2	Db2	Ab1	D2	E2	F2	D2	G#2	E2	C2	A1	E2	F2	G2	A2
Eb3	7	7	C3	Ab2	F2	7	7	7	E3	7	D3	C3	G#2	E2	D2	C2	D2	E2	G2
C3	Ab2	F2	Db2	7	7	7	7	C3	E3	7	7	C3	7	7	7	C3	7	7	Bb2
7	7	7	7	7	7	7	Eb3	Eb3	7	7	7	Eb3	7	7	Db3	C3	Bb2	A2	G2
C2	Ab1	Bb1	C2	Db2	Eb2	F2	Ab2	C3	G#2	E2	C2	A2	7	7	E2	G2	E2	F2	C2
Db3	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2	D2	E2	F2	D2	G#2	E2	C2	G#1	F2	G#2	A2	C3
C3	7	7	Ab2	F2	Db2	7	7	7	7	7	D3	7	7	C3	Bb2	A2	F2	E2	G2
Ab2	F2	Eb2	Db2	F2	7	A2	G2	G2	7	7	E2	G#2	7	E2	A2	A2	C3	7	7
Ab3	7	7	7	7	7	7	7	C3	Eb3	7	C3	C3	Bb2	A2	G2	F2	G2	7	C3
C3	Ab2	Bb2	C3	Ab2	F2	Db2	Bb1	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2
	B				**B**				**F - 7**				**Bb7**				**Eb**		
Ab2	F2	Eb2	Db2	F2	7	A2	G2	G2	7	7	D2	G#2	E2	C2	Bb1	A2	C2	D2	E2
Ab2	F2	Eb2	Db2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	D2	E2
Ab2	F2	Eb2	C2	F2	7	Ab2	C3	7	7	7	7	C3	7	7	Bb2	A2	F2	E2	G2
C3	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2	D2	E2	F2	D2	G#2	E2	C2	Bb1	A1	C2	D2	F2
Eb3	7	7	C3	Ab2	F2	7	7	C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	7	C3
7	Ab1	Bb1	C2	Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	A2	7	F2	D2
Ab2	7	7	F3	Eb2	7	Db2	7	A2	A2	G2	F2	E2	D2	C2	Bb1	A1	C2	E2	F2
Ab2	7	7	Gb2	F2	7	7	Eb2	A2	7	G2	F2	E2	7	7	7	7	7	7	7
	B				**B**				**F - 7**				**Bb7**				**Eb**		
C3	7	7	Ab2	F2	7	7	7	C3	Db3	Eb3	7	C3	Bb2	A2	G2	F2	G2	7	C3
F2	Ab2	F2	Eb2	Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2

	B				**B**				**F - 7**				**Bb7**				**Eb**		
F2	7	7	C2	F2	Ab2	C3	Bb2	Bb2	7	7	D2	E2	7	A2	F2	F2	7	7	C2
Ab2	F2	D2	Ab1	F2	Ab2	C3	Bb2	Bb2	7	7	D2	E2	F2	G2	A2	F2	G2	A2	C3
C2	Ab1	Bb1	C2	Db2	Eb2	F2	Ab2	C3	7	C3	G#2	C3	G#2	E2	C2	A2	F2	7	7
Eb3	7	7	C3	A2	F2	7	7	7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	G2
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	A2	F2	D2	Bb1	E2	A2	C2	D2	E2	7	7	7
Ab2	F2	7	7	Eb2	7	7	Db2	D2	E2	F2	D2	G#2	E2	C2	A1	A2	7	C2	F2
7	7	7	C2	F2	Bb2	Eb3	7	7	C2	D2	G2	F3	7	7	C3	7	E3	7	D3
Ab2	Bb2	C3	Ab2	7	F2	Db2	7	C3	B2	Bb2	A2	G2	F2	E2	C2	A2	7	F2	7
F2	Ab2	Bb2	C3	Ab2	F2	Eb2	Db2	A2	F2	D2	Bb1	E2	A2	7	7	F2	7	7	7
	B				**B**				**F - 7**				**Bb7**				**Eb**		
