Tonal Dynamics and Metrical Structures in Jazz Improvisation

Topi Järvinen

JYVÄSKYLÄ STUDIES IN THE ARTS 58

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"[While improvising] I'm calling upon all the resources of all the years of my playing at once: my academic understanding of the music, my historical understanding of the music, and my technical understanding of the instrument that I'm playing. All these things are going into one concentrated effort to produce something that is indicative of what I'm feeling at the time I'm performing" (Berliner 1994, 16)

Arthur Rhames, jazz musician

Dedicated to my parents, Sirkka and Olli Järvinen

ABSTRACT

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In the statistical analyses reported in this study 17 bebop styled jazz improvisations were examined. The goal was to determine some of the ways that the musicians utilize in order to cope with the cognitive constraints of improvisation. In particular, the tonal, harmonic and metrical preferences of the improvisers were investigated.

These results seem to suggest that at least in this type of music both global and local tonal orientation affect the process of improvisation, for the global tonality and certain important chords seem to serve cognitive reference points. Also various metrical structures were used to emphasize important tonal material or mark phrase boundaries. Moreover, it was found that the improvisers used patterns of tension and release in order to maintain both interest and coherence in the improvisation.

The results give strong evidence that bebop styled jazz improvisation is at the same time remarkably structured and dynamic. It seems that the process of improvisation is to a considerable degree based on various interrelated hierarchical principles which help the musicians to maintain coherence and interest in their improvisations. Further they show that the human cognition is able to handle very sophisticated hierarchical structures while improvising music. It is also noteworthy that these principles are well in concordance with the empirical research on music cognition.

Keywords: improvisation, tonal hierarchy, meter, cognitive reference points, jazz, Rhythm Changes

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Jyväskylässä 5.5.1997

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1 INTRODUCTION

The study of music cognition has been mainly concerned with how music is perceived by the listener. Although there are many interesting studies, for example, on music performance (e.g., Palmer 1992), composing (e.g., Heinonen 1995), and improvisation (e.g., Pressing 1988), the listener's point of view has clearly dominated the field. Still, it would seem that our knowledge of the cognitive processes regarding music is significantly incomplete if we do not scrutinize the making or production of music with equal precision. Improvisation seems an especially interesting subject of investigation for the study of music cognition. Namely, it offers material on how both high and low level cognitive processes are used in a setting which is temporally very restricted. For while improvising one cannot go back and revise or change completely some past event that in retrospect appears unsuitable in conjunction with the other events in the improvisation. It is noteworthy that although there are certainly some processes particular to improvisation, our everyday cognitive functions are also limited by similar temporal constrains. Thus, it would appear plausible that the evidence obtained from the study of improvisation could also be employed to a certain extent when more general questions concerning human cognition are contemplated.

Musical improvisation is often defined as "composing on the spur of the moment" (Schuller 1989, 865), or "the creation of a musical work as it is being performed" (Horsley 1980, 31). It would seem that explicit or implicit in these definitions is that improvisation is something which can be distinguished from musical composition or something which is a subset of composition. These definitions lead us to believe that unlike composition improvisation lacks, for example, planning and preparation (Treitler 1991). Still, studies clearly show that improvisations are not created on the "spur of the moment." For it appears that even though the musician does not know exactly how the improvisation will turn out, there must be at least some procedural plan which will guide the performance (Treitler 1991, 68; see also Treitler 1974). Many studies also indicate that the improvisations are usually preceded by a period of practice and rehearsal in which many or even most of the elements of the actual improvisation are present (cf,. Berliner 1994, Nettl 1974). Improvisation is, then, "the domain of the expert, rooted as it is in knowledge and experience" (Hall 1992, 233). Moreover, composition can sometimes involve very little planing, preparation, or very few revisions (e.g., Nettl 1974, 10-11; Nettl 1983, 28-29; Heinonen 1996). Thus, the distinction between improvisation and composition seems to be quite ambiguous, for they may be seen as two overlapping parts of the same continuum (cf., Nettl 1974, 7).

Even though improvisation and composition seem to be closely related processes, many writers have argued that the analysis or criticism should take into account the special constraints and characteristics of improvisational process (e.g., Alperson 1984, Treitler 1974). In particular, when talking about the analysis of jazz improvisation, it has been noted that the traditional techniques of music analysis (e.g., Schenkerian analysis) may not be suitable for the analysis of jazz improvisations (e.g., Brownell 1994, Järvinen 1994, Keil 1966). Still, keeping in mind the close relationship between improvisation and composition, this argument could be profitably rephrased. It might be better to say that different styles of music (whether improvised or composed) may require different set of methods of analysis (cf., Nettl 1991, 5; see also Meyer 1956, 62-63). In other words, since one does not analyze a serial composition with exactly the same methods as a fugue, why should we expect to be able to use the same methods in the analysis of a Beethoven sonata and an improvisation by Miles Davis. This sounds trivial, but the way in which the various techniques of music analysis have been utilized on jazz improvisations indicates that in practice it is seldom remembered (see Järvinen 1994).

Analytical studies on jazz have been divided into those which view improvisation as a relatively static product and those which hold that improvisation is a process (Brownell 1994, cf., Keil 1966). Most of the studies fall into the former category: the unifying factor in these studies is that most utilize some reductive methods of analysis (e.g., Kernfeld 1981, Schuller 1958, Stewart 1973). The studies in the latter category have tried to understand the improvisation as dynamic unfolding of music. For example, there has been the growing interest in applying the theory of formulaic composition proposed by Millman Parry and Albert Lord (1960) to jazz improvisations (e.g., Smith 1983, 1991). Further examples of processual approaches are, for example, David Sudnow's (1978) introspective account on the process of learning how to improvise, Jeff Pressing's (1989) associationistic model of jazz improvisation, and Charles Keil's (1995) theory of participatory discrepancies[1].

This thesis approaches bebop styled jazz improvisation from both perspectives. Namely, both the fairly static issues concerning, for example, tonality and meter and the dynamic issues concerning, for example, the development of tonality are considered. In contrast to most of the previ-

1 See also Prögler 1995.

ous studies, this thesis discusses jazz improvisation from the point of view of cognitive musicology. In other words, jazz improvisation is contemplated as a mode of human functioning. The intention is not so much to provide information to a music analyst or a jazz pedagogue as to see jazz improvisation in a general context of a few cognitive principles that have been found to be important with respect to music in general. Therefore many problems and questions that have been central to most of the previous studies are not given much space. The main theoretical starting-point in this thesis is the notion of tonal hierarchy which has been put forward most notably by Carol L. Krumhansl. The general goal of this thesis is to determine some of the ways that the musicians utilize in order to cope with the cognitive constraints of improvisation. Numerous improvisations are examined in a bottom-up manner by means of statistical methods of analysis in order to determine, for example, tonal, harmonic and metrical preferences of the improvisers[2].

The style of jazz music which is investigated in this thesis, namely bebop, is a fruitful subject of investigation, because it is well documented both as recordings and transcriptions. Also since bebop is the central style in jazz curriculum in most of the institutions offering degrees in jazz music, there is a fairly large body of both pedagogical and theoretical writings as well. In fact bebop is many times considered as the basic jazz style. It has even been noted that "during the 1990's, musicians frequently evaluated new players according to their ability to play bop. Mastery of this style was considered the foundation for competence as a jazz improviser" (Gridley 1992, 139; see also Owens 1995, 236-245). All of the improvisations that were used in this study are based on the so-called Rhythm Changes chord progression which is the second most used chord progression in the history of jazz (see e.g., Levine 1995, 237).

For the sake of convenience, I will follow the established practice of using the word jazz as a synonym for bebop and hard bop styles. I believe that this narrow definition is justified if one considers the central role of bebop in today's jazz music. Whenever the words bebop or hard bop are used, they are meant to emphasize the connection between the results and these styles — applicability of the results to later jazz styles is not implied at any point. Furthermore, the transcriptions are called improvisations, but it is not implied that it is an exhaustive representation of the original improvisation. Strictly speaking the transcription is taken as a representation which illustrates the melodic, harmonic, rhythmic, and metrical preferences of the improvisers.

2 It should be noted that some results from the previous stages of this research have been published earlier (Järvinen 1994, 1995, 1996). However, the methodology and particularly the body of materials have been modified and extended for this thesis

2 THEORETICAL AND EMPIRICAL FOUNDATION

2.1 Tonal Hierarchy

2.1.1 Perceived Tonal Hierarchies

When we describe perceptual or conceptual objects, we often compare them with other similar objects. Expressions such as "reddish" or "almost square" are used, because within categories of objects certain members are thought to be more typical, stable, or "good" than others. These elements are cognitive reference points that help us to organize and remember information efficiently. Much music in the world is also based on principles that are congruent with the hierarchical notion of reference points. In most western music the most central and stable tone is called the tonic: it is the tonal center on the basis of which the functions of the other tones in the chromatic scale are defined. (Krumhansl 1990a, 17-18).

Although some music theorists have made assumptions in the past about the hierarchical ordering of the tones in the chromatic scale (e.g., Meyer 1956, 214-215), only after Carol L. Krumhansl's and Roger N. Shepard's empirical tests has this claim been substantiated. In their article "Quantification of the Hierarchy of Tonal Functions Within a Diatonic Context" (1979; see also Krumhansl 1990a) they were able to determine the relative perceived stability of the twelve chromatic tones in the given tonal context. In the experiments, a so called tone-profile technique was used in which the listeners first heard some musical element (scale, chord or cadence), which was followed by a probe tone. The participants were asked to rate on a scale from 1 to 7 how well the probe tone "fit with" the previously heard context.

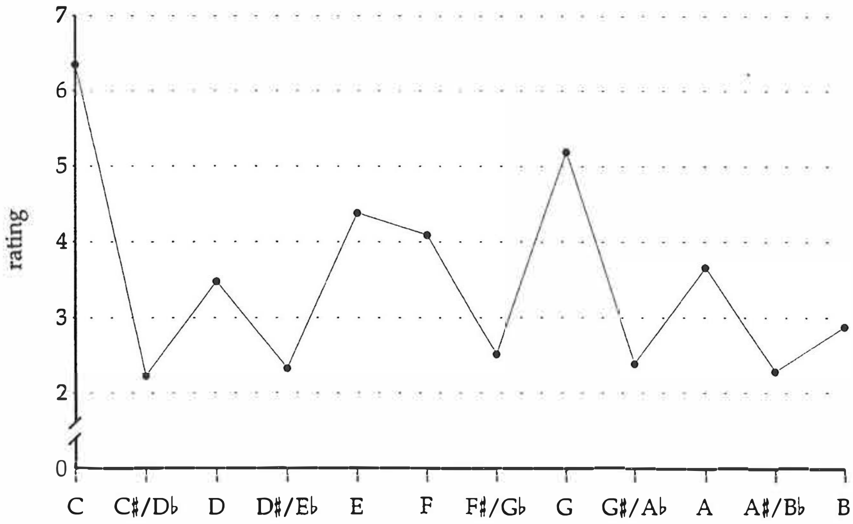

FIGURE 1. Probe tone ratings for major key context. The graph illustrates the results in reference to C major (Krumhansl 1990a, 31).

The results of this experiment can be seen in Figure 1 which represents the key profile in the C major context[3]. The graph indicates clearly that there are differences in the perceived stability of the tones: highest ratings are given to the tonic (C) and the other two tones of the tonic triad (G, E), which are followed first by the rest of the diatonic scale (F, A, D, B) and finally by the nondiatonic tones (F♯/G♭, G♯/A♭, D♯/E♭, A♯/B♭, C♯/D♭). (Krumhansl 1990a, 25-31).

In a subsequent study Krumhansl investigated with Edward J. Kessler (1982, 334-368; see also Krumhansl 1990a, 25-31) how listeners' sense of key develops and changes while a given chord sequence progresses. The experimental procedure was similar to the probe tone method used in Krumhansl and Shepard's study; only now the participants were asked to rate the relative stability of the twelve tones in the context of the heard chord sequence. There were two nonmodulating chord sequences and eight modulating chord sequences with nine chords in each. In each of the modulating progressions the initial key lasted for the first four chords. The modulation was prepared by the fifth chord which had a function both in the first and the second key (pivot chord). The second key which was used for the rest of the progression, was established in the sixth chord which did not have a function in the first key. The twelve probe tones were sounded after each chord in the sequence. However, after every trial the sequence was played from the beginning to next chord to be tested, so that before the first trial only the first chord was played, and before the last trial the participants heard the whole sequence.

3 This figure is sometimes equaled with the term tonal hierarchy (e.g., Krumhansl 1990a, 68). Strictly speaking this is not accurate, for the profile only depicts a set of twelve values which by themselves do not give any information about the relationships between the tones that are represented. In other words, the hierarchy is not immanent in the profile itself, rather it is infered from from the data. (see Gjerdingen 1992, 485-486.)

The solid line in Figure 2 shows the correlation between the listeners' responses to the nonmodulating chord sequence in C major and the C major key profile; the dotted line, on the other hand, represents the correlation between the probe tone ratings for isolated chords and the C major key profile.

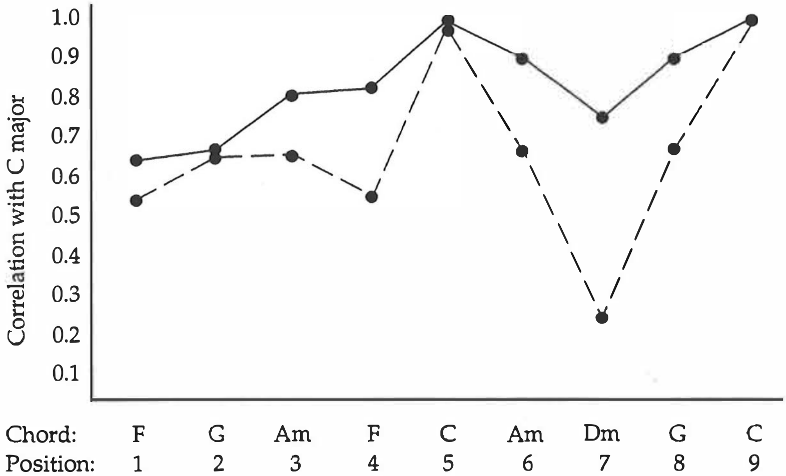

FIGURE 2. The development of the sense of key in the C major context. Solid line represents the correlation between listeners' answers and the C major key profile; dashed line represents the correlation between the chords in isolation and the C major key profile. (Krumhansl 1990a, 218).

The correlations between listeners' responses and the intended key are quite high, and they seem to increase as the sequence progresses. This suggests that listeners develop a sense of key that is partly independent of the individual chords. Nevertheless, comparison between these two correlation lines reveals that the strength of the intended key varies during the course of the sequence. Since the correlations between the responses and the intended key profile are not perfect, there is reason to believe that there are local effects of tonicization — i.e. a nontonic chord tries to assume the role of the tonic. Thus, sometimes the prevailing key is stronger than the underlying chord, and sometimes the individual chords assume a much greater role than their place in the tonal hierarchy would imply. Moreover, the results suggest that the listeners entertain various harmonic functions for each chord and integrate the information over time to reach a sense of key. (See Krumhansl & Kessler 1982, 356-357 and Krumhansl 1990a, 217-219).

The results for the modulating sequences suggest that when the modulation occurred to a closely related key (e.g., C major to G major), the sense of the initial key was preserved during the entire sequence. After the modulation, however, the first key gradually lost its strength, and it seemed to be evident only when the underlying chord was closely related to it. Moreover, it was found that as soon as the first chord unique to the new key was sounded, the listeners were able to assimilate the new tonal orientation. In a way the chords in the first key prepared the modulation to the closely related key, because – as was noted above – the listeners contemplate the possible harmonic functions that a given chord may have. In the progressions which modulated to relatively distant keys (e.g., C major to B♭ major), the development of key displayed dissimilar tendencies. The experiments suggested that the listeners do not preserve the sense of the first key long after a modulation to a distantly related key. However, unlike close modulations, the listeners first seemed to resist the second key and then suddenly shift to the new key. In general in both types of sequences it was found that the distance between the keys is important in the perception of the modulation. Still, the distance is only one factor, for the construction of the sequence is also of primary importance: in particular, the way in which the two keys are mediated has considerable effect on how the modulation is perceived (See Krumhansl & Kessler 1982, 365-366 and Krumhansl 1990a, 219-226).

The results obtained for minor key contexts were, in general, "less intelligible, more problematic than for major" (Gjerdingen 1992, 489). Although, for example, the minor chord is the second most common chord in mainstream Western music, the results are not as consistent and clear as the results for the major chord (cf., Krumhansl 1990a, 171-174 and 179-181, but also 30-31; see also Gjerdingen 1992, 489)[4].

Even though there is extensive empirical evidence for the existence of tonal hierarchy as an important aid in the perception of tonality, it has been strongly criticized by a number of researchers. In particular, David Butler and his associates (Brown 1988, Butler 1989, 1990, 1992 Brown, Butler, & Jones 1994) have questioned the results and the meaning of the empirical tests conducted by Krumhansl and others. Essentially Butler argues that the notion of tonal hierarchy is static, and it cannot account for the various time-dependent processes of perception (Butler 1989, 223). Furthermore, he asserts that the empirical procedure (i.e., the probe-tone method) for obtaining the results is ambiguous and even flawed (Butler 1989, 228-233; 1990, 329). The experimental results are interpreted to be confounded by the effects of short term memory (primacy and recency effects). Also it is argued that the design of the experiment leads participants to prefer some tones: the profile reflects the stimulus material rather than mental representations of pitch relations (Butler 1989, 230-231).

Brown (1988) differentiate two approaches to perception of tonality: structural and functional. The temporal intervallic relations and their implications are emphasized in functional approaches which are seen to be in contrast to the structural views represented by Krumhansl and others. Specifically, in Butler (1989) it is asserted that the perception of tonality can be explained with the theory of intervallic rivalry, which in its simplest form asserts that "any tone will suffice as a perceptual anchor – a tonal center – until a better candidate defeats it" (1989, 238). In particular, it assumes that listeners actively try to discover the tonal center by first identifying the most likely candidates and then eliminating rivals on the basis of rare intervals (most notably tritone, minor seconds) which give the most unambiguous cues about the key. Furthermore, it is proposed in the model that the temporal order of tones is important factor in perception (see Brown, Butler, & Jones 1994, 372).

4 The minor chord has proved to be difficult to explain also for a number of music theorists (for a historical overview, see Parncutt 1989, 69).

Although the initial criticism was hard, recently it has been acknowledged that the two approaches may be complementary, and that the perception of tonality may require both (Brown, Butler, & Jones 1994, 404). Many of the arguments against methodology and the results do not seem justified[5], but several important issues, such as the effects of temporal order, were raised during the debate. Huron & Parncutt (1993) conducted a study in which they presented a structural model of tonality which took into account the temporal factors (echoic memory), and the subsidiary pitches and pitch saliences[6]. With this modified model they were able to improve significantly the results obtained by Krumhansl & Kessler (1982); still, some of the experimental data presented, for example, by Brown (1988) could not be explained with this structural model. Therefore the authors concluded – in agreement with Brown et.al. (1993) – that "both 'structural' and 'functional' factors play a role in the determination of key or tonality perceptions". However, some recent empirical research which investigated the effects of tonality on the perceived similarity of tones and chords did not find much support for the intervallic rivalry model: only the hypothesis regarding temporal order was supported by the data (Krumhansl, in press).

2.1.2 Statistical Distribution of the Twelve Chromatic Tones in Actual Music

There are several studies that have investigated statistical properties of actual musical pieces. These studies were mostly inspired by information theory, and their objectives differ substantially from the ones assumed in this study as well as Krumhansl's experiments. However, they provide us with useful comparison data, since they contain tables of the statistical distribution of the twelve chromatic scale tones in actual music. These analyses are in many ways limited and even problematic (Krumhansl 1990a, 66), but, nevertheless, it is reasonable to assume that they demonstrate the overall statistical tendencies. In their study on entropy as a measure of style, Leon Knopoff and William Hutchinson counted the frequencies of all twelve chromatic scale degrees in 45 vocal compositions by Franz Schubert, Wolfgang Amadeus Mozart, Johann Adolf Hasse, and Richard Strauss. Figure 3 presents the frequency statistics for the major key compositions that were used in their study. It shows the total number of times that each scale degree was sounded in reference to C major in the analyzed composition.

If we compare Krumhansl's experimental findings represented in Figure 2 with Knopoff and Hutchinson's statistical results, we can clearly see that the they are remarkably similar. This indicates that the kind of hierarchical ordering that can be found in the ratings that Krumhansl obtained is important also in actual compositions in tonal-harmonic tradition. Some minor differences are apparent: for example, unlike the probe tone ratings, the fifth scale degree occurred more often in the statistical

5 Krumhansl elaborated response to the criticism can be found in Krumhansl (1990b). Further discussion on tonal hierarchy, its applications and the methodology can be found in Krumhansl (1990a).

6 Pitch saliences will be explained in section 2.3.

analysis than the first scale degree. This is understandable if one considers the functions of these two tones: the first degree is the stable tonic, whereas the fifth degree is the dominant, which is crucial in establishing the key. Also since the frequencies were counted only from melodic lines, the relatively high frequency of the second scale degree can be though to reflect its important melodic role adjacent to the tonic. (See Krumhansl 1990a, 66-72)[7].

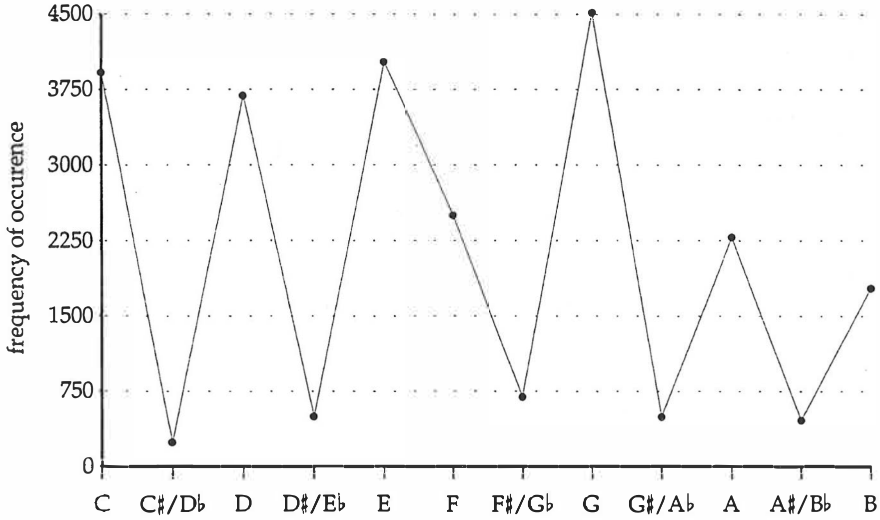

FIGURE 3. The average frequency of the 12 chromatic tones in selected major key vocal compositions by F. Schubert, W.A. Mozart, J.A. Hasse and R. Strauss. (See Knopoff — Hutchinson 1983, 95).

2.2 Studies on Musical Rhythm and Meter

Meter is commonly regarded as an accent structure which comprises a series of equally spaced perceived pulses or beats (Dowling & Harwood 1986; Palmer & Krumhansl 1990). These form a nested hierarchy, which has at least two levels of pulsation at the same time: in Western music the ratio of the pulses is usually limited to 1:2 (binary) and 1:3 (ternary). Lerdahl and Jackendoff (1983) illustrate the commonly accepted view of metrical hierarchy with series of dots as in Figure 4. The horizontal rows of dots represent the metrical levels. Each vertical column denote the metrical accent of that particular tone: the more dots there are under a given tone, the more metrical importance it has.

7 It should be noted that Butler (1989) criticizes Krumhansl for trying to substantiate her empirical results by comparing them with this type of data on the statistical distribution of the tones in actual music. He argues that profiles, such as the one in Figure 3, "does not describe how we hear moment-to-moment harmonic successions" (p. 224).

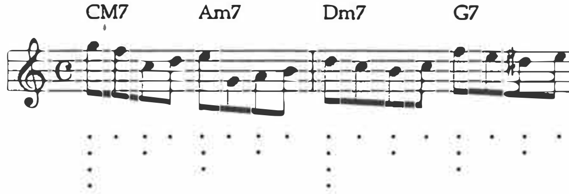

FIGURE 4. Grid representation of metrical hierarchy. Adapted from Lerdahl and Jackendoff (1983).

In addition to metrical accents, Lerdahl and Jackendoff (1983, 17-18; see also Palmer & Krumhansl 1990) distinguish other types of accent structures that contribute to rhythmic organization of music. Phenomenal accent occurs when the properties of the sound or stimulus are changed (timbre, contour, pitch-height, duration etc.) in order to give sensory emphasis for some surface level event in the music. Structural accents are cadences or other points of melodic or harmonic gravity; they convey abstract structural information which is thought to be essential for the overall tonal organization. Lerdahl and Jackendoff propose that metrical accent is a mental construct which is inferred from the patterns and cues implied by phenomenal and structural accents. Although the notion that temporal accents initiate major metrical locations is favored among many theorists and psychologists, there is some data which would seem to indicate that particularly formally trained listeners in particular use harmonic rhythm to infer the metrical structure (Dawe, Platt, & Racine 1994). Furthermore, there is also some evidence which suggests that in music itself there may be information about the metrical structure which does not depend on the some high level cognitive schema (see Gjerdingen 1992). Namely, it has been found that the periodicity of the loudness pattern in the raw acoustical signal of music outlines a metric hierarchy. Thus, "meter may be a very low-level psychological construct both separate from, and transparent to, the perception of rhythmic groupings" (Gjerdingen 1992, 237).

Lerdahl and Jackendoff assert also that grouping and meter are fundamentally different, because " groups do not receive metrical accent, and beats do not possess any inherent grouping" (1983, 26). This is in contrast with the traditional view proposed by many music theorists, who maintain that meter and grouping are determined by the same accent structure (e.g., Cooper & Meyer 1960). It has been noted that this distinction is problematic, because "meter itself may be regarded as a kind of grouping" in which tones are grouped into equivalence classes (Parncutt 1994a, 410; cf,. also Benjamin 1984, 3754-376). Although this may be more of a question of semantics than an actual problem, Parncutt (1994a) used less ambiguous terms to describe these rhythmic phenomena: serial and temporal grouping[8]. Serial grouping refers primarily to the rhythmic production of temporally adjacent events which are proximate in pitch and timbre (motives, themes, phrases, etc.). Periodic grouping refers to the organization of nonadjacent events, and it can be divided into two stages, pulse sensation and perceived meter (cf., Martin 1972, 488). In the first stage the listener

8 Jones (1987) used terms horizontal (serial) and vertical (metrical) in order to make the same distiction.

perceives the different pulses in the music, and in the second the pulses or rhythmic levels are combined to form the metrical structure (cf., Palmer & Krumhansl 1990, 736). It bears resemblance to the commonly accepted hierarchical representation of meter (see Fig. 4) which is constructed of regular alternation of strong and weak beats.

Mari Riess Jones has argued convincingly that in music there are various time periods which guide the attention of the listeners' (e.g., 1976,1986, 1992). It has been found that the temporal placement of tones affects the listeners ability to detect similar pitch relations (Jones, Kidd, & Wetzel 1981; see also Dowling, Lung, & Herrbold 1987). Also pitch changes are detected more accurately when they occur at metrically salient beats (Jones, Boltz, & Kidd 1982). Furthermore listeners' expectations seem to be influenced in part by the global time structure (Jones & Boltz 1989). Based on these and other related results, Jones has proposed a model which separates three different levels of attending: analytic, referent, and future-oriented. The referent level is a kind of anchoring time level implied by beat or tempo which gives the listener a point of reference in the middle of the other two levels[9]. The analytic level supports short time periods and is suitable for analytical attending, whereas the future-oriented level supports longer time spans; it should be noted that both levels can have several stages. An important feature of this model is that it is based on the idea that listeners can shift between the levels effortlessly in order to gain a different perspective on the temporal flow of the music. This is similar to the notion of periodic grouping proposed by Parncutt, for both assert that the perception of metrical structure is based on the perception of the different temporal levels. Palmer and Krumhansl (1990, 732) found evidence which also suggested that multiple temporal periodicities affect listener's perception of the same pattern.

Meter has also been found to affect learning and memory for temporal patterns in music. Povel (1981) found that listeners seem to have mental temporal structures upon which they try to map temporal sequences: only when a sequence fits that structure completely, are they able to imitate it correctly. Similarly, when pitch structures conform with temporal structures, recall seems to improve (Deutsch 1980). Furthermore, a sequence which suggests a metrical structure takes less time to memorize than a sequence which is more ambiguous in this regard (Povel & Essens 1985). Additional support for the importance of meter comes from a study (Palmer & Krumhansl 1990) in which the frequencies of tone onsets on each metric location were investigated. It was found that "frequency distribution of musical event in different metrical locations provide a robust cue to meter" (p. 732) – the results were consistent across different tonal styles of European art music. The investigators suggest that composers might use the statistical regularities on different metrical locations to control and direct the attention and expectations of the listeners. Performers also seem to emphasize the metric structure which provides listeners additional cues for segmentation (Drake & Palmer 1993; Sloboda 1985, 84-85).

9 This is consistent with the observation that when asked to tap along a variety of rhythms and tempos, listeners tend to favor a moderate tempo of tapping regardless of the note rate of the rhythm (Parncutt 1994, 454); cf., also Lerdahl & Jackendoff 1983, 21.

A number of music theorists have also put forward the notion that structural tones normally appear at metrically salient beats (e.g., Meyer 1973, 121). In fact, Krumhansl also points in this direction, when she says that "the tonic is emphasized both melodically and rhythmically; it is sounded with relative frequency and with longer duration; and it tends to appear near the beginning and end of major phrase boundaries and at points of rhythmic stress" (1990a, 16). Furthermore, some empirical evidence supports the view that the structural importance of a tone is determined by its metrical placement (Serafine, Glassman, & Overbeeke 1989; see also Dippen 1994). Still, this view has not gone unchallenged: Eugene Narmour (1982, 112), for example, has criticized Leonard B. Meyer's thinking in this respect as too straightforward, because "meter is a summarizing result of all the parametric interactions that produce the emergence of structural tones rather than the cause of them". Although the criticism is undoubtedly justified to a certain extent, it would seem that this depends on the style of music. For example, the situation is a bit different in most jazz music, because the piece that is used as the basis of the accompaniment determines the meter: consequently, the musician improvises the melodic lines on top of a metrical structure that is independent of the improvisations' existence as far as the basic metrical structures are concerned (cf., Berliner 1994, 358).

In summary, the available evidence suggests that metrical organization is an important factor in the perception of music, for meter has been found to affect, for example, such central processes as expectancy, learning, and attention. It seems that the perception of metrical structure does not require formal training[10], rather it may be learned through exposure to the statistical regularities in music (Palmer & Krumhansl 1990, 739); also the systematic performance variations or just the physical signal may contain information which gives the listener cues about metrical organization or segmentation. Furthermore, the listener may utilize a high-level cognitive schema which uses the various accent structures to infer the metrical framework. Therefore it seems that there may be many different sources of information involving both low and high level cognitive processing that the listener can use in order to grasp the metrical structure of a given piece of music. The evidence seems to indicate that the listeners are able to process simultaneously many different metrical levels based on which, for example, the expectancies are formed. Finally, this information is used in conjunction with other musical variables (tonality, harmony, timbre, contour, etc.) to assign structural importance to some events in the music.

10 Formal training may, however, help listeners to make finer discriminations between the metrical levels (Palmer & Krumhanls 1990, 732).

2.3 Psychoacoustical Model of Harmony

Ernst Terhardt and his colleagues (1974; Terhardt, Stoll, & Seewann 1982a, 1982b)[11] have proposed that our auditory system is conditioned to be sensitive to certain pitch patterns. In particular, he argues that a system of pattern recognition is developed by repeated exposure to complex tones in our environment (specifically speech vowels). Terhardt's work bears resemblance to composer and theorist Jean-Philippe Rameau's work, who emphasized the importance of the harmonic series in his theory (e.g., 1722/1971). The important difference is, however, that central to Rameau's theory is the physical entity (i.e. harmonic complex tone) whereas Terhardt's theory is based on sensation and perception (i.e. the familiarity of the auditory system with harmonic complex tones) (Parncutt 1989, 17).

Terhardt argues that whenever a complex tone is heard, the pitch pattern is unconsciously compared with the learned templates of interval patterns: in most cases the listener is aware of only the fundamental or the first harmonic of the complex tone. Moreover, even if the fundamental is missing or part of the harmonic pitch pattern is masked, a tone sensation will usually be experienced at the fundamental, because the listener can reconstruct the complex tone on the basis of the pitch pattern template (Parncutt 1989, 69). A good example is a telephone call, because the bandwidth of the signal is limited and cannot represent the full spectrum of human voice. Therefore the auditory system has to infer the fundamental of the voice on the basis of incomplete harmonic pitch pattern (Leman 1995, 43). The pitch of this complex tone sensation is called virtual pitch; it is distinct from the sensation of a pure tone which is called spectral pitch (Terhardt 1974, 1063). In addition to single complex tone sensations, the model can be utilized to explain the perception of musical chords or any other simultaneous complex tones. It is maintained that perception of a major triad played on a piano consists of

> "(1) several spectral pitches which correspond to individual harmonics of the piano's complex tones, (2) several virtual pitches which correspond to the chord's musical notes, and (3) some additional virtual pitches in the frequency region below the lowest fundamental of the lowest chord note; these virtual pitches correspond to the major triad's 'fundamental note' in a musical sense, i.e., the harmonic root" (Terhardt, Stoll, & Seewann 1982b, 679).

