6

ANALYSIS OF SELECTED COMPOSITIONS

This chapter is devoted to the entropic analysis of a number of selected compositions, the results of which are summarised in Chapter 7. The first part of this chapter deals with the more fundamental aspects of entropy calculations—in other words, sets comprising single elements such as pitch distribution. In the second part, compound calculations, those comprising more than one order, are shown and discussed. These are pitch analyses based on ratio, and analyses based on pitch combined with note values.

For the sake of reference, a distinction is made between note values and rhythm. When referring to note values, the duration of a note (or rest) as an independent unit is implied, with the smallest unit being 128^{th}. For instance, a quarter note has a value of 32, while a whole note has a value of 128. Rhythm refers to the grouping of notes (and rests) according to patterns of note sequences. In other words, whereas note value refers to a note's temporal property, rhythm refers to its recurrent position in a linear sequence of notes.

6.1 Selection of the music

The melodies of twenty-two compositions analysed were selected from three categories of music: seven from the popular repertoire of the last twenty years, eight from the Art song tradition of the 18^{th} century, and seven songs from the repertoire of Art songs of the 20^{th} century. The reason the Classical Art song group has one more composition than the other groups is that one composition,

Schubert's *Ave Maria* shows characteristics that are similar to those of the Popular Music group. As will be made clear in the following section, this composition is treated separately.

In the following discussion, tables, and graphs the abbreviations 'P', 'S' and 'M' are used to refer to the categories 'Popular songs', 'Serious Art songs' and 'Modern Art Songs' respectively. These labels are not intended to imply any qualitative attributes to any of the categories, but are merely used for the sake of expediency and identification. They distinguish between three styles of music which are different in character, style, and in many ways, in purpose.

Appendix I contains the scores of the melodies of the twenty-two songs.

6.1.1 Popular contemporary music

The selection of the popular music for analysis proved to be more difficult than had been anticipated. Originally the intention was to request sales statistics from the larger recording companies and publishers. For many years, weekly or monthly charts were made available by these companies indicating the 'Top Ten' or 'Top Twenty' most popular recordings for that week or month. Because of the complex preference for different kinds of music in South Africa, these popularity charts are no longer made available on a regular basis, the reason being that only sales of Western popular music used to be represented in these charts, disregarding the popularity and sales of township music which often exceeds the sales of Western pop music in this country.

A number of record companies were nevertheless prepared to provide the candidate with the sales figures for 1994, but is was soon realised that by limiting the selection of items from this list would in reality limit the choice to a specific and limited period. This could mean that a song appeared on the list of top sellers because of greater promotional efforts by the publishers or exposure by the media. That an artist may already enjoy a degree of popularity with his audience could have an important influence on the sales of a new recording. However, many of the songs that appear on popularity lists do not maintain their popularity for extended periods and are soon forgotten.

An additional problem was that very few of the compositions that appear on popularity lists are immediately available as sheet music. Transcriptions are usually only made available after a piece has proven its popularity over an extended time, and depending on popular demand. The information provided by the record companies was of the most popular albums sold during 1994. Sales figures of record albums do not necessarily give any indication which individual song (or songs) in the collection is the most popular. The decision therefore was to select songs based on their consistent popularity. In other words, songs that essentially have become 'classics' in their own right. That the more consistently popular items usually come out in print, already suggested which items to choose from the repertoire available. Obviously, the choice had to be limited to only a small selection from this large repertoire. In a sense, based on the arguments mentioned, the music publishing industry has made the

selection of popular music possible by its own dynamics[1]. Periodically, collections of compositions of the most popular items are being made available in both recorded and printed form. Since these collections are expensive to produce, it is obvious that mainly those compositions that have a proven record of popularity over a longer period are included in such collections.

A variety of CD catalogues and guides were used to ascertain the most popular recordings and which appeared most frequently in the recording guides. The sheet music for these items were also readily available, most often in albums or collections that confirmed the continuing popularity of the chosen items.

Items included in the popular music selection all became popular during the 1970s and the 1980s and therefore have a proven popularity history of between one and two decades. They are:

1. Benny Andersson & Björn Ulvaeus (music and lyrics), *Thank you for the music*, London: Bocu music, 1977. Made popular by the Swedish group, ABBA.

2. Phil Collins (music and lyrics), *One more night*, London: Hit and Run Music, 1984. Recorded on Virgin Records by Phil Collins himself, and one of the singer's most popular compositions to date.

3. John Denver (music and lyrics), *Annie's song*, London: Winter Hill Music, 1974. Recorded on RCA Records by the composer.

4. Claudio Gizzi (music), *Summer love*, Johannesburg: EMI-Brigadiers Music, 1976. Another instrumental piece, made popular by the Pan-flute player Zamfir on Philips (TOS 1072). The cover of the score states that this piece was '16 weeks on the Springbok Top 20'.

5. Johnny Pearson (music), *Sleepy shores*, theme from the BBC TV series *Owen M.D.*, Johannesburg: Bandstand Publications, 1971. This is not a song; it is a piano solo of which the melody is still very popular today.

6. Stevie Wonder (music and lyrics), *You are the sunshine of my life*, Hollywood: Stein & van Stock and Black Bull Music, 1972. Recorded on Tamla Records. This item was made popular by Stevie Wonder himself and is one of his songs that helped to make him popular.

7. Victor Young (music) and Edward Heyman (lyrics), *Love letters*, Woodford Green: Warner Bros/IMP, 1988. Originally published in 1945. Although this piece was composed fifty years ago, it was included because of the fact that it was revived during the 1980s. It would therefore be interesting to see how it compared with the more recent compositions.

All the items in the list above are by different composers, and were made popular by different artists. Because of their lasting popularity amongst the general public, these items may be regarded as representative of the popular music that appeared over a twenty year period. It seems a fair deduction

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[1] In this case Market forces.

that they therefore contain those elements that are appealing to the listeners.

6.1.2 Classical Art Song selection

Since most art songs are available in print and have been on the market for many years, the popularity of music from the 'serious music' repertoire could not be judged by the availability of published albums. A different method had to be used to establish the popularity of this category of music. Here the selection was based on the inclusion in *The Gramophone Good CD Guide 1994*.[2] Those compositions that were recorded most frequently by a variety of performers was the primary criterion for the selection of this list. Performers of this category of music are usually highly professional and know the preferences of their audiences. Recording companies are also more likely to invest in recordings that–because of the music or the fame of the performer–ensures maximum financial returns.

The items included in this list are:

1. Johannes Brahms, 'Nachtigall', Op. 97, No. 1, *15 Selected Songs*, Book II, London: Alfred Lengnick, 1931, p. 10.
2. Johannes Brahms, 'Liebestreu', Op. 3, No. 1, *15 Selected Songs*, Book II, London: Alfred Lengnick, 1931, p. 21.
3. Franz Schubert, Die schöne Müllerin: 'Halt', *Schubert First Vocal Album*, New York: Schirmer, 1895, p. 12.
4. Franz Schubert, Die schöne Müllerin: 'Das Wandern', *Schubert First Vocal Album*, New York: Schirmer, 1895, p. 3.
5. Franz Schubert, 'Rosamunde', *Schubert First Vocal Album*, New York: Schirmer, 1895, p. 292.
6. Franz Schubert, 'Ave Maria', *Schubert First Vocal Album*, New York: Schirmer, 1895, p. 258.
7. Robert Schumann, Dichterliebe: 'Ich will meine Seele tauchen', Op. 48, *Norton Critical Scores*, edited by Arthur Komar, New York: Norton, 1971, p. 22.
8. Robert Schumann, Dichterliebe: 'Das ist ein Flöten und Geigen', Op. 48, *Norton Critical Scores*, edited by Arthur Komar, New York: Norton, 1971, p. 31.

One of the items in the list, Schubert's *Ave Maria*, proved a particularly interesting choice. It is not only a well know Arts song, but featured on various popularity charts during the 60s and 70s. In this chapter, continuous reference is made to this fact and the effects it has on the results of the analysis.

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[2] Christopher Pollard (Ed.), Harrow: General Gramophone Publications, 1994.

This composition is included in the S-group because of its historic placement in the Classical period.

6.1.3 20th Century Art Song selection

Whereas the compositions of the Popular Music group and the Classical Art Song group were selected because of their proven popularity, the 20th Century Art Song group are compositions that have had relatively little exposure as recordings. That no, or few recordings of these songs are available on the market, tends to indicate that they are generally unknown and possibly less popular. An important factor is that these songs all demonstrate contemporary tonal or rhythmic elements, which distinguishes them from the other two categories as well.