Ab2	Gb2	F2	Eb2	Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	A2	C2	D2	G2
C3	7	7	Ab2	F2	Db2	7	7	C3	Eb2	7	D3	C3	Bb2	A2	G2	F2	G2	7	C3
F3	7	Eb3	C3	C3	7	7	7	C3	D3	E3	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	G1	C2	A1
C3	7	7	Ab2	C3	7	Ab2	C3	C3	7	7	Ab2	C3	Ab2	E2	C2	A2	7	F2	7
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	C3	7	7	7	C3	7	7	7	C3	A2	7	7
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	A2	A2	G2	F2	E2	D2	C2	A2	F2	C2	7	7
C3	7	7	A2	F2	Eb2	7	7	7	7	7	C3	C3	7	7	7	C3	7	B2	D3
7	C2	F2	C3	Eb3	7	7	Db3	C3	7	7	7	C3	7	7	Bb2	A2	F2	E2	G2
Eb3	7	7	C3	Ab2	F2	Db2	Bb1	D3	C3	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	A2	F2	D2	Bb1	E2	A2	7	7	F2	7	7	7
Eb3	7	C3	Ab2	7	Ab2	F2	7	7	7	7	C3	C3	7	7	Bb2	A2	F2	E2	G2
Ab3	7	F3	C3	7	7	7	7	C3	E3	7	7	C3	Bb2	A2	G2	F2	G2	A2	C3
	B				**B**				**F - 7**				**Bb7**				**Eb**		
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	G1	A1	C2
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	A2	Bb2	G2	C3	G#2	E2	C2	A2	F2	E2	G2
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	A2	Bb2	C3	A2	7	E2	G2	G2	7	7	F2
Eb3	7	7	C3	C3	7	7	7	E3	7	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Ab2	F2	Eb2	D2	Db2	7	7	7	7	7	A2	7	A2	7	7	C2	E2	F2	G2	E2
C3	7	7	Ab2	F2	Db2	7	7	7	7	F3	7	F3	D3	Bb2	E3	E3	A2	F2	7
C3	Eb3	7	D3	C3	Ab2	F2	Db2	G2	A2	Bb2	G2	C3	G#2	E2	C2	A2	F2	E2	G2
C3	7	7	Ab2	F2	7	Db2	7	D3	7	7	Bb2	D2	F2	D2	Bb2	C3	7	7	7
C3	7	7	Ab2	F2	Db2	7	C3	C3	7	7	7	C3	7	C3	Bb2	A2	C2	D2	E2
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	G1	A1	C2
C3	7	7	Ab2	F2	7	Db2	7	D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	G2
C3	7	7	Ab2	F2	7	C2	7	7	F3	Eb3	Bb2	G2	7	7	C3	E3	7	7	D3
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2	F2	E2	G2	E2
	B				**B**				**F - 7**				**Bb7**				**Eb**		
Db2	Eb2	F2	Ab2	7	7	7	7	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	D2	E2	G2
F2	7	7	C2	Eb2	D2	Db2	Bb1	D2	E2	F2	D2	A2	G2	E2	D2	C2	A2	Bb1	C2
C2	7	7	7	7	7	7	7	D3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Db2	Eb2	F2	Ab2	C3	Ab2	F2	Db2	A2	7	7	7	A2	A2	G2	F2	E2	D2	C2	Bb1
Eb3	7	7	C3	Ab2	7	F2	7	C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