In the case of simultaneous complex tones the auditory system has to assign the audible pure tone components to the possible complex tones which, then, will be perceived by the listener[12]. This process of subharmonic matching is simulated mathematically in Terhardt et al. (1982b).

Terhardt's model has been used to investigate the determination of the root of a chord (e.g., Terhardt 1982, Parncutt 1988). This application of the model is essentially an octave generalized version of the subharmonic matching process. In other words, the two basic ideas in the chord root model are octave equivalence and the recognition of harmonic pitch pat-

11 See also Parncutt 1989, 1988, and Leman 1995, 43-48.
12 See Parncutt 1988, 68-69 for an overview of the model.

terns. The model takes into account the first ten elements in the harmonic series. All tones are transposed into a single octave which results in five different intervals above fundamental: unison (P1), perfect fifth (P5), major third (M3), minor seventh (m7), and major second (M2). These intervals are also called root support intervals. For example, the tones in the C major triad (C, E, G) correspond with the following subharmonic pitch classes: the root {C, F, A♭, D, B♭}; the third {E, B, C, G♭, D}; the fifth {G, C, E♭, A, F}. The comparison of the pitch classes reveal that the tone C is a subharmonic for each of the tones in the C major triad. In other words, the tone C is said to have more root support than any other tone in the chromatic scale. A slightly different representation of this is presented in Table 1.

TABLE 1. Root support table for the C major triad.

	C major triad (C, E, G)											
Interval	C	D♭	D	E♭	E	F	G♭	G	A♭	A	B♭	B
P1	C	-	-	-	E	-	-	G	-	-	-	-
P5	G	-	-	-	-	C	-	-	-	E	-	-
M3	E	-	-	G	-	-	-	-	C	-	-	-
m7	-	-	C	-	-	-	E	-	-	G	-	-
M2	-	-	E	-	-	G	-	-	-	-	C	-
number of supports	3	0	2	1	1	2	1	1	1	2	1	0

The model is an important contribution for the understanding of the perception of harmony[13], but still it fails to predict some important elements of music, such as the root of the minor triad (Parncutt 1988). In the extension to the work of Terhardt and his colleagues, Parncutt has investigated the sensory basis of some of the conventions of Western music theory and issues concerning the perception of music (e.g., Parncutt 1988, 1989, 1993, 1994b, and Huron & Parncutt 1994). In attempt to overcome some of the shortcomings of the original chord-root model, Parncutt has presented a modified version which is better in accordance with music theory. In particular, different weights were assigned to each interval[14], and the minor third interval was included in the set of root support intervals (Parncutt 1988, 73-78). Table 2 illustrates the revised Root support table for the C major chord – the corresponding chord template is shown in Figure 5.

13 See Brown 1988, 234 for criticism on psychoacoustic models in general.

14 It should be noted that in the subharmonic matching procedure of Terhardt et al. (1982a, 1982b) different weights were assigned to the components of a complex tone.

TABLE 2. Revised root support table for the C major triad.

	C major triad (C, E, G)											
Interval	C	D♭	D	E♭	E	F	G♭	G	A♭	A	B♭	B
P1 (1.00)	1.00	-	-	-	1.00	-	-	1.00	-	-	-	-
P5 (0.50)	0.50	-	-	-	-	0.50	-	-	-	0.50	-	-
M3 (0.33)	0.33	-	-	0.33	-	-	-	-	0.33	-	-	-
m7 (0.25)	-	-	0.25	-	-	-	0.25	-	-	0.25	-	-
M2 (0.20)	-	-	0.20	-	-	0.20	-	-	-	-	0.20	-
m3 (0.10)	-	0.10	-	-	0.10	-	-	-	-	0.10	-	-
weight (sum)	1.83	0.10	0.45	0.33	1.10	0.70	0.25	1.00	0.33	0.85	0.20	0.00

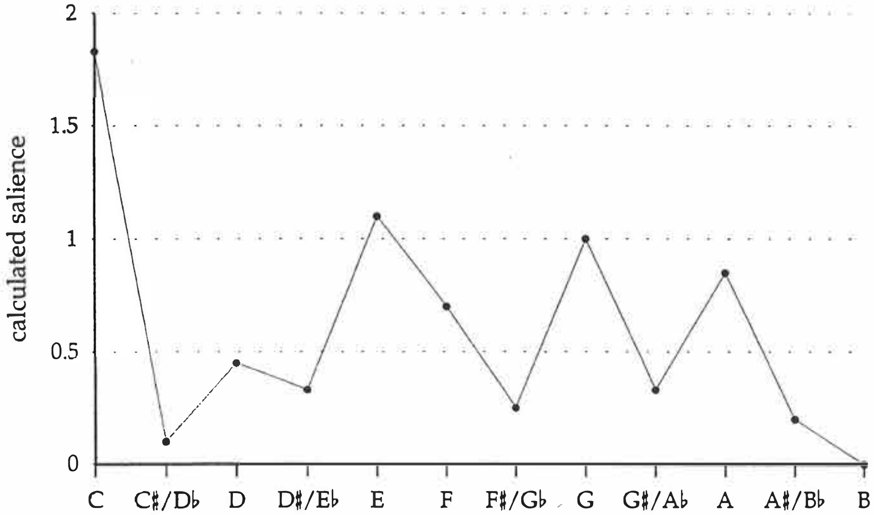

FIGURE 5. The chord template for the C major triad.

The weights are obtained by assigning the nth subharmonic the weight 1/n. This is expressed in general terms in the simple formula in (1), where k is the weight[15].

$$k_n = 1/n \tag{1}$$

The final weights for each tone in Table 2 can be considered as a template for the C major triad which shows calculated salience for each pitch-class (examples of various pitch and chord templates can be found in Appendix 1). The weights are consistent with the fact that the higher the harmonic the less is its effect. Although the process of obtaining the weights for the

15 This equation gives the weights only for the interval which occur within the first ten harmonics. Therefore the minor third which does not belong to that set is given an approximate weight of 0.10 which would seem to be appropriate considering it perceptual importance relative to the other intervals. See Parncutt (1988, 74-75) for a more thorough explanation.

tones is somewhat arbitrary, the results seem to correspond with musical experience (see Parncutt 1988, 74 and Leman 1995, 47). The modified model was found to produce chord templates which were well in agreement with the predictions of music theory (Parncutt 1988). Moreover, the model has been found to concur with empirical results (Parncutt 1993).

2.4 Basic Harmonic Concepts of Tonal Jazz Improvisation

Jazz has close historical ties with European music, particularly as far as harmony and musical forms are concerned (Berendt 1986, 175-181; Gridley 1994, 39-41). Still, jazz musicians have adopted and developed many techniques which are not commonly found in traditional European harmonic and melodic practices (cf., Lawn & Helmer 1993, xiii). In this section some of the basic theoretical concepts of tonal jazz improvisation will be explained. In particular, only the most common chord and scale substitutions were explained with emphasis on the kinds of techniques that are of special interest to this particular study. No attempt is made to give a thorough account of the vast possibilities of chord and scale substitutions. Excellent overviews can be found, for example, in Baker (1983), Levine (1995), and Liebman (1991).

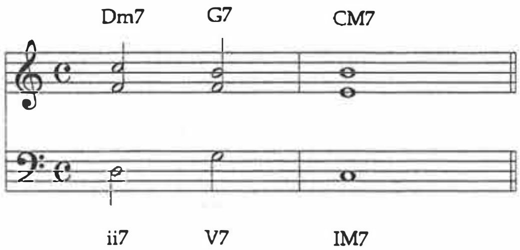

FIGURE 6. ii7-V7-IM7 -progression in C major. See text for further explanations.

Most tonal jazz harmony operates with the basic diatonic major, minor and dominant chords. All jazz musicians, pedagogues and theorists seem to agree that the seventh chord is the basic chordal formation. The most common progression in jazz is the ii7-V7 -progression which can be depicted in Figure 6 with resolution to the tonic (IM7). Also, the sequence illustrates the typical voice-leading which complies well with traditional rules of voice-leading. Although the ii7-V7-IM7 progression is the core of jazz harmony, there are variety of scale and chord substitutions that the musicians use to make the harmony more interesting. When using substitutions the musicians change the local quality of the chord usually without affecting the function of the chord or changing substantially the progression itself. Jazz musicians usually use the names of the medieval church modes to describe the scales within the diatonic scale.

For major seventh chord there are only a few possible substitutions (see Fig. 7). The sixth could be played instead of the seventh (Fig. 7.2) or the ninth, raised eleventh[16], and the thirteenth could be added on top of the basic seventh chord (Fig. 7.3). Sometimes the musicians play the major ninth chord without the root (Fig. 7.4): the minor seventh chord starting from the third of the major chord. Similarly, the other extended chords (eleventh and thirteenth) could be played without some of the tones in the basic seventh chord. An extreme possibility, suggested, for example, by Charlie Parker, would be to omit the whole seventh chord and use just the major triad formed by the ninth, raised eleventh, and thirteenth as the basis of the improvisation (see, e.g., Berliner 1994, 223). Usually the scale choice is the basic major scale (ionian scale) in Figure 7, but in some cases also the lydian scale (raised eleventh/fourth) is used.

FIGURE 7. The major scale (ionian), and some substitutions that are commonly used for the major seventh chords (IM7). The basic major seventh chord (Fig. 7.1); major sixth chord (Fig. 7.2); major ninth chord with added raised eleventh and thirteenth (Fig. 7.3); major ninth chord without the root (Fig. 7.4); basic major scale (C ionian)(Fig. 7.5); C lydian scale (Fig. 7.6).

The basic minor seventh chords build on the second scale degree can be extended to include the ninth, eleventh and thirteenth (Fig. 8.2). Sometimes the third of the chord can be raised to change the quality of the chord to dominant seventh (Fig. 8.3). As with the major ninth chords, the minor ninth chord can be played without the root (Fig. 8.4): major seventh chord starting from the third of the minor seventh chord. It is important to notice that the dominant chord (V) of the same key can also be used as an substitution for the submediant (ii), because these chords are often though of as interchangeable (Fig. 8.5). The scale of choice is usually the dorian mode, i.e., the scale starting from the second scale degree of the major scale (Fig. 8.6).

FIGURE 8. The dorian scale (Fig. 8.6), and some substitutions that are commonly used for the minor seventh chords (ii7). The basic minor seventh chord (Fig. 8.1); minor ninth chord with added eleventh and thirteenth (Fig. 8.2); dominant seventh chord substitutions (Fig. 8.3 and 8.4); minor ninth chord without the root (Fig. 8.5). See text for further explanations.

The dominant seventh chord is more interesting than the other two, because it allows a variety of possibilities for substitution. As the other chords, it can also be extended to include the ninth, raised eleventh and thirteenth (Fig. 9.2); the ii7-chord of the same key can be also used as its

16 If the eleventh is considered as a part of the chord it is usually raised in order to avoid the conflict with the third (cf,. Baker 1983, 33-34).

substitutions (Fig. 9.3). Figure 9.4 illustrates the half diminished seventh chord which is the dominant ninth chord without the root (Fig. 9.4). If the seventh of the half diminished chord is lowered, a diminished chord results (Fig. 9.5). It outlines the dominant seventh flat ninth chord which is an important chord jazz harmony (see also Fig. 10.2 and text below on diminished scales). Another important dominant seventh chord substitutions is the tritone substitution (Fig. 9.6). The theoretical basis is that all dominant seventh chords which are a tritone apart share two tones which define the quality of the chord, namely the tritone between the third and the seventh. The fifth and the ninth of the dominant seventh chord can be altered: for example, the fifth of the tritone substitution is often lowered.

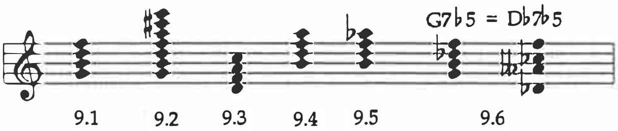

FIGURE 9. Some substitutions that are commonly used for the dominant seventh chords (V7). The basic dominant seventh chord (Fig. 9.1); dominant ninth chord with added raised eleventh and thirteenth (Fig. 9.2); ii7-chord (Fig. 9.3); dominant ninth chord without the root (Fig. 9.4); dominant seventh flat ninth chord without the root (Fig. 9.5); tritone substitution (Fig. 9.6). See text for further explanations.

The basic scale to be used with dominant seventh chords is the mixolydian scale (Fig. 10.1), which is the fifth mode of a given major scale. This scale, however, does not offer many possibilities, for it is quite consonant with the dominant seventh chord and contains no altered tones. In order to create more chromatic harmony, musicians often employ two symmetrical scales, the diminished scale (Fig. 10.2) and the whole-tone scale (Fig. 10.3), and various modes of the ascending melodic minor, or jazz minor: the most frequently used are the altered scale (Fig. 10.4) and the lydian dominant scale (Fig. 10.5).

The basic structure of the diminished scale is made up of successive half steps and whole steps. There are two types of diminished scales: the one that starts with a half step is used with dominant seventh chords, and the one that starts with a whole step is used with diminished seventh chords; the diminished scale is sometimes also called the octatonic scale. In a study by Krumhansl and Schmuckler (1986) it was investigated whether the diminished scale starting with a half step can be used to account for some of the bitonal passages in Stravinsky's *Petroushka*. It was concluded that as a whole the scale did not provide a satisfactory explanation for the ambiguous tonality. However, the results suggested that this particular configuration of the scale functioned perceptually as a tonally functional dominant seventh chord which is in accordance with the way jazz musicians use it.

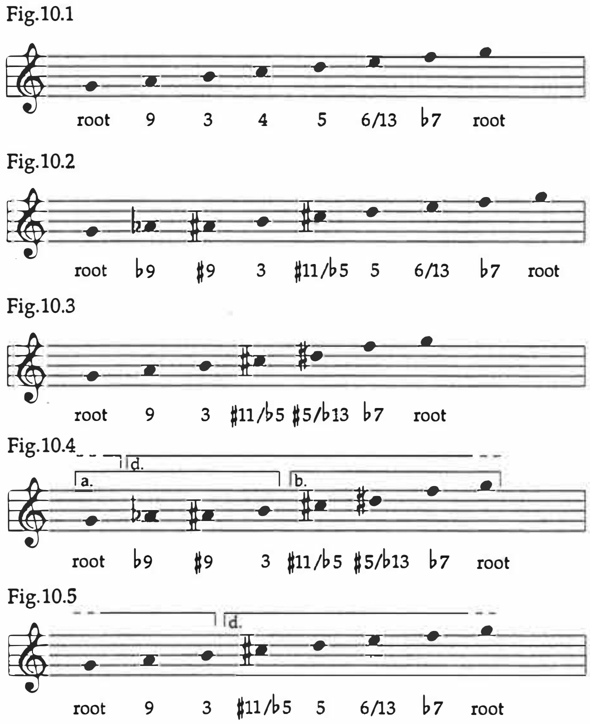

FIGURE 10. Some scales that are commonly used when improvising on dominant seventh chords: mixolydian scale (Fig. 10.1); diminished scale (Fig. 10.2); whole-tone scale (Fig. 10.3); altered scale (Fig. 10.4); lydian dominant scale (Fig. 10.5). The scales are shown in reference to the G7 chord. See text for further explanations.

The whole-tone scale is constructed entirely of whole steps, and it is probably the least used of the scales presented here. The more modern scale substitution is the altered scale which is the seventh mode of the ascending melodic minor scale (see letter d. in Fig. 10.4), but it can be also derived by combining the first half of the diminished scale (see letter a. in Fig. 10.4) and the second half of the respective whole tone scale (see letter b. in Fig. 10.4). Many times in order to avoid the clash with the chord tones the fourth scale degree of the mixolydian scale is raised: the corresponding scale is called the lydian mixolydian or the lydian dominant scale (Fig. 10.5). This scale is the fourth mode of the ascending melodic minor (see letter d. in Fig. 10.5).

FIGURE 11. The blues scale. The blue tone regions marked with brackets.

The final scale is the blues scale which is not used on any particular chord. Instead it can be used to add blues flavor to any part of the improvisation (cf,. Levine 1995, 230). There is no one single blues scale, for the tones that are used depend much on the style of the music and the personal preference of the musician (cf., Titon 1994, 152-153). The only thing that is agreed upon is that it contains some tones the exact pitch height of which is undetermined (Lawn & Hellmer 1993, 18). These so-called blue tones are located at the third, fifth, and seventh scale degrees. Figure 11 illustrates one conceivable way to represent the blues scale. This is only an approximation, because with standard notation it is not possible to represent the blue tones unambiguously. The term scale is a bit misleading, because it is almost never used as a complete scale (cf., Titon 1994, 154): for example, one rarely hears a complete ascending or descending scale passage. Thus, it might be better to consider it as a collection of reference tones which can be used and elaborated in a variety of contexts.

3 MATERIALS AND METHODOLOGY

3.1 Description of the Materials

The sample of this study consists of 17 improvisations (42 choruses[17]) by nine famous jazz musicians whose playing styles can roughly be categorized as bebop. The improvisations and the musicians are listed in Table 3. In order to avoid over-representation of any single improvisation, the maximum number of choruses was set to five – if some improvisation was longer than that, the additional choruses were excluded[18]. All the improvisations are played on the so-called Rhythm Changes chord progression (Fig. 12), which is a 32-bars long AABA form. It is based on a composition by George Gershwin titled I Got Rhythm which was originally made for 1930's Broadway show called *Crazy Girl.* Harmonically it is very simple, major key progression with a cycle of dominant seventh chords in the B-section. It uses many of the same devices as most of the tonal jazz compositions, and therefore it is reasonable to assume that the results would be

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17 In jazz the term chorus means an improvisation one time through the chord progression of the song; the length of the chorus depends on the song, but usually it is 12- or 32-bars long (blues or AABA, respectively).

18 The material for this study comes from publicly available transcriptions. I acknowledge that this is problematic, because they are, in fact, secondary sources. Whenever possible, however, I have tried to check their approximate accuracy, and I believe that there are no mistakes that would distort the results substantially. Also there is one important advantage, for this way anyone can try to replicate the results with exactly the same materials.

TABLE 3. The body of materials.

Composition	Improviser	Number of choruses	Tempo	Key	Source
Anthropology	Navarro, Fats	2	264	B♭	Baker 1982, 59-61
Anthropology	Parker, Charlie	3	300	B♭	Aebersold 1978, 10-13
Crazeology	Mobley, Hank	4	288	B♭	Kynaston 1989, 4-7
Eb Pob	Navarro, Fats	1	224	B♭	Baker 1982, 37
Everyone Does	Stitt, Sonny	5	304	B♭	Keller, 1990, 28-34
Goin' To Minton's	Navarro, Fats	1	256	B♭	Baker 1982, 41-42
Moose the Mooche	Parker, Charlie	1	224	B♭	Aebersold 1978, 4-5
Oleo	Coltrane, John	4	270	B♭	Kynaston 1989, 7-10
Oleo	Davis, Miles	3	215	B♭	Isacoff 1978, 27-29
Oleo	Davis, Miles	4	270	B♭	Washburn 1987, 43
Oleo	Rollins, Sonny	2	215	B♭	Nash 1978, 36-37
Passport	Parker, Charlie	1	220	B♭	Aebersold 1978, 102-103
Red Cross	Parker, Charlie	1	210	B♭	Aebersold 1978, 66-67
Rhythm-A-Ning	Griffin, Johnny	5	276	B♭	Kynaston 1989, 11-20
Salt Peanuts	Gillespie, Dizzy	1	295	F	Owens 1974, 300-304
Tenor Conclave	Mobley, Hank	3	232	B♭	Campbell 1989, 6-8
Wail	Navarro, Fats	1	288	E♭	Baker 1982, 73
		Σ 42	$\bar{x} = 256$		

similar to other chord sequences as well. I think that the decision to limit the investigations in this way is well-founded if one considers the popularity of this chord progression amongst jazz musicians (cf,. Levine 1995 237; Lawn & Helmer 1993, 203).

measures 1-4

12.1	4/4	CM7 Am7	Dm7 G7	CM7 Am7	Dm7 G7
12.2	4/4	CM7 A7	Dm7 G7	Em7 A7	Dm7 G7
12.3	4/4	CM7 C♯°7	Dm7 D♯°7	CM7 Am7	Dm7 G7
12.4	4/4	C			

measures 5-8

12.1	Gm7 C7	FM7	CM7 Am7	Dm7 G7
12.2	CM7 C7/E	FM7 F♯°7	CM7/G A7	Dm7 G7
12.3	Gm7 C7	FM7 B♭7	CM7 E♭7	Dm7 G7
12.4		F		

FIGURE 12. Four possible chord sequences for the A-section of the Rhythm Changes chord progression.

In the Figure 12 there are some possible chord progressions that can be used in the A-section of the Rhythm Changes[19]. Some of the common chord substitutions are illustrated in Figures 12.1-12.3, but basically the progression is a prolongation on the tonic chord (CM7) with a characteristic subdominant chord (FM7) in the sixth bar. Consequently, the progression can be reduced to the scheme in Figure 12.4.

The B-section of the Rhythm Changes -chord progression is an eight measures long cycle of fifths sequence on dominant seventh chords each of which lasts for two measures. Figure 13 shows three possible variants of this progression.

13.1	4/4	E7	E7	A7	A7	D7	D7	G7	G7
13.2	4/4	Bm7	E7	Em7	A7	Am7	D7	Dm7	G7
13.3	4/4	E7	B♭7	A7	E♭7	D7	A♭7	G7	D♭7

FIGURE 13. Three possible sequences for the B-section of the Rhythm Changes chord progression.

The basic progression for the B-section is very simple (Fig. 13.1), but often the musicians use, for example, chord substitutions in order to add interest to the original progression. The most commonly used substitution is to replace the dominant seventh chord with the supertonic chord of the same key. This is illustrated in Figure 13.2, where, for example, in the first measure the E7 chord (V7) is substituted with Bm7 chord (ii7). Another frequently used substitution is the so-called tritone substitution, which is

[19] The following chord type notations have been used (shown here in reference to the tone C): CM7 denotes major seventh chord, C7 dominant seventh chord, Cm7 minor seventh chord, C°7 diminished seventh chord, and C/G C major triad with the tone G in the bass.

illustrated in Figure 13.3. The chord change, however, may not always be as clear as is depicted in Figure 13. For example, the dominant seventh chord and the supertonic seventh chord are often though as entirely interchangeable[20], and the emphasis may be sometimes irregular as is evident in Figure 14.

FIGURE 14. An example of irregular chord changes in an actual improvisation. Hank Mobley: Tenor Conclave (Campbell 1989, 6-7). Measures 17-24 (B-section).

The first measure and the first two beats of the second measure in Figure 14 clearly outline the Bm7 chord. Only in the third beat of the second measure does Mobley seem to emphasize the original chord, E7, by playing its third, G♯; its importance is stressed by the chromatic approach by the tones A and G in the previous beat. In the third measure the phrase begins with an Em7 arpeggio, but in the third beat the implied chord is changed into A7, which is the original chord in measures three and four. In the fourth measure the chord is also clearly A7: especially the metrical emphasis put on the third (C♯) and the seventh (G) of the A7 chord should be noted. The chromatic nature of the fifth measure makes it difficult to determine the implied harmony, but the voice-leading from the tone G in the fourth beat of measure five to F♯ in the first beat of measure six implies at least some emphasis on the Am7 chord. With metrical emphasis put on F♯ (third) and C (lowered seventh), the sixth measure seems to be clearly based on the D7 chord, which is the original chord for this measure. The improvisation in the last two measures is mostly based on a short three note motive, which is repeated in intervals of major and minor thirds; this polyrhythmic sequence implies the Dm9 chord. The underlying harmony in the last two beats of measure eight seems to be G7♭9, although the improvisation seems to be based more on linear rather than vertical thinking. The intention appears to be to prepare the following chord, CM7, rather than to outline the underlying harmony: in particular, the tones A♭ and F♯ prepare chromatically the tone G, which is the first note in the following A-section.

Most of the improvisations in the sample can roughly be categorized as bebop or hardbop. All of the nine musicians that are represented in the sample play some wind instrument (two alto saxophones, four tenor saxophones and three trumpets), which minimizes the need to take in-

20 See, e.g., Baker 1983, 85.

strument related differences into account. This is further enhanced by the fact that fifteen out of the seventeen improvisations are in the concert key of B♭ major, which is an easy key both for trumpets and saxophones. The remaining two pieces are as unproblematic, since they are played by a trumpet player in keys that are also technically natural for that instrument (concert keys of E♭ major and F major). For the sake of convenience, however, the improvisations have been transposed to a common key of C major. — The tempos are also quite uniform ranging from 210 to 304 beats per minute, which equals 52,5 to 76 measures per minute.

3.2 Analysis Procedures

The frequency with which the tones occurred in the improvisations was calculated. The frequency data was analyzed with the aid of a few simple statistical parameters, such as average, standard deviation standard deviation, correlation. To facilitate the comparison across the data, the profiles that will be presented have been normalized by dividing the frequencies with the sum of the frequencies of all the twelve tones and rests. Since the amount of rests varies greatly, the frequencies of some of the profiles are generally lower than in others. The inclusion of rests, however, seems justified or even preferable if we consider this matter from a perceptual point of view. The tonal organization that is formed in the listener's mind is certainly affected by the amount of rests used along with the tones. Hence it does not seem plausible to examine the use of the tones without taking into account what is actually heard.

In the reports that have been published earlier on the previous stages of this study, in addition to the total frequency of tones, the placement of the tones was also taken into account. It was argued that since tones on different metrical beats have different perceptual importance for the listener (Palmer & Krumhansl 1990, 734-736) and undoubtedly also for the improviser, the statistical distribution of the tones on the various metrical positions should be considered as well. In particular, the frequencies of the tones were investigated on four metrical levels which correspond to the traditional view metrical hierarchy (cf,. eg., Lerdahl & Jackendoff 1983): eighth-note level (all eighth-notes), quarter-note level (first, second, third and fourth beats), half-note level (first and third beats) and whole-note level (first beat). Since this is a somewhat problematic assumption (cf,. Large & Kolen 1994, 181), the existence of other possible metrical periodicities was investigated (see section 4.1). To foreshadow the results, it was found that the basic metrical structures conform well with the traditional view of metrical organization. Moreover, they also appear to attest the weighting of tones depending on which metrical position they are played on. For this reason the four metrical levels will be taken into account. In order to make the data more accessible, in most cases only the average of the normalized tone-frequency profiles obtained from the four metrical levels is presented. If, however, the different levels seem to clarify or add new information to the data, the levels will be presented separately. Figure

15 illustrates the basic procedures. The eighth-note level is the actual music that the improviser played, and the staves above it show which tones are picked for each level and how each tone is weighted.

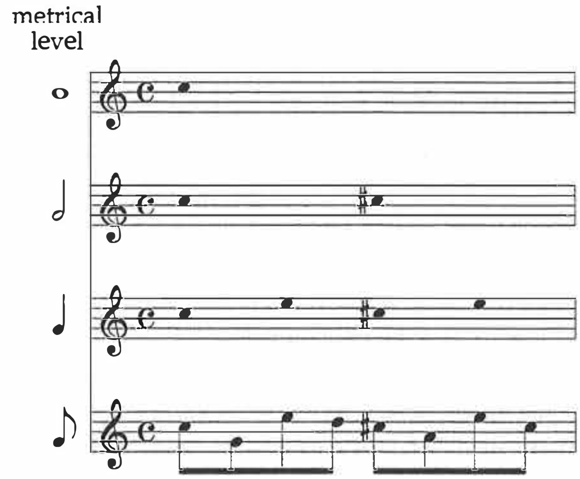

FIGURE 15. Basic reductions necessary in differentiating the metrical levels.

It should be noted that because of the nature of the material, it is not possible to calculate whether or not the differences are statistically significant – ie. whether the differences found in the materials would hold in some general population. This is because no random sampling methods were (or even can be) used to pick the data, and also because the data, for example, for the different metrical levels are dependent on each other. Without proper testing the risk of false conclusions increases, but based on the size of the body of materials in this study, it seems reasonable to assume that the risk is not great. The special nature of the data is also taken into account in the treatment and analysis of the data. In particular, the focus of this study is not on minute detail, but on general tendencies or patterns in the data. The improvisers that are included in this study were some of the most important and influencial musicians during the forties and fifties (see Table 3). To such an extent that we can assume that their improvisations represent the general style of playing during the bebop and hardbop eras, it seems plausible to make more general inferences about the practices of other musicians based on the this body of materials.

To prevent unnecessarily complex results eighth-notes were taken as the smallest units of study, which means that statistics are stated as multiples of eighth-notes. This restriction has some noteworthy consequences: namely, all note values smaller than an eighth-note cannot be fully represented. The eighth-note is often regarded as the basic note value in bebop styled jazz melody (eg., Baker 1979, 5; Coker 1980, 10); the body of materials used in this study also attest that all other note values occur significantly less frequently. The average ratio of eighth-notes, triplets and sixteenth-notes in the body of materials is illustrated in Figure 16 which shows a part of an improvisation by trumpetist Fats Navarro.

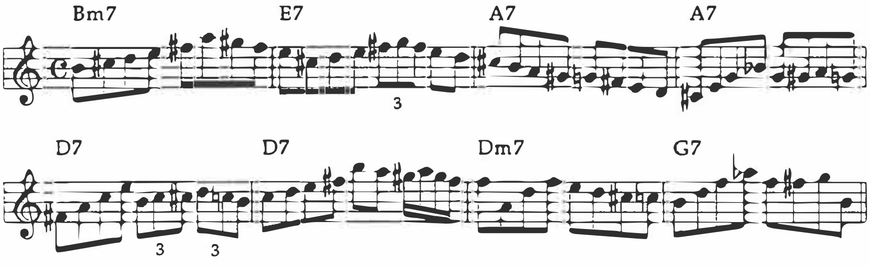

FIGURE 16. Fats Navarro (trpt): Anthropology (Baker 1982, 59). Measures 17-24 (B-section).

There were 257 sixteenth-notes and 546 triplet eighth-notes in the body of materials. This means that in each section there are approximately four sixteenth-notes and eight triplet eighth-notes (see Fig. 16). As multiples of eighth-notes the total number of sixteenth-notes and triplet eighth-notes equal to 128,5 and 91, respectively. The total number of eighth-notes in the body of materials is 8582, which indicates that sixteenth-notes and triplets are quite rare. Therefore it seems reasonable to assume that the exclusion of certain sixteenth-notes and triplets do not have a considerable affect on the results. When some other note values — most notably triplets and sixteenth-notes — occur, I have observed the guidelines that can be seen in Figure 17.

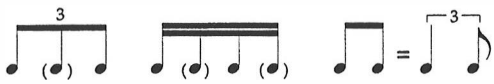

Fig. 17.1 Fig. 17.2 Fig. 17.3

FIGURE 17. The notes shown in parentheses are omitted in the analysis in order to avoid needlessly complex results. Fig. 17.3 shows approximately how eighth-notes are interpreted in jazz music.

The middle note is omitted from a triplet figure (Fig. 17.1), thus leaving the first and the third note. Similarly the second and fourth notes are omitted from the sixteenth-note figure (Fig. 17.2), thus leaving the first and the third note, which are on the strong beats. As for the treatment of sixteenth-note figures, there is evidence suggesting that if the processing of auditory information is masked by some other auditory information within 40 msec, the listener will be unable to discriminate the previous information; only after the mask is delayed 250 msec can the listener distinguish the characteristics of the information perfectly (Massaro 1970, 411-413; see also Kintsch 1977, 125)[21]. The average tempo in the sample is ca. 260 beats per minute which means that one sixteenth-note lasts for 58 msec before the next note is played. This result is on the lower end of the described auditory range, which, together with metrical preferences in perception, suggests that the off-beat notes of a sixteenth-note figure may be

21 Without masking, the auditory sensory store can hold usable memory trace for two seconds; after three or four seconds it is completely lost (Kintsch 1977, 123)

hard to perceive[22]. The rationale for omitting the middle note from the triplet figure is that in jazz music eighth-notes are played in a triplet-like manner (Fig. 17.3), which makes the first and the third note perceptually prominent ("swing eighths"). There is also some evidence that listeners place subjective accent on the initial and final events of a three event sequence (Povel & Essens 1985, 415). The reason that the triplet itself cannot be taken as the basic unit, in spite of its perceptual importance, is that it is impossible to determine the exact ratio between these two notes exhaustively, because so many things can influence the outcome. When tempo is very fast, for example, the eighth-notes are played almost evenly.

In any case I should note that these are minor details. There is little reason to believe that these restrictions would have a significant effect on the results, for the number of tones that are excluded is quite small. Namely, only approximately 128 sixteenth-notes and 180 triplet eighth-notes were not included into the analysis. The excluded sixteenth-notes equal to 64 and triplets equal to 30 as multiples of eighth-notes. Moreover, on the quarter-note level these problems do not exist.