The eight items selected for this purpose are:

1. Alban Berg, 'Nun ich der Riesen', No. 3 from Four Songs, Op. 2, *Anthology of Twentieth-century Music*, edited by Mary H. Wennerstrom, Englewood Cliffs: Prentice-Hall, 1969, pp. 30-31.
2. Lennox Berkeley, 'How love came in', *A Heritage of 20th Century British Song*, Vol. 2. Boosey & Hawkes, 1977, pp. 6-8.
3. Arthur Bliss, 'Being young and green and green', *A Heritage of 20th Century British Song*, Vol. 2. Boosey & Hawkes, 1977, pp. 9-11.
4. Benjamin Britten, 'Since she whom I loved', *A Heritage of 20th Century British Song*, Vol. 2. Boosey & Hawkes, 1977, pp. 50-51.
5. Martin Dalby, 'Cupid and my Campaspe', *A Heritage of 20th Century British Song*, Vol. 2. Boosey & Hawkes, 1977, pp. 59-61.
6. Charles Ives, 'In Flanders fields', *Norton Anthology of Western Music*, edited by Claude V. Palisca, New York: Norton, 2nd edition, 1988, pp. 719-721.
7. Peter Warlock, 'Whenas the rye', *A Heritage of 20th Century British Song*, Vol. 2. Boosey & Hawkes, 1977, pp. 211-213.

6.2 Entropy analysis

Five elements of each composition in the three groups were subjected to analysis with Information Theory:

1. *Entropy values for pitch distribution*. The results for this method are the easiest to obtain and could be done manually, although it is laborious and prone to errors. In essence each pitch name constitutes a single element.

2. *Entropy values for pitch distribution and note values combined.* For these calculations the pitches and duration values combined to establish the elements of a set. A single element therefore has two dimensions, pitch and duration. A quarter note G, for example, is a different element than an eighth note G.

3. *Temporal ratios of pitches.* Unlike the two criteria above, which are based on the frequency of each element expressed as a ratio of the total number of elements, the temporal ratios of pitches are derived from the total duration that these pitches are heard as a ratio of the total duration of the music.

4. *Stochastic interval values.* The principle behind this method is that specific intervals or sequences of intervals may influence the selection of subsequent intervals, which in turn may again influence the next interval or groups of intervals. To obtain these values, a combination or *order* of interval sequences of increasing length are isolated as elements. The process begins with a single interval (order 1).

5. *Stochastic rhythmic values.* In essence the calculation of these values is similar to those for stochastic interval values, except that rhythmic values are used for the basis of the calculations instead of intervals.

The scores of each of the melodies are collected in Appendix I and may be used as reference in the following discussion. Appendix II contains a complete summary of all the entropy values, together with graphs for each of the compositions mentioned.

As mentioned earlier in this chapter, Schubert's *Ave Maria,* presents a unique situation. Although composed by a Romanticist, it has become very 'popular' and has been recorded by pop musicians and performers of Art songs alike. In fact this piece of music is one that has become very popular amongst various popular vocalists and instrumentalists of the last fifty years. The problem was, therefore, to which category it belonged. Eventually, the decision was made that it uniquely supports the hypothesis of this thesis. Hence it was treated as an individual item, a decision that proved invaluable to link the values of the Popular music group with those of the Serious music group. In the following tables and graphs the results of the analyses of this item are usually separated from the other compositions of the S-group and given additional attention throughout this chapter.

In the process of entering data in the database, all note values and pitches were used as they appear on the score. In traditional methods of analysis, repeats in music that are indicated by repeat signs are often ignored. For this research all repeats were included in the database, except when a composition as a whole is repeated, in which case there would be no change in its entropy. The reason is that repeats form an essential part of a composition's overall structure and contribute to the quantifiable elements of the music: number of pitches, groups of rhythmic and interval sequences as well as overall duration. Since repeated sections are an essential part of the character or style qualities of a composition it is important that they are included in an analysis of this nature.

6.2.1 Pitch entropy values

As was pointed out in Chapter 4, the study of Information Theory as applied to music began with the study of pitch distribution, and since this is also the least complex to calculate, it seems an appropriate point of departure. The following table lists all the pitch entropy values for the three groups of compositions described above. Column 3 shows the number of different pitches used in each composition. Pitch in this sense also refers to silences, in other words rests.

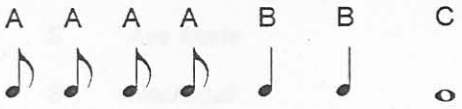
The entropy values of this analysis indicate how the composer chose his pitches. A lower entropy (or higher redundancy) indicates that is there less equality in the distribution of the pitches or alternatively, that the composer has shown a predilection for certain pitches. Perhaps the similarity of the entropy values is predictable, since most of the pieces are tonal and would, because of the inherent characteristics of tonal music, produce a similar pitch distribution in which certain degrees of the scale have greater tonal weight than others. It is noteworthy that the entropy value of *Ave Maria* is the lowest of all the items of the list. Alban Berg's *Nun ich der Riesen*, a dodecaphonic composition has the highest entropy.

From the table it is clear that the entropy values for the different groups show relatively little difference. The S-group shows a higher entropy than the P-group, and the average entropy of the M-group is slightly higher than the S-group. The difference between the lowest (*Ave Maria*) *and* highest entropy value is nearly 13.08 points.

Group	Title	Pitches	Pitch Entropy
P	*Annie's song*	9	82.54%
P	*You are the sunshine of my life*	13	83.87%
P	*Summer love*	21	84.40%
P	*Love letters*	13	85.77%
P	*One more night*	14	87.02%
P	*Sleepy shores*	29	89.11%
P	*Thank you for the music*	17	90.16%
		Average	86.12%
S	*Ave Maria*	13	81.42%
S	*Ich will meine Seele*	7	84.04%
S	*Das ist ein Flöten*	11	87.57%
S	*Liebestreu*	19	88.38%
S	*Halt*	10	89.46%
S	*Rosamunde*	11	90.33%
S	*Das Wandern*	9	91.90%
S	*Nachtigall*	18	93.02%
		Average	89.24%
M	*How love came in*	17	87.76%
M	*Whenas the rye*	23	88.43%
M	*Cupid and my Campaspe*	26	89.06%
M	*In Flanders fields*	13	89.69%
M	*Being young and green and green*	18	91.66%
M	*Since she whom I loved*	21	91.79%
M	*Nun ich der Riesen*	18	94.50%
		Average	90.41%

Table 6-1. Pitch entropies for the three composition groups

As was mentioned in Chapters 2 and 3, calculations based exclusively on pitch names are not sufficient to make any conclusive deductions. Table 6-1 seems to support this argument, especially since there is so much overlapping among the three groups. This suggests that unless all the notes in the music are of equal length, pitch quantity by itself does not accurately reflect the true information of the pitch distribution in a piece of music. For example, the sequence of notes below contains 4 As, 2 Bs and 1 C, a ratio of 57.14%, 28.58% and 14.28% respectively:



If the same sequence is considered according to the total time that each note is heard, in other words if the temporal properties are also considered, there is a radical change in ratios: A = half note, B = half note and C = whole note. The ratios then are 25%, 25% and 50% respectively. Since the maximum entropy for the three notes remains the same, regardless of the type of calculation, it is obvious that the two calculations would produce widely disparaging relative entropy values. The calculations that incorporate the temporal values seem to be more accurate since it reflects the actual duration that each note is heard as a ratio of the duration of the whole piece.

For the sake of comparison and completeness, and where applicable, the tables that follow include the entropy values for pitches.

6.2.2 Pitch-ratio entropy values

In Communication Science entropy is usually measured in terms of time, it seems logical that the temporal element should somehow feature in the calculations. Table 6-2 illustrates the entropies of pitches calculated as a ratio of duration. The last column in the table contains the entropy values of Table 6-1 to facilitate comparison.

The effect of calculating pitches by their ratios, instead of by merely counting them, is already obvious by the different position of each of the compositions in the table. For instance, *Sleepy shores* has the sixth highest entry for the P-group in Table 6-1 but moves to the position with the highest entropy for the S-group in Table 6-2. *Nachtigall*, which has the highest entropy value in the preceding table now moves to the second position overall. The reasons for these changes were explained in the preceding section and are confirmed here; the actual period that a pitch is sounded may be much shorter or longer than might be suggested by the frequency of pitches.

The entropy value of *Ave Maria* maintains its low position in the list, and shows an even lower entropy value than in Table 6-1, confirming that it is not only the most predictable as far as the pitch distributions is concerned, but also when the entropy of the pitches are calculated in respect of their temporal values. In fact the temporal pitch entropy suggests a predictability of just under 25% (75.5% entropic).