C3	7	7	Ab2	F2	7	Db2	7	C3	E3	7	D3	C3	Bb2	A2	G2	F2	G2	A2	C3
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	G1	A1	C2
C3	7	7	Ab2	F2	7	Eb2	7	C3	E3	7	D2	C3	Bb2	A2	G2	F2	G2	A2	C3
Ab2	Bb2	Ab2	F2	7	F2	Db2	7	7	7	7	7	C3	E3	7	D3	C3	Bb2	A2	G2
Ab2	F2	7	7	F2	Ab2	Bb2	C3	7	7	7	7	C3	B2	Bb2	A2	G2	F2	E2	D2
Eb3	7	C3	Bb2	Ab2	F2	Db2	Bb1	D2	E2	F2	D2	A2	G2	E2	D2	C2	F2	A2	C3
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	Bb1	A1	G1	F1	G1	A1	C2
C3	7	7	Ab2	Bb2	C3	7	7	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	A1	G1	F1
Db2	Eb2	F2	Ab2	C3	B2	Bb2	A2	G2	F2	E2	D2	C2	A1	G1	F1	A1	F1	E1	G1
Ab2	7	7	F2	Eb2	D2	Db2	Bb1	D2	E2	F2	D2	A2	G2	E2	D2	C2	D2	E2	G2
Ab2	7	7	F2	Eb2	D2	Db2	Bb1	D2	E2	F2	G2	A2	G2	E2	D2	C2	D2	E2	G2

Eb				Db-7				Gb7			
	Eb				**Db-7**				**Gb7**		
F3	C3	7	7	7	7	C3	Db3	C3	7	7	Ab2
7	7	7	7	7	Eb2	Gb2	Db3	Ab2	Bb2	C3	Eb3
F1	G1	A1	C2	F2	7	7	7	7	7	7	7
F3	7	7	7	7	F3	Eb3	Db3	C3	7	7	Ab2
F3	7	7	7	7	Eb3	7	7	Eb3	7	7	C3
F2	G2	A2	C3	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
7	A2	C3	7	7	7	7	7	7	C3	7	7
F2	7	7	7	7	7	7	Ab2	Ab2	7	7	7
G2	F2	E2	D2	F2	D2	Bb1	Gb1	C2	7	7	Ab1
F3	7	C3	D3	7	C3	7	7	C3	7	7	7
F2	G2	A2	C3	F2	Db2	Bb1	Gb1	C2	7	7	Ab1
F2	G2	A2	C3	Db3	7	7	7	7	7	7	7
7	7	7	Eb2	F2	Ab2	G2	7	7	7	7	7
	Eb				**Db-7**				**Gb7**		
F3	A2	7	7	7	7	7	7	7	7	7	7
F3	C3	7	7	7	7	7	7	7	7	7	7
F3	A2	7	7	7	7	7	7	7	7	7	7
F2	7	7	7	7	7	7	7	7	Ab2	7	Gb2
F2	7	7	7	7	7	7	Ab2	Ab2	7	7	Gb2
F3	C3	7	7	7	7	7	Eb3	Eb3	7	7	Ab2
C3	7	7	7	Eb2	Gb2	7	C3	C3	7	7	Ab2
F2	D2	7	7	7	7	7	Ab2	Ab2	7	7	Gb2
C3	7	7	7	7	7	7	C3	C3	7	7	Bb2
F2	D2	7	7	7	7	7	Ab2	Ab2	7	7	7
	Eb				**Db-7**				**Gb7**		
G1	C2	7	7	7	7	7	Bb2	C3	7	7	Ab2
A1	7	7	7	7	7	7	7	7	7	7	7
F2	G2	A2	C3	Eb2	Gb2	7	Bb2	C3	Ab2	7	7
F2	G2	7	C3	F3	A3	7	Ab3	7	7	7	7
A2	F2	E2	G2	Gb2	Eb2	Bb1	Ab1	F2	7	7	Db2
F2	G2	7	C3	Eb3	7	7	C3	7	C3	7	Ab2
F3	F2	7	7	7	7	7	C3	C3	7	7	Ab2
C3	7	7	7	7	7	7	C3	C3	7	7	Bb2
F2	G2	7	C3	Db3	Bb2	Gb2	Eb2	C3	7	7	Ab2
7	7	7	7	7	7	7	C3	C3	7	7	Bb2
F3	7	C3	D3	C3	7	7	7	7	7	7	7
F2	G2	A2	C3	Db3	Bb2	Gb2	Eb2	Ab2	7	7	7
	Eb				**Db-7**				**Gb7**		
G2	F2	7	7	7	7	7	7	7	7	7	7
G2	F2	E2	D2	F2	Db2	Bb1	Gb1	C2	7	7	Ab1