When we are trying to determine the statistical distribution of tones on a written tonal composition the task is fairly simple, since the score usually gives unambiguous information about the pitches, rhythms, durations, etc.[23]. This is not the case when we are dealing with improvised music, because the only sources of information are the recording and a notated transcription of the performance. The problem is, of course, that different people hear different things when they listen to the same music, and it is hardly possible to come up with a transcription that would satisfy everybody, let alone be the correct one. In addition to the sometimes unclear pitch height, there are several rhythmic features in jazz that cause discord even amongst competent transcribers. For example, someone may say that a given tone is an eighth-note, whereas someone else may say that it is a slightly short quarter-note. This problem is apparent especially in rhythms such as the ones in Figures 18.1 and 18.3.

Fig. 18.1 Fig. 18.2 Fig. 18.3 Fig. 18.4

FIGURE 18. In fast tempos the rhythms in Fig. 18.1 and Fig. 18.3 are hard to distinguish from Fig. 18.2 and Fig. 18.4, respectively: for this reason the latter alternative is used in the analyses.

I have chosen to interpret Figure 18.1 as Figure 18.2, because in the average tempo of 256 beats per minute (one beat is 234 msec long), it is unlikely that the listener can recognize the difference between Figures 18.1 and 18.2.

22 The results of the described experiment were obtained in a laboratory situation, whereas jazz improvisations are performed in situations where there is a multitude of interference factors (accompanists, audience etc.) that may have an effect on the perception process.

23 I acknowledge that this view is oversimplified, for if one were to analyze actual performance of a Beethoven sonata, there would undoubtedly be similar problems. Still, I think that this is valid distinction, because most analysis of notated compositions is done with the manuscript not the performance as the main source.

Also, it is common in jazz music that the second note of the syncopated figure anticipates the upcoming beat melodically. A similar, but somewhat infrequent, case is in Figures 18.3 and 18.4, although it is not as obvious, because the anticipation effect is not present. Nevertheless, with the support of the reviewed evidence, it is reasonable to make the same rounding as with the syncopated figure when the tempo is fast, as is the case in every improvisation in the sample.

Figure 19 is a part of an improvisation played by Hank Mobley on the Rhythm Changes -chord progression, and it demonstrates well the aforementioned points.

FIGURE 19. Hank Mobley (ten.sax): Tenor Conclave (Campbell 1989, 6). Measures 9-16 (second A-section).

In the fifth measure of Figure 19 there is a triplet figure B flat-D-F which in the statistical analysis is reduced to perceptually prominent notes B flat and F. Similarly, from the sixteenth-note figure E-G-B-D the second and the fourth notes are omitted leaving the notes on the strong metrical positions, namely E and B. Finally, the C on the last eighth-note of bar seven is extended to the first beat of the next bar in compliance with the principles that were illustrated in Figure 18.

The types of scale and chord substitutions that were presented earlier can be problematic for this type of statistical study. For example, the results could be distorted, if several improvisers had used a considerable amount of substitutions that differ substantially from the ones that the others have used. As has been noted before, however, it seems plausible to assume that these individual differences have little affect on the final results, because this study is based on a fairly large and diverse body of materials in which the these "deviations" are evened out by the general tendencies.

4 RESULTS

4.1 Meter

Empirical studies on meter suggest that listeners attend to certain metrical positions more than others (e.g., Palmer & Krumhansl 1990). Moreover, music theory often assumes that metrical structure is hierarchically organized (e.g., Lerdahl & Jackendoff 1983). In Järvinen (1995) it was presumed that jazz complies with the same metrical structure as, for example, compositions from the tonal-harmonic tradition of the Western art music. This type of premise may be somewhat problematic, because one might be tempted to assume that the metrical structures are different, because syncopations and various polyrhythms are thought to be common even in tonal jazz (cf., Large & Kolen 1994, 181).

In order to investigate the effect of meter on the use of tones, a set of metrical grids were constructed. Each grid was specified by its period and phase: period $p = 1 \ldots 8$ eighth-notes, phase $\phi = 0 \ldots p-1$ eighth-notes. For each grid, a tone profile was calculated, so that only the notes whose metrical position coincided with the grid were taken into account. Figure 20 illustrates all eighth different periods ($p = 1 \ldots 8$) without any phase shift ($\phi = 0$).

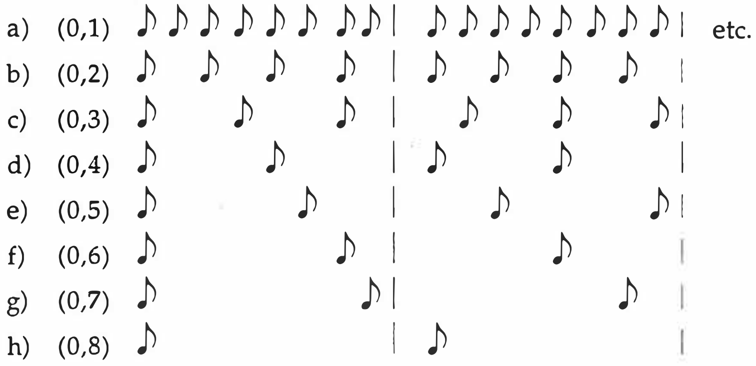

FIGURE 20. The first two measures of the investigated periods without phase shift. Letter *a* corresponds to eighth-note level, letter *b* to quarter-note level, letter *d* to half-note level, and letter *h* to whole-note level.

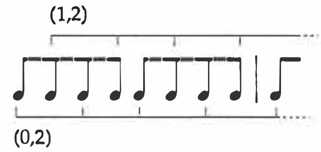

FIGURE 21. The two possible phases for metrical grid of period 2.

Different versions of each period were created in order to take into account all possible metrical positions that a particular period can occupy. For example, the two possible phases for the quarter-note level are represented in Figure 21. A total of 36 tone-frequency profiles were obtained by investigating all the possible period and phase combinations. Below, these profiles will be referred to as phase-shift profiles. In particular, it was investigated how well the different periods in the found A-section correlate with the basic global profile, ie. the tone-frequency profile obtained by counting all the eighth-notes in the A-section (letter a in Figure 20).

The bubble graph in Figure 22 represents the correlations between these profiles and the basic tone-frequency profile. The period is shown on the y-axis and the phase of a given period is shown on the x-axis. For example, the correlation of the basic eighth-note level tone-frequency profile with itself is at origo (0,1) where phase is 0 (no shift) and period is 1 (every note); at (1,2) the phase is 1 (shifted by one eighth-note) and period is 2 (every other eighth-note), etc. The size of the bubble at each co-ordinate indicates the relative amount of correlation.

The correlations between the basic eighth-note level profile and tone-frequency profiles are very high: between 0.938 and 1.0. The highest correlations seem to cluster around the origo, while the lowest correlations seem to coincide with the greater periods and phase-shifts. The relatively low correlation on the whole-note level (0,8) is particularly interesting, because traditionally it has been thought of as the strongest metrical position in each measure. One reason for this result may be that there is simply statistical noise on the whole-note level, because there are eight times fewer notes than on the eighth-note level. Another feasible explanation may be that the musicians approach these metrical positions differently. For example, if they have stressed the important tones of the underlying tonality more than the other tones, the resulting tone-frequency profile is not likely to be very similar to the eighth-note level profile: in other words, the whole-note level profile may be less diffused than the eight-note level profile which reflects the musicians' general tonal preferences. In order to clarify the results obtained by correlation, standard deviation was calculated for each of the 36 tone-frequency profiles (see Figure 20). If standard deviation is high, some tones are emphasized in the profile. If standard deviation is low, the tones in the profile are used relatively evenly – i.e, the profile is diffused.

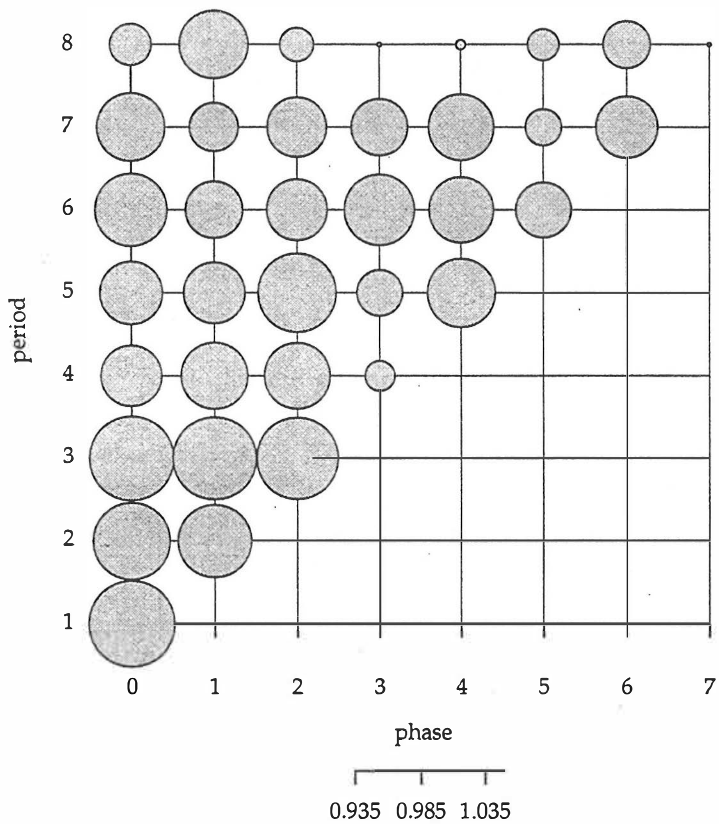

FIGURE 22. The correlations between the eighth-note level tone-frequency profile and 35 other possible phase-shift profiles. The size of the bubble indicates the amount of correlation. See text for further explanation.

Figure 23 shows that the profiles which were obtained from even periods were generally less diffused than the profiles on the odd periods. Moreover, the even period profiles which are not shifted at all (phase=0) have the highest standard deviations. With the exception of period 6 starting on the first eighth-note of the measure, these are the metrical positions which are traditionally thought to be important. In particular, it should be noted that the profile that was constructed by investigating the use of tones on the first eighth-note on each measure (0,8) has the highest standard deviation. The high standard deviation of (0,6) is understandable, because it coincides with the other even periods and starts at the beginning of the measure after every three measures.

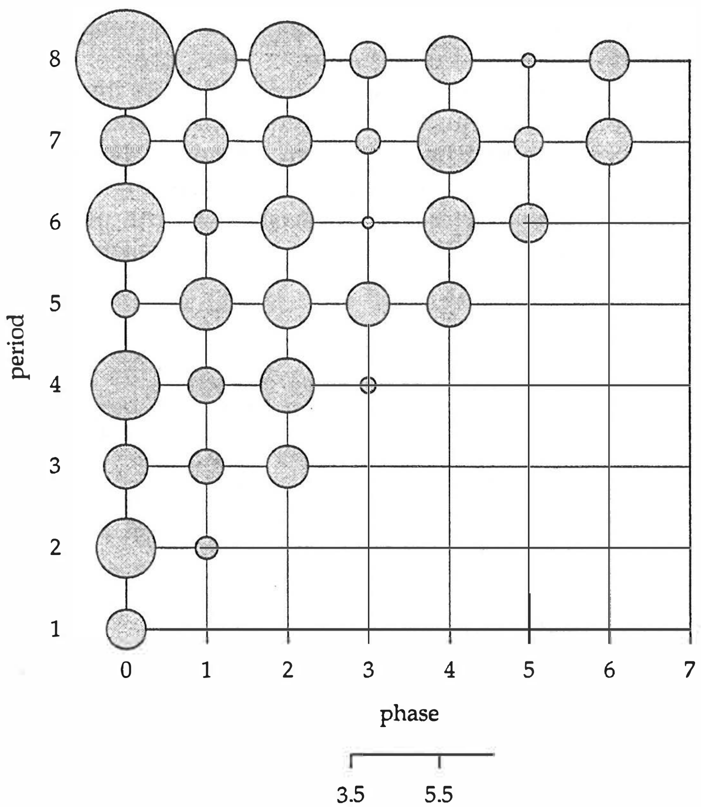

FIGURE 23. The standard deviations for the 36 phase-shift profiles. The size of the bubble indicates the amount of standard deviation. See text for further explanation.

This suggests that some tones are emphasized on these strong metrical positions and on others the tones are used more evenly thus creating a more balanced profile (low standard deviation). This supports the idea that musicians emphasize some central material at these positions. Since the standard deviation itself does not give any information about the tones which are stressed, we need to look at the actual tone-frequency profiles.

The graph in Figure 24 displays the normalized whole-note level (0,8) and the eighth-note level graphs (0,1). It shows that on the whole-note level the important tones (C and G) of the C major tonality are emphasized whereas all of the other tones are de-emphasized compared to the eighth-note level graph.

Although this treatment of meter is simplistic and probably does not do justice to its polymorphous nature, the results seem clear enough to show the overall tendencies. Therefore at present it appears justified to use them as basis for the analysis of meter. Specifically, these results give further evidence for the idea that in this type of music the basic metrical structures conform well with the traditional view of metrical organization. Moreover, they also appear to attest the weighting of tones depending on which metrical position they are played on. In other word, since these metrical positions hold a special importance for the improviser and for the listener, the tones on these positions should be treated accordingly.

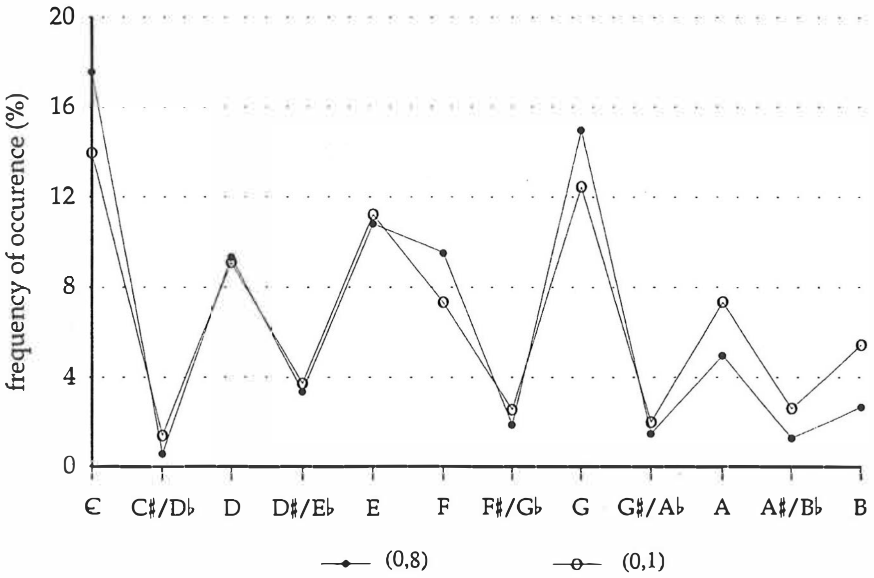

FIGURE 24. Comparison of the unshifted eighth-note (0,1) and whole-note (0,8) level profiles.

In the following discussion on the results, the four metrical levels will be taken into account. In order to make the data more accessible, in most cases only the average of the normalized tone-frequency profiles obtained from the four metrical levels is presented. If, however, the different levels seem to clarify or add new information to the data, the levels will be presented separately. Implicit in this treatment is the assumption that the performer and the listeners can attend to the different metrical levels simultaneously (cf,. e.g, Jones 1992). In a way, the eighth-note level represents the steady rhythmic and temporal flow, whereas the whole-note level represents the structure below surface level.

4.2 A-section of the Rhythm Changes Chord Progression

4.2.1 Global tone-frequency profiles

One hundred and thirty three A-section of the Rhythm Changes chord progression were investigated. In particular the statistical distribution of the tones of the chromatic scale within the C major context was examined in these improvisations. The tone-frequency profiles were obtained from each of the four metrical levels and examined to determine in particular, the extent to which the tone-frequency profiles resemble the probe-tone ratings that Krumhansl and Kessler acquired in their empirical tests and also the frequency tables published in Knopoff and Hutchinson's study on actual music.

The graph in Figure 25. shows the average of each metrical level computed across the A-sections. These results indicate that in the analyzed improvisations the musicians have clear preferences for certain tones over others. Namely, it seems that the tonic triad and the rest of the diatonic tones are favored. Although all of the nondiatonic tones occur less often than the other tones in the chromatic scale, stylistic features have caused some nondiatonic tones to occur more often than would be expected. The tones that are referred to here are E♭, G♭ and B♭ the frequency of which is due to the use of the so called blues scale, where the tones in the third, seventh and sometimes in the fifth scale degrees of the diatonic scale are (slightly) flatted.

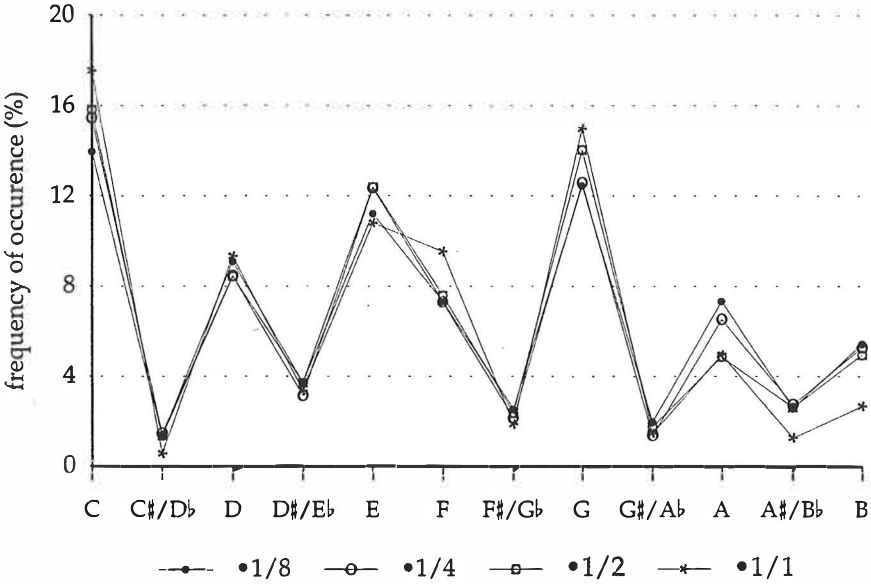

FIGURE 25 .The tone-frequency profiles for the four metrical levels.

The differences between the levels are very small, but nevertheless, these divergences are especially illuminating, since they demonstrate how metrical structure is used to emphasize or de-emphasize tones. The graph in Figure 25. shows that the important scale degrees of the C major tonality, namely the tones C and G, are used more frequently in the highest level (whole note) compared to the lower levels. The sixth scale degree (A), however, is sounded more frequently on the lower levels, which emphasizes its melodic function.

TABLE 4. The standard deviations of the tone-frequency profiles on different metrical levels.

Metrical level	Standard deviation
eighth-note level	4.341
quarter-note level	4.791
half-note level	5.011
whole-note level	5.761
weighted average profile	4.936

The standard deviations of the four metrical levels indicate a similar tendency. Table 4 shows a clear, almost linear pattern in which the eighth-note level has the lowest standard deviation and the whole-note level the highest. This means that on the eighth-note level the tones are used more relatively evenly, and on the whole-note level some of the tones are emphasized.

Figure 26 represents the weighted global tone-frequency profile, which was constructed by averaging the tones on the four metrical levels, with Krumhansl & Kessler's probe-tone rating profile, and the profile constructed from the Knopoff & Hutchinson's data[24]. From this it seems clear that the obtained tone-frequency profile shares many key features particularly with Krumhansl and Kessler's empirical findings: the most emphasis is given the tonic triad, which is followed first by the rest of the diatonic scale and finally by the nondiatonic tones.

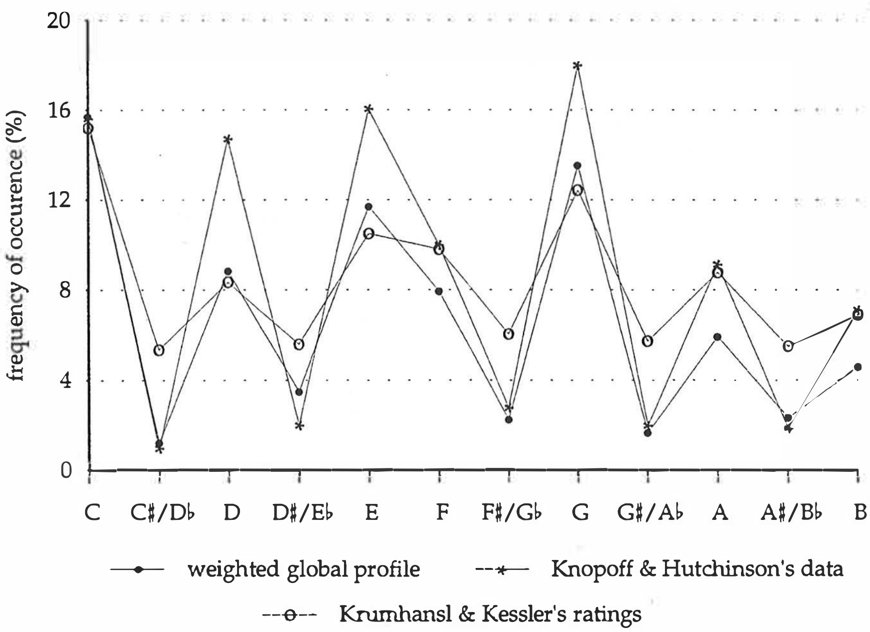

FIGURE 26. The weighted global tone-frequency profile, Krumhansl & Kessler's probe-tone rating profile, and the profile constructed from the Knopoff & Hutchinson's data.

In the Knopoff & Hutchinson data there seems to be much more preference for the second (D) third (E) and the fifth (G) scale degrees. It has been proposed that the reason that these tones have relatively high frequency of occurrence is that the data was taken from melodic lines only: certain melodic relationships (e.g, second scale degree to tonic) make some tones more prominent than they would be if the tones in the accompaniment were included into the data (see Krumhansl 1990, 69). This explanation seems reasonable in the light of the present data, for jazz improviser are

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[24] It should be noted that the metrical placement of tones is not taken into account in the Knopoff & Hutchinson's data, and therefore the comparison with the present data is not entirely unambiguous.

expected to be able improvise on a preset chord progression without any accompaniment (cf., Berliner 1994, 171). Therefore even when the accompaniment is present, the musician may emphasize the chord progression by using some tones which provide partial accompaniment for his melodic lines.

The use of the non-diatonic tones is almost the same as in the tone-frequency profile obtained from the improvisations, although the slight difference in the frequency of E♭ (blue note) should be noted. In the probe-tone rating profile there seem to be much more preference for the non-diatonic tones than in either of the profiles obtained from real music. Some of these differences (high ratings for the non-diatonic tones?) are undoubtedly due to the laboratory situation and the experimental stimulus used in the Krumhansl & Kessler study. The effects are, however, hard to determine, because the weighted tone-frequency profile shares features with both profiles, namely, the relative frequency of diatonic tones with the probe-tone profile and the relative frequency of the non-diatonic tones with the Knopoff & Hutchinson's data.

TABLE 5. The correlations between the tone-frequency profiles and Krumhansl & Kessler's probe-tone ratings and Knopoff & Hutchinson's frequency data.

	Correlations	
Metrical level	Probe-tone ratings	Knopoff & Hutchinson
eighth-note level	0.952	0.969
quarter-note level	0.961	0.949
half-note level	0.956	0.938
whole-note level	0.969	0.920
weighted average profile	0.968	0.950

The correlations with the weighted global profile are high: r=0.968 for Krumhansl's probe-tone ratings and r=0.950 for the Knopoff & Hutchinson data. Interestingly, as Table 5. shows, the whole-note level has the highest correlation with the probe-tone ratings whereas Knopoff & Hutchinson's data has the highest correlation with the eighth-note level. The high correlation of the probe-tone rating with the whole-note level and he weighted average profile seems to further support the idea of metrical weighting. For if we assume that "abstract tonal and harmonic relations are learned through internalizing distributional properties characteristic of the style" (Krumhansl 1990, 286; see also Meyer 1956, 60), then according to the correlation the metrically weighted profile is closer to what we learn to perceive than the plain eighth-note level profile. The correlations with the Knopoff & Hutchinson's data, which do not take meter into account, are also instructive, for the profile has relatively low correlation with the whole-note level and relatively high correlation with the eighth-note level. It may be possible that the relatively low correlation that this data has with the weighted tone-frequency profile could be improved if the other metrical levels were included. Also if the metrical levels were present, perhaps the relatively low correlation (r=0.882) between the

Krumhansl & Kessler's probe-tone profile and the Knopoff & Hutchinson's data could be improved.

This speculation, however, has problems, for in this case the simple correlation is not a very precise instrument of measurement. Aside from the fact that the methodology for obtaining the data for each profile is different, the investigation of the profiles (see Fig. 26.) does not seem to support entirely the high correlations. The standard deviation for each profile (see Table 6) shows that the level of diffusion varies greatly. The Krumhansl & Kessler's probe-tone profile has the lowest standard deviation, which most likely reflects the relatively high rating of the non-diatonic tones in the experiment. The highest standard deviation was obtained for the Knopoff & Hutchinson's data, and it seems to display the frequent use of some of the diatonic tones.

TABLE 6. The standard deviation for the weighted tone-frequency profile, Krumhansl & Kessler's probe-tone profile, and Knopoff & Hutchinson's frequency data from actual classical compositions.

Source	Standard deviation
probe-tone profile	3.15
weighted average profile	4.94
Knopoff & Hutchinson's data	6.45

These standard deviation values seem to provide important information about the profiles, which is not carried over from the calculation of the correlation. Thus, it appears that the correlation gives an approximate measure of the similarity, which seems useful in conjunction with standard deviation and the actual inspection of the profile, but by itself it may be ambiguous and not very informative.

In the preceding discussion the three A-sections were not differentiated. In order to investigate the possible divergencies between the sections, the graph in Figure 27 was constructed. The profiles show that there are some differences among the sections, for, although the general tendencies are the same, there seems to be some variation on the use of diatonic tones. Table 7 clarifies the differences, for it seems that compared to the final A-section, in the first two A-sections the musicians are somewhat "adventurous". Although the correlation is the same for the A1 and A2, the lower standard deviation for A2 indicates a more even preference for the tones in the second A-section – the profiles in Figure 27 seem to confirm this. Both the correlation and the standard deviation for the last A-section (A3) are higher than for the other two. This appears to suggest that the musicians may want to bring the element of closure to the improvisation in the last section of the chorus by emphasizing the central elements of the global tonality.

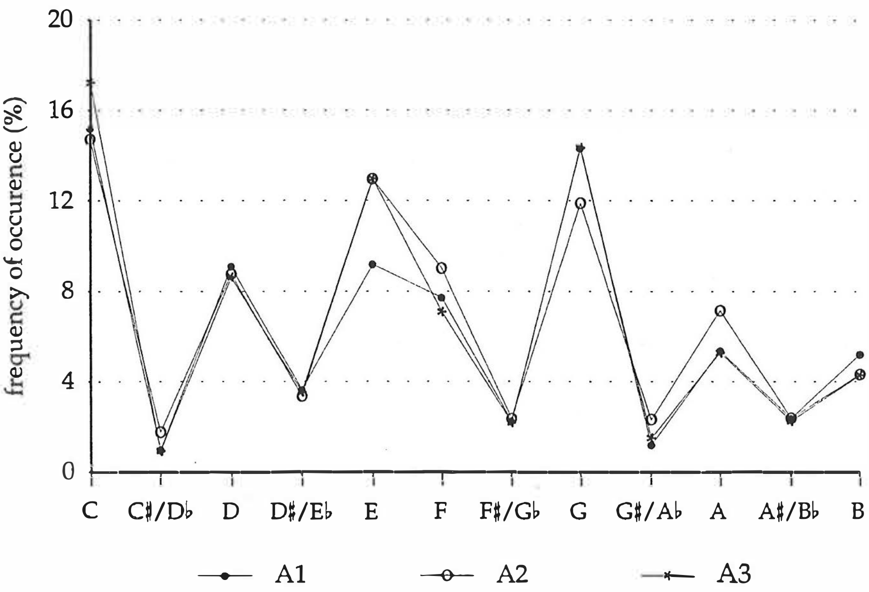

FIGURE 27. The weighted average tone-frequency profiles for the three A-sections in the Rhythm Changes chord progression.

TABLE 7. The standard deviations of the weighted tone-frequency profiles obtained from the three A-sections, and the correlations between profiles and the weighted global profile.

Section	Standard deviation	Correlation
A1	4.835	0.985
A2	4.653	0.985
A3	5.485	0.996

In summary, these results give support for the notion that the general characteristics of the statistical distribution of tones in bebop styled jazz improvisation are comparable to the way listener have been found to perceive tonality; the results also indicate that the distribution of the tones is similar to the one found in the tonal repertory of western music. Moreover, it was found that also the meter governed the improvisers choices of notes: the important tones (C, G) of the global tonality were given more attention on salient beats than the tones (A) that are not as central in the tonality (C major).

4.2.2 Local tone-frequency profiles

If a jazz improviser follows the chord changes literally, it would be logical that in addition to the global tonality, there are numerous local tonalities within a given chord sequence. In local tonalities the tones would, then, be hierarchically ordered according to their relation to the underlying chord which has its own distinctive tonal template, which varies according to the music culture in question. In European art music the triad is thought to be the most important and stable chordal formation. In jazz, on the other hand, the harmony appears to be more extended, since seventh, ninth, eleventh and thirteenth chords are often employed. It does seem to be reasonable to assume that in bebop seventh chords along with triads can be considered as stable, but it has been uncertain whether the upper structure of the chord (9, (♯)11, 13) can be included as well.

In this section the tone-frequency profiles for six chords (CM7, Am7, Dm7, G7, C7, FM7) were investigated by analyzing forty one improvised choruses with similar statistical procedures that were explained earlier. As in the previous section the point of view is atemporal. The chords are not treated as parts of the progression, rather the intention is to examine what tones are played on a particular chord. Therefore the whole-note level is excluded, because each one of the chords lasts only for two beats at a time. The chords are given equal treatment in order to find out what tones the improvisers use on a certain chord and what tones are emphasized. All local tone-frequency profiles were compared with 44 different calculated chord profiles. The chords are listed in Table 8 - the data for the profiles can be found in Appendix 2. In addition to the chords that are in the original progression also other chords were included into the analysis. The aim was to choose the ones that jazz theory usually predicts as the most probable substitutions.

TABLE 8. The chords that were used as comparisons in the chord progression analysis.

Chord type	Chords
M7	CM7, FM7, DM7, GM7, CM9, FM9
dom7	G7, A7, C7, D7, E7, B♭7, B♭7♭5, E♭7♭5, A♭7♭5, D♭7♭5, B7, E9, A9, D9, G9, C9
m7	Am7, Dm7, Gm7, Fm7, Bm7, Em7, Dm9, Am9, Em9, Bm9
diminished	F♯°7, G♯°7, C♯°7
half-diminished	Bm7♭5, Em7♭5, G♯m7♭5, C♯m7♭5, F♯m7♭5, D♯m7♭5,

TABLE 9. The standard deviations CM7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	6.05
quarter-note level profile	6.68
half-note level profile	7.44
weighted average profile	6.63

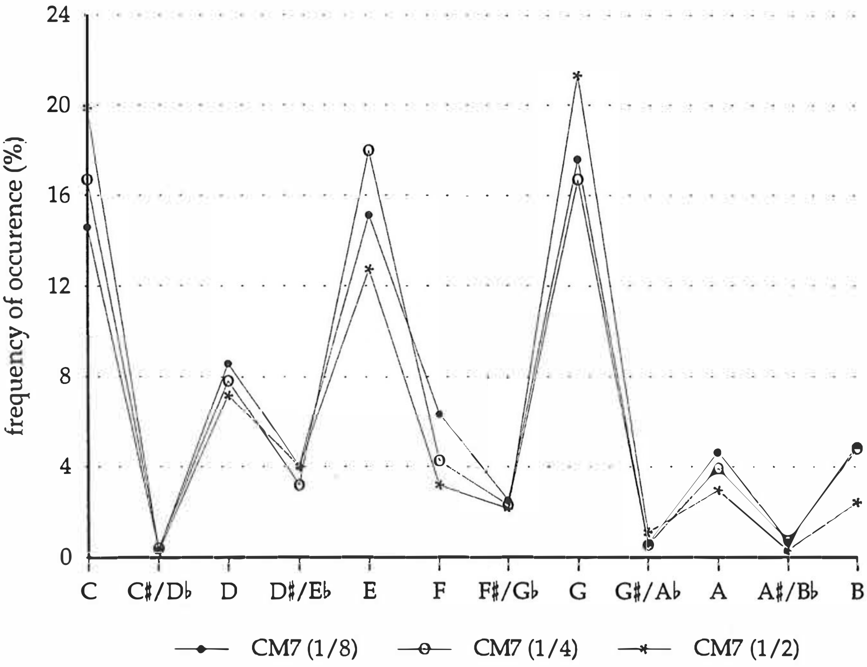

FIGURE 28. Tone-frequency profiles for the CM7 chord.