Group	Title	Pitches	Pitch ratio Entropy	*Pitch only*
P	*You are the sunshine of my life*	13	78.42%	*83.87%*
P	*One more night*	14	82.70%	*87.02%*
P	*Summer love*	21	83.46%	*84.40%*
P	*Annie's Song*	9	83.87%	*82.54%*
P	*Thank you for the music*	17	85.95%	*90.16%*
P	*Love letters*	13	86.73%	*85.77%*
P	*Sleepy shores*	29	88.15%	*89.11%*
		Average	84.18%	86.12%
S	*Ave Maria*	13	75.70%	*81.42%*
S	*Nachtigall*	18	83.79%	*93.02%*
S	*Liebestreu*	19	87.32%	*88.38%*
S	*Rosamunde*	11	87.45%	*90.33%*
S	*Ich will meine Seele*	7	88.27%	*84.04%*
S	*Das ist ein Flöten*	11	88.21%	*87.57%*
S	*Halt*	10	88.93%	*89.46%*
S	*Das Wandern*	9	94.21%	*91.90%*
		Average	88.31%	*89.24%*
M	*Cupid and my Campaspe*	26	83.81%	*89.06%*
M	*How love came in*	17	84.27%	*87.76%*
M	*In Flanders fields*	13	87.17%	*89.69%*
M	*Whenas the rye*	23	88.60%	*88.43%*
M	*Being young and green and green*	18	89.47%	*91.66%*
M	*Nun ich der Riesen*	18	90.66%	*94.50%*
M	*Since she whom I loved*	21	90.93%	*91.79%*
		Average	87.84%	*90.41%*

Table 6-2. Pitch ratio entropies for the three composition groups

The difference between the lowest and highest entropy values has now increased to 18.51 points, an indication that the duration of the pitches has made a dramatic difference to the pitch distribution. On average, the S-group (excluding *Ave Maria*) has a slightly higher entropy than the M-group.

A graph illustrates the tendency of higher entropy values for the S-group and the lower tendencies of the values for the P-group. There is, however, an area where the higher values of the P-group and S-group overlap with the lower ranges of the S-group and M-group, indicated by the dotted rectangle:

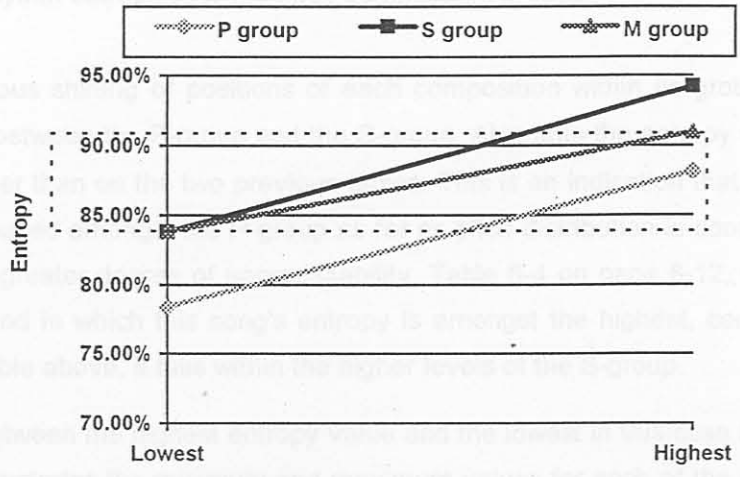


Figure 6-1. Maximum and minimum ranges for the pitch-ratio entropies

6.2.3 Pitch-Rhythm entropy values

A third method of calculating the entropy values of pitches is to combine them with their rhythmic values (in contrast to duration). In other words, a note, C, with the rhythmic value of a quarter note differs from a C with a value of an eighth note. This approach effectively combines the predictability (redundancy) of the pitch distribution with that of the first order rhythmic entropy. The entropy values are shown in the next table. The entropy values shown in Table 6-1, and Table 6-2 are shown again for the sake of comparison.

Group	Title	Pitches	Pitch/Rhythm Entropy	*Pitch Ratio Entropy*	*Pitch only*
P	*Summer love*	21	82.96%	*83.46%*	*84.40%*
P	*Love letters*	13	84.76%	*86.73%*	*85.77%*
P	*Annie's song*	9	86.57%	*83.87%*	*82.54%*
P	*You are the sunshine of my life*	13	87.22%	*78.42%*	*83.87%*
P	*Thank you for the music*	17	88.95%	*85.95%*	*90.16%*
P	*Sleepy shores*	29	89.70%	*88.15%*	*89.11%*
P	*One more night*	14	90.42%	*82.70%*	*87.02%*
		Average	87.23%	*84.18%*	*86.12%*
S	*Ave Maria*	13	90.81%	*75.70%*	*81.42%*
S	*Ich will meine Seele*	7	87.94%	*88.27%*	*84.04%*
S	*Halt*	10	88.89%	*88.93%*	*89.46%*
S	*Liebestreu*	19	91.32%	*87.32%*	*88.38%*
S	*Das Wandern*	9	93.06%	*94.21%*	*91.90%*
S	*Das ist ein Flöten*	11	94.10%	*88.21%*	*87.57%*
S	*Rosamunde*	11	94.66%	*87.45%*	*90.33%*
S	*Nachtigall*	18	95.42%	*83.79%*	*93.02%*
		Average	92.20%	*88.31%*	*89.24%*
M	*Since she whom I loved*	21	90.88%	*90.93%*	*91.79%*
M	*Cupid and my Campaspe*	26	91.31%	*83.81%*	*89.06%*
M	*How love came in*	17	92.24%	*84.27%*	*87.76%*
M	*Whenas the rye*	23	93.05%	*88.60%*	*88.43%*
M	*In Flanders fields*	13	93.06%	*87.17%*	*89.69%*
M	*Being young and green and green*	18	94.88%	*89.47%*	*91.66%*
M	*Nun ich der Riesen*	18	97.94%	*90.66%*	*94.50%*
		Average	93.34%	*87.84%*	*90.41%*

Table 6-3. Pitch-rhythm entropies for the three composition groups

Besides the obvious shifting of positions of each composition within its group, there is now also a greater disparity between the P-group and the S-group. Also note the entropy value of *Ave Maria* that is now much higher than on the two previous tables. This is an indication that although this particular piece may be grouped amongst the P-group as far as pitch distribution is concerned, its rhythmic entropy indicates a greater degree of unpredictability. Table 6-4 on page 6-12, which contains the first order entropies and in which this song's entropy is amongst the highest, confirms this observation. Likewise in the table above, it falls within the higher levels of the S-group.

The difference between the highest entropy value and the lowest in this case is nearly 16 points. The following graph illustrates the minimum and maximum values for each of the groups. The dotted rec-

tangle indicates the area where minimum and maximum entropy levels of the three groups overlap:

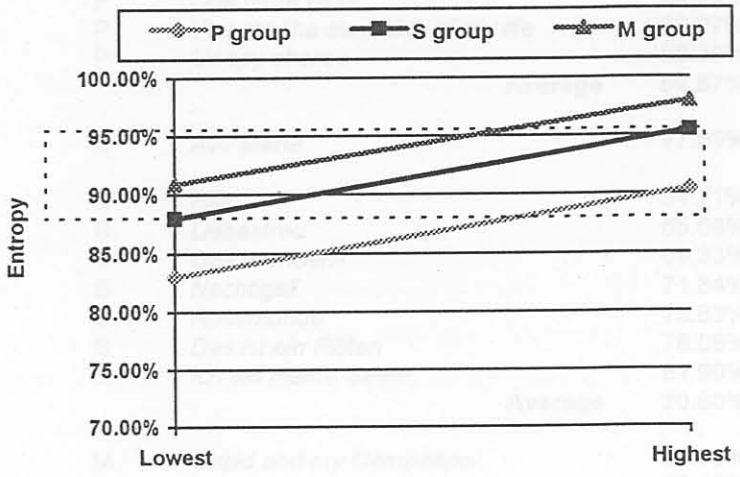


Figure 6-2. Maximum and minimum ranges for the pitch-rhythm entropies

Unlike the graph of Figure 6-1 where the S-group is higher than the M-group, Figure 6-2 shows that the positions have reversed. From Table 6-2 and Table 6-3 it is obvious that the Popular music selection (P-group) generally has a higher redundancy rate than the Serious Art music group (S-group), but that the lesser known 20th century songs (M-group) are essentially similar to the Serious Art song selection. That entropies which take the rhythms in consideration are more redundant in the case of Popular songs, is an indication that these pieces are rhythmically more stagnant, more repetitive and less varied; in other words more predictable.

6.2.4 Rhythm entropy values

The difference in the distinct rhythmical character of each of the groups of songs is even more evident by isolating the rhythms for entropic analysis. The following table only shows the first order of rhythmic grouping. Later in this chapter all the rhythmic orders are shown.

From the table below it is obvious that the rhythmic coherency or predictability is especially marked in the P-group and M-group. Important is the fact that—compared to the entropy values for pitches only, and entropy values for the pitch ratios—the rhythmic entropy values for all the compositions are significantly lower. One of the items, *Thank you for the music*, is below 50%, indicating that its rhythmic structure is more than 50% predictable. This seems to indicate that rhythmic coherency is an important factor in music's appeal to the listener. The Classical group of songs are rhythmically much more complex than the Popular group and, to a lesser extent, than the 20th century group.