F2	G2	A2	C3	Db3	Bb2	Gb2	Eb2	C3	7	7	Ab2
F2	7	7	7	7	7	7	7	7	7	7	7
F3	7	C3	D3	C3	7	7	7	Db3	C3	7	7
F2	7	7	Eb2	F2	Db2	7	7	7	7	7	7
F2	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7	7	7
	Eb				**Db-7**				**Gb7**		
F3	7	Eb2	Bb2	C3	7	7	Bb2	Ab2	7	7	Gb2
F2	G2	A2	C3	Db3	7	7	C3	7	C3	Ab2	7

	Eb				**D b - 7**				**Gb7**		
E2	D2	7	7	7	7	7	7	7	7	7	7
F3	C3	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	C3	C3	7	7	Ab2
F2	G2	A2	C3	Db3	E3	C3	Bb2	7	Bb2	Ab2	7
7	7	7	7	7	7	7	7	F2	Gb2	Ab2	Bb2
F2	7	7	7	7	F2	Db2	C2	Bb1	Bb1	7	7
C3	7	7	7	7	7	7	7	7	7	7	7
F2	7	7	7	7	7	7	7	Ab2	7	7	7
7	7	7	Ab2	Ab2	7	7	F2	Ab2	7	F2	7
	Eb				**D b - 7**				**Gb7**		
7	G2	F2	7	7	7	7	7	7	7	7	7
F3	7	A2	7	7	7	7	7	7	7	7	7
E2	7	G2	F2	F2	7	7	7	7	7	7	7
F2	7	7	7	7	7	7	7	7	7	7	7
F2	7	7	Eb2	Gb2	Eb2	Gb2	Db3	C3	7	7	Ab2
7	7	7	7	Ab2	7	7	F2	Ab2	7	7	7
7	7	7	7	7	7	7	Ab2	Ab2	7	7	G2
A2	G#2	Bb2	A2	7	7	7	7	Db3	7	7	7
F2	G2	A2	Db3	Db3	E3	Db3	C3	7	C3	Ab2	7
F2	G2	A2	C3	Db3	Bb2	Gb2	Eb2	C3	Ab2	7	Bb2
7	7	7	7	7	7	7	Ab2	Ab2	7	7	Gb2
F2	G2	7	C3	Db3	A2	F#2	D2	Ab2	7	7	7
F3	7	7	7	7	7	7	F3	F3	7	Eb3	7
	Eb				**D b - 7**				**Gb7**		
F2	7	7	7	7	F2	Db2	Gb1	C2	Ab1	Bb1	C2
F2	G2	A2	C3	F2	Db2	Bb1	Gb1	C2	7	7	Ab1
G2	F2	7	7	7	7	7	7	7	7	7	7
F3	7	7	7	Db3	7	7	C3	C3	7	7	Ab2
F2	G2	A2	C3	F2	Db2	Bb1	G1	C2	7	7	Ab1
7	7	7	Eb3	Eb3	7	7	7	7	7	7	7
F2	G2	A2	C3	Db3	Bb2	Gb2	Eb2	Ab2	7	7	7
C3	A2	G2	F2	Ab2	7	7	F2	7	F2	Eb2	Ab1
G2	7	F2	7	7	7	7	7	7	7	7	E3
F2	7	7	7	7	F2	C2	Gb1	Gb1	7	7	7
F2	G2	A2	C3	Db3	Bb2	Gb2	Eb2	Ab2	7	7	E2
C3	7	F2	7	7	7	7	7	Eb3	7	7	7
F2	G2	A2	C3	Ab2	F2	Db2	Ab1	Eb2	7	7	Db2
	Eb				**D b - 7**				**Gb7**		
F2	G2	A2	C3	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
Db2	E2	F2	G2	F2	Db2	Bb1	Gb1	C2	Ab1	Bb1	C2
F3	C3	7	7	7	7	7	7	7	7	7	7
A2	C2	D2	E2	F2	7	7	7	C2	7	7	Ab1
F3	C3	7	7	7	Eb2	Gb2	Db3	C3	7	7	Ab2
F3	7	7	7	7	7	7	Db3	Db3	7	7	Ab2
F2	7	7	7	7	7	7	7	F2	7	7	Eb2
C3	7	7	7	7	7	7	7	7	7	7	7
F2	E2	G2	E2	F2	G2	A2	C3	F2	Eb2	C2	Ab1
C2	A2	G1	F1	Gb1	Ab1	Bb1	Db2	C2	Ab1	Bb1	C2
7	C3	F3	7	7	7	7	7	7	7	F3	7
F2	7	7	7	F2	7	Db2	Bb1	C2	Ab1	Bb1	C2
G1	7	7	7	F2	Eb2	Db2	Bb1	C2	7	7	Ab1
F1	A1	7	7	7	7	7	7	7	7	7	7
F2	G2	A2	C3	Db3	A2	Gb2	Eb2	7	7	7	7
F2	G2	A2	C3	Ab2	7	7	Ab2	7	7	7	7