Figure 28. presents the tone-frequency profiles for the CM7 chord (I) on eighth-note, quarter-note, and whole-note levels. The preference for the tones of the triad (C, E, G) over the other nine tones including the seventh is demonstrated unambiguously. The high standard deviations in Table 9 also indicate that some tones are emphasized in the profiles. On the whole the discrepancies between the tones on different metrical levels are relatively small (average standard deviation computed for tones across all metrical levels is 1.49), although in some cases there are interesting differences, for the root, C, and the fifth, G, of the CM7 chord are further emphasized metrically. The weighted average profile has the highest correlation with the global tonality (r= 0.958), but also the correlations with the CM9 (r= 0.922) and CM7 (r=0.856) calculated chord profiles are high. The high correlation with the CM9 profile seems to reflect the preference for the tone D. However, since it is de-emphasized on the half-note level, and since the improvisers have used the seventh, B, very little, it can most likely be explained as a melodic passing tone or upper neighbor-tone (Cf., Krumhansl 1990, 69).

The tone-frequency profiles for the Am7 chord also show preference for the tones of the C major chord, although the profiles in Figure 29 display more emphasis on the other diatonic tones as well as the non-diatonic tones. The musicians use the tone A relatively little, and it seems that they continue to play as though the underlying chord were C major and not A minor or A dominant. The weighted average profile has the highest correlation with the CM9 chord (r=0.967) which further substantiates this analysis; the correlation with the global profile is r= 0.914 and with Am7 profile r= 0.667. Even though the some tones are clearly emphasized in the tone-frequency profiles, the standard deviations (see Table 10) are lower than for the C major chord, because the non-diatonic tones are used relatively often.

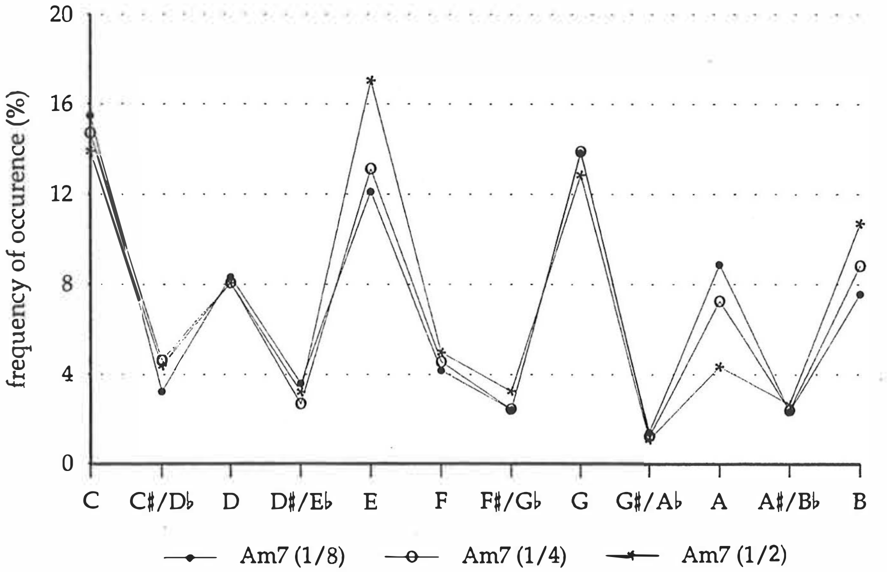

FIGURE 29. Tone-frequency profiles for the Am7 chord.

TABLE 10. The standard deviations Am7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	4.84
quarter-note level profile	4.81
half-note level profile	5.20
weighted average profile	4.85

In the tone-frequency profiles for the D minor chord the preference for tones displays a different pattern than in the C major and A minor tone-frequency profiles. The standard deviations in Table 11 indicate that there is some emphasis placed on certain tones. Figure 30 shows that for Dm7 chord the root, D, the third, F, and the seventh, C, are used frequently, whereas the fifth, A, is used considerably less often. However, the emphasis received by the ninth, E, is the most surprising result, since it is so consistent on all levels. There may be several explanations for this: it could be interpreted as the ninth of the D minor chord, it may be a frequently used upper neighbor-tone for the root D, or it may reflect the use of the global tonality. The weighted tone-frequency profile gets the highest correlation with the global tone-frequency profile (r=0.895), whereas the correlations with the calculated D minor chord profiles are relatively low (Dm7: r=0.604; Dm9: r=0.758). This suggests that the global tonal orientation may have affected the musicians' tone preferences for this particular chord.

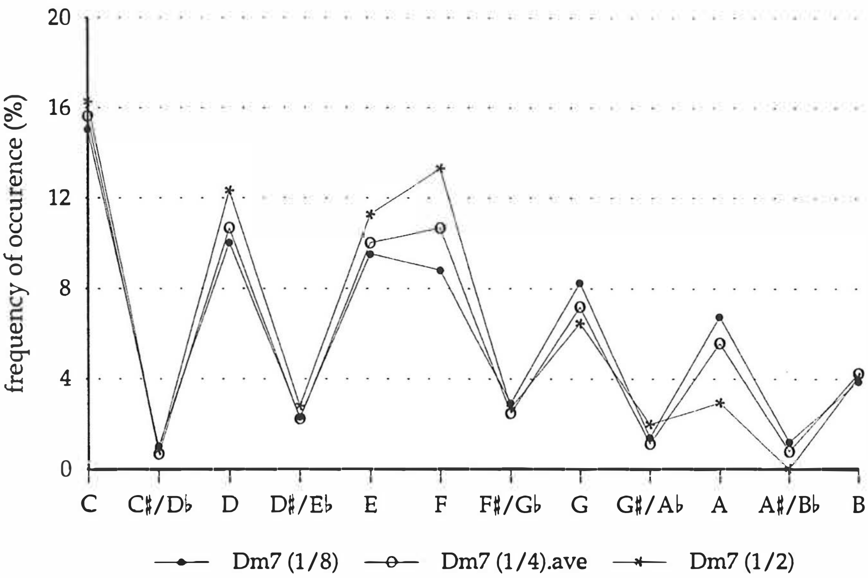

FIGURE 30. Tone-frequency profiles for the Dm7 chord.

TABLE 11. The standard deviations Dm7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	4.48
quarter-note level profile	4.89
half-note level profile	5.55
weighted average profile	4.91

The G7 tone-frequency profile seems to support the explanation proposed for the D minor chord tone-frequency profile, for the tone E is used relatively frequently during the G7 chord, as well (see Fig. 31). It is not likely that the improvisers would imply G13 just by using the thirteenth, E, without giving much emphasis on the ninth, A, and the eleventh, C sharp. Therefore it is probable that the tone E reflects the global tonality of the chord progression rather than local hierarchy created by the individual chord (Cf., Krumhansl & Kessler 1982, 357). This is also supported by the high correlation that the G7 tone-frequency profile has both with the global tone-frequency profile (r=0.918) and CM7 calculated chord profile (r=0.926). Again, the correlations with the calculated chord profile of the original chord, namely G dominant, are relatively low: for G9 r=0.721 and for G7 r=0.727. It should also be noted that the standard deviations for the G7 tone-frequency profiles are lower than for any other chord study (see Table 12). This lack of emphasis seems to suggest that this chord is not a very important one in the progression.

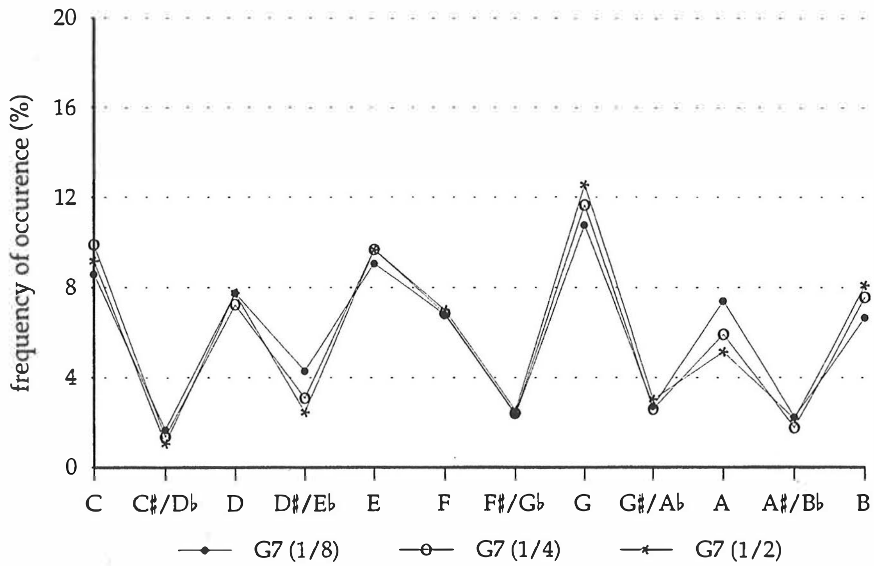

FIGURE 31. Tone-frequency profiles for the G7 chord.

TABLE 12. The standard deviations G7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	3,08
quarter-note level profile	3,54
half-note level profile	3,67
weighted average profile	3,40

The tone-frequency profile in Figure 32 displays that the musicians' preferences for the C dominant chord in the latter part of the fifth measure. It shows that they clearly emphasize some tones. This observation is further established by the high standard deviations (see Table 13) which indicate that the tone-frequency profiles are not diffused. The musicians seem to have favored the chord tones of the underlying C7 chord: particularly, the root, C, the third, E, and the seventh, B♭, are emphasized.

TABLE 13. The standard deviations C7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	5.40
quarter-note level profile	6.90
half-note level profile	8.31
weighted average profile	6.81

The correlation between the weighted tone-frequency profile and the C7 calculated chord profile is r=0.845. The highest correlation is, however, with the C9 chord (r= 0.907) which is supported also by the profile in Figure 32, for also the ninth and the thirteenth are used quite often. The global tonality does not seem to be an important influence for this chord, because the correlation with the global tone-frequency profile is relatively low (r=0.790).

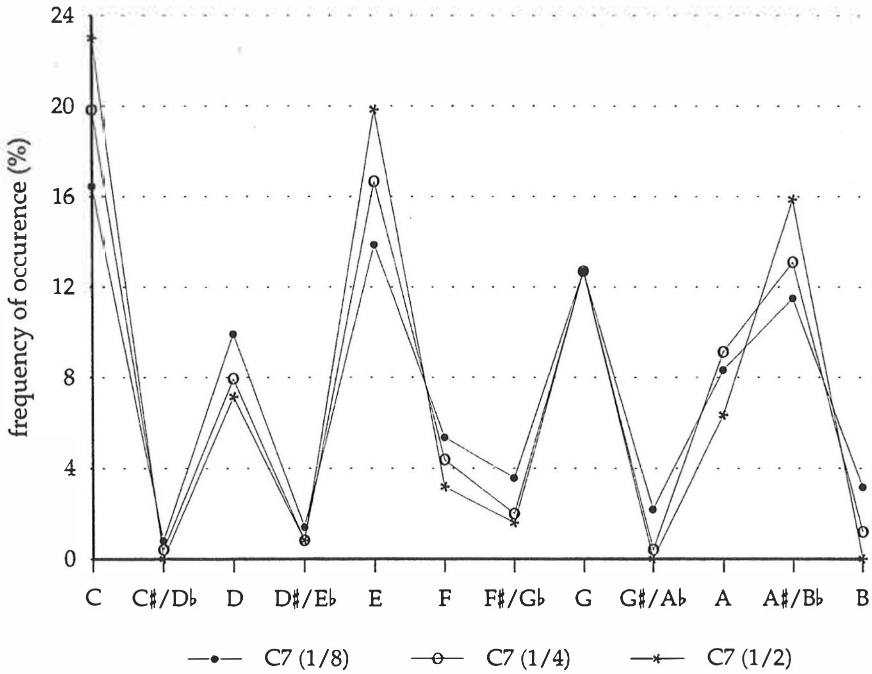

FIGURE 32. Tone-frequency profiles for the C7 chord.

The results for first FM7 chord in measure six (see Fig. 33 and Table 14) also indicate clearly the priority of the triad, although on the half-note level the fifth of the chord (C) is used less frequently than on the lower levels. The correlation between the average tone-frequency profile and the FM7 calculated chord profile is r=0.873, but highest correlation is with the FM9 calculated chord profile (r=0.968). Still, the tone-frequency profile does not support this unambiguously, for since the seventh, E, is used relatively little, the ninth G may be better interpreted as a melodic passing tone. Specifically, the relatively high frequency of the tone G on the first eighth-note of the measure suggests that it may have been used as an upper neighbor tone which delays the root, F. The correlation with the global tone-frequency profile is low (r=0.672) which, similar to the C dominant profiles, suggests that the global tonality does not seem to be an important influence for this chord. The high frequency of the tone G on the first beat of the measure (half-note level) supports this proposition.

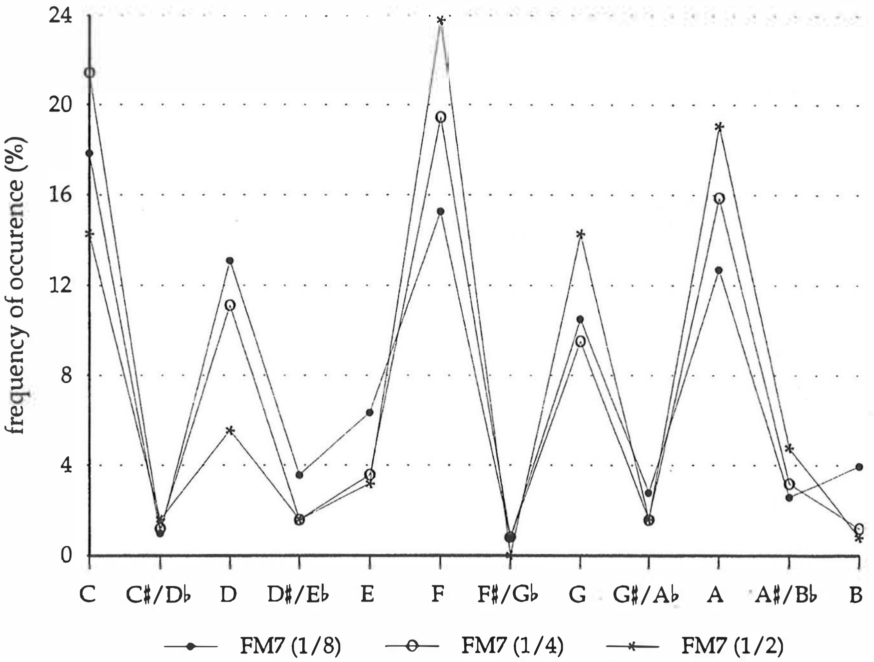

FIGURE 33. Tone-frequency profiles for the first FM7 chord.

TABLE 14. The standard deviations for the tone-frequency profiles obtained from the three A-sections for the first FM7 chord.

Metrical level	Standard deviation
eighth-note level profile	6.02
quarter-note level profile	7.70
half-note level profile	8.13
weighted average profile	7.04

In the latter part of the sixth measure there seems to be little agreement on the tones (see Figure 34). This understandable, because musicians often use various chord substitutions in this place: the most common are B♭7, Fm7, F♯°7. The profiles in Figure 34, however, do not indicate much support for these chords, and, moreover, the correlations are quite low (B♭7 r=-0.269; Fm7 r=0.085; F♯°7 r=0.169). Instead, there seems to be emphasis on the tones C and G, which is reflected in the relatively high correlation with the global tone-frequency profile (r=0.859) and in the moderate standard deviations shown in Table 15.

In summary, these results indicate that underlying chords and meter are important in the improvisation process. Still, evidence concerning underlying chords is a bit ambiguous, for different chords are given unequal treatment. It appears that in the chord progression improvisers have reference points that are clearly stressed. The other chords in the progression receive less attention, and thus the global tonality may influence the improviser more than the individual tonal orientation of the underlying chord. This explanation is in accordance with Krumhansl and Kessler's findings which indicated that at certain points of a chord sequence listeners perceive the prevailing key as more important than the individual chord, whereas at others the local effect of the sounding chord influence perception to a certain degree.

TABLE 15. The standard deviations for the second FM7 chord tone-frequency profiles obtained from the three A-sections.

Metrical level	Standard deviation
eighth-note level profile	4,52
quarter-note level profile	5,63
half-note level profile	6,44
weighted average profile	5,35

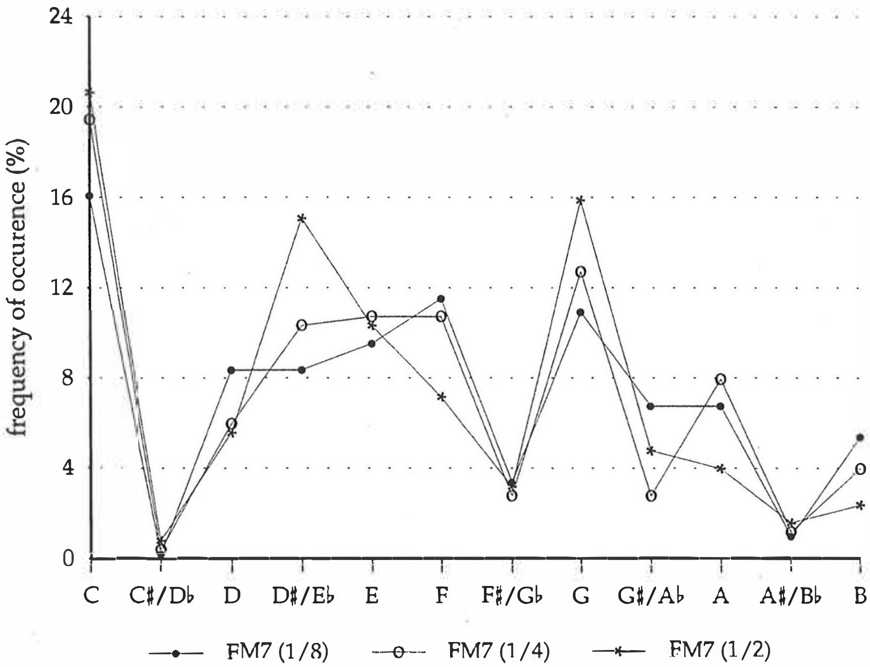

FIGURE 34. Tone-frequency profiles for the second FM7 chord.

These results give neither unequivocal proof nor disproof for the notion that triads and seventh chords are preferred over the more extended chords. In the C major and F major chord tone-frequency profiles the triad was favored, and to some degree this was further emphasized by the metrical structure. The profiles for the C dominant chord indicated clear preference for the tones underlying seventh chord. For the D minor and G dominant chord tone-frequency profile the results were not as clear, for the overall tonal orientation of the chord progression was found to effect the local profiles. In other words, it seems that there is no single way to play or think about chords, for the role of a particular chord determines how it is handled.

The triad appears to be stressed in the two focal chords (C major and F major), whereas in the third important chord in the progression, namely C dominant, the tones of the seventh chord are emphasized. This is understandable if we consider the roles of these three chords. On one hand, C major (tonic) and also F major (subdominant) are both quite stable within that progression, and the emphasis on the tones of the basic triad makes the impact of the chords even more distinct. On the other, the C dominant chord is not stable, and it requires resolution, for it is the secondary dominant for the F major chord in the sixth measure. Although the root movement from C to F is cadencial, the voice-leading from the seventh of the C dominant chord, B♭, to the third of the F major chord, A, makes the transition much stronger (cf,. Berliner 1994, 86). The rest of the chords do not appear to be structurally important for the progression, and accordingly they are given less attention as individual chords.

For most chords the profiles seemed to indicate some emphasis on the ninth of the chord. Nevertheless, with the possible exception of the C dominant chord, it seems that it can be explained as an melodic passing tone, rather than a tone which occupies a relatively stable position in the chord. For example, if the tone G, which is the upper neighbor tone for F, is played on the first eighth-note of a given measure and then resolved immediately to F, it gets more emphasis in the tone-frequency profile than its probable perceptual importance would merit (cf., Bharucha 1984, 515).

4.2.3 Chord progression

In the two previous sections the treatment of the data was for the most part atemporal. Therefore in this section it is discussed how the tonality changes in the course of the A-sections. All three A-sections were investigated by examining the similarity of each of the 16 weighted local profiles with both the weighted global profile (see Fig. 26 in section 4.2.1) and the calculated chord profiles. All local tone-frequency profiles were compared with same 44 calculated chord profiles that were used in section 4.2.2. (See also Appendix 2). The local tone-frequency profile for each half measure was constructed by averaging the tones on the four metrical levels.

It should be noted that since each chord lasts only for two beats, the whole-note level is the same for both chords in a given measure. In practice this means that the tones on the first eighth-note of the measure (ie. the whole-note level) are carried over to the second chord of the same measure. This may distort the results for individual the chords, but it may better account for the global tonal development as it is perceived by the listener.

Figure 35 shows the correlations between the local tone-frequency profile (loc.chord) and both the weighted tone-frequency profile (wt.glob.prof) and the calculated chord profile (calc.chord) based on the original progression. The graph indicates that the correlation between the local profile and the global tonality is higher than the correlation between the local profile and the calculated profile for almost every chord. There are, however, two notable exceptions. In the latter part of the fifth measure the importance of the global tonality drops and at the same time there seems to be more emphasis on the local tonality of the chord.

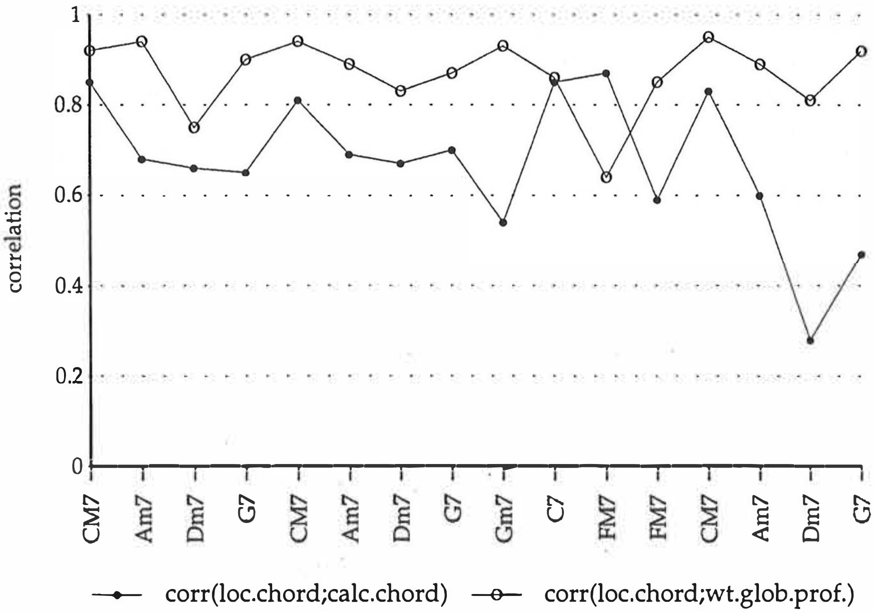

FIGURE 35. The correlations between the local tone-frequency profile (loc.chord) and both the weighted tone-frequency profile (wt.glob.prof) and the calculated chord profile (calc.chord) based on the original progression.

These results suggest that most of the time the global tonality is the most important tonal reference point. The problem is, however, that the musicians may have used chord substitutions, and thus the results give distorted view of the improvisers preferences. For that reason, whether the players had used some substitutions in place of the basic chords used in Figure 35 was also examined. Each of the chords in listed in Appendix 2 were correlated with each local tone-frequency profile, and the chord that yielded the highest correlation was chosen. Based on the results a new chord progression was constructed (see Fig. 36).

The correlations for the chords are higher than in Figure 35. According to these results the CM9 chord is used extensively: ten out of the sixteen chords are C major chords. In this graph the importance of the F major chord and the preceding C dominant chord is even more unambiguous than in Figure 36. The Figures 37 and 38 clearly illustrate that the chord tones are emphasized in these local profiles: the F major chord profile shows emphasis particularly on the root (F), third (A) and the fifth (C); the C dominant chord profile demonstrates stress on the root (C), third (E), fifth (G), and also on the seventh (B♭).

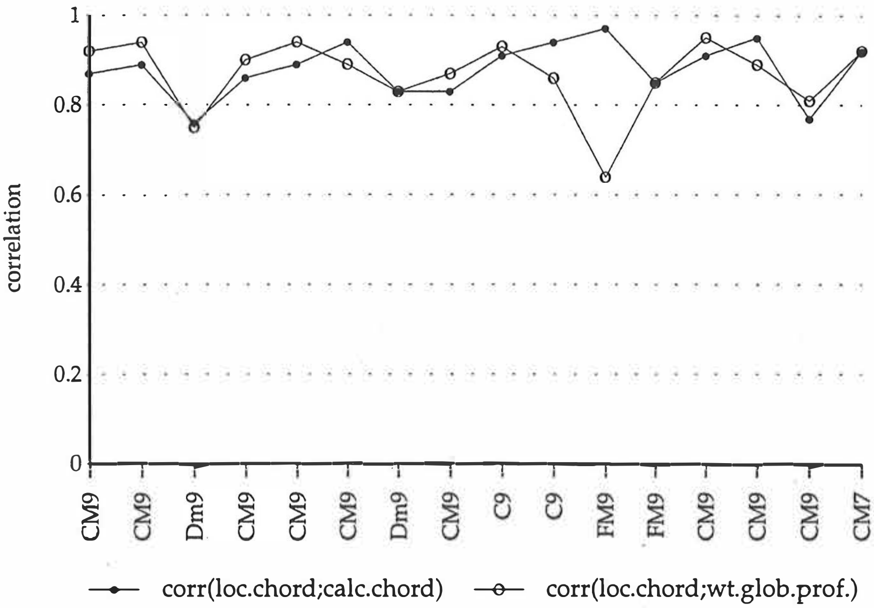

FIGURE 36. The correlations between the local tone-frequency profile and both the weighted tone-frequency profile and the calculated chord profile.

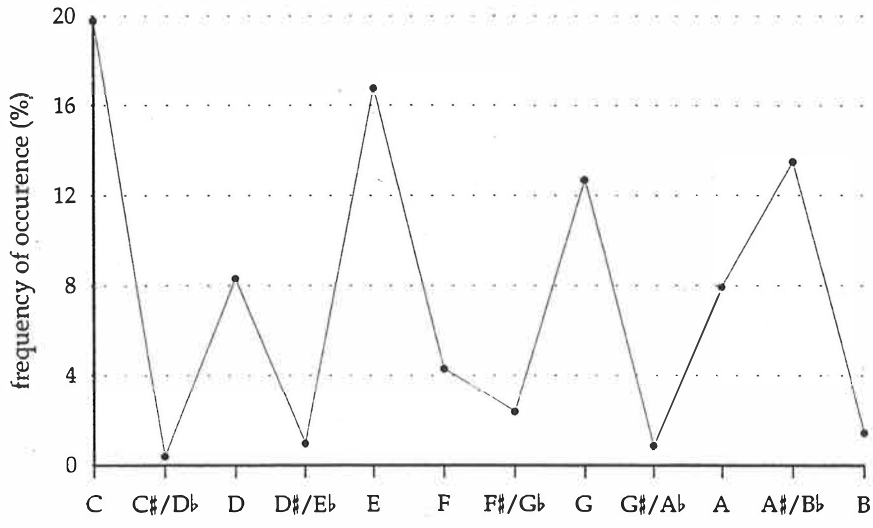

FIGURE 37. The weighted local tone-frequency profile for the first half of measure six. It yielded the highest correlation with the C9 chord.

The use of the tones E and G – the seventh and the ninth, respectively – is interesting in the F major chord profile. The correlation suggests that the FM9 chord is closer to the local profile than the plain FM7 chord, but the profile in Figure 38 shows that the musicians have used the seventh (E) very little. Therefore it seems plausible that the relatively high frequency of the ninth is due to its important melodic function as the upper neighbor tone for the root of the F major chord rather than its use as a chord tone. This raises some doubt about whether or not it is appropriate to use the constructed progression in Figure 36 rather than the basic progression in Figure 35 as an indicator of the tonal changes in the A-section. However, as was noted in the previous section the ways in which the musicians handle different chords are disparate. Therefore it is not an easy task to determine unambiguously where, for example, the ninth is stable part of the underlying chord and where it can be regarded as a melodic passing tone.

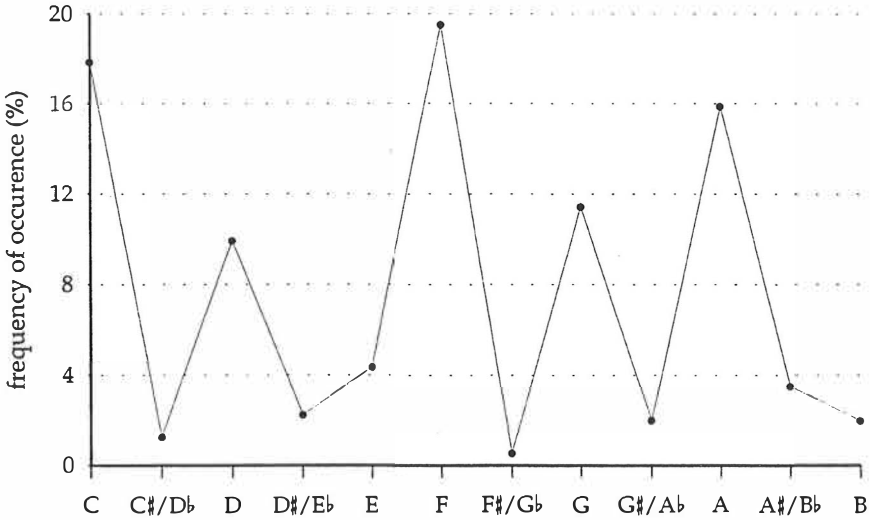

FIGURE 38. The weighted local tone-frequency profile for the first half of measure six. It yielded the highest correlation with the FM9 chord.

The D minor chord in the second measure is interesting, because the correlation for both with the calculated profile and the global profile is relatively low. This might seem to indicate that the musicians do not have a common, established way of playing on these chords. This would mean that the profiles would have to be quite diffused, because the preference for the tones varies among improvisations. The D minor chord tone-frequency profile, however, does not support this, for the tone-frequency profile for that chord indicates that the musicians have used the root and the third as well as the seventh and the ninth extensively (see Fig. 39). The other tones – most notably the fifth (A) – are used considerably less often.

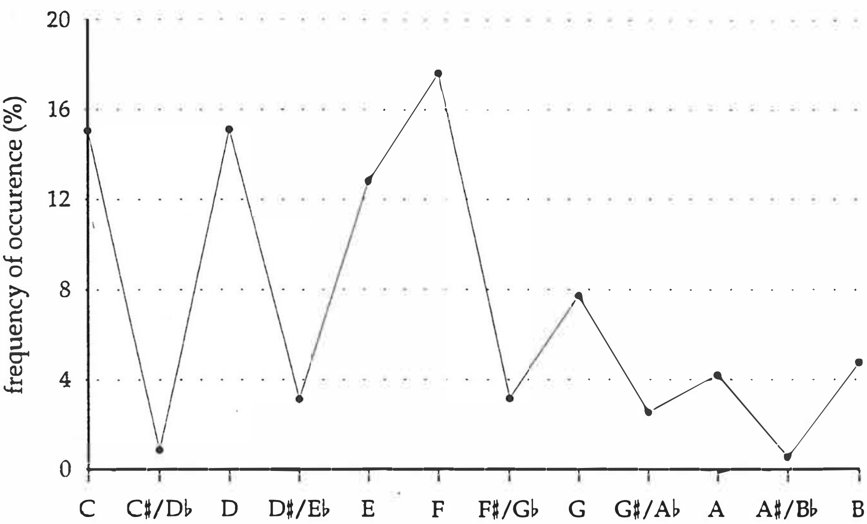

FIGURE 39. The weighted local tone-frequency profile for the D minor chord in measure two.

In order to investigate further how diffused the local profiles are, standard deviation values were obtained for each profile (see Fig. 40). The result indicate that the profiles for the C major (first and seventh measure), F major chord (sixth measure), and C dominant chord are relatively sharp focus compared to the other local profiles. In other words, the musicians have clearly favored some tones over the others. Moreover, the standard deviation values further confirm the results on metrical levels that were presented in section 4.1.

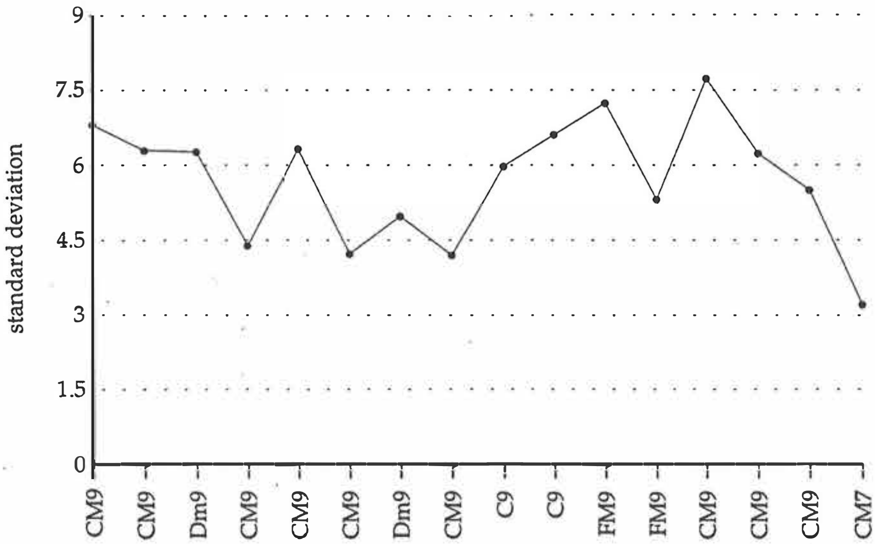

FIGURE 40. Standard deviations for the weighted average A-section tone-frequency profile.