Group	Title	Rhythmic Entropy
P	*Thank you for the music*	48.24%
P	*Summer love*	50.85%

P	*Love letters*		57.66%
P	*Annie's song*		61.57%
P	*One more night*		64.40%
P	*You are the sunshine of my life*		68.07%
P	*Sleepy shores*		68.30%
		Average	**59.87%**
S	*Ave Maria*		77.89%
S	*Halt*		54.71%
S	*Liebestreu*		65.68%
S	*Das Wandern*		68.33%
S	*Nachtigall*		71.84%
S	*Rosamunde*		73.63%
S	*Das ist ein Flöten*		78.08%
S	*Ich will meine Seele*		81.90%
		Average	**70.60%**
M	*Cupid and my Campaspe*		53.73%
M	*Since she whom I loved*		59.12%
M	*How love came in*		63.38%
M	*In Flanders fields*		66.56%
M	*Whenas the rye*		70.45%
M	*Being young and green and green*		74.40%
M	*Nun ich der Riesen*		84.63%
		Average	**67.47%**

Table 6-4. Rhythmic entropies for the first order for the three composition groups

The difference between the highest and lowest values in this case is 46.39 points. The graph below shows the maximum and minimum entropy values for the first order rhythmic entropy values of each group. The dotted rectangle indicates where there is overlapping of maximum and minimum values:

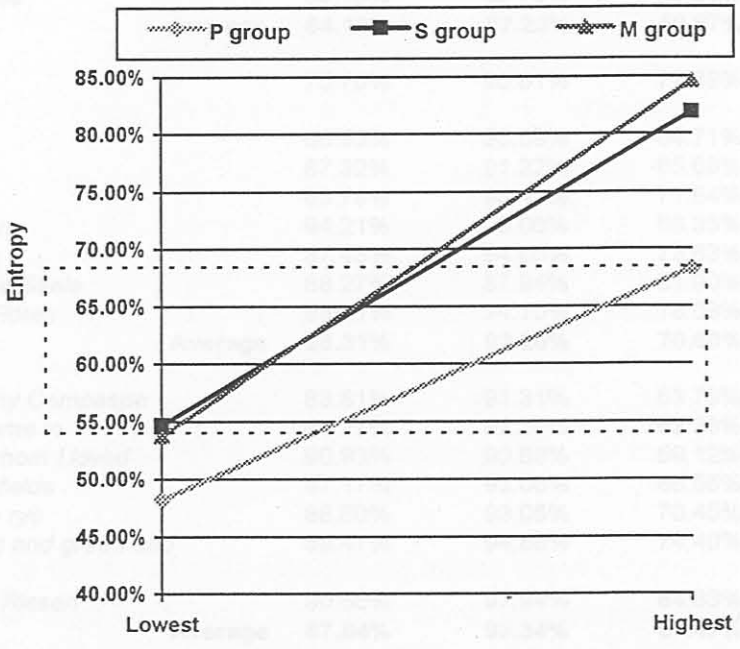


Figure 6-3. Maximum and minimum ranges for the first order rhythm entropies

In the discussion of the interval orders later in this chapter, it will be shown that the composers of the modern pieces have relied more on interval variation, and that they possibly resorted to a greater rhythmic redundancy to achieve musical coherency. The difference between the pitch entropy and the rhythmic entropy of *Ave Maria*, may be a similar balancing factor in which the greater rhythmic entropy compensates for the predictability of the pitch set.

At this stage it is clear that the selected compositions are mainly differentiated in respect of their temporal pitch distribution (Table 6-2), rhythmic entropy and a combination of both (Table 6-3). It has also been shown that pitch entropy by itself has little bearing on the intrinsic stylistic character of the music but that pitch-entropy calculations only become effective when note values and rhythm are taken into account. Considering the tables shown so far, many of the calculations for exclusive pitch distribution actually contradict the entropies calculated for the combination of pitch and rhythmic values.

The entropy values illustrated in Table 6-2, Table 6-3, and Table 6-4 are summarised in the table below. Although there is some overlapping of values, the averages of the pitch-ratio, pitch-rhythm and rhythm entropy values already provide a good pointer to the stylistic entropy values of the various genres. The entropy values for pitch distribution are not included for the reasons already expounded on earlier in this chapter.

Group	Title	Pitch ratio Entropy	Pitch/Rhythm Entropy	Rhythmic Entropy	Average entropy
P	*Summer love*	83.46%	82.96%	50.85%	72.42%
P	*Thank you for the music*	85.95%	88.95%	48.24%	74.38%
P	*Love letters*	86.73%	84.76%	57.66%	76.38%
P	*Annie's song*	83.87%	86.57%	61.57%	77.34%
P	*You are the sunshine of my life*	78.42%	87.22%	68.07%	77.90%
P	*One more night*	82.70%	90.42%	64.40%	79.17%
P	*Sleepy shores*	88.15%	89.70%	68.30%	82.05%
	Average	**84.18%**	**87.23%**	**59.87%**	**77.09%**
S	*Ave Maria*	75.70%	90.81%	77.89%	81.47%
S	*Halt*	88.93%	88.89%	54.71%	77.51%
S	*Liebestreu*	87.32%	91.32%	65.68%	81.44%
S	*Nachtigall*	83.79%	95.42%	71.84%	83.68%
S	*Das Wandern*	94.21%	93.06%	68.33%	85.20%
S	*Rosamunde*	87.45%	94.66%	73.63%	85.25%
S	*Ich will meine Seele*	88.27%	87.94%	81.90%	86.04%
S	*Das ist ein Flöten*	88.21%	94.10%	78.08%	86.80%
	Average	**88.31%**	**92.20%**	**70.60%**	**83.70%**
M	*Cupid and my Campaspe*	83.81%	91.31%	53.73%	76.28%
M	*How love came in*	84.27%	92.24%	63.38%	79.96%
M	*Since she whom I loved*	90.93%	90.88%	59.12%	80.31%
M	*In Flanders fields*	87.17%	93.06%	66.56%	82.26%
M	*Whenas the rye*	88.60%	93.05%	70.45%	84.03%
M	*Being young and green and green*	89.47%	94.88%	74.40%	86.25%
M	*Nun ich der Riesen*	90.66%	97.94%	84.63%	91.08%
	Average	**87.84%**	**93.34%**	**67.47%**	**82.88%**

Table 6-5. Summary of pitch and rhythm entropy values

A graph illustrates the entropic differences between the maximum and minimum values of the three

groups and shows that there is a degree of overlapping of the maximum values of the P- and M-groups and the minimum values of the S-group.

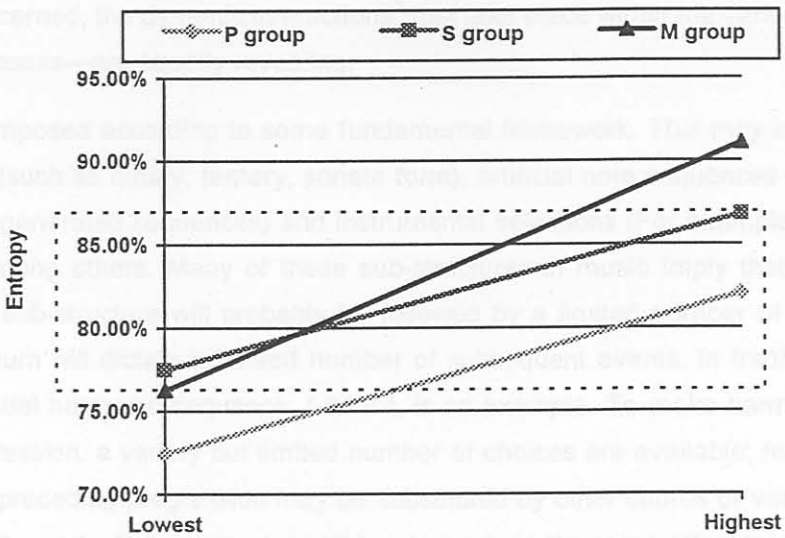


Figure 6-4. Maximum and minimum range of average entropy values

The results thus far indicate that:

1. both pitch distribution and rhythmic organization is more complex in the Classical Art songs (S-group) than in the other two groups; and
2. there seems to be a lower entropy limit for both pitch and rhythmic distribution. It appears that the lower limit for pitch distribution is around 80% while that for rhythm is around 60%. These figures are approximations and not fixed and may even be lower for other genres of music or individual pieces. Children's songs and certain types of folk songs, which centre on the pentatonic scale would probably have lower limits and lower entropy values.

Intuitively one may suspect that much popular music relies on rhythmic simplicity and repetitiveness for its popularity. Should the repetitive accentuation of beats, so often found in popular music, be taken into account along with the indicated redundancy levels, the overall entropy values of this music would drop dramatically. Some years ago, various recordings of some of the better known 'Classics' were released in which the beats are strengthened by percussion instruments and bass guitars that enhance the basic harmonic progressions. These recordings became very popular possibly because the entropy of both the rhythm (percussion) and the harmony (reinforced bass line) were lowered.

It is conceivable that music that generates entropy values below a certain limit may be equally unpopular as music of which the entropy is too high. Music with entropy values that are too low could then be described as monotonous and boring, while music with very high entropy values would be described as being too 'heavy'. Nevertheless, this is probably a matter of individual preference with different people having different entropy tolerances.