The standard deviation is higher for the profiles in the first half of the measure and lower in the second half of each measure. Thus, a pattern emerges which is similar to the one that can be found in the metrical structure, namely the alternation of strong (even) and weak (odd) parts of the measure/beat. The most prominent exception of this pattern is in the fifth measure where the C9 chord gets a relatively high standard deviation. This result is, however, well in accordance with the earlier findings. For the C9 chord has an important function in the chord progression as the secondary dominant for the F major chord.

In the case of the D minor chord in the second measure it seems that there is, in fact, relatively little disagreement among the musicians about the tone choices. This may be a another case where simple correlation by itself gives results that are somewhat misleading or at least uninformative. Namely, although the correlation is relatively low, the standard deviation and the inspection of the profile itself reveal that some of the important chord tones are clearly emphasized. It is not entirely clear, however, whether the source of those tones is the underlying chord or the global tonality, but the frequent use of the tones D and F and the lack of tone G suggest that the underlying chord is evidently an important source for the improvisation. It is hard to determine why this chord is treated this way, but one possibility is that the musicians may deliberately restrict their playing to just a few important tones in the beginning of one or all of the section. However, the data that was used in the above analysis was constructed by averaging the all A-sections, and for this reason it does not tell much about the possible differences between the sections. Therefore in the following the individual A-sections will be investigated briefly.

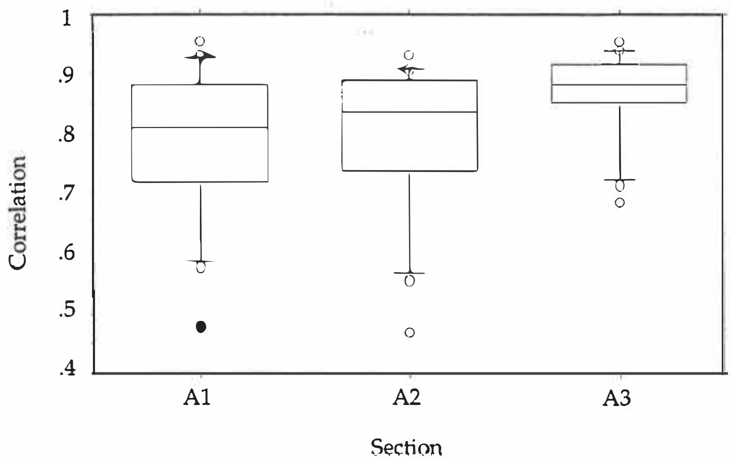

FIGURE 41. Frequency distributions of the correlations between each of the three A-sections and the weighted global average profile. See text and Appendix 3 for further details.

Each tone-frequency profile in the three A-sections (A1, A2, and A3) was correlated with the weighted global tone-frequency profile. The results are shown in Figure 41 with so-called box-plot charts, which indicate the frequency distribution of the correlations. 50% of the values are within the box – the horizontal line inside the box denotes the median. On top and bottom of the box there is a vertical line which indicate where 80% of the values are located (see Appendix 3 for further explanation). The circles identify the values which lie outside this range.

In general it seems that there is some variability on how the musicians approach the A-sections. Both in the first and second A-section the total range of the correlations is quite wide. The medians of these sections suggest that the correlations are generally lower in the first A-section, but the difference is small. Furthermore it should be noted that there are more high correlations in the first A-section. The last A-section, however, seems to be close to the global tonality through-out the chorus, for the range of the values is quite small. The box-plot charts show that the improvisers may have stretched the local tonalities of the progression in the first two A-sections, whereas in the third A-section they return back to more tonal material. This seems to suggest a build-up of tension in the first A-sections and release or closure in the third A-section, which follows the tonally unstable B-section. It should be noted that in section 4.2.1 (see, e.g, Figure 27) it was found that the average tone-frequency profiles were quite similar in each section. This suggests that there is a stable sense of global tonality upon which the musicians improvise: locally this tonality may be stretched, but even on the level of an eight measures long section, organization of the tones remains remarkably similar.

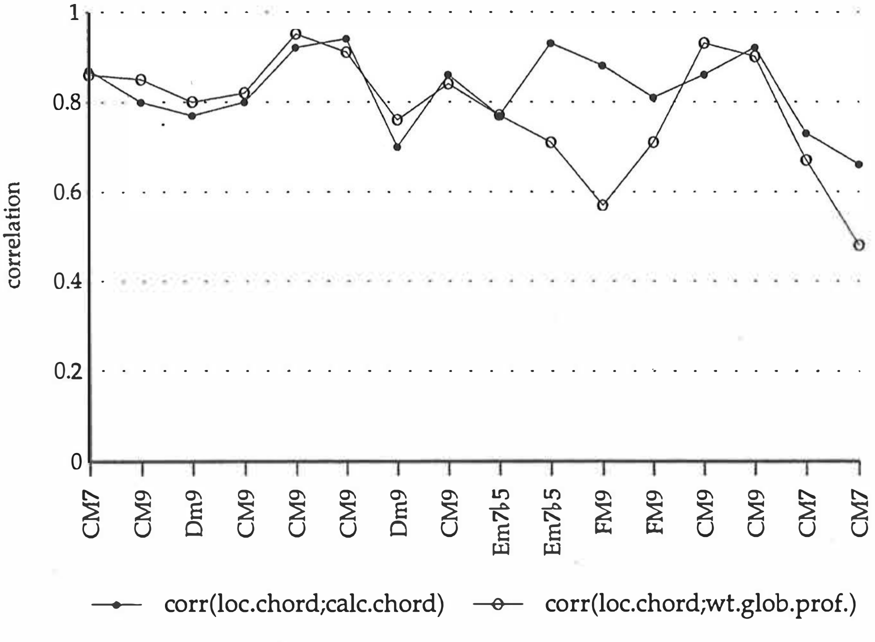

FIGURE 42. The correlations between the local tone-frequency profile (loc.chord) in the first A-section (A1) and both the weighted tone-frequency profile (wt.glob.prof) and the calculated chord profile (calc.chord).

Figure 42 shows the development of tonality in the first A-section (A1). The correlations with the global tonality and calculated chord profiles both give similar results, but the preference for the CM9 chord shows that the important tones of the underlying tonality are favored. The only discrepancy between the correlations occurs in the fifth and sixth measures, where the correlation with global tonality drops at the same time as the correlation with the calculated chord profile shows emphasis on the C dominant and F major chords. Interestingly, the C9 chord has higher correlation than the FM9 chord. This is, however, well in accordance with the earlier proposal that the F major chord is a focal point in the progression, for the emphasis on the C dominant chord only strengthens the effect of F major even though it itself is not as clearly stressed. Another unexpected result is the relatively low correlation of the first C major chord in the progression. The reason for this seems to be that the improviser have used almost only the tones of the basic triad (see Fig. 43), and therefore the correlation with either the calculated chord profile or the global profile is relatively low. Thus, the basic tonal framework is stated clearly in the first chord after which the musicians are free to explore the other tonal possibilities.

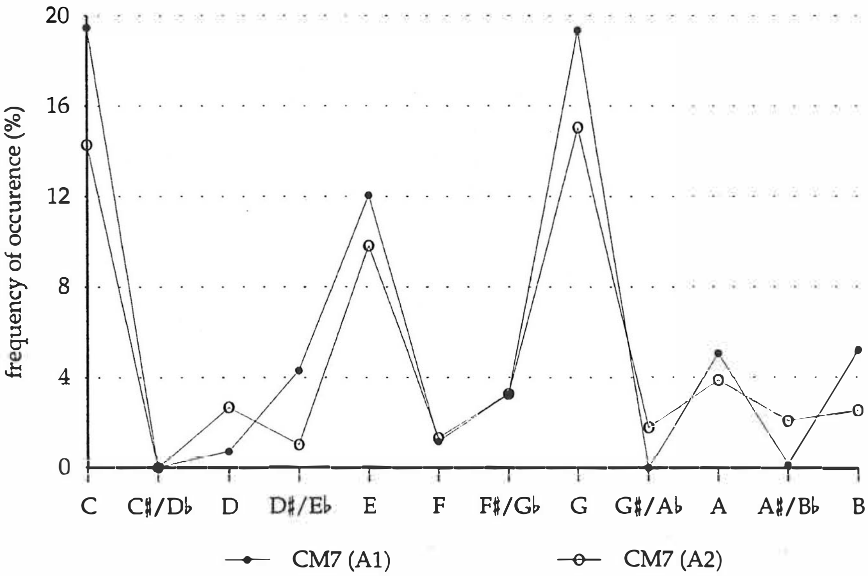

FIGURE 43. The tone-frequency profile for the C major chord in the first measure of the first and second A-section.

The distinct C major triad shape of the first profile is noteworthy, since the body materials hold improvisations of different lengths: most are one or two choruses long, but some are as much as six choruses long. Therefore it seems that in the beginning of each chorus the musicians return to the basic tonal material and reinforce the tonal reference points in the mind of the listeners and also themselves. The tone-frequency profile for the first C major chord in the second A-section displays similar emphasis on the tonic triad, but it not as clear as the standard deviations indicate: s=7.17 for the C major chord in the first A-section and s=5.21 for the same chord in the second A-section.

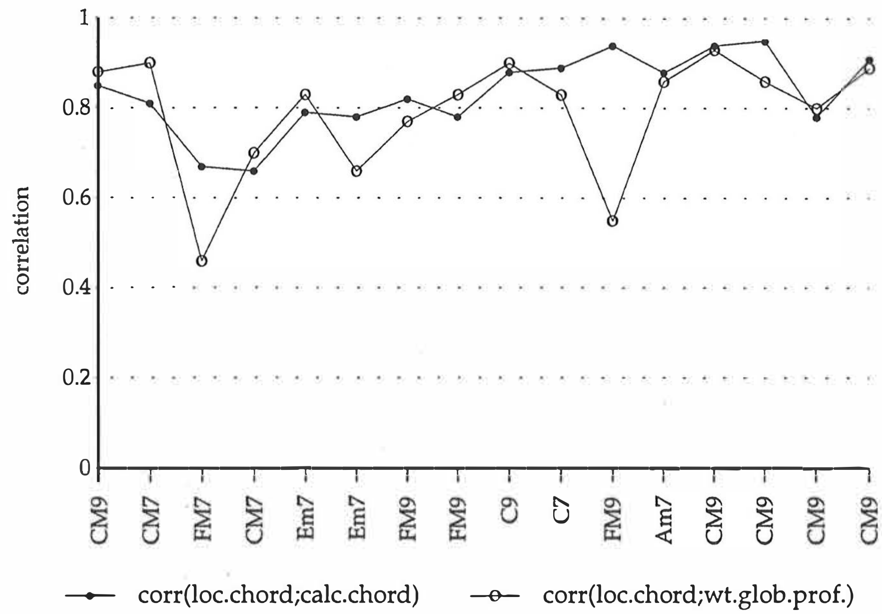

FIGURE 44. The correlations between the local tone-frequency profile (loc.chord) in the second A-section (A2) and both the calculated chord profile (calc.chord) and the weighted tone-frequency profile (wt.glob.prof).

The second A-section (see Fig. 44) displays a somewhat different pattern of emphasis. There seems to be some emphasis on the tonic chord in the first measure after which the correlation drops and slowly rise as the F major chord in the sixth measure is approached. Compared to the first A-section, particularly in the measures after the first tonic chord, the musicians seem to take some liberties by using chord substitutions or at least place emphasis on different tones. In particular, the chords FM9 and Em7 are favored. Both chords are, however, close to the C major chord, and therefore the deviation on the preference for tones is not great. Moreover, the main features of the progression remain the same as in the first A-section. Namely, the tonic and subdominant chords are emphasized.

As the box-plot chart in Figure 41 illustrated, the correlations for the third A-section are all relatively high (see Fig. 45). The correlation with the global profile seems to be the highest in most cases, but there are a few notable exceptions. Again the correlations indicate that the improvisers have emphasized the subdominant chord in the sixth measure at the same time as the correlations with global tonality is relatively low. Something similar, although not as obvious, occurs in the third and fourth measures: the correlation with the global profile drops, but the correlations with the calculated chord profiles remain relatively high.

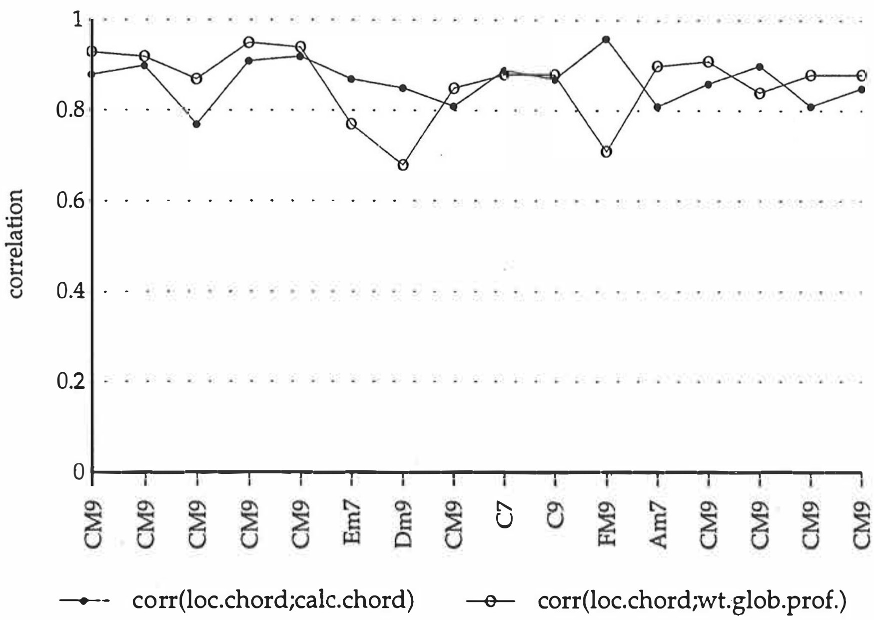

FIGURE 45. The correlations between the local tone-frequency profile (loc.chord) in the third A-section (A3) and both the weighted tone-frequency profile (wt.glob.prof) and the calculated chord profile (calc.chord).

Figure 46 presents tone-frequency profiles for the chords in question, namely Em7 and Dm9. A closer look at the profile in the latter part of the third measure (Em7) reveals that the root, E, and the third, G, of the E minor chord are emphasized, but still the profile appears somewhat ambiguous. For there seem to be some chromatic alterations which suggest other interpretations as well. In particular, the use of B♭, C♯, and E♭ is interesting, because they seem to imply the use of A dominant seventh chord with chromatically altered fifth, and ninth. In fact, the C♯°7 chord, which is the same as A7♭9 without the root, has the correlation of 0.376 with tone-frequency profile. This is, however, only one possibility, for the profile suggests also other alternatives (e.g, A9), but in general they all seem to prepare the next chord, D minor. The tone-frequency profile in the first half of the fourth measure seems to indicate relatively clear stress on the D minor chord. The use of the tones C and in particular, G, suggest the presence of the global tonality, but E♭, F♯ and the clear emphasis on the root, D, make it less prominent than in many of the other profiles.

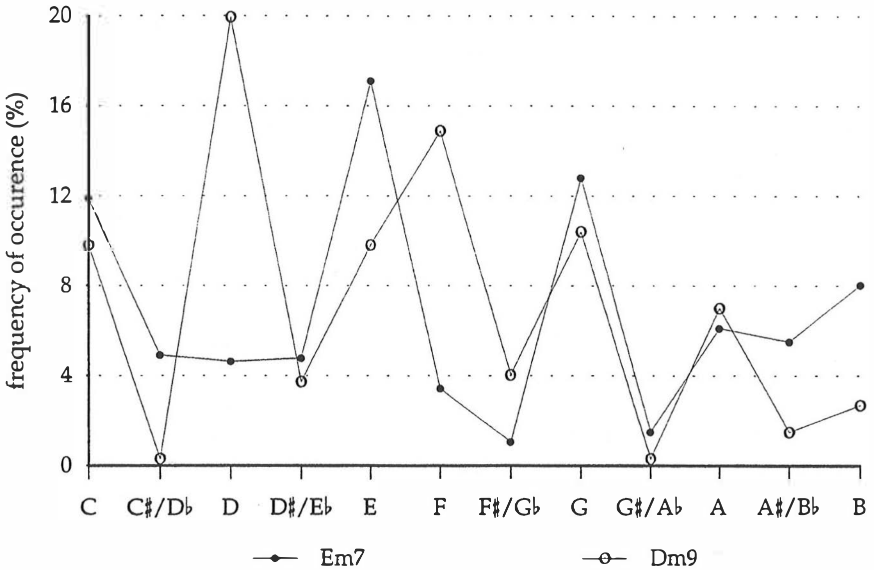

FIGURE 46. The tone-frequency profile for the Em7 in the second half of the third measure and Dm9 in the first half of the fourth measure.

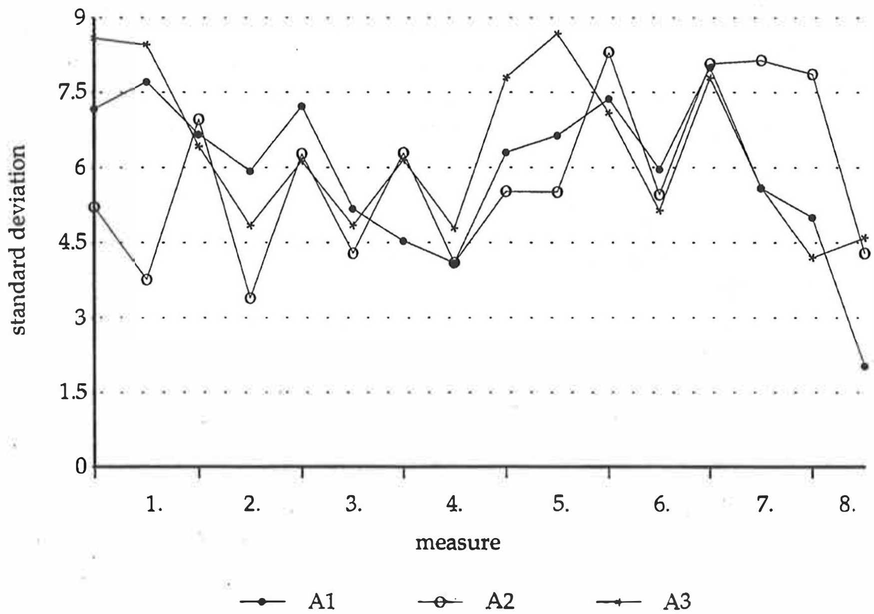

FIGURE 47. Standard deviations for the three A-sections.

The standard deviations for the individual sections also show some incongruity (see Fig. 47), but the general pattern appears to be similar to one suggested by the average results. First of all, the highest standard deviations seem to be in the beginning of the sections and in the fifth and sixth measures: between these two focal points the standard deviations are consistently lower. Secondly, the chords on the first half of each measure are outlined more carefully (ie., tone-frequency profile have relatively sharp focus) than the chords on the latter half of the measure.

In summary, there are some differences among the individual A-sections, but they all seem to retain the same general characteristic. The global tonality is prominent almost through all A-sections. The role of the underlying chord is strong particularly in the beginning and in the end of each section (tonic or C major) and in the fifth and sixth measures (subdominant F major and its secondary dominant C dominant). Still, some of the other underlying chords also seem to be taken into account, in particular when they are analyzed as ninth chords. This is not, however, entirely unproblematic, for in most cases, the ninth was likely to be a melodic passing tone rather than a stable element in the underlying chord. The tone-frequency profiles also indicated that the strong metrical positions were used to emphasize the important tones of the local or global tonality. Similar strong vs. weak -tendency was found for the chords, as well: the musicians seemed have to have focused on some tones in the chords in the first half of the measure whereas in the second half of each measure the tone-frequency profiles displayed a more diffused pattern of preference.

4.2.4 Time-weighted tone-frequency profiles

The preceding discussion on the global and local tone-frequency profiles does not take into account the possible affect of time on the development of tonality: the global and individual local or chord profiles represent a totally atemporal view of the music. One can, however, look at the individual local profiles in succession and see how the musicians' preference for the tones varies as a function of underlying chord. Still, this type of analysis does not address the question of the effect of time itself. Therefore in this part of this study it is investigated how the tone-frequency profiles in the A-section would change if there were a memory for the previous tones. Only the A-section will be investigated at this time, because it is uncertain how a new section would affect the memory for the past events. It would seem unlikely that when the progression moves from the second A-section to the following B-section, the memory would be unaffected, for the distinctly different tonal implications, possible rhythmic or dynamic variations etc. may have some masking effect on memory. Therefore since effects cannot be determined, only the A-section will be investigated in the following. As in earlier parts of this study, the effect of meter was also taken into account.

The time-weighted tone-frequency profile ($\overline{w}(t)$)for each eight-note is obtained by adding its previous *(t-1)* value, multiplied by a decay factor *k*, to the tone-frequency profile on time point *t*. This is shown in vector notation in (2).

$$\overline{w}(t) = \begin{cases} \overline{p}(t) & ,t = 0 \\ \overline{p}(t) + k\overline{w}(t-1), & t > 0 \end{cases} \qquad (2)$$

The continuous stream of eighth-notes in a fast tempo puts a heavy strain on the memory. Therefore the length of the memory cannot be very long: even the typical estimates of the capacity and duration of the short-term memory seem problematic (e.g, Dowling & Harwood 1986, 139-140; Norman 1976, 83-102). The average tempo in the body of materials is approximately 256 beats per minute. Thus, on the average one measure lasts a little less than a second. This corresponds to the upper limits of the echoic or sensory memory (cf., Huron & Parncutt 1993, 165-166) or so-called psychologically present which extends to several seconds (cf., Dowling & Harwood 1986, 179-181). Consequently, the decay factor was chosen so that the contribution of each local profile to the time-weighted profile halves within one measure. The decay factor can be calculated from the half-life formula[25] in (3).

$$k^n = \frac{1}{2} \tag{3}$$

where n is the number of time-points (ie. eighth-notes) within one half life. If n=8 (there are eight eighth-notes in one measure), the decay factor (k) is 0.917.

Figure 48 shows the correlation between the time-weighted tone-frequency profile and the global tone-frequency profile. The graph indicates that if the effect of memory is taken into account, the influence of the global tonality is even greater than in the previous results. Still, even in this data there is a clear decrease of correlation in the sixth measure. Also, the correlations in the first measure are noticeably lower than the rest of the correlations, but this is attributable to the way the profiles are constructed. For it takes a few eighth-notes before the effect of meter can be seen.

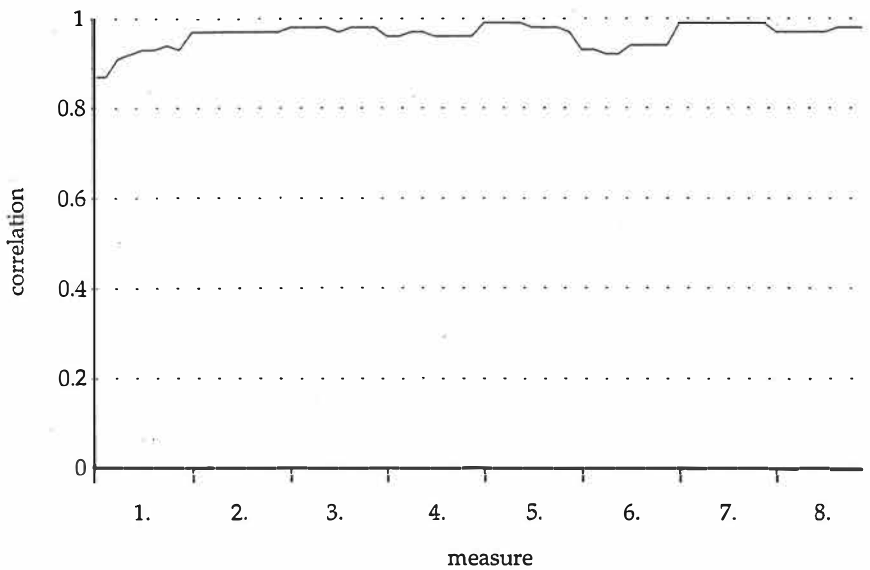

FIGURE 48. The correlations between the local time-weighted profiles and global tone-frequency profile in the A-section. The measures are shown on the x-axis and the correlation on y-axis.

[25] Huron & Parncutt (1993) used a similar formulation of memory in a study where the affect of memory on the perception of tonality was investigated.

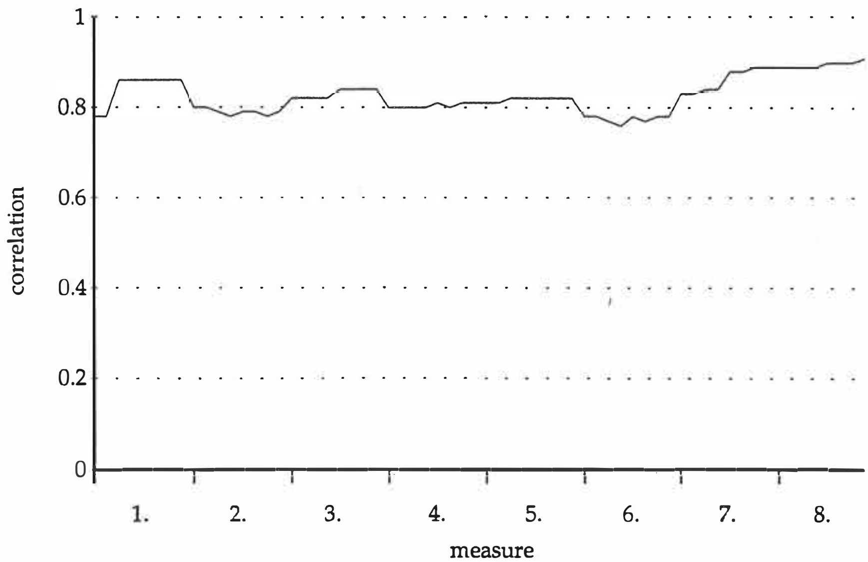

FIGURE 49. The correlations between the local time-weighted profiles and calculated CM7 tone-frequency profile in the A-section. The measures are shown on the x-axis and the correlation on y-axis.

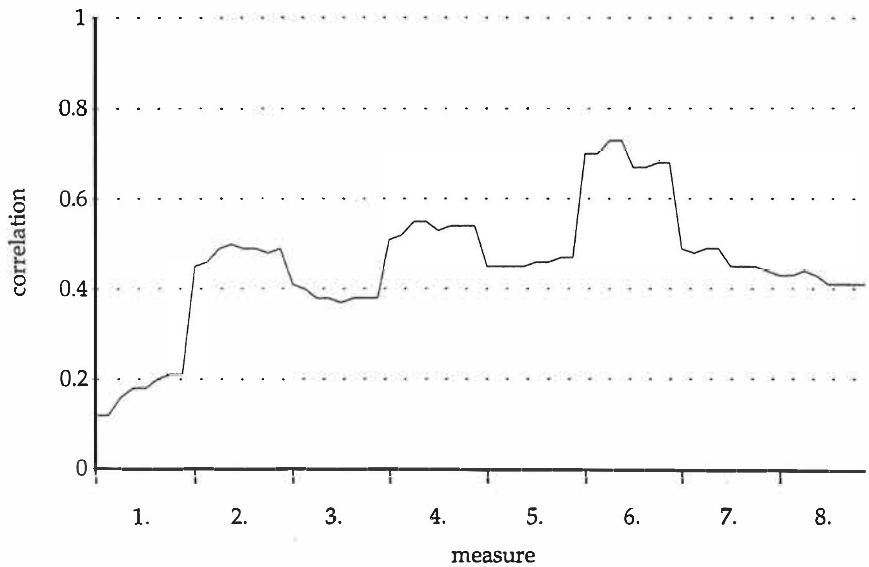

FIGURE 50. The correlations between the local time-weighted profiles and calculated FM7 tone-frequency profile in the A-section.

The correlations between the local time-weighted profiles and the calculated CM7 profile are depicted in Figure 49. The correlations for the CM7 chord are also high, and it appears that it is prominent particularly in the beginning and in the end of the section. It is also noteworthy that also the correlation for the CM7 chord drops in the sixth measure where the underlying chord is FM7. The time-weighted tone-frequency profile for FM7 chord is displayed in Figure 50. There is a peak in the sixth measure: it seems that the prominence of this chord increases as the sixth measure becomes nearer in the chord progression and decreases markedly in the following measure. The two other peaks are in the second and fourth measures where the underlying chord is Dm7, which is closely related to the FM7 chord.

These results seem to further indicate that tonality is not a static concept. Rather it seems to change and evolve as the music progresses. In addition to this, however, it seems that at least in this type of music there can also be found a relatively atemporal aspect of tonality. It appears to serve as a general reference point that ties everything together, and thus it may be essential in the cognitive processes involved both in playing and listening.

4.3 B-section of the Rhythm Changes Chord Progression

This part of this dissertation deals with the B-section of the Rhythm Changes chord progression. Unlike the A-section, which was investigated in the previous sections, it is not based on a single tonal center. Rather it is a cycle of fifths progression on dominant seventh chords. It was concluded in the section on local tone-frequency profiles that the notion that triads and seventh chords are favored over the more extended chords (9, (♯)11, 13) received neither unequivocal proof or disproof. The results were somewhat ambiguous, because the global tonal orientation of the progression seemed to affect the local hierarchies of individual chords. Furthermore it also seemed that the use of some tones as frequent melodic passing tones caused those tones to have more emphasis in the tone-frequency profile than its probable perceptual importance would merit. If it is found that the musicians do not retain in the B-section some of the characteristics of the tonality of the A-section (C major), the B-section would seem to be an ideal subject for the study of individual chords. Furthermore, the B-section is interesting from a more general point of view as well. In the A-section the musicians seemed to use the global tonality as a reference point which helped them to maintain coherence in their improvisation. If no single tonal center can be found for the B-section, the musicians must, then, have some other guiding principles or reference points.

The objective was to determine the global tone-frequency profile as well as the local tone-frequency profiles of each measure by examining the statistical distribution of the tones in the chromatic scale. In particular, two goals were set: 1) to find how many tones can be considered as stable chord tones in dominant seventh chords; 2) to determine if there are any principles that the musicians seem to use in order to maintain coherence in spite of the lack of a common tonal center.

4.3.1 Global tone-frequency profiles

The statistical distribution of the tones in the chromatic scale within the C major context was investigated by examining 41 B-sections of the Rhythm

Changes chord progression. Figure 51 presents the global tone-frequency profile for the whole B-section. The profile was constructed by averaging the profiles obtained from each metrical level. The frequencies of the tones are shown in percentages.

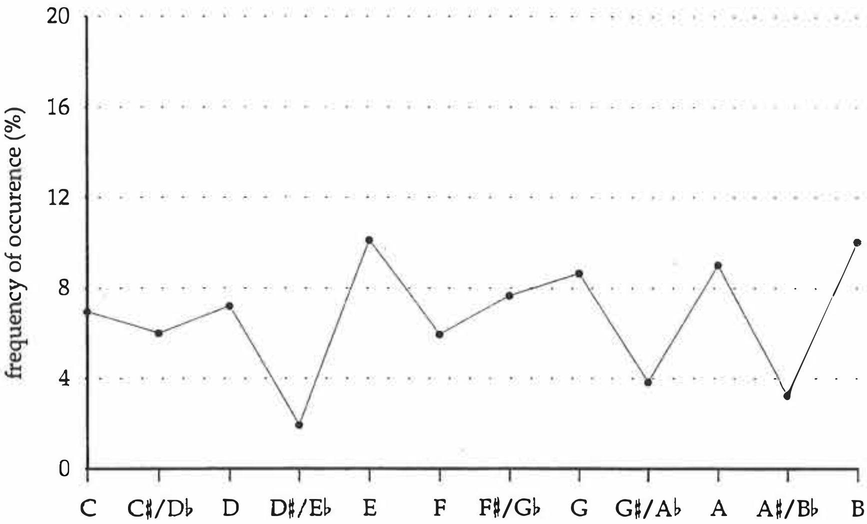

FIGURE 51. Weighted average global tone-frequency profile from the B-section of the Rhythm Changes chord progression.

Although some slight divergencies between the frequencies of tones are evident, no tonal center seems to emerge. The distribution of the tones is quite even, for the standard deviation s=2.648 is much lower than any of the standard deviations acquired from the A-section: for example, the standard deviation for the weighted tone-frequency profile obtained from the A-sections is 4.936. It is more likely that the profile reflects the combined preferences for the tones in individual chords rather than some global tonal orientation – Figure 52 illustrates these relationships.

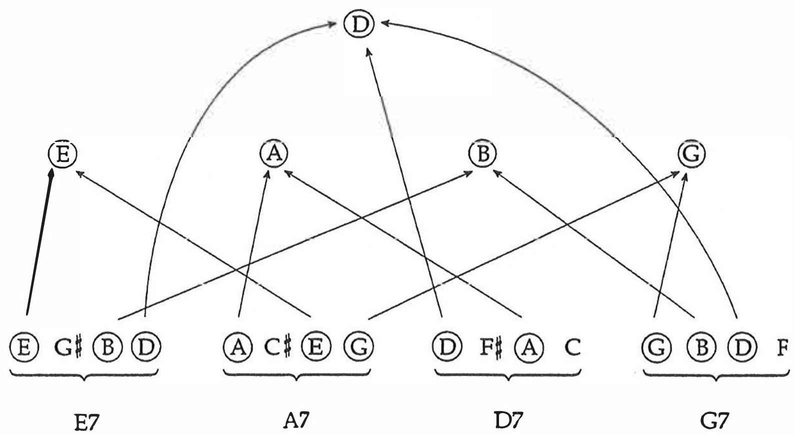

FIGURE 52. The chord and the respective chord tones of the B-section of the Rhythm Changes chord progression.

Only two tones in the chromatic scale, namely E♭ and B♭, are not part of any chord found in the progression, and as Figure 52 illustrates, these two tones are the ones that are used the least. On the other hand, E, G, A, and B, which are the most used tones, are each part of two different seventh chords. Further, the tones that belong to only one chord (C, C♯, F, F♯, G♯) are used moderately compared to the extremes. The relatively low frequency of the tone D is somewhat unexpected, because it is part of three different chords in the progression: E7 (seventh), D7 (root), and G7 (fifth). Also the relatively high frequency of the tone E is somewhat surprising, but this can be explained at least partly by its important role in the first two chords, namely E7 (root) and A7 (fifth); moreover, it may have been used as an upper extension tone for the D7 (ninth) and the G7 (thirteenth) chords. This global profile, however, does not by itself give sufficient information on this matter.

On the basis of the presented tone-frequency profiles it seems plausible to infer that in the B-section the use of tones is governed by the underlying chord rather than by some global tonal center. To confirm this the B-section tone-frequency profile was compared with twelve major key profiles, which were acquired by transposing the profile obtained from the A-section to all major keys in the chromatic scale.

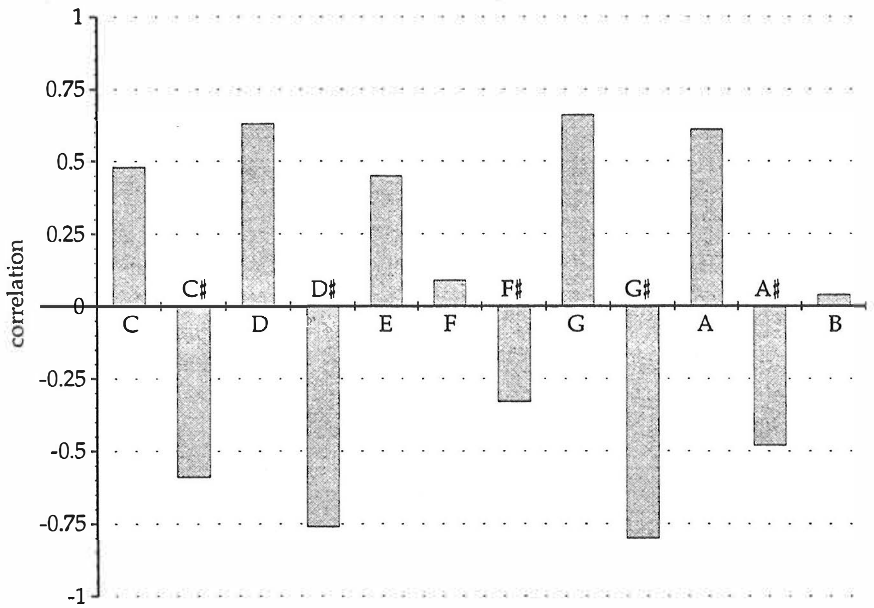

FIGURE 53. Correlations between the global B-section tone-frequency profiles and the global A-section tone-frequency profile, which has been transposed to all keys.

The correlations in Figure 53 are only moderately high, and no single key seem to emerge as the most similar. Instead, the results appear to suggest that the global profile obtained from the B-section is somewhat related to several keys (at least A, D, and G). One reason for this is undoubtedly that the chords in this progression are not distant, rather the keys that they belong to are tonally closely related. Thus, the global tone-frequency profile seems to be moderately similar to many keys and at the same time none in particular. This seems to further support the conclusion that there is no single tonal center in the B-section.

4.3.2 Local tone-frequency profiles

The statistical distribution of the tones was also investigated in each of the eight measures in the B-section. The profiles were constructed by averaging the profiles obtained from each metrical level. The frequencies of tones are shown in percentages.

Figure 54 illustrates the weighted average statistical distribution of the tones in the first and second measure. Both measures seem to display comparable tendencies, but in spite of these apparent similarities, the measures have some distinctive qualities. The tone-frequency profile obtained from the first measure shows there is emphasis on the tones of the Bm9 which is the closest substitute for E dominant chord: specifically, the use of the tones B, F♯, and to some extent C♯ and A ought to be noted. However, since A is used less frequently than the third of the E7 chord, G♯, there also seems to be emphasis on the E7 chord. The correlations with calculated chord profiles show that the similarity with the E7 chord is relatively low (r=0.503), but the E9 chord yields much higher correlation. The highest correlations, however, were obtained for Bm9 (r=0.751) and G♯m7♭5 (r=0.787) which is the same as the E9 chord without the root.

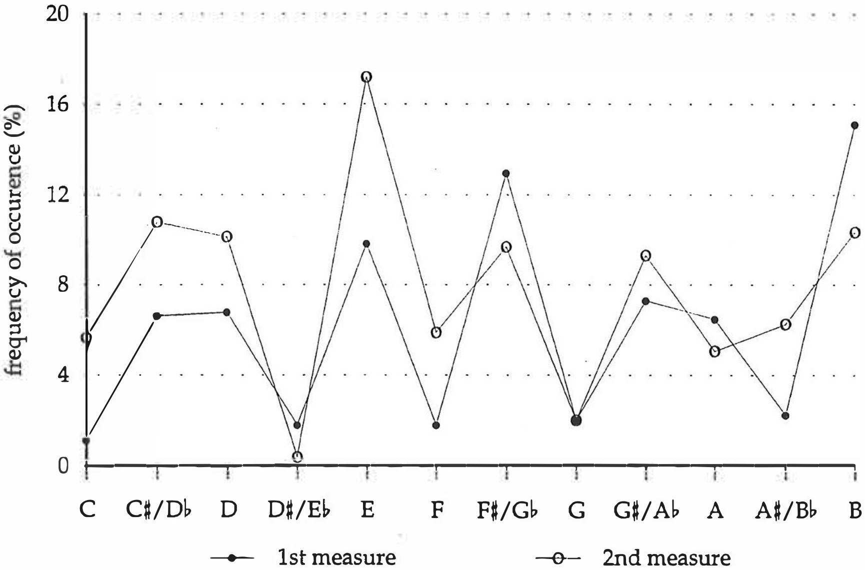

FIGURE 54. E7 weighted average tone-frequency profiles. First and second measure.

The second measure of the B-section seems to be more clearly based on the E7 (r=0.769) or E9 (r= 0.849) chord. As the profile in Figure 54 shows, however, there is much more chromatism than in the first measure. Compared to the first measure, the ninth, F♯, is used less whereas the lowered ninth, F, is given much more emphasis. Also the raised eleventh (or lowered fifth), B♭, the raised fifth (or lowered thirteenth), C, and the thirteenth C♯ have been emphasized in the second measure. The use of the lowered ninth and the thirteenth along with the chord tones (E, G♯, B, and D) especially seems to suggest that the musicians have used the diminished scale (E, F, G, G♯, B♭, B, C♯, and D). This is also manifested in the moderate correlation with the G♯°7 ($r=0.416$); the correlation between the G♯°7 chord and the tone-frequency profile in the first measure is 0.097.

In the third and fourth measures of the B-section of the Rhythm Changes the original chord is A7. As Figure 55 clearly illustrates musicians have preferred the tones of the A7 chord in the third measure: especially the root, A, the third, C♯, and the seventh, G, are emphasized, but also the relatively frequent use of the ninth, B, should also be noted. The correlation with the A9 chord is 0.860. Overall the use of tones is fairly conservative with little emphasis on the non-diatonic tones.

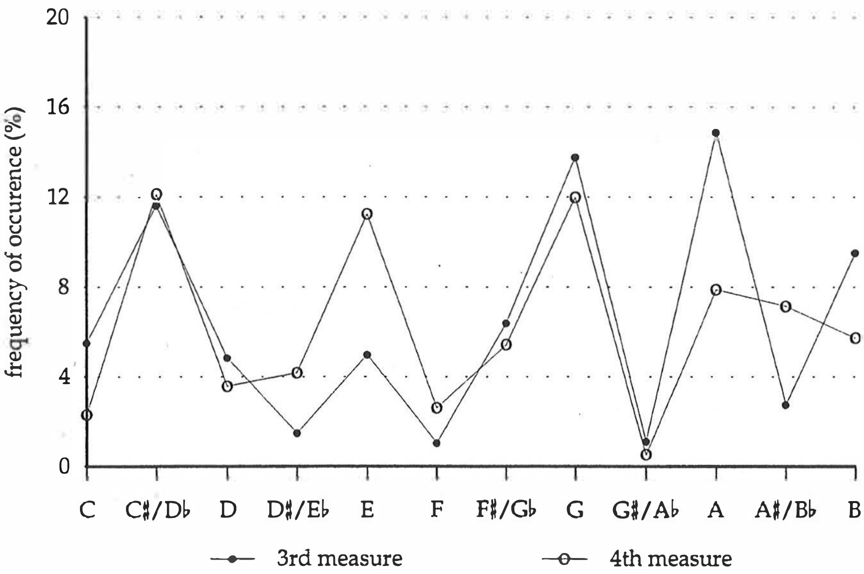

FIGURE 55. A7 weighted average tone-frequency profiles. Third and fourth measure.

On the basis of the obtained tone-profile, A7 seems to be also the underlying chord in the fourth measure. Although the root, A, is used considerably less often, the third, C♯, the fifth, E, and the seventh, G, are the three most used tones. The highest correlation was obtained with the C♯m7♭5 chord ($r=0.769$). As the Figure 55 shows musicians have adopted a much more chromatic approach than in the previous measure. The relatively high frequency of the lowered ninth, B♭, seem to suggest again the use of the diminished scale: correlation with the C♯°7 chord is 0.598.

Figure 56 shows the tone-frequency profiles for the fifth and sixth measures. The original chord is D7. In the fifth measure the tones, C, E, F♯, and A are used quite frequently, and it seems that the musicians have emphasized both the original chord, D7, and its most common substitution Am7. Still, it seems that D7 is more strongly stressed, because F♯ is used so frequently. Moreover, the relatively infrequent use of the tone G, which is the seventh in Am7 chord, is in accordance with this explanation, since it is not a stable tone in D7 context. This explanation is supported by the comparison with the calculated chord profiles, for the F♯m7♭5 chord yields the highest correlation with the tone-frequency profile (r=0.825); the correlation with the Am7 chord is 0.588.

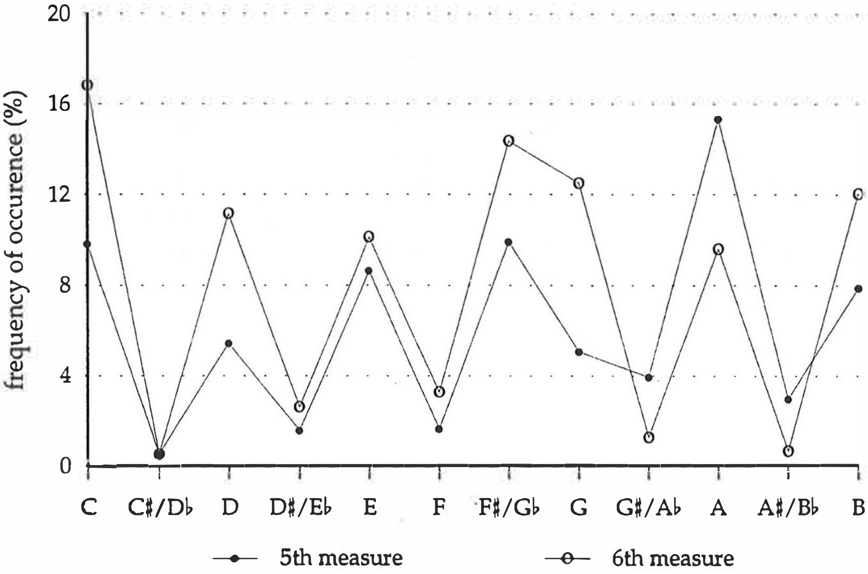

FIGURE 56. D7 weighted average tone-frequency profiles. Fifth and sixth measure.

The distribution of the tones in the sixth measure displays a much clearer emphasis on D7, because especially the third, F♯, and the seventh, C, are used quite frequently; also the root, D, along with the ninth, E, are preferred. The musicians do not seem to use the appropriate diminished scale as in the two previous even measures (two and four), for the characteristic tones of that scale are not emphasized. The correlation with the F♯°7 chord is also lower (r=0.252) than in the other even measures. The correlation with the calculated D7 chord is 0.571, but the Am7 and D9 chords give higher values (r=0.700 and r= 0.696, respectively). the most surprising result is that the highest correlation was obtained with the Em9 chord (r=0.774). Also, the correlation with the global profile is unexpectedly high (r=0.652) which suggests that musicians may start to anticipate the coming A-section already in this point of the progression. There is, however, so much emphasis on the underlying chords (the tone F♯) that the possible presence of the global tonality is not clear.

The chord for the final two measures of the B-section of the Rhythm Changes is G7 (see Fig. 57). The tone-frequency profile for the seventh measure shows a clear emphasis on the tones of the G7 chord. The root, G, the third, B, the fifth, A, and the seventh, F, are used quite frequently, but also the ninth, A, and the thirteenth, E, are stressed. The comparison with the calculated chord profiles give highest correlations with Bm7♭5 (r=0.813) and G9 (r=0.800).

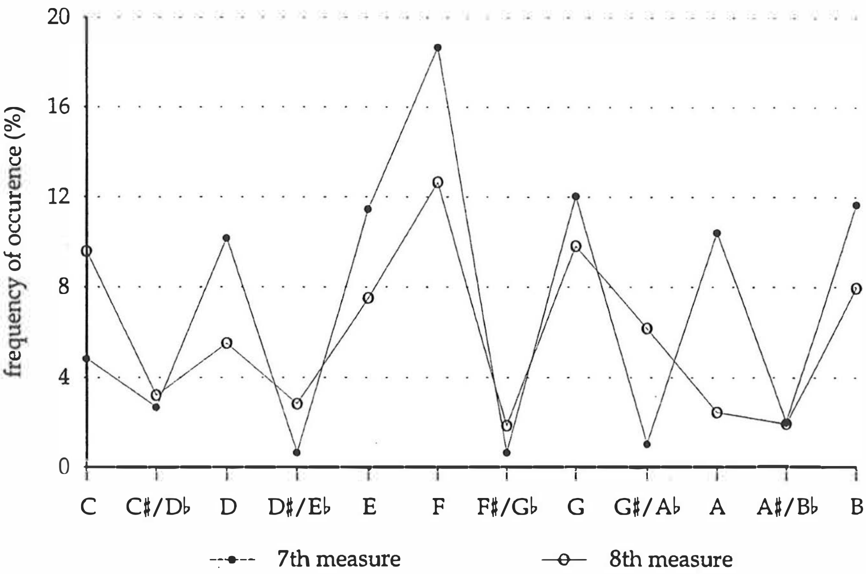

FIGURE 57. G7 weighted average tone-frequency profiles. Seventh and eighth measure.

The profile obtained from the final measure is more ambiguous. The tones G, B, and F, which are used frequently, imply the G7 chord, but the rest of the profile is not quite in accordance with this explanation. The somewhat increased frequency of the tone C and the tone E is especially surprising. The tone E is the thirteenth in reference to G7, but since the ninth is used very little it does not seem a plausible explanation. Rather it seems that the musicians may have already anticipated the tonality of the upcoming A-section by stressing the important tones of the C major tonality along with the chord tones of G7 chord. This analysis is supported by the relatively high correlation that the tone-frequency profile has with the global tonality(r=0.679) and the low correlation with the G7 chord (r=0.297). Additionally, the emphasis on the lowered ninth, A♭, should be noted, for once again there seem to be some use of the applicable diminished scale; the correlation with the G♯°7 chord is 0.370.

On the basis of the tone-frequency profiles obtained from individual measures in B-section, it seems that musicians approach some odd and even measures of this particular progression differently. In order to clarify this, two average profiles were constructed from the profiles which were first transposed to a common key: the first profile consisted of the profiles obtained from the odd measures (first, third, fifth, and seventh) and the second profiles obtained from the even measures (second, fourth, sixth, and eighth).

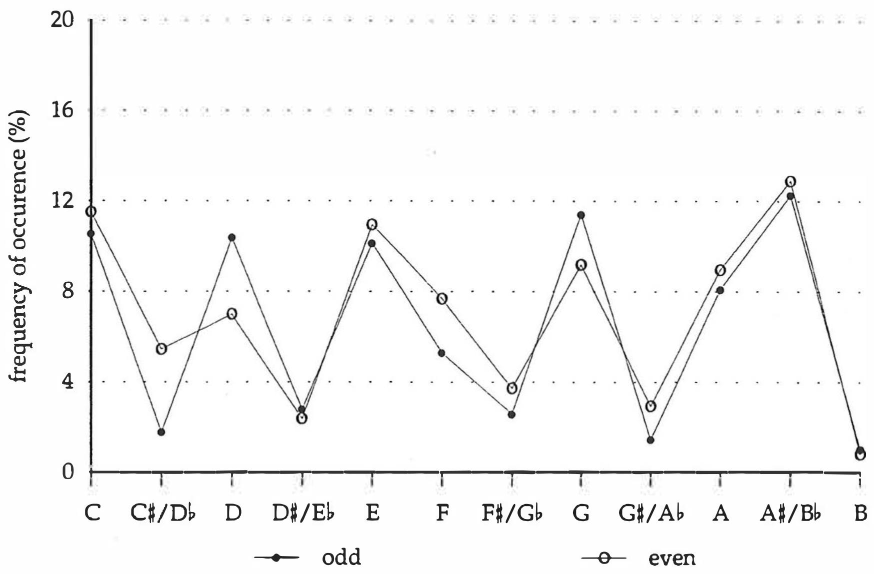

FIGURE 58. Comparison between the tone-frequency profiles obtained from odd and even measures.

Figure 58 illustrates the odd and even measure profiles. In the odd measures the use of tones is fairly diatonic: the root, third, and the lowered seventh are used the most often, but also the other diatonic tones are employed frequently. Also the profile obtained from the even measures displays a clear preference for the root, third, and the seventh of the chord. The profile for the odd measures has the highest correlation with the Em7♭5 chord (r= 0.898), but both profiles have relatively high correlation with the C9 calculated chord profile: r= 0.884 for odd measures and r= 0.780 for even measures. The profile obtained from the even measures is, however, more chromatic than the odd measure profile, for the musicians seem to have altered the ninth and the fifth chromatically. The lowered ninth especially has been used relatively frequently along with the ninth; also the lowered fifth have been used to some extent. The profile obtained from the even measures suggests that also on a more general level the preference for the tones of the diminished scale (root, ♭9, ♯9, 3, ♯11 (♭5), 5, 13, and ♭7) is evident. The correlation between the even measure profile and the C♯°7 chord is 0.448 which is higher than the correlation between the same chord and the profile obtained from the odd measures (r=0.331).

Finally, in order to investigate on a more general level the use of tones and the extent of chords, the profiles obtained from the B-section were averaged into a single tone-frequency profile. The profile shows the average tonal hierarchy that is formed on dominant seventh chords in the B-section of the Rhythm Changes.

The tone-frequency profile in Figure 59 shows clearly that the root, third, fifth, and the lowered seventh are the favored tones. Furthermore, along with the basic four note chord the ninth and thirteenth (or sixth) seem to occupy a relatively stable position. Therefore Figure 59 seems to suggest that along with the triad and the seventh chord also at least the ninth chord added with the thirteenth can be thought to be quite stable. In the comparison with the calculated chord profiles, the dominant ninth chord gave the highest correlation (r=0.856).

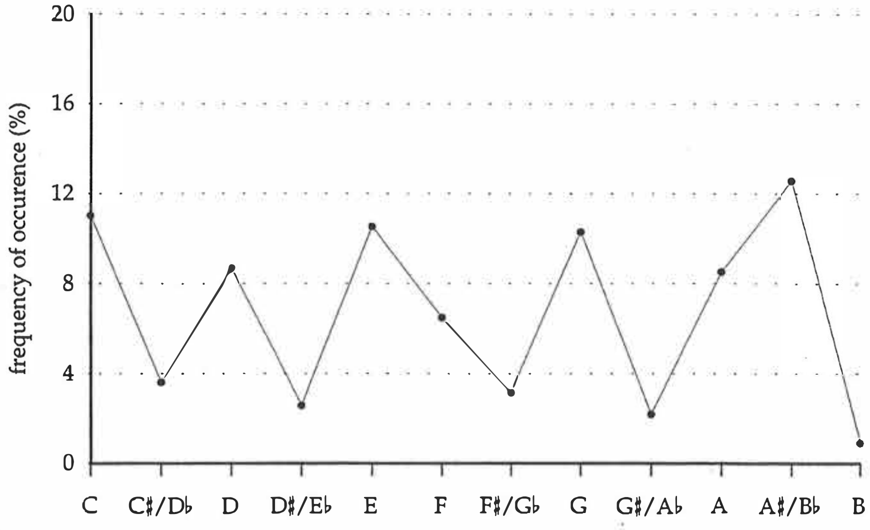

FIGURE 59. The preferred chord structure in the B-section. The data was obtained by transposing the tone-frequency profiles to a common key.

In summary, the tone-frequency profiles for the B-section indicated that unlike the A-section of the Rhythm Changes chord progression, the B-section does not have a single tonal center. Thus, the tone-frequency profiles in this cycle of fifths sequence based on dominant seventh chords displayed clearer emphasis on the chord tones. The acquired tone-frequency profiles suggest that along with the basic four note chord (root, third, fifth, and lowered seventh) also the ninth and the thirteenth seem to occupy a relatively stable position. There were, however, some interesting divergencies, for the chords in the even measures were approached somewhat differently than the ones in the odd measures. Namely, the tone-frequency profiles obtained from the odd measures were fairly diatonic with little emphasis on the non-diatonic tones. The profiles acquired from the even measures indicated much more chromatic approach with relatively much emphasis put especially on the characteristic tones of the so-called diminished scale (for example, lowered ninth): this was apparent particularly in the latter part of the even measures. Although this tension and release - pattern seemed to be the guiding principle in this section, in each measure the characteristic tones of the local tonality were always present. There appeared to be some tendency to avoid playing the root of the chord, but still most tone-frequency profiles indicated that the musicians maintained the structure of the basic progression. In each measure the most important tones of the underlying chord, namely the root, the third, and the lowered seventh were emphasized.

4.3.3 Chord progression

Development of tonality in the B-section was investigated by examining the statistical distribution of the tones in each of the eight measures to determine in particular if there are any principles that the improvisers seem to use in order to maintain coherence.

The minor seventh chord built on the second scale degree is often used as a substitute for the dominant chord of the same key. In order to investigate how these chords were used in the section of the Rhythm Changes chord progression, each tone-frequency profile was correlated both with the calculated dominant seventh chord profiles (calc.chord(V)) that correspond to the original progression and the appropriate calculated supertonic (ii) chord profiles (calc.chord(ii)). The results, which are illustrated in Figure 60, are somewhat ambiguous, for the correlations are relatively low and no clear pattern can be found. Therefore it seems that in contrast to the A-section the basic triads and seventh chords cannot be used to explain the tonal development.

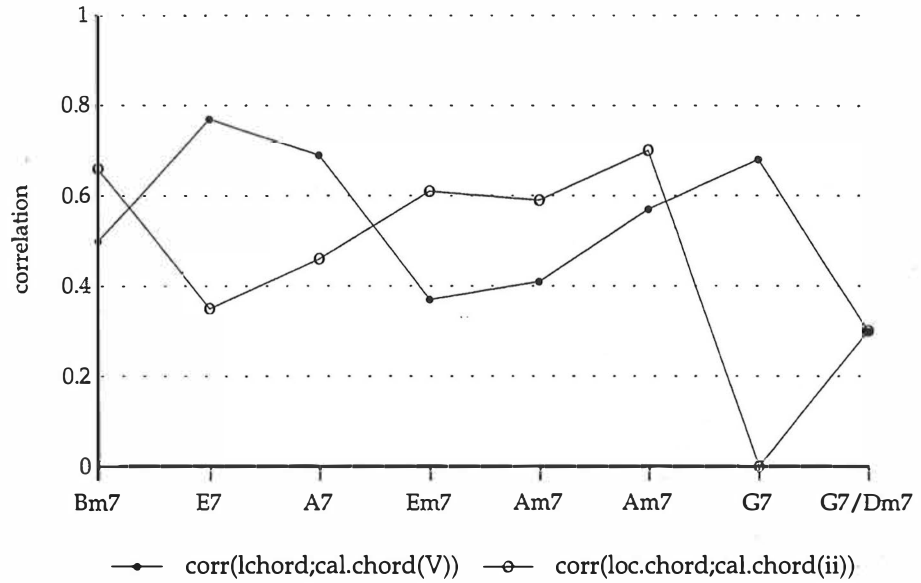

FIGURE 60. The use of the supertonic (calc.chord (ii)) and dominant (calc.chord(V)) chord in the B-section.

To investigate the development of this progression further, each of the weighted tone-frequency profiles obtained from each measure were correlated with the same set of 44 calculated chord profiles which were used in sections 4.2.2 and 4.2.3 (see also Appendix 2). Figure 61 shows the correlation of the local profile with the global A-section tone-frequency profile (ball), with the most similar chord the in the set of calculated chord profiles (diamond), and with the diminished chord one half-step above the original chords root (triangle). The chords on the x-axis display the calculated chord profile which has the highest correlation with the tone-frequency profile in that measure. As was already concluded in the previous section, Figure 61 illustrates that musicians seem to favor chords that extend beyond the basic triad and seventh chord. It also clarifies some of the remark made on the individual profiles. First of all, although the correlation for the diminished seventh chords is never the highest in the set, the graph indicates that it is an important element in first half of the progression.

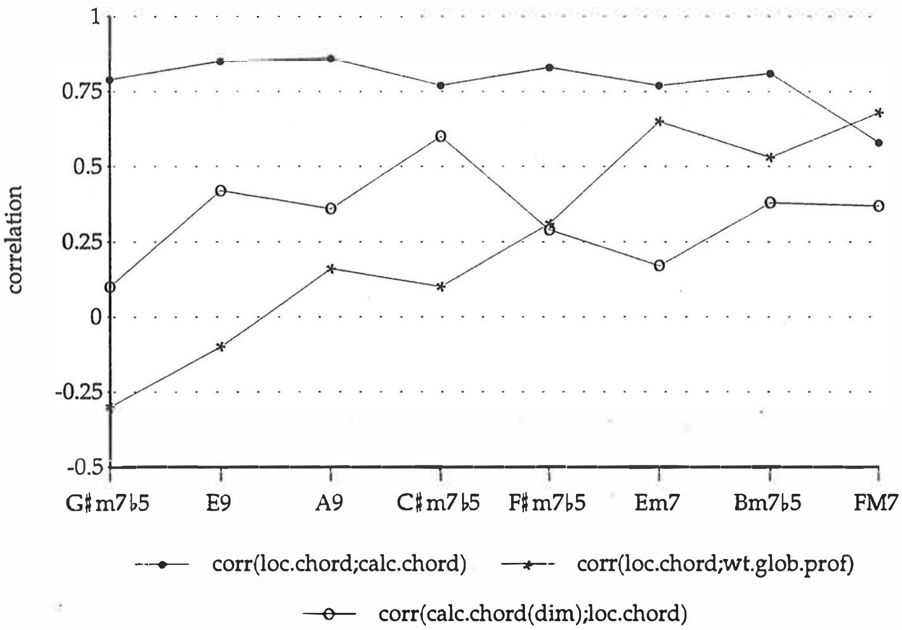

FIGURE 61. The development of tonality in the B-section of the Rhythm Changes chord progression – measure level version. The ball is the correlation between the local tone-frequency profile (loc.chord) and the global A-section tone-frequency profile (wt.glob.prof), the diamond denotes the highest correlation found in the set of calculated chord profiles (calc.chord) for that particular local profile, and the triangle represents the correlation between the local profile the diminished chord (calc.chord (dim.)) one half-step above the original chords root.

Secondly, the relationship of the global A-section profile and the local profiles of the B-section is interesting. The negative correlations in the beginning of the section are surprising. It may imply that the musicians want to emphasize the beginning of this new section by avoiding the tonality of the previous section. Thirdly, as was noted earlier, the relatively high correlation between the global A-section profile and the local tone-frequency profile in the sixth measure seems to suggest that the musicians may start to anticipate the tonality of the following A-section. This seems to be a reasonable assumption, for the original underlying chord is D dominant is secondary dominant for the dominant chord of C major, and therefore it is fairly closely related to key of the A-section.

For the sake of comparison a few imaginary scenarios were investigated. In the first case the global A-section tone-frequency profile was correlated with the calculated chord profile (diamond) of the underlying chord: the assumption is that the local profiles have perfect correlation with the calculated chord profiles. In the second case the global A-section tone-frequency profile was correlated with the key of the original underlying chord (triangle)[26]: the assumption is that the musicians would emphasize the key of the underlying chord. Since the data for these two sets of correlations are artificial, they can be used to investigate how the progression would develop without any influence of the tonality of the A-section. The results are depicted in Figure 62 along with the correlations between the global A-section profile and the actual local profiles for each two measure segment (ball)[27]. The correlations for the calculated chord profiles (calc.chord) and the keys (transp.wt.glob.prof) display a gradual rise which is similar to the rise in the correlations between the actual tone-frequency profile (loc.chord) and the global A-section profile. This would appear to suggest that there is very little influence of the global tonality and that much of it can be explained without any reference to the global tonality.

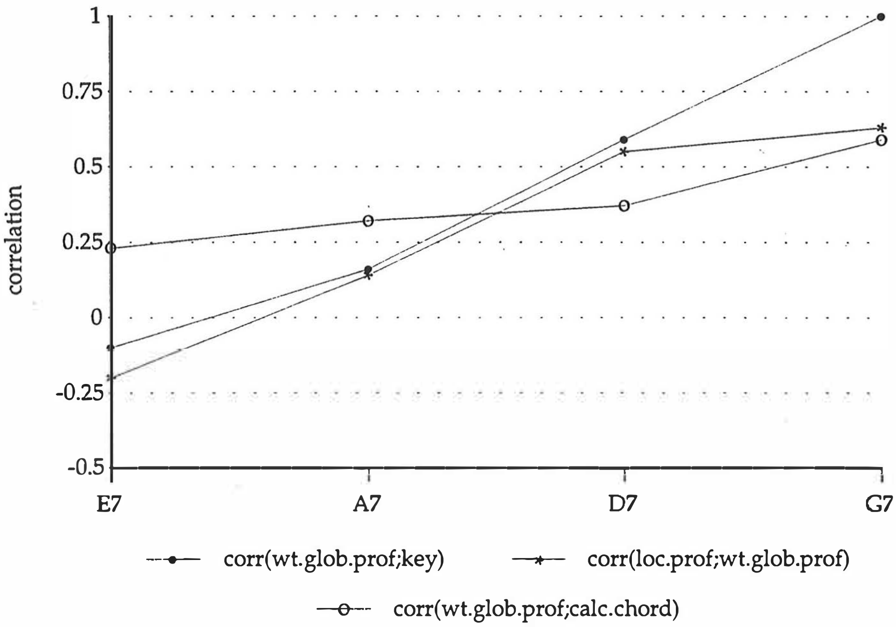

FIGURE 62. The correlation between the global A-section tone-frequency profile and the calculated tone-frequency profiles (diamond), the keys (triangle) of the original chords, and the actual tone-frequency profiles (ball) of each two measure segment.

To facilitate the comparison of these results with the results obtained from the A-section, the tone-frequency profiles were obtained also for each half measure. As in the analysis of the chord progression in the A-section, the whole-note level was taken into account in both chords. This version duplicates most of the results presented in Figure 61, but there are a few things that should be noted. The first tone-frequency profile indicates that B7 which is the dominant of the E7 chord is used in the beginning of the B-section. The influence of the B7 chord, however, is brief, for the presence of the E9 chord is strong in the second tone-frequency profile. Al-

26 The different keys were obtained by transposing the global profile.

27 It should be noted that these correlations cannot be used to determine the similarity, for example, of the local tone-frequency profile and the key profiles. In other words, even though they have similar correlations with the global tonality, their mutual similarity cannot be inferred from that information.

though the E dominant chord is delayed, this cadencial motion from B to E would seem to emphasize the first chord. Also the correlations for the diminished chords are interesting, for they clarify the results presented in Figure 61. The results show that the correlations with the appropriate diminished chord are always the highest right before the chord changes. In measures two and four the influence of the diminished scale is evident, but Figure 63 shows that to some extent it is used also in the sixth and eight measure. In other word, in the even measures there seems to be tendency for the musicians to prepare for the next chord by using tension.