6.3 Stochastic music analysis

Although the figures obtained so far have already provided some significant information about the compositions concerned, the dynamic interactions[3] that take place within the various aspects of music —stochastic processes—are equally revealing.

Most music is composed according to some fundamental framework. This may include tonality, pre-conceived forms (such as binary, ternary, sonata form), artificial note sequences (for example serialism, or computer generated sequences) and instrumental selections (For example SATB choir, string quartets, etc.), among others. Many of these sub-structures in music imply that each new musical event within that sub-structure will probably be followed by a limited number of other and different events, which in turn will dictate a limited number of subsequent events. In traditional harmony, the well-known cadential harmonic sequence, I-IV-V-I, is an example. To make harmonic sense at each stage of the progression, a variety but limited number of choices are available; for example, some of the chords in the preceding progression may be substituted by other chords or variations of the same chord: I-II-V^7-I. If the cadential progression still has to produce the same effect this kind of substitution of chords cannot be done at random but is controlled by convention. The keyword here is 'progression', which in itself implies that there are certain self-generating dynamics within the tonal system. Even the most rudimentary handbooks on harmony make this abundantly clear. Similar 'rules' apply to many other aspects of music, including the progression of melodic intervals, or what is also referred to as voice leading.

Nevertheless, within the mentioned structures (melodic, harmonic, rhythmic) there is also a factor of randomness. The mentioned examples have a single common denominator—random selection from a limited set of possibilities. Amongst Information scientists this is referred to as stochastic[4] processes.

6.3.1 Stochastic interval entropy

Stochastic analysis of the interval contents of in music is the next step in the entropic analysis of the music for this research. To obtain the results shown in the following pages, ever increasing series (orders) of interval sequences were compared. The results obtained, essentially reflect the frequency at which specific events—in this case intervals—are followed by other specific events, in ever increasing complexity and expressed as a ratio of the overall number of events of the same order.

The number of orders generated by each composition varies and is specific and directly related to the complexity of the intervals used. In the charts that follow the generation of orders was halted when the entropy values reached 100%, or when the order number reached 70. Once the entropy has

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[3] Structural principles that are inherent in voice leading and rhythmical coherency.

[4] Derived from the Greek word 'stochos' which means to aim for or to target.

reached 100% each order thereafter also has an entropy of 100%. Essentially this means those interval sequences that belong to these orders only occur once and, in other words, have reached maximum distribution or randomness. The software used to generate these values could not accurately manipulate character strings that exceeded 256 characters. Since each interval is represented by 3 characters (size, octave and direction) the number of intervals per order was limited to 85. For the sake of accuracy the number of orders was reduced to a maximum of 70. This was not seen as a major drawback since only four of the compositions used for this study exceeded the 70th order, while the next highest was 54 orders (*Rosamunde*).

All the interval orders for the compositions under discussion are shown below:

Group	Title	Interval Orders
P	*Summer love*	22
P	*Love letters*	34
P	*Annie's song*	39
P	*You are the sunshine of my life*	40
P	*Thank you for the music*	70
P	*One more night*	70
P	*Sleepy shores*	70
	Average	49.29
S	*Ave Maria*	70
S	*Nachtigall*	4
S	*Das ist ein Flöten*	14
S	*Das Wandern*	15
S	*Halt*	18
S	*Ich will meine Seele*	19
S	*Liebestreu*	25
S	*Rosamunde*	54
	Average	21.29
M	In Flanders fields	7
M	Whenas the rye	8
M	Being young and green	3
M	Nun ich der Riesen	3
M	Cupid and my Campaspe	9
M	Since she whom I loved	9
M	How love came in	20
	Average	8.43

Table 6-6. Comparative Interval-Order quantities

Keeping in mind that the extent of the interval orders is directly related to the inherent structural arrangement of the intervals of a composition, the table above is rather revealing. The P-group of songs on average has the largest number of orders with three of the individual items generating more than 70 orders.

Excluding *Ave Maria,* the S-group produced orders that are on average less than half that of the P-group, indicating a greater overall interval complexity, fewer repeated sequences, and greater variety–in other words, a lower degree of predictability. Again, *Ave Maria,* which also produced more than 70 orders, is the exception for the S-group. This suggests that, besides the redundancy of the pitch

distribution, this song's popularity may also be ascribed to its predictable interval relationships.

Whereas, the M-group indicated little to distinguish in the comparison of the pitch, pitch-ratio, pitch-rhythm, and rhythmic entropies, it features far fewer interval orders than the other two groups. This indicates that the interval sequences of these songs are even less predictable than those of the S-group, further supporting the argument that the composers of these songs relied more on rhythmic unity, and—in some instances—pitch distribution to provide musical coherency, and that they used interval variation to provide musical interest.

However, the quantity of interval orders is not the most important aspect of the interval analysis. Each order is associated with an entropy value as well. The most convenient manner of illustrating these entropy values is by presenting them as graphs. The following series of graphs show the curves of the change in entropy values of each composition in the order they are listed in the table above. Since the first number orders show the transition between orders most clearly and to ensure similar visual representation, only the first 15 orders of each of the songs are shown. See Appendix II for a complete list of orders and entropies for each of the songs.

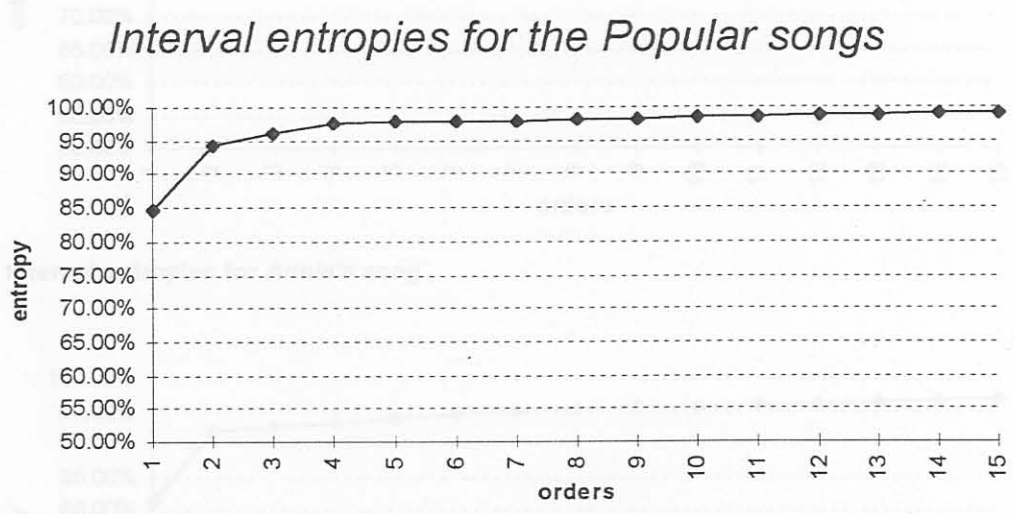

Figure 6-5. Interval entropies for *Summer love*

Figure 6-6. Interval entropies for *Love letters*

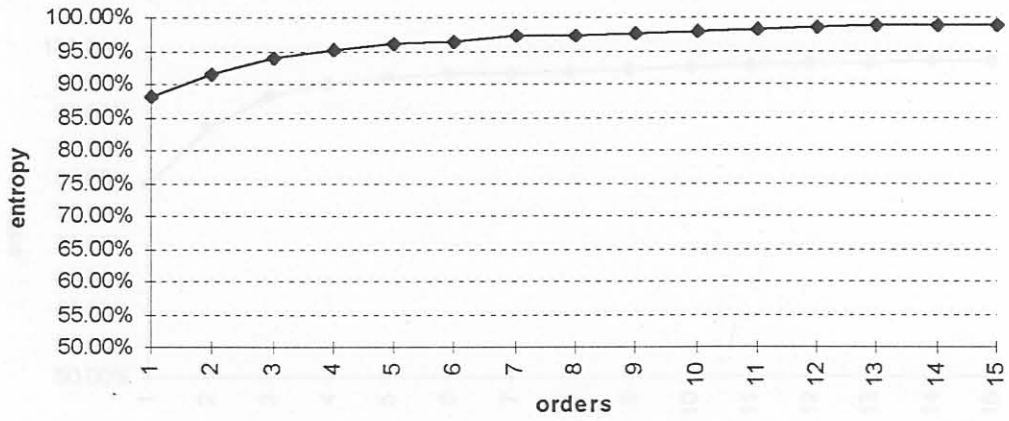

Figure 6-7. Interval entropies for *Annie's song*

Figure 6-8. Interval entropies for *You are the sunshine of my life*

Figure 6-9. Interval entropies for *Thank you for the music*

Figure 6-10. Interval entropies for *One more night*

Figure 6-11. Interval entropies for *Sleepy shores*

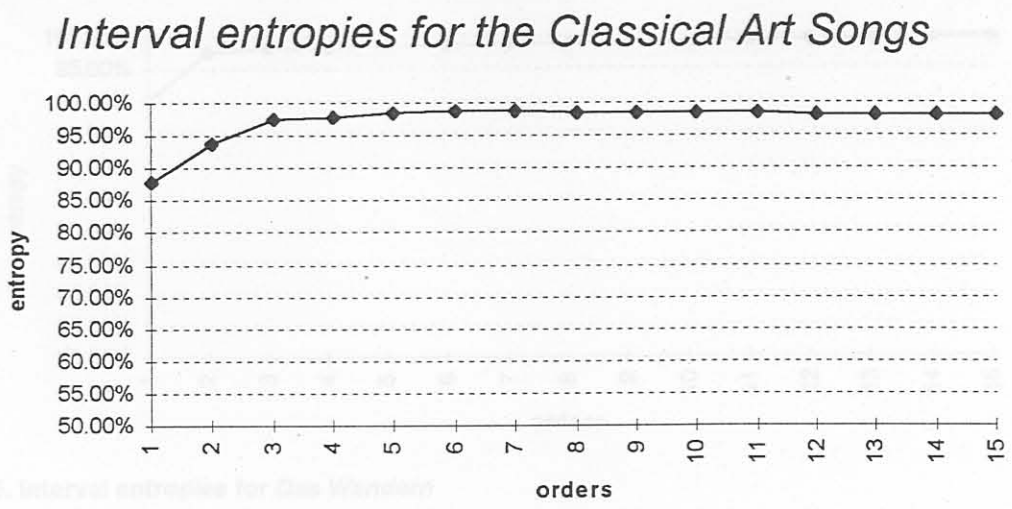

Figure 6-12. Interval entropies for *Ave Maria*

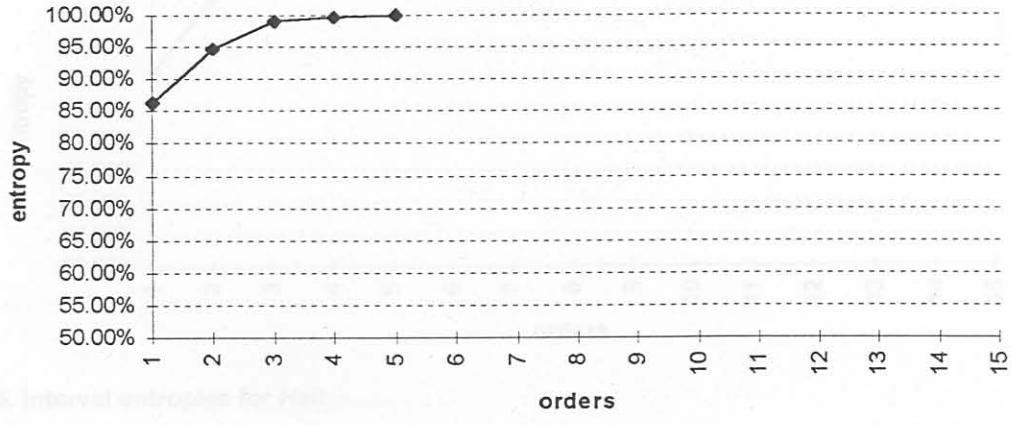

Figure 6-13. Interval entropies for *Nachtigall*

Figure 6-14. Interval entropies for *Das ist ein Flöten*

Figure 6-15. Interval entropies for *Das Wandern*

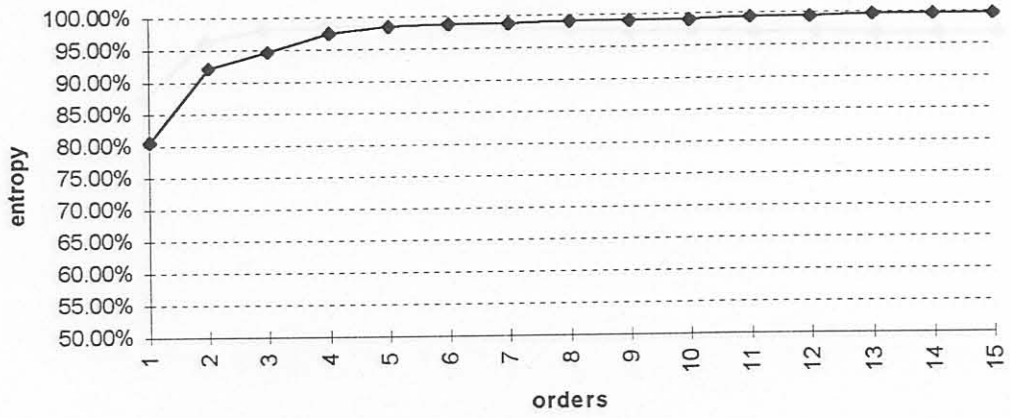

Figure 6-16. Interval entropies for *Halt*

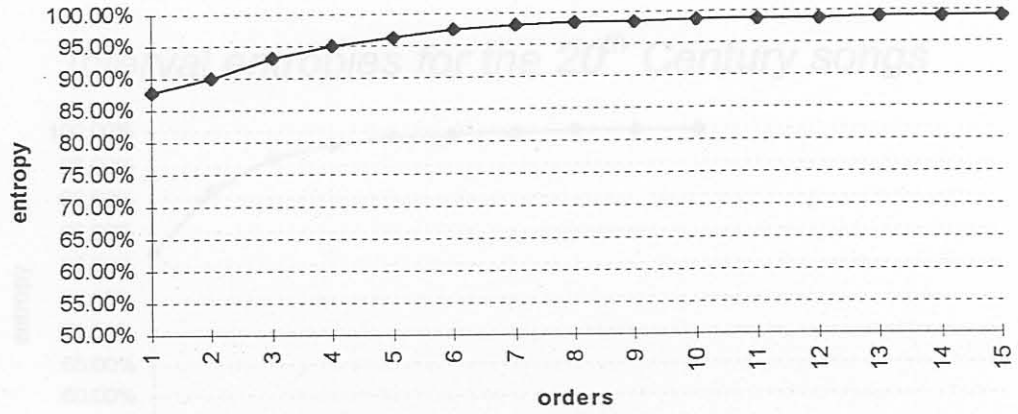

Figure 6-17. Interval entropies for *Ich will meine Seele*