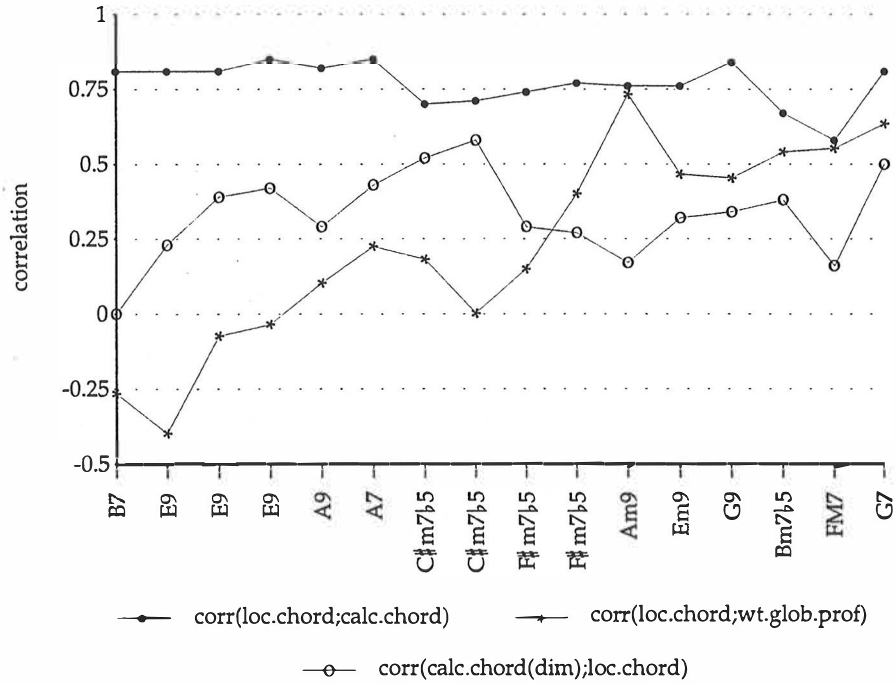

FIGURE 63. The development of tonality in the B-section of the Rhythm Changes chord progression – half measure level version. The ball is the correlation between the local tone-frequency profile (loc.chord) and the global A-section tone-frequency profile (wt.glob.prof), the diamond denotes the highest correlation found in the set of calculated chord profiles (calc.chord) for that particular local profile, and the triangle represents the correlation between the local profile the diminished chord (calc.chord (dim.)) one half-step above the original chords root.

The standard deviations obtained from the B-section (see Fig. 64) indicate that in most measures the tone-frequency profiles are more diffused in the second half than in the first half. In other words, musicians place different amount of emphasis on the chords depending on the position within the measure.

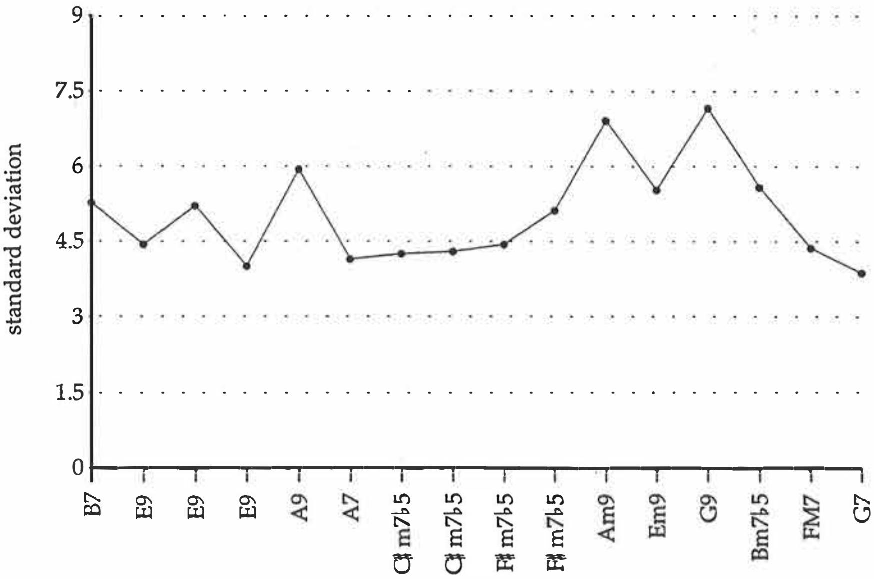

FIGURE 64. Standard deviations for the tone-frequency profiles the B-section.

To summarize, the results obtained for the whole chord progression in the B-section confirmed the results for the individual chords. In particular, the underlying chord or its substitute seemed to be the main source for the improvisations. Although in the end of the progression the influence of the global A-section tonality seemed to be apparent, no consistent global tonality for the B-section was found. Furthermore, in the even measures the musicians seemed to use the appropriate diminished scale or chord in order to create tension.

4.4 Phrasing and the Use of Rests

In addition to the investigation of statistical distribution of the tones, the use of rests was also considered in each section of the Rhythm Changes chord progression. In particular, it was examined how the musicians use rests to divide the improvisation to phrases of different length. Figure 65 shows how rests were used in the first A-section (A1). The vertical axis displays the relative frequency of rests in percentages at a given moment, and the horizontal axis shows the time in eighth-notes: for example, 2.1.1 denotes the first eighth-note of the first beat of the second measure. At the end of the section in the beginning of the eighth measure, there seems to be a clear boundary, which seems to indicate the end of a major phrase. It should be noted that there is some more activity after the highest peak, but that is likely to indicate anticipation of the following section. The rest of the section is not as unambiguous, for although the peaks occur around the beginning of the measures, no clear pattern seems to emerge. Only the low frequency of rests in the fifth and sixth measures implies consistent structural emphasis. This seems to support the conclusion that was made based on the investigation of the local profiles and the chord progression that the chord in the sixth measure is a focal point in the progression.

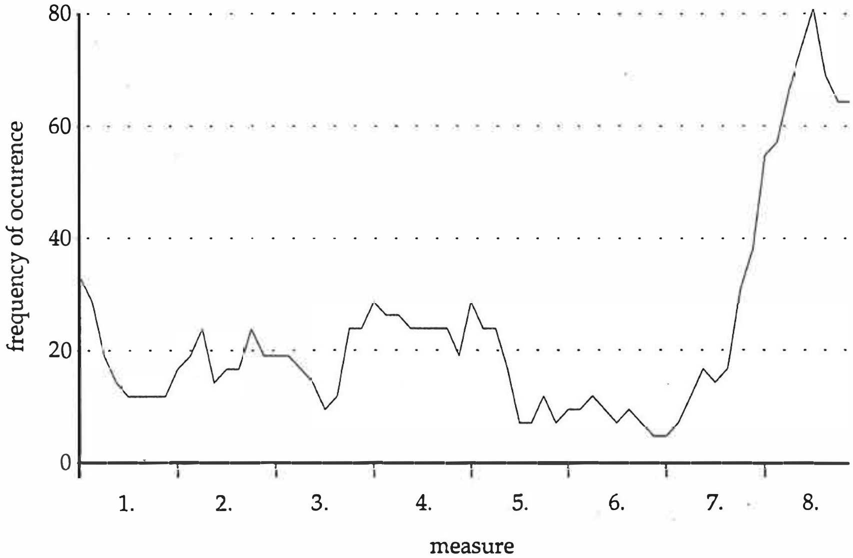

FIGURE 65. The use of rests in the first A-section of the Rhythm Changes chord progression.

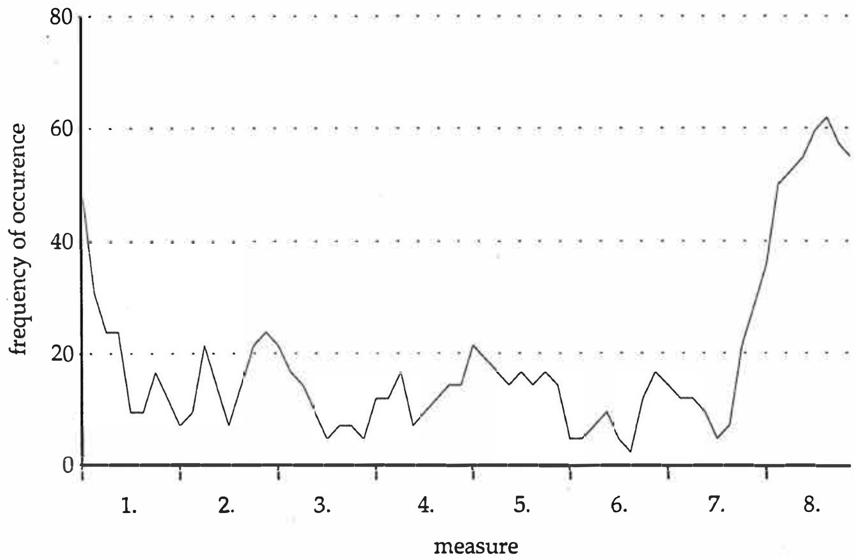

FIGURE 66. The use of rests in the second A-section of the Rhythm Changes progression.

The figure for the second A-section (Fig. 66) is similar to the chart on the first A-section, for there is a high peak at the end of the section and the lower peaks can be found around the beginnings of the measures. The emphasis in the sixth measure is not as clear as in the first A-section, but still the improvisers seem to use rests relatively little in that place. However, rests are used less in this section than in the previous section, for the average frequency of occurrence in percentages in the first A-section is 23.33% whereas the same for the second A-section is only 18.90%

The B-section displays a very different kind of structure, for Figure 67 reveals a clear phrase structure, which divides the B-section into two four-bar phrases the first of which is further divided into two two-bar phases. The latter four-bar phrase is also divided into smaller units, but the division is not as clear as in the first half of the B-section. Rather there seems to be first a two or three measures long phrase which would seem to be the end of the B-section phrase. There is, however, more activity again in the last measure, and it seems plausible to assume, together with the obtained tone-frequency profiles, that it anticipates the next section. – In percentages the average frequency of occurrence for rests is 17.97 %.

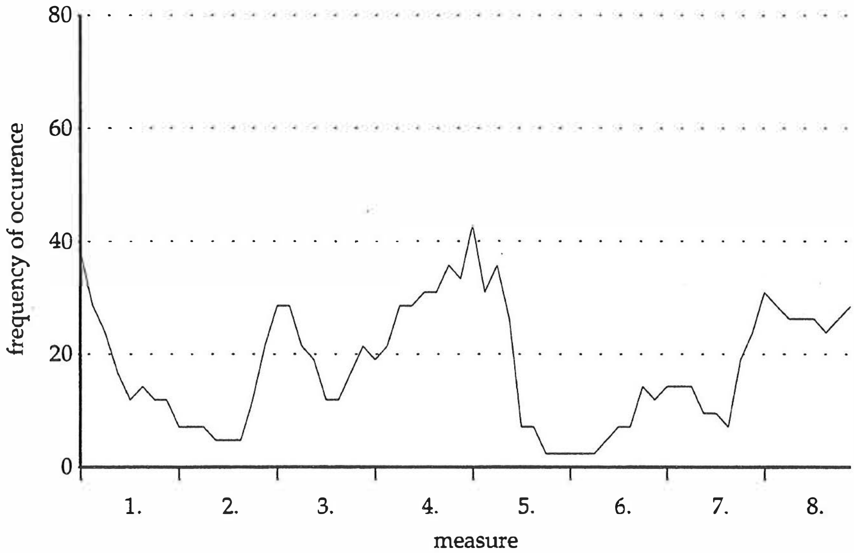

FIGURE 67. The use of rests in the B-section of the Rhythm Changes progression.

Finally, the use of rests in the third A-section of the Rhythm Changes chord progression is illustrated in Figure 68. It also has a high peak at the end of the section like the first and the second A-section, but the rest of the graph does not conform very well with the other two figures, for there seems to be less emphasis on the beginnings of the measures. Moreover, although the there seems to be some increased in the frequency of tones in the fifth and sixth measures, compared to the other two A-sections the area of emphasis is a bit earlier. This fits well with the earlier finding which showed that, unlike the first two A-sections, the C dominant chord in the fifth measure of the third A-section had higher standard deviation than the F major chord in the following measure. – In percentages the average frequency of occurrence for rests is 20.54 %.

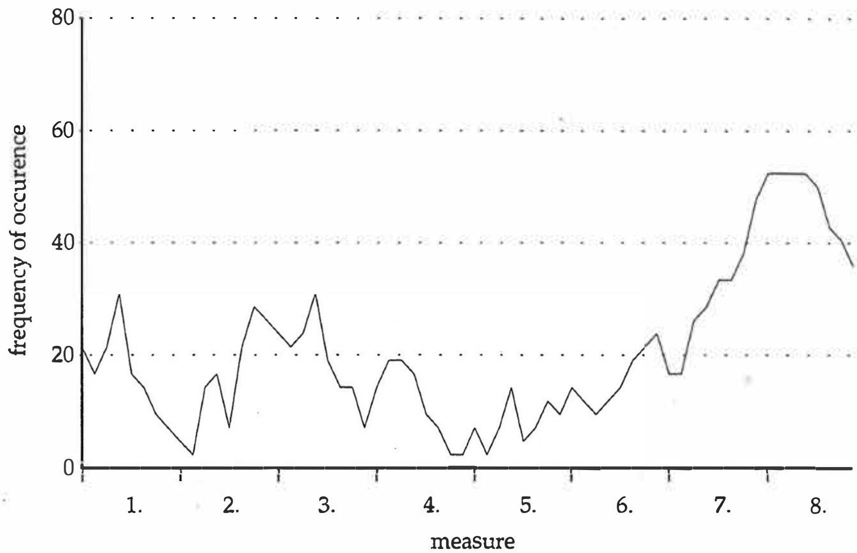

FIGURE 68. The use of rests in the third A-section of the Rhythm Changes progression.

The investigation on the use of rests suggest that improviser use them to structure the improvisations (cf., Berliner 1994, 157). In particular, the relative frequencies of rests seem to divide the improvisations into distinct phrases. These results are similar to the evidence obtained from studies on expressive performance of composed music (Palmer 1989). In particular, it has been found that performers seem to mark the phrase boundaries by changes in the tempo. Most performers lengthened phrase endings, which is comparable to the way jazz improviser seem to mark the phrase endings: the musician leaves space between the phrases. This would seem to suggest a fairly general principle of phrasing which is not dependent on a particular style of music.

The comparison of the results obtained for the A-section and the B-section illustrate that there are many factors which contribute to way the structure is realized. In particular, it seems that the chord progression in each section led the improviser to make certain kinds of phrases. The B-section has no stable tonality, but it has a very clear progression in which the underlying chord changes after every two measures. Since there is no global tonality which would help the improviser to maintain coherence, there must be some other guiding principles: the results on the use of rests seem to indicate that the unambiguous phrase structure is one of these reference points. The A-sections, however, have a clear chord progression with a distinct tonal orientations, and it has two chords, tonic and subdominant, which serve as focal points for the improvisers. Therefore it seems that the clear phrase structure is not necessarily needed in order to maintain coherence: rather the improvisers can take some liberties with the phrase structure. Furthermore the progression itself is not well suited for traditional four-measure phrases, because the F major in the sixth measure is so strong. In other words, it leads easily to a one, six or seven measures long phrase which is exactly what was found in the investigation on the use of rests.

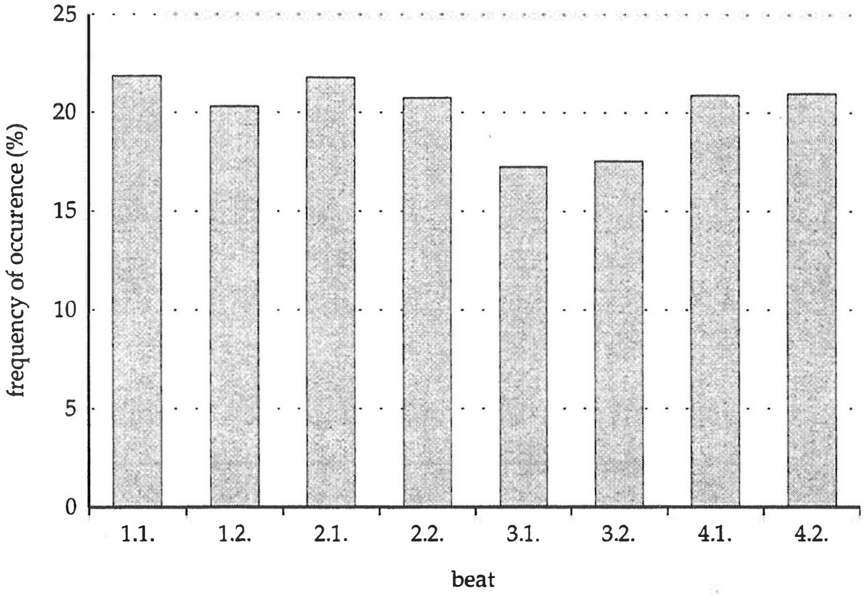

FIGURE 69. The use of rests on different metrical positions in the A- and B-section of the Rhythm Changes progression.

The placement of rests within the metrical structure was also examined. The results are illustrated in Figure 69. Frequency of rests (or tones) on each metrical position displays little variation, although there seems to be somewhat more melodic activity on the fifth and sixth eighth-note. This figure is not entirely comparable with the results of Palmer & Krumhansl (1990), for the tone durations are taken into account. However, since the most common duration in this type of jazz is the eighth-note (see Section 3.2), it does not seem likely that the result would be considerably different if only the number of onsets were taken into account. It is noteworthy that Palmer & Krumhansl obtained a similar result for a composition which was also based on frequent use of just one tone duration (p. 733).

5 SUMMARY, CONCLUSIONS, AND DISCUSSION

In the statistical analyses reported in this study 17 bebop styled jazz improvisations were examined. The goal was to determine some of the ways that the musicians utilize in order to cope with the cognitive constraints of improvisation. In particular, the tonal, harmonic and metrical preferences of the improvisers were investigated. In the following sections the main results will be summarized, and their meaning and significance will be discussed. To clarify the summary, Figures 70 and 71 have been produced to depict the main results for the A- and B-section, respectively. These figures illustrate the interpretation of the data as a whole, not any actual data found in the body of materials.

5.1 Summary

A-section

The tone-frequency profiles suggest in the A-sections of the Rhythm Changes chord progression there is a distinct global tonal orientation in which the tonic triad and the rest of the diatonic tones are favored (see Fig. 70.a, 70.c and 70.d). It is noteworthy that even though in the three A-sections there were some local differences, the global tonal orientation remained the same across the sections. The investigation of the development of tonality during the chord progression indicated that the global tonality also has a considerable effect on the way musicians approach individual chords. Some chords seemed to be outlined quite precisely, but the tone-frequency profiles for most chords displayed also emphasis on the important tones of the global tonality along with the tones of the underlying chord. Therefore it appears that the improvisers have reference chords or points in the chord progression that are taken into account more carefully than the rest of the chords. Specifically, in all three A-section the tonic (CM7) and subdominant (FM7) chords seemed to be emphasized; the importance of the subdominant chord was further stressed by the emphasis on its secondary dominant C7. Figure 70.d displays the progression that was constructed based on the results. Furthermore the result was even clearer when the effect of echoic memory was taken into account. Namely, these time-weighted tone-frequency profiles indicated that the global tonality dominates throughout the A-sections. Still, despite this fairly static global tonality, there seemed to be tonal movement in which the focal chords were prepared. For example, the results indicated that in the improvisations the subdominant chord in the sixth measure was prepared by a gradual rise towards this chord during the first five measures of the A-section (see the dashed line in Fig. 70.a).

In the tone-frequency profiles for the tonic (CM7) and the subdominant (FM7) chords the favored chordal formation seemed to be the basic triad (see Fig. 70.d). The third important chord, C dominant, displayed emphasis also on the chord tones above the basic triad and seventh chord, for even the ninth and the thirteenth seemed to be quite stable. The tone-frequency profile of the supertonic (Dm7) and the dominant (G7) chord, however, were not as clear, because of the effect of the underlying tonality.

It was also found that meter was an important factor in the improvisations. The existence of various periodic structures were investigated, but the results suggested that traditional view of metrical organization (e.g., Lerdahl & Jackendoff 1983) is relevant also when bebop styled jazz improvisations are contemplated (see Fig. 70.e). The global tone-frequency profile obtained from the A-section illustrated that the musicians used this metrical structure to emphasize or de-emphasize tones depending on their tonal function. For example, the important scale degrees of the C major tonality, namely the tones C and G, were used more frequently in the whole-note level. The sixth scale degree (A) was sounded more frequently on the lower metrical levels, which emphasized it melodic function. The effect of metrical structure seemed to extend to the level of individual chords. In particular, the musicians seemed to have focused on some tones in the chords in the first half of the measure whereas in the second half of each measure the tone-frequency profiles displayed a more diffused pattern of preference (see Fig. 70.b). It was also found that improvisers use rests to structure the improvisations (see Fig. 70.f). The A-section seemed to consist of only one long phrase which was in concordance with the structure of the chord progression.

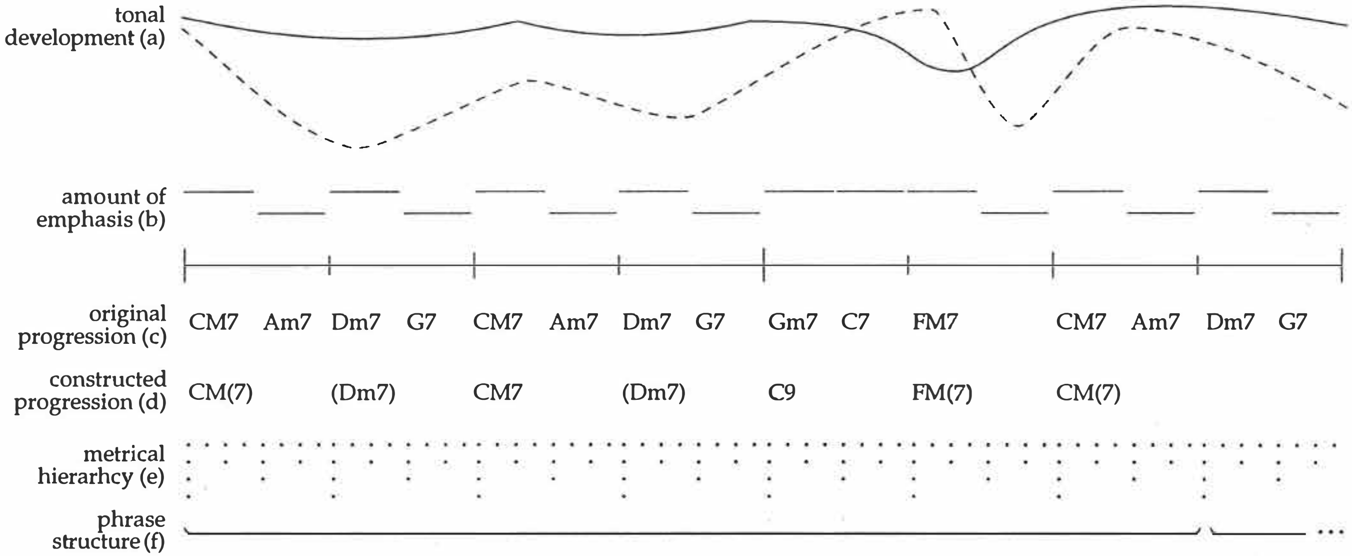

FIGURE 70. Interpretation of the results on the A-section of the Rhythm Changes chord progression. In tonal development (a) the dashed line represents the local chords (see (c) and (d)), and the solid line represents the global tonality. See text for further explanations.

B-section

The tone-frequency profiles for the B-section indicated that unlike the A-section of the Rhythm Changes chord progression, the B-section does not have a single tonal center. Thus, the tone-frequency profiles in this cycle of fifths sequence based on dominant seventh chords displayed clearer emphasis on the chord tones (see the dashed line in Fig. 71.a). There was, however, some indications that the global tonality had influenced the tone-frequency profiles for the D7 and G7 chords (see the solid line in Fig. 71.a). This is understandable, because both chord have a relatively stable positions in the key of C major: G7 is the dominant chord and D7 the secondary dominant for G7. The acquired tone-frequency profiles suggest that along with the basic four note chord (root, third, fifth, and lowered seventh) the ninth and the thirteenth also seem to occupy a relatively stable position (see Fig. 71.e). There were, however, some interesting divergencies, for the chords in the even measures were handled somewhat differently than the ones in the odd measures. The tone-frequency profiles obtained from the odd measures indicate that the musicians have preferred relatively diatonic material based on the underlying dominant ninth (V9) chord (with or without the root) or its closest substitute the supertonic (ii7) chord. The profiles from the even measures suggest a more chromatic approach, because especially the ninth and the fifth are frequently chromatically altered. It seems that the musicians have used frequently the so-called diminished scale (root, ♭9, ♯9, 3, ♯11 (♭5), 5, 13, and ♭7) in the even measures in order to create tension: this was apparent particularly in the latter part of the even measures. The effect of the diminished scale could also be seen in the moderately high correlations between the diminished seventh chords and the tone-frequency profiles in the even measures (see Fig. 71.b and 71.d).

Although this tension and release -pattern seemed to be one of the guiding principles in this section, in each measure the characteristic tones of the local tonality were almost always present (see the dashed line in Fig. 71.a). In particular, the musicians maintained the structure of the basic progression by emphasizing in most measures the important tones of the underlying chord, namely the root, the third, and the lowered seventh. These three tones in each chord establish clearly the nature of both the progression and the individual chords: the third and the lowered seventh define the quality of the chord and the roots of the chords emphasize the cycle of fifths -movement.

Also in the B-section meter was used to emphasize important tones in the improvisations (see Fig. 71.f). Furthermore, the tone-frequency profiles for the B-section displayed some evidence for the notion that musicians place different amounts of emphasis on the chords depending on the position within the measure (see Fig. 71.c). Moreover, the investigation on the use of rests suggest that the improvisations were divided into a regular phrase structure (see Fig. 71.g). On the basis of the statistical frequency of the rests on a given moment during the B-section, it was possible to isolate two four-bar phrases which were further divided into smaller units.

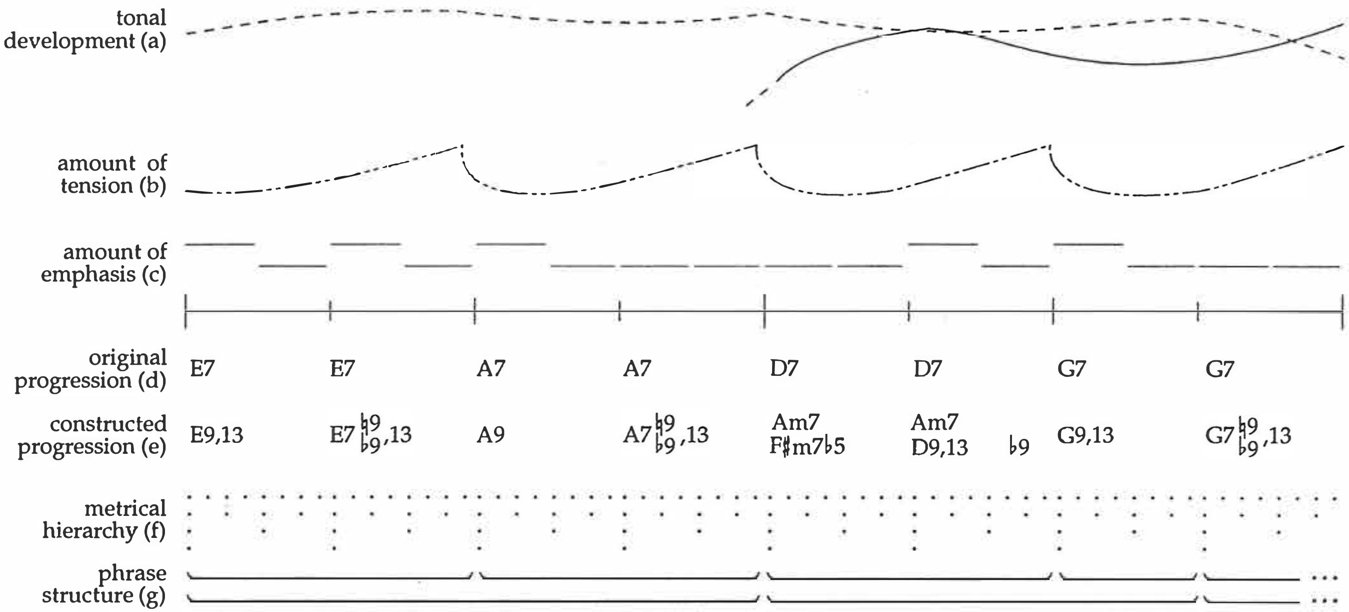

FIGURE 71. Interpretation of the results on the B-section of the Rhythm Changes chord progression. In tonal development (a) the dashed line represents the local chords (see (c) and (d)), and the solid line represents the global tonality. See text for further explanations.

5.2 Conclusions

These results appear to indicate that in this type of jazz improvisation the musicians utilize many interrelated principles, which ease the cognitive strains present in real time music making process. It is also noteworthy that these principles are well in concordance with the empirical research on music cognition.

1) The global tonal orientation of the A-section of the Rhythm Changes chord progression parallels strongly the perceived tonal hierarchy obtained by Krumhansl and Shepard in their empirical tests (1979). This kind of distribution of the tones is also consistent with the data on the relative frequencies of the twelve chromatic tones in European art music (cf., Knopoff & Hutchinson 1983).

2) The development of the tonality in the A-section displayed similar tendencies that have been found in the empirical tests conducted by Krumhansl and Kessler (1982): the improvisers seemed to use principles comparable to the way listeners' sense of key develops and changes while a given chord sequence progresses.

3) Meter had a significant role in the improvisations. On the basis of the obtained results, it seems that improvisers operate on comparable principles to those found by a number of researchers who have investigated the effect of meter to processing and performance of music (e.g., Palmer and Krumhansl 1990; Jones 1992; Drake & Palmer 1993).

4) In the improvisations there seemed to be a distinct phrase structure, which emphasized the hypermetric (cf., Kramer 1988, 452-453) structure of the improvisations. It is noteworthy that comparison with evidence obtained from studies on expressive performance of composed music (e.g., Palmer 1989) suggest that the general principle of phrasing maybe be quite similar in performance of both improvisation and composed music.

It has been argued that among other things inventiveness and the achievement of coherence are important factors in improvisation (Pressing 1989, 166). Pressing notes that "in more fixed skill these are less important, since inventiveness provides few tangible advantages, and coherence is built in by the rigidity of the task demands" (1989, 166). Although in some cases this might seem a reasonable assumption, the results obtained in this study seem to indicate that this view is extremely oversimplified. The Rhythm Changes chord progression is a very rigid task environment, but even at the average tempo of 256 beats per minute the improvisations display high level of both inventiveness and coherence. Although there were many different kinds of schemata which the improvisers appeared to use, some common principles seem to emerge. The improvisations seem to display dynamic interaction of various hierarchical structures which help the musicians to maintain both coherence and interest. Namely, it appears that the musicians used cognitive reference points in order to emphasize the relatively more stable, central elements in the global tonality, single chords, whole chord progressions, and meter. While these provide the coherence in the improvisations, the musicians also displayed inventiveness in the way they complemented these central elements with other material. In particular, they seemed to maintain interest by using, for example, patterns of tension and release (see also Figures 70 and 71).

The most obvious examples of tension and release can be found in the metrical structure where both the simple metrical alternation of strong and weak beat provides such structures (Fig. 70.d, 70.b, 71.e, and 71.c). The same pattern can also be found across measures, for in the B-section the improvisers seemed to play more chromatically in the even measures than in the odd measures. Although the adjacent chords in this chord progression are a perfect fifth apart, in a strict sense there is no dominant to tonic movement. Still, musicians seem to want to structure the improvisation in a similar manner by using tension and release. However, the musicians also maintained the structure of the basic progression by emphasizing in most measures the most important tones of the underlying chord, namely the root, the third, and the lowered seventh. Furthermore the inner coherence was clarified by the distinct phrases which divided the improvisation into a regular phrase structure. It should also be noted that since there is no tonal center, the underlying harmony does not enforce or provide any cues for such division, for example, by harmonic closure. Therefore it seems that the improvisers may have used also a relatively large-scale metric schema, which gave further reference points for their improvisation.

The tension and release pattern can also be found in the A-section of the Rhythm Changes chord progression, although it is not as apparent as in the B-section. It was found that the tonic (CM7) and the subdominant (FM7) chords were outlined more carefully than the supertonic (Dm7) and the dominant (G7) chords. In other words, in the tone-frequency profiles of the CM7 and FM7 chords the tones of the underlying chord were emphasized. The global tonality, however, seemed to have affected the profiles for the Dm7 and G7 chords: the local hierarchy of the tones was, then, less consonant against the underlying chord than was the case in the CM7 and FM7 contexts. Hence a pattern seems to emerge where the tonic and subdominant chords were the release elements and the supertonic and the dominant chord the tension elements. The importance of this tonal movement is further emphasized by the phrase structure in the A-section.

Therefore it seems that the notion of tension and release is an important principle in the improvisational process in this type of jazz music. The same principle that is crucial in dominant-tonic -relationships is employed in a much broader sense in order to maintain both interest and inner coherence of the improvisation on various levels of activity. On one hand, it can be found from the surface level events such as the alternation of strong and weak beats; on the other, it is apparent in the events which occupy relatively large time-span, such as the tonal movement between focal chords. Still, although on a fairly local level it may be viewed as something which elaborates the fairly static reference points, it is also noteworthy that any *pattern* of tension and release itself serves as a reference point which maintains coherence[29].