Figure 6-18. Interval entropies for *Liebestreu*

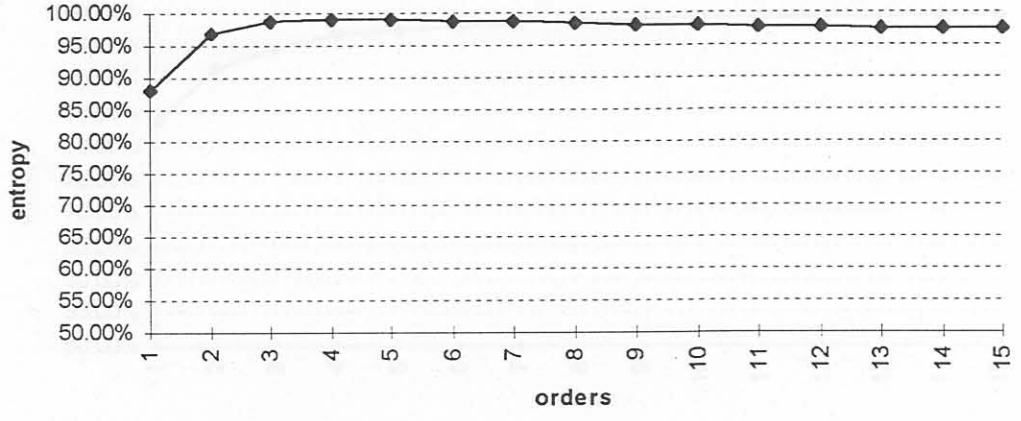

Figure 6-19. Interval entropies for *Rosamunde*

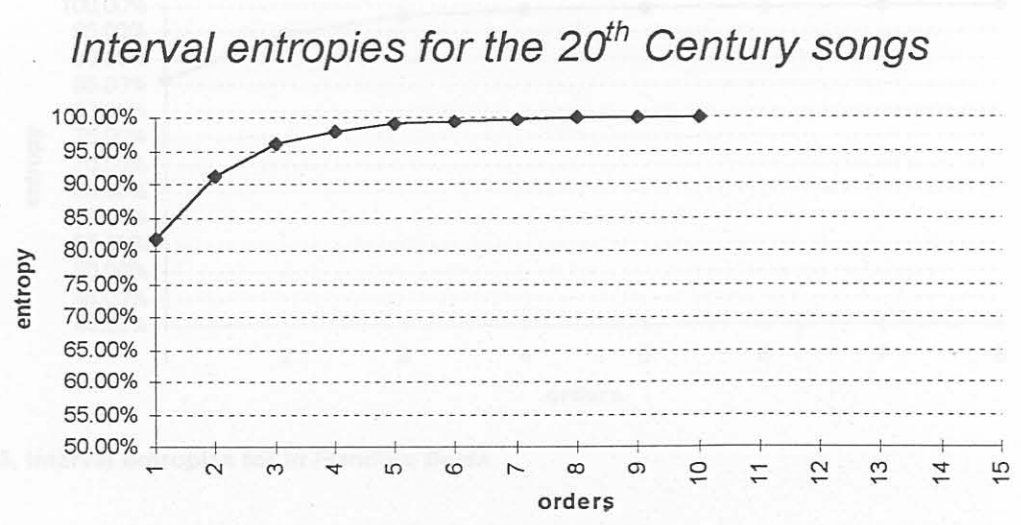

Figure 6-20. Interval entropies for *Cupid and my Campaspe*

Figure 6-21. Interval entropies for *Since she whom I love*

Figure 6-22. Interval entropies for *How love came in*

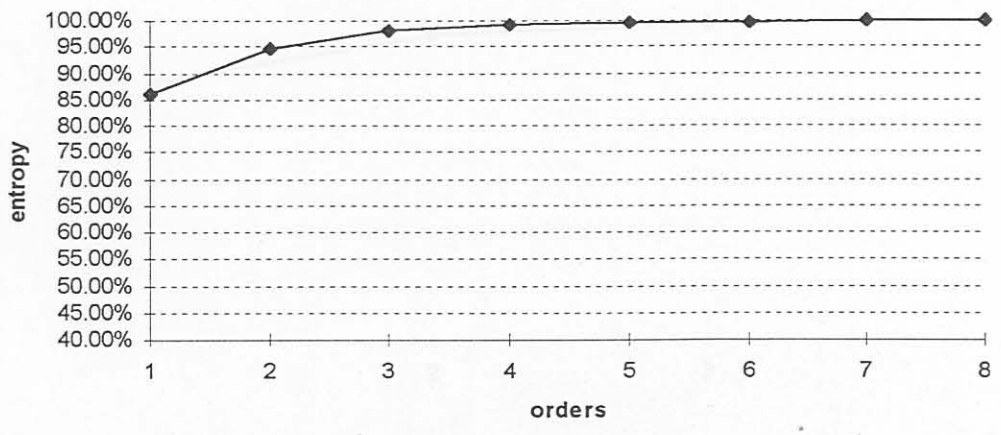

Figure 6-23. Interval entropies for *In Flanders fields*

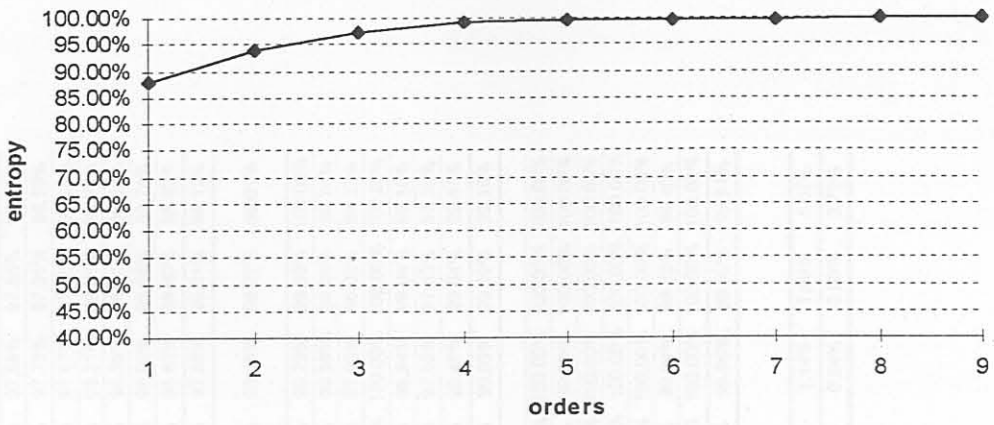

Figure 6-24. Interval entropies for *Whenas the rye*

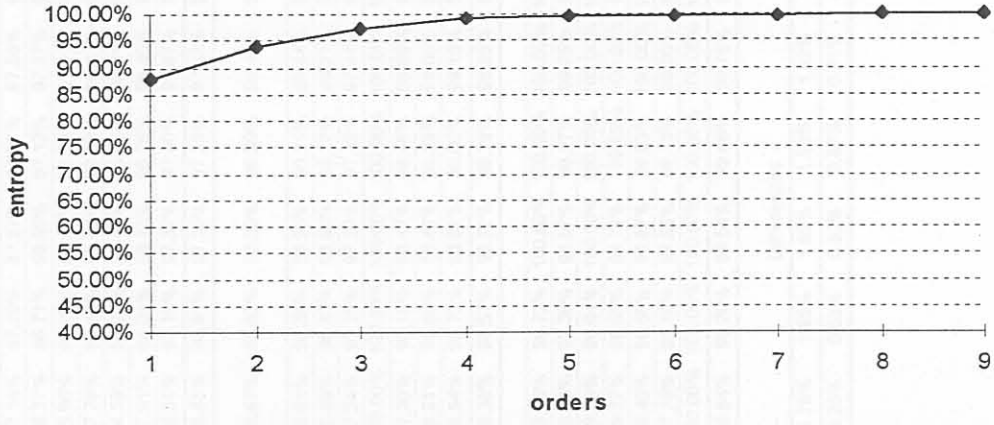

Figure 6-25. Interval entropies for *Being young and green*

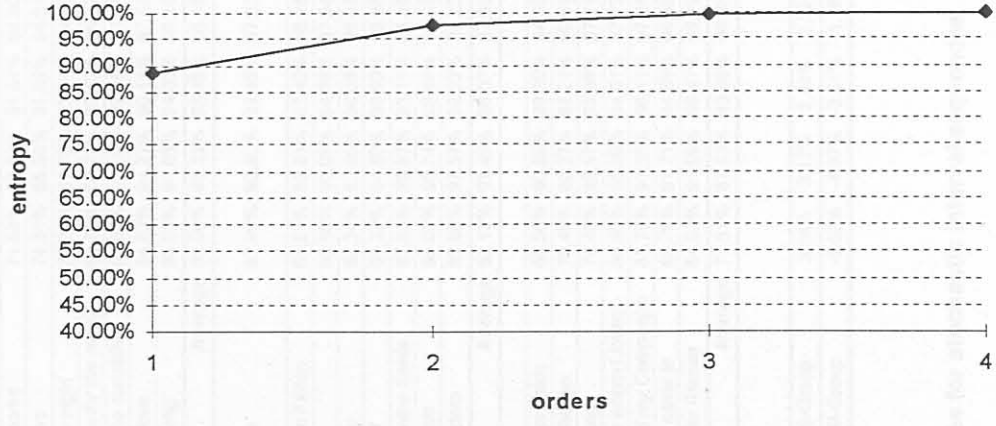

Figure 6-26. Interval entropies for *Nun ich der Riesen*

To facilitate a sensible explanation of the preceding graphs the values for the first fifteen orders are shown in tabular form on the following page.