These results seem to suggest that at least in this type of music both global and local tonal orientation affect the process of improvisation. The relationship, however, is not fixed or static, because there seemed to be many local differences depending on the section and also on the specific part of a section. Thus, on the basis of this material the notion of tonality should be considered as dynamic, for it seems to change and evolve as the music progresses. It is important to note, however, that this does not mean that there is no fairly static global tonality or tonal hierarchy. Despite the local differences in the three A-section, they all displayed remarkably similar tonal orientation at the level of the whole section. It seems that locally the musicians approach each A-section differently, but on a global level the improvisations still conform with the same general tonal preferences that have been found to be important, for example, in numerous perceptual studies. In other words, the three A-sections are just different realizations of the tonal hierarchy.

The B-section provides an interesting contrast to the A-section, because it clarifies the significance of global tonality relative to some of the other reference structures. Namely, the B-section seems to demonstrate that the existence of global tonality is not mandatory in order to achieve coherence. Instead it seems to be one of the possible reference points which will be used if the progression supports it. The comparison of the A- and B-section provides interesting insight into the process of improvisation also from a more general point of view. Although it is hard to quantify the extent to which musicians use various reference points in their improvisations, there seems to be some sort of equilibrium across the sections, for some principles seem to be used in both sections whereas some seem to have more importance in the other. For example, the phrase structure does not seem to be very important in the A-section, but in the B-section it appears to have a central role in improvisations.

In the B-section the improvisers seemed to base their improvisation on more extended chords than in the A-section. It appears to be conceivable that this can be largely attributed to the difference in the pace of the chords. In the A-section, where each chord lasts only for two beats at a time, the improviser has only four eighth-notes to play during each chord. If we leave out the effect of the global tonality, it is likely that in order to maintain coherence the musician is going to choose to emphasize the notes of the basic triad or seventh chord rather than some extension tones. Or conversely it is also possible to think that the musician can easily maintain interest just by following the basic set of chord changes, because there is a plethora of musical devices that can be used to ornament the basic chord tones. In contrast, the local tone-frequency profiles obtained from the B-section, where each chord in this progression lasts for two measures, displayed more extended chord structures. Thus, when the underlying chord lasts for a longer period of time the musician uses more chord substitutions and chromatic alterations, either because there is more time or because the basic chord tones do not offer enough possibilities in order to

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29 This discussion bears resemblance to the general principles of Meyer's form and process dichotomy (see e.g., 1956, 1972).

maintain interest[30]. It is likely that the effect of the pace of the chord progression can be explained by the limitations of the basic cognitive processes such as memory. It would even seem plausible that there is a fairly well-defined relation between these cognitive capacities and the way the global and local tonal tonalities interact in different harmonic rhythms, when everything else remains the same.

It should be noted that the results presented in this thesis are well in accordance with the results that have been published in the earlier stages of this research (Järvinen 1994b, 1995, 1996). Since the body of materials used in this thesis are partly different, the results may be viewed as partial replications of the earlier results. The high conformity of the results across these studies suggests that the findings are robust and not result of the styles of individual musicians.

5.3 Discussion

The results give strong evidence that bebop styled jazz improvisation is at the same time remarkably structured and dynamic. It seems that the process of improvisation is to a considerable degree based on various interrelated hierarchical principles which help the musicians to maintain coherence and interest in their improvisations. Further they show that the human cognition is able to handle very sophisticated hierarchical structures while improvising music. From the point of view of cognitive musicology these results are significant, because they are well in concordance with the empirical psychological studies on how, for example, tonality and meter are perceived. On a more general level, it would seem that the notion of cognitive reference points can be used to explain these various structures and processes found in the analyzed improvisations. Although only bebop styled jazz improvisations were considered, it would seem reasonable to assume that the general principles would hold in other jazz styles as well. For example, in certain type of free jazz there could be a certain timbre which serves as the reference point in the improvisation. Furthermore the results could also benefit the study of improvisation in general. Namely, it seems that epic poetry, which has been transmitted through

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30 The effect of the pace of the chord sequence is illustrated well, for example, in the work of saxophonist John Coltrane. In March 2, 1959 he recorded a composition called So What as a member of the Miles Davis Quintet. The composition in AABA form, and there are only two chords: namely, Dm7 in the A-section and Ebm7 in the B-section. This extremely slow pace of chords allowed Coltrane to depart far away from the chord tones of the underlying chords, although he certainly kept them as the basic reference points of his improvisation. A few months later he recorded with his own quartet a composition called Giant Steps (Coltrane 1959), which is a fast 24 measures long chord sequence with a modulation in almost every measure. In this improvisation there is hardly anything left of the melodic excursions, which can be heard in the improvisation on So What, for Coltrane used almost only the tones of the underlying chords.

oral tradition operates on principles similar to musical improvisation[31], and therefore similar cognitive principles could possibly be used to explain its structure. On the other hand, the cognitive principles found in the analyzed improvisations seem to have much in common with many general cognitive processes which are not particular to only music or improvisation. Rather concepts such as the hierarchical notion of reference points can be used to explain a wide variety of cognitive functions, for example, the perception of colors or shapes. Therefore it would seem more interesting to try to relate jazz improvisation to various everyday cognitive processes rather than try to link it to some grandiose explanation of improvisation in general.

Salience Effect

It is interesting to note that many of the results do not comply with the common conceptions of the basic characteristics of bebop improvisation. Many times it is noted that, for example, the ninth, eleventh, and thirteenth are used often, roots are avoided, syncopations and polyrhythms are common[32]. The results indicate that these principles seem to be used, but also that they are actually quite rare compared to some of the other things found in this study. This does not mean that there is something wrong with the ears or musical abilities of these listeners. Instead these conceptions are probably the result of the so-called salience effect[33] which refers tothe distinctiveness of a stimulus relative to the context (see Fiske & Taylor 1983). In other words, the listeners have confused the salience with frequency[34]. At the same time they have disregarded the basic structures which, in fact, provide the essential background for the salient surface features. Although these features are undoubtedly important for the sound and character of the music, it would seem that they may not be very important for the inner coherence and structure of the improvisation.

Since these features are salient they naturally affect listener perception of the improvisation. Still, it does not seem plausible to make inferences about the possible cognitive principles of the improviser by using the listeners' perception as the main source of information. Alto saxophonist Charlie Parker's improvisation on a composition called Hot House is a good, albeit extreme example. For many listeners probably the most salient and memorable moment of the improvisation is when Parker quotes Rossini's Overture to *William Tell* (see Owens 1974b, 387). Still, this quote can hardly be used to explain but a little of the underlying cognitive processes.

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31 See, e.g., Treitler 1974; Smith 1991.

32 It ought to be noted that these results only apply to melodic lines – the distribution of the tones used in the accompaniment (e.g., piano) could be different.

33 Vividness effect, which refers to the intensity or emotional interest of the stimulus, is a related concept to salience effect (Fiske & Taylor 1983). However, the empirical data for vividness effect is more mixed (Taylor & Thompson 1982).

34 Others have also observed similar tendency. For example, Thomas Owens noted in his extensive study on Charlie Parker's improvisations that many writers have overemphasized the use of the flatted fifth in Parkers improvisations (Owens 1974a, 23).

Music Analysis and Jazz Pedagogy

These result may also have some practical significance for at least for two different, although interrelated, domains: music analysis, and jazz pedagogy. As has been noted elsewhere (Järvinen 1994a) the analysis of jazz music has mainly been based on the analytical procedures developed for European art music. The obtained evidence suggests that in part this practice has been justified, because certain jazz styles do in fact share a similar tonal hierarchy with the European tonal-harmonic tradition. Still, there seem to be some characteristic features that should be observed[35]. First of all, there are structural chords that serve as cognitive reference points for the improviser. For the analyst this means that in order to determine, for example, the structural tones one has to ascertain where, in the course of the chorus, the musician bases the improvisation on the underlying harmony and where on the overall tonality. Secondly, the metrically salient beats also serve as cognitive reference points. Therefore the relative structural importance of the tones in an improvised melody can be judged partly by their relation to the metrical structure. Furthermore the kind of statistical approach that was utilized in this study could be used to extend the traditional methods of music analysis. They provide one possible approach which permits the analyst to investigate at least tonality and meter in a precise and relatively objective manner.

From the point of view of jazz pedagogy it seems that some of the teaching practices have been somewhat misleading. Jazz improvisation is many times taught as a process where one outlines every chord with an arpeggio or proper scale (e.g., Salvatore 1970, 3-4), connects two or four bar formulas (e.g., Fraser 1983, 177) or uses motivic development (e.g., Coker 1964, 54-58). Although all of these approaches are certainly useful, they all lack the awareness of the relative importance and large scale connections of harmony and meter in improvisation. The presented results give clear indications that improvisers use cognitive reference points in order to create coherent bebop improvisation, and it seems that in order to gain a more comprehensive view of jazz improvisation in general, a student should be aware of these relationships[36]. It should be noted that these results are not to be confused with the two improvisational approaches which have sometimes been called vertical and horizontal or scale and chord based improvisation. It would seem that the improvisational principles described in this thesis are more general and that they apply equally well to both approaches. On note-to-note level they are just realized in different ways depending on the musicians style and preferences.

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35 It is not implied here that tonality, meter, phrase structure, and chord are the only characteristic features to be observed. It is fair to assume, however, with the support of the presented evidence it seems that they cannot be dismissed as unimportant. In addition to various melodic considerations, at least the effect of tempo would appear to require a thorough investigation (cf., Collier & Collier 1994 and Ashley 1996).

36 It should be noted that these ideas are not totally new, for composer George Russell asserted as early as 1959 that improvisers have in the chord structure so called tonic stations which are more carefully observed than the rest of the chord structure (1959, xviii-xix). Although his ideas for example on chord-scale relationships have been very influential, this side of his thinking has not been widely recognized

TonalHierarchy

One of the most important sources of inspiration for this study has been the workof Carol Krumhansl particularly on tonality. As noted in section 2.1.1 some researchers have doubted the usefulness of the notion of tonal hierarchy in explaining the perception of music (e.g., Brown 1988). Furthermore it has been suggested that listeners' stability ratings obtained by Krumhansl and others are artifact of experimental procedures rather than proof of the existence of some fairly stable tonal hierarchy (e.g., Butler 1989). Since this thesis has been concerned with the production of music, the questions concerning the perception of music (e.g., the identification of the key) cannot be dealt with directly. Still, the results of this study seem to provide further support for the notion of tonal hierarchy as suggested by Krumhansl. Namely, the results suggest that the notion of tonal hierarchy is quite real and that it is useful at least in explaining some aspects of improvisation. The improvisations display a quite stable tonal orientation which seems to be an important cognitive reference point. It should be pointed out that the improvisers do not have to infer the tonality, for in this type of jazz the musician must be able to hear the tonality even before the first tone is sounded (cf., Berliner 1994, 71). Therefore in the light of the present data it seems plausible that musicians have an abstract knowledge of tonality which is used as an aid during the act of improvisation. This assumption is further supported by the little variation on the global tonal orientation which was found across the different sections.

Thus, the obtained evidence also appears to suggest that the tonal hierarchy, where the tonic triad is followed by the diatonic tones and finally by the rest of the chromatic scale, has some universality at least in western music. As the results show, the underlying structures of two different sounding pieces of music, for example a Schubert lied and an improvisation by Hank Mobley, seem to share a remarkably similar tonal hierarchy. One might be tempted to infer that the remarkable similarity of the tonal orientation in bebop styled jazz and classical music with the listeners tonal preferences is an indication that this type of tonality is somehow innate. A more feasible explanation is, however, that the correspondence shows listeners' sensitivities to the statistical distributions of tones in their environment; this is supported, for example, by cross-cultural studies on tonality (e.g., Castellano, Bharucha & Krumhansl 1984; see also Krumhansl 1990a). Still, it seems that there are some general principles that may be fairly constant from culture to culture. It is not likely that they are particular to just music, rather they may have to do with the way we attend to our environment in general. In other words, the realization of tonality varies depending on the culture, but the underlying cognitive principles are the same.

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APPENDIX 1

Examples of calculated tone and chord profiles (pitch-class saliences according to Parncutt, 1988).

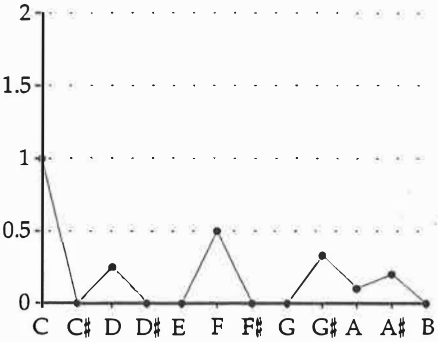

FIGURE 72. Calculated pitch saliences for the tone C

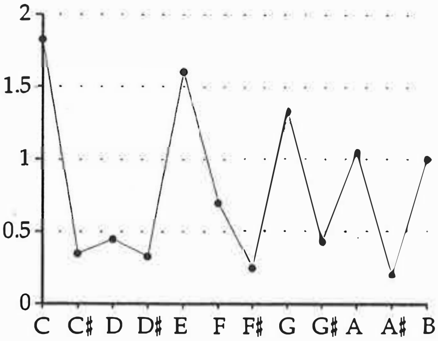

FIGURE 73. Calculated pitch saliences for CM7

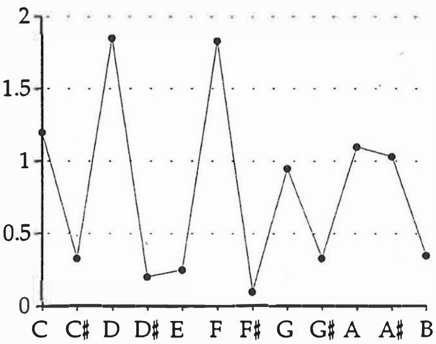

FIGURE 74. Calculated pitch saliences for Dm7.

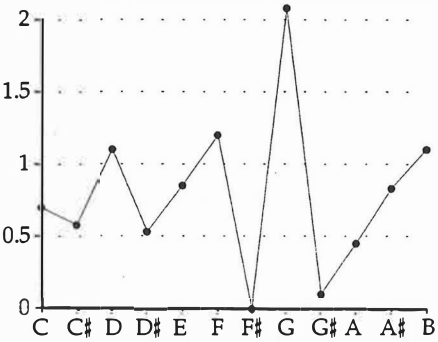

FIGURE 75. Calculated pitch saliences for G7

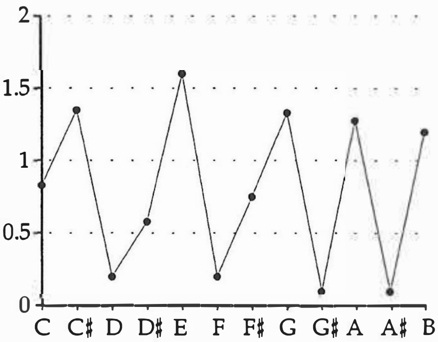

FIGURE 76. Calculated pitch saliences C♯m7♭5.

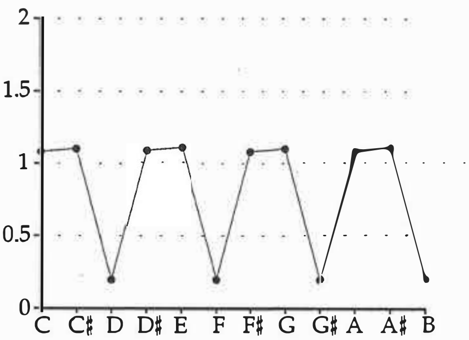

FIGURE 77. Calculated pitch saliences for C♯°7.

APPENDIX 2

The data for the calculated chord profiles used in the analysis. All chords are normalized, and the values are shown in percentages (%).

TABLE 16. Calculated major seventh and ninth chords.

tone	CM7	FM7	DM7	GM7	CM9	FM9
C	19.22	13.97	2.10	7.35	17.06	15.38
C♯	3.68	4.52	10.50	2.63	2.94	3.61
D	4.73	11.03	19.22	13.97	12.18	8.82
D♯	3.47	2.10	3.68	4.52	2.77	4.45
E	16.81	10.50	4.73	11.03	15.55	9.24
F	7.35	19.22	3.47	2.10	5.88	17.06
F♯	2.63	3.68	16.81	10.50	2.1	2.94
G	13.97	4.73	7.35	19.22	15.38	12.18
G♯	4.52	3.47	2.63	3.68	3.61	2.77
A	11.03	16.81	13.97	4.73	8.82	15.55
A♯	2.10	7.35	4.52	3.47	4.45	5.88
B	10.50	2.63	11.03	16.81	9.24	2.10

TABLE 17. Calculated minor seventh and ninth chords.

tone	Am7	Dm7	Gm7	Fm7	Bm7	Em7	Dm9	Am9	Em9	Bm9
C	19.22	12.61	9.98	11.55	2.10	10.82	12.86	15.38	8.66	1.68
C♯	1.05	3.47	3.47	10.82	2.63	3.68	3.61	2.94	2.94	10.50
D	9.98	19.43	11.55	3.68	19.22	12.61	17.23	7.98	12.86	15.30
D♯	3.47	2.10	10.82	12.61	1.05	3.47	1.68	2.77	3.61	2.94
E	11.55	2.63	3.68	3.47	9.98	19.43	10.50	13.45	17.23	7.98
F	10.82	19.22	12.61	19.43	3.47	2.10	15.38	8.66	1.68	2.77
F♯	3.68	1.05	3.47	2.10	11.55	2.63	2.94	2.94	10.50	13.40
G	12.61	9.98	19.43	2.63	10.82	19.22	7.98	12.86	15.38	8.66
G♯	3.47	3.47	2.10	19.22	3.68	1.05	2.77	3.61	2.94	2.94
A	19.43	11.55	2.63	1.05	12.61	9.98	13.45	17.23	7.98	12.80
A♯	2.10	10.82	19.22	9.98	3.47	3.47	8.66	1.68	2.77	3.61
B	2.63	3.68	1.05	3.47	19.43	11.55	2.94	10.50	13.45	17.23

TABLE 18. Calculated dominant seventh chords.

tone	A7	G7	C7	D7	E7	B♭7	B7
C	8.72	7.35	21.85	12.61	5.57	4.73	1.05
C♯	11.55	6.09	1.05	0.00	8.93	8.72	4.73
D	7.35	11.55	4.73	21.85	12.61	11.55	8.72
D♯	6.09	5.57	8.72	1.05	0.00	7.35	11.55
E	11.55	8.93	11.55	4.73	21.85	6.09	7.35
F	5.57	12.61	7.35	8.72	1.05	11.55	6.09
F♯	8.93	0.00	6.09	11.55	4.73	5.57	11.55
G	12.61	21.85	11.55	7.35	8.72	8.93	5.57
G♯	0.00	1.05	5.57	6.09	11.55	12.61	8.93
A	21.85	4.73	8.93	11.55	7.35	0.00	12.61
A♯	1.05	8.72	12.61	5.57	6.09	21.85	0.00
B	4.73	11.55	0.00	8.93	11.55	1.05	21.85

TABLE 19. Calculated dominant ninth and flatted fifth chords.

tone	E9	A9	D9	G9	C9	B♭7♭5	E♭7♭5	A♭7♭5	D♭7♭5
C	4.45	6.97	12.86	5.88	19.16	8.19	6.30	12.61	5.25
C♯	7.14	11.34	0.84	4.87	0.84	6.30	12.61	5.25	16.60
D	12.86	5.88	19.16	13.45	12.18	12.61	5.25	16.60	1.05
D♯	0.84	4.87	0.84	4.45	6.97	5.25	16.60	1.05	8.19
E	19.16	13.45	12.18	7.14	11.34	16.60	1.05	8.19	6.30
F	0.84	4.45	6.97	12.86	5.88	1.05	8.19	6.30	12.61
F♯	12.18	7.14	11.34	0.84	4.87	8.19	6.30	12.61	5.25
G	6.97	12.86	5.88	19.16	13.45	6.30	12.61	5.25	16.60
G♯	11.34	0.84	4.87	0.84	4.45	12.61	5.25	16.60	1.05
A	5.88	19.16	13.45	12.18	7.14	5.25	16.60	1.05	8.19
A♯	4.87	0.84	4.45	6.97	12.86	16.60	1.05	8.19	6.30
B	13.45	12.18	7.14	11.34	0.84	1.05	8.19	6.30	12.61

TABLE 20. Calculated diminished and half-diminished chords.

tone	F♯°7	G♯°7	C♯°7	Bm7♭5	Em7♭5	G♯m7♭5	C♯m7♭5	F♯m7♭5	D♯m7♭5
C	11.55	2.10	11.34	2.10	13.45	2.10	8.72	13.97	1.05
C♯	2.10	11.34	11.55	6.09	1.05	7.88	14.18	1.05	12.61
D	11.34	11.55	2.10	16.81	12.61	13.97	2.10	13.45	8.72
D♯	11.55	2.10	11.34	2.10	8.72	1.05	6.09	1.05	14.18
E	2.10	11.34	11.55	7.88	14.18	13.45	16.81	12.61	2.10
F	11.34	11.55	2.10	13.97	2.10	1.05	2.10	8.72	6.09
F♯	11.55	2.10	11.34	1.05	6.09	12.61	7.88	14.18	16.81
G	2.10	11.34	11.55	13.45	16.81	8.72	13.97	2.10	2.10
G♯	11.34	11.55	2.10	1.05	2.10	14.18	1.05	6.09	7.88
A	11.55	2.10	11.34	12.61	7.88	2.10	13.45	16.81	13.97
A♯	2.10	11.34	11.55	8.72	13.97	6.09	1.05	2.10	1.05
B	11.34	11.55	2.10	14.18	1.05	16.81	12.61	7.88	13.45

APPENDIX 3

A box-plot is a graphic method for displaying the 10th, 25th, 50th, 75th, and 90th percentiles of a variable. Figure 78 illustrates how the frequency distribution is displayed with a box-plot.

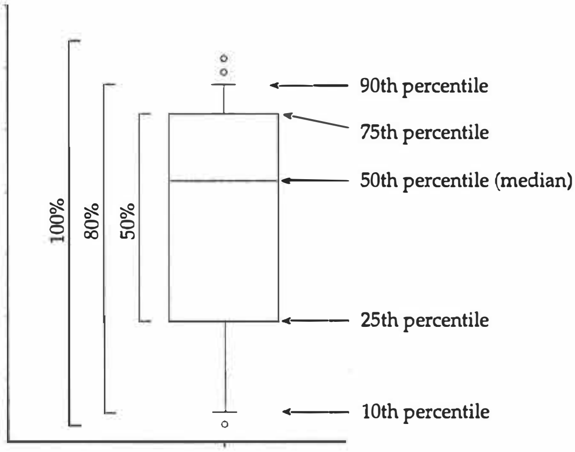

FIGURE 78. Box-plot chart.

YHTEENVETO

Musiikillisen kognition tutkimus on aikaisemmin keskittynyt lähinnä siihen, kuinka ihminen havainnoi, prosessoi tai muistaa kuulemaansa musiikkia tai ääniä (esim. tonaliteetin, äänensävyjen tai rytmin havaitseminen). On toki olemassa mielenkiintoisia tutkimuksia esimerkiksi musiikin esittämisestä (esim. Palmer 1992), säveltämisestä (esim. Heinonen 1995) tai improvisaatiosta (esim. Pressing 1988), mutta silti kuulijan näkökulma on ollut vallitseva useimmissa tutkimuksissa. Kuitenkin näyttäisi siltä, että tietämyksemme musiikkiin liittyvistä kognitiivisista toiminnoista on merkittävällä tavalla vaillinainen, jos emme perehdy samalla tarkkuudella myös musiikin tuottamiseen tai tekemiseen liittyviin prosesseihin. Erityisesti musiikillinen improvisaatio on kognition kannalta mielenkiintoinen tutkimuskohde, koska siinä muusikon täytyy yrittää luoda yhtenäisiä musiikillisia kokonaisuuksia reaaliajassa: hänellä ei ole esimerkiksi mahdollisuutta palata taaksepäin korjatakseen jonkin kokonaisuuden kannalta epäsopivan yksityiskohdan.

Tässä työssä on tutkittu tilastollisesti bebop-tyylisiä jazz improvisaatioita. Tutkimusaineistona oli 17 ns. Rhythm Changes sointukulkuun perustuvaa improvisaatiota. Päämääränä oli selvittää sävelten tilastollisen distribuution avulla, millaisia kognitiivisia periaatteita jazzmuusikot käyttävät improvisoidessaan. Erityisesti tutkittiin miten soittajat käyttävät hyväkseen tonaliteettia, harmoniaa ja metriä. Aineistoa verrattiin psykologisissa testeissä saatuihin mm. tonaliteetin ja metrin havaitsemista koskeviin tuloksiin. Erityisesti C.L. Krumhanslin (esim. 1990a) psykologiset testit ovat keskeisiä tämän tutkimuksen kannalta. Niiden perusteella ihmiset näyttäisivät hahmottavan musiikissa käytettävät sävelet tietynlaisena hierarkkisena kokonaisuutena. Tämä ns. tonaalinen hierarkia antaa siten kuulijalle kognitiivisia referenssipisteitä, jotka helpottavat havainnoimista. Samalla tavalla myös musiikillisen metrin on huomattu olevan tärkeä kiinnekohta musiikin havaitsemisessa. Tutkimusten mukaan metrillä näyttäisi olevan merkitystä mm. musiikillisen oppimisen, odotusten ja huomion kiinnittämisen kannalta. – Vertailuaineistona käytettiin myös Ernst Terhardtin psykoakustista sointumallia (Terhardt et. al 1982a, 1982b; Parncutt 1988), jonka avulla voitiin määritellä tarkasti kullakin hetkellä soiva sointu.

Rhythm Changes -sointukulku perustuu AABA-rakenteelle. A-osa on yksinkertainen duurisointukulku, josta löytyy useita jazzille tyypillisiä harmonisia ratkaisuja. A-osasta saadut tulokset viittaisivat siihen, että tämän tyyppisessä jazzissa tonaliteetti on koko kappaleen tasolla hyvin samankaltainen empiirisissä kokeissa saatujen sävelprofiilien kanssa (tonaalinen hierarkia). Yksittäisten sointujen tasolla improvisoijilla näyttäisi olevan kognitiivisia referenssipisteitä tai -sointuja, jotka huomioidaan tarkemmin kuin muut rakenteessa olevat soinnut. Tulosten perusteella yleinen tonaliteetti ei ole staattinen kokonaisuus, vaan se kehittyy ja muuttuu dynaamisesti sointukulun edetessä. Silti on huomionarvoista, että AABA-rakenteen eri A-osien yleinen tonaliteetti oli lähes identtinen, vaikka osissa olikin paikallisia eroavaisuuksia. Lisäksi havaittiin, että sekä koko kappaleen että yksittäisten sointujen tasolla metristä rakennetta käytettiin hyväksi tonaalisesti tärkeiden sävelten painottamisessa. Metrisen rakenteen merkitys tuli ilmi myös siinä, että muusikot näyttivät painottavan enemmän sointuja, jotka olivat tahdin alussa kuin sointuja, jotka olivat tahdin jälkimmäisellä puoliskolla. Toisin kuin yleensä ajatellaan, synkopointia ja polymetriikkaa ei käytetty improvisaatioissa kovin usein, vaan metrin perusrakenne noudatti tavallisia 4/4-tahtilajin painotuksia (vrt. esim. Lerdahl & Jackendoff 1983).

Rhythm Changes -sointukulun B-osa on kvinttikiertoon perustuva sointukulku, jossa on ainoastaan dominanttisointuja. Tämän takia siinä ei ole mitään yksittäistä tonaalista keskusta toisin kuin A-osassa. Tulosten perusteella näyttäisi siltä, että jokaisen tahdin tonaliteetti pohjautuu alla olevaan sointuun, sillä tahdeissa painotettiin lähes aina alla olevan dominanttiseptimisoinnun tärkeimpiä säveliä. Kuten A-osassakin myös B-osassa muusikot painottivat metrisen rakenteen avulla tärkeitä säveliä; lisäksi improvisaatioissa näytti olevan selkeä fraasirakenne. Saadut tulokset viittaisivat myös siihen, että muusikot käyttivät tonaalista jännitystä ja sen laukaisemista hyväkseen. Tämä tuli ilmi siinä, että parittomissa tahdeissa käytettiin melko diatonista materiaalia, kun taas parillisissa tahdeissa soittajat näyttivät suosivan kromaattisempaa lähestymistapaa: erityisesti ns. vähennetyn asteikon keskeisiä säveliä painotettiin.

Nämä tulokset näyttäisivät osoittavan, että bebop-tyylinen jazzimprovisaatio on samanaikaisesti sekä dynaamista että erittäin pitkälle strukturoitua. Improvisaatioprosessi näyttäisi perustuvan suurelta osin erilaisille hierarkkisille periaatteille, jotka ylläpitävät sekä musiikin sisäistä koherenssia että mielenkiintoa. Lisäksi tulokset osoittavat, että improvisoidessaan ihminen pystyy hallitsemaan kognitiivisesti monimutkaisia hierarkkisia rakenteita ja apukeinoja, jotka helpottavat improvisaatiolle ominaisia kognitiivisia rajoituksia. On myös huomattava, että nämä tulokset ovat sopusoinnussa musiikillisen kognition alueella tehtyjen empiirisen tutkimusten kanssa: erityisesti on mainittava tonaliteetin havaitsemiseen ja kehittymiseen liittyvä tutkimus (esim. Krumhansl & Shepard 1979 sekä Krumhansl & Kessler 1982) sekä tutkimukset, joissa on selvitetty metrin vaikutusta musiikin prosessointiin ja esittämiseen (esim. Palmer 1989, Palmer and Krumhansl 1990, Jones 1992 sekä Drake & Palmer 1993).

Näillä tutkimustuloksilla lienee merkitystä yleisemminkin musiikin tutkimuksen kannalta. Ne nimittäin antavat täsmällisiä tietoja eräistä jazzimprovisaation kognitiivisista perusteista, jotka tulisi ottaa huomioon sekä tutkimuksessa että opetuksessa. Musiikin ja erityisesti improvisaation opetuksen kehittämisen kannalta tulokset näyttäisivät osoittavan, että saattaisi olla hyödyllistä ottaa opetuksessa aikaisempaa enemmän huomioon musiikissa olevat laajat harmoniset ja metriset rakenteet sekä niiden luomisessa käytettävät kognitiiviset strategiat. Joidenkin opiskelijoiden saattaisi olla helpompi sisäistää tietyn tyylinen improvisaatio, jos he tuntevat myös millaisia yleisperiaatteita jazzimprovisoijat ovat käyttäneet luodessaan merkittäviä improvisaatioita. Lisäksi käytetyt tilastolliset menetelmät antavat musiikin tutkijoille suhteellisen objektiivisen tavan lähestyä musiikkianalyysin ongelmia (esim. rakenteellisten sävelten paikallistaminen). Tulokset antavat myös mielenkiintoista tietoa bebop-improvisaatiossa käytettävistä tyylikeinoista ja niiden esiintymistiheyksistä. Tulokset näyttäisivät nimittäin olevan mielenkiintoisella tavalla ristiriidassa monien bebop-improvisaatiota koskevien luonnehdintojen kanssa. Siten ne ovat hyvä esimerkki siitä, kuinka ihmiset helposti yliarvioivat joidenkin ympäristöstä selvästi erottuvien elementtien esiintymistiheyden (vrt. Fiske & Taylor 1983).

Tutkimus osoitti myös, että erityisesti Krumhanslin esittämä ajatus tonaalisesta hierarkiasta on käyttökelpoinen käsite tutkittaessa bebop-tyylistä jazzimprovisaatiota. Tulosten perusteella näyttäisi olevan perusteltua olettaa, että jazzimprovisoijat käyttävät soittaessaan hyväkseen jonkinlaista abstraktia yleistä tonaliteettia. On myös mielenkiintoista, että improvisaatioiden yleinen tonaliteetti vastaa suurelta osin myös tonaalisesta eurooppalaisesta taidemuusikista löydettyä sävelten tilastollista distribuutiota (vrt. Knopoff & Hutchinson 1983). Tämän tyyppinen tonaliteetti näyttäisikin olevan jossain määrin musiikinlajista riippumaton ainakin länsimaisessa musiikissa. Siten esimerkiksi Schubertin lied ja tenorisaksofonisti Hank Mobleyn improvisaatio ovat yleisellä tonaalisella tasolla samankaltaisia, vaikka ne kuulostavatkin hyvin erilaisilta. Kuitenkin on huomattava, että nämä eri musiikinlajien ja musiikin havaitsemisessa löydetyt yhtäläisyydet eivät ole todiste tällaisen tonaliteetin universaaliudesta tai sen jonkinlaisesta synnynnäisestä pohjasta. Pikemminkin on luultavaa, että ihmiset omaksuvat tietyn tyyppisen tonaliteetin kuunnellessaan musiikkia (vrt. Castellano, Bharucha, & Krumhansl 1984). Tonaliteetti saattaa siten poiketa kulttuurista riippuen, mutta näyttäisi olevan perusteltua olettaa, että se silti aina noudattaa samankaltaisia yleisiä kognitiivisia periaatteita.