Orders	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sleepy shores	71.68%	83.82%	91.54%	94.80%	96.13%	97.16%	97.20%	97.27%	97.37%	97.50%	97.53%	97.62%	97.58%	97.55%	97.51%
Love letters	74.31%	85.96%	91.89%	94.01%	95.80%	96.37%	96.71%	96.96%	97.13%	97.27%	97.41%	97.57%	97.73%	97.91%	98.10%
One more night	79.24%	87.78%	92.65%	94.63%	95.59%	95.96%	96.20%	96.49%	96.74%	97.01%	97.23%	97.46%	97.67%	97.88%	98.02%
Thank you for the music	80.75%	89.72%	95.42%	96.77%	97.46%	97.76%	97.86%	97.94%	98.03%	98.12%	98.22%	98.22%	98.21%	98.21%	98.22%
You are the sunshine	81.57%	92.09%	92.78%	93.43%	94.06%	94.59%	95.21%	95.51%	95.63%	95.81%	95.99%	96.18%	96.39%	96.61%	96.83%
Summer love	84.83%	94.27%	96.11%	97.52%	97.81%	97.91%	98.01%	98.13%	98.26%	98.40%	98.55%	98.72%	98.90%	99.08%	99.24%
Annie's song	88.03%	91.65%	94.02%	95.18%	95.92%	96.51%	97.19%	97.37%	97.60%	97.87%	98.17%	98.49%	98.69%	98.80%	98.92%
Average	80.06%	89.33%	93.49%	95.19%	96.11%	96.61%	96.91%	97.10%	97.25%	97.43%	97.59%	97.75%	97.88%	98.01%	98.12%
Ave Maria	87.99%	93.80%	97.46%	97.93%	98.53%	98.67%	98.62%	98.59%	98.50%	98.42%	98.32%	98.23%	98.15%	98.07%	98.01%
Das ist ein Flöten	66.81%	82.61%	92.43%	96.28%	97.34%	98.01%	98.38%	98.96%	99.21%	99.44%	99.61%	99.70%	99.79%	99.89%	100.00%
Halt	80.60%	92.05%	94.76%	97.54%	98.41%	98.69%	98.87%	98.98%	99.12%	99.21%	99.32%	99.43%	99.56%	99.65%	99.74%
Liebestreu	82.34%	93.80%	96.08%	96.97%	97.25%	97.24%	97.25%	97.29%	97.35%	97.44%	97.56%	97.69%	97.85%	98.03%	98.23%
Nachtigall	86.32%	94.80%	98.99%	99.68%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Ich will meine Seele	87.88%	89.87%	93.10%	94.86%	96.11%	97.39%	98.18%	98.47%	98.56%	98.69%	98.76%	98.85%	98.94%	99.04%	99.16%
Rosamunde	88.02%	96.74%	98.86%	99.07%	99.05%	98.81%	98.60%	98.42%	98.26%	98.05%	97.86%	97.70%	97.55%	97.43%	97.39%
Das Wandern	89.89%	97.57%	98.22%	98.23%	98.44%	98.54%	98.73%	98.91%	99.00%	99.10%	99.21%	99.34%	99.48%	99.64%	99.81%
Average	83.12%	92.49%	96.07%	97.52%	98.09%	98.38%	98.57%	98.72%	98.79%	98.85%	98.90%	98.96%	99.03%	99.10%	99.19%
In Flanders fields	66.56%	80.89%	89.30%	94.69%	98.03%	99.05%	99.72%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Whenas the rye	70.45%	82.27%	87.21%	90.91%	94.42%	95.83%	97.38%	98.57%	98.97%	99.25%	99.41%	99.59%	99.79%	100.00%	100.00%
Being young	74.40%	85.57%	93.96%	97.21%	98.31%	99.20%	99.84%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Since she whom I loved	80.95%	88.99%	94.61%	97.23%	98.43%	99.27%	99.65%	99.79%	99.89%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Cupid and my Campaspe	81.78%	91.26%	96.11%	97.91%	98.96%	99.40%	99.66%	99.87%	99.93%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
How love came in	83.76%	91.71%	94.55%	96.59%	97.31%	97.76%	98.15%	98.55%	98.79%	99.05%	99.11%	99.17%	99.24%	99.32%	99.40%
Nun ich der Riesen	84.63%	91.99%	98.47%	99.79%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average	77.51%	87.53%	93.46%	96.33%	97.92%	98.64%	99.20%	99.54%	99.66%	99.76%	99.79%	99.82%	99.86%	99.90%	99.91%
Differences															
P-Group/S-Group	3.06%	3.17%	2.58%	2.32%	1.98%	1.78%	1.66%	1.62%	1.53%	1.42%	1.32%	1.21%	1.14%	1.09%	1.07%
S-Group/M-Group	-5.62%	-4.97%	-2.61%	-1.18%	-0.16%	0.26%	0.63%	0.82%	0.87%	0.91%	0.88%	0.86%	0.84%	0.80%	0.72%

Table 6-7. Entropy values for stochastic interval sequences, order 1 - 15

Because each of the graphs also represents a different composition, it is obvious that all the curves would be quite different. This then also confirms the difference in character between each composition—if the graphs were similar or had appeared similar, they would have sounded the same or similar as well. The distinctiveness of each of the songs' interval graphs can be used as one component of a complex graph that identifies each song. Examples of such complex graphs are shown towards the end of this chapter.

However, if the average figures in Table 6-7 are used in conjunction with the graphs, the entropy value of the S-group (including *Ave Maria*) at each order is clearly higher than those of the P-group. At the first order the difference between the entropies of the two groups is more than 3 points but as the orders progress the difference in values gradually decreases; at order 5 the difference is nearly 2 points; at order 10 the difference is 1.4 points at order 15 it is about 1 point.

Similarly, there is a difference between the average entropies of the S-group and the M-group but the order 1 difference is -5.62; order 5 is -0.16; order 10 is 0.91 and order 15 has a difference of 0.72.

To summarise the above, the S-group on average begins with a higher entropy for the stochastic interval values, than both the P-group and the M-group. The S-group maintains its higher values compared to the P-group, but this difference gradually decreases as the order number increases. Whereas the M-group starts with a lower value than the S-group, at order 5 the entropy value of the M-group is higher than that of the S-group, reaches its greatest difference at order 10. The difference gradually decreases as the order numbers increase. The difference in entropy values at each order, would suggest that the predictability of the interval sequences of the S-group generally reduces faster than those of the S-group, which in turn reduces faster than those of the P-group. This information together with the number of orders each composition generates provides the overall predictability of each composition as well as for each group. The interval entropies of the Popular songs are relatively low while the number of orders indicates that the structural dynamics of these songs stretch over a greater length of the music.

In the case of the Modern songs, maximum entropy is reached comparatively fast, hence the steeper curve. This indicates that the music of the M-group does not rely as much on interval coherency than either the Popular songs or the Art songs.

6.3.2 Stochastic rhythm entropy

The same methods applied to obtain the stochastic interval entropies are applied to the rhythms of each of the songs and the values thus obtained may be illustrated similarly. Below is a table of the number of the rhythmic orders generated by each of the compositions.

Group	Title	Rhythmic Orders
P	*Summer love*	22
P	*You are the sunshine of my life*	41
P	*Annie's song*	50
P	*Love letters*	69
P	*Thank you for the music*	70
P	*One more night*	70
P	*Sleepy shores*	70
	Average	56
S	*Ave Maria*	70
S	*Nachtigall*	13
S	*Ich will meine Seele*	13
S	*Das ist ein Flöten*	15
S	*Das Wandern*	15
S	*Halt*	18
S	*Liebestreu*	22
S	*Rosamunde*	54
	Average	21.43
M	*Nun ich der Riesen*	4
M	*In Flanders fields*	7
M	*Being young and green*	7
M	*Since she whom I loved*	11
M	*Cupid and my Campaspe*	12
M	*How love came in*	12
M	*Whenas the rye*	13
	Average	9.43

Table 6-8. Comparative rhythm-orders

As with the values obtained for the rhythmic elements of the songs in the first part of this chapter, the stochastic character of the rhythm – in terms of the numbers of orders generated – again shows a marked difference among the three groups.

Keeping in mind that those compositions with orders of 70 could possibly generate even higher orders, the average of the P-group and *Ave Maria* would, in other words, be even higher than shown. However, the figures provided in Table 6-8 adequately indicate the difference among the three groups. In essence the relative values indicate how soon the stochastic processes at work in the rhythms of each group of songs reach maximum entropy. In the case of the pieces under discussion, the S-group reaches maximum entropy more than twice as fast than the P-group, while the M-group reaches maximum rhythmic entropy nearly twice as fast as the S-group. The argument stated earlier in this chapter, that the acceptability of a piece of music by certain sectors of the listening public is largely dependent on the rhythmic structure, seems to be reinforced by the figures shown above.

The following series of charts illustrate the curves of the rhythmic entropies of the songs to the 15th order.

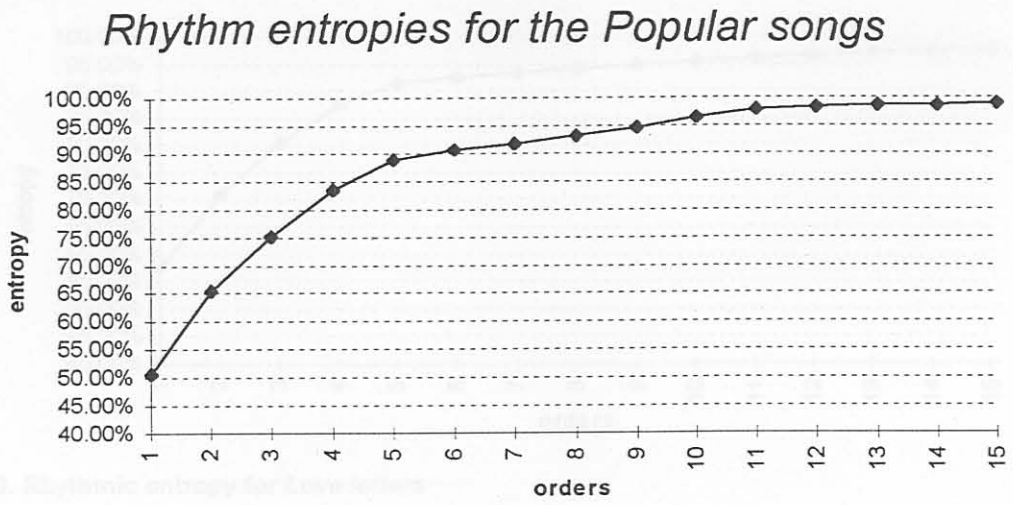

Figure 6-27. Rhythmic entropies for *Summer love*

Figure 6-28. Rhythmic entropies for *You are the sunshine of my life*

Figure 6-29. Rhythmic entropies for *Annie's song*

Figure 6-30. Rhythmic entropy for *Love letters*

Figure 6-31. Rhythmic entropies for *Thank you for the music*

Figure 6-32. Rhythmic entropies for *One more night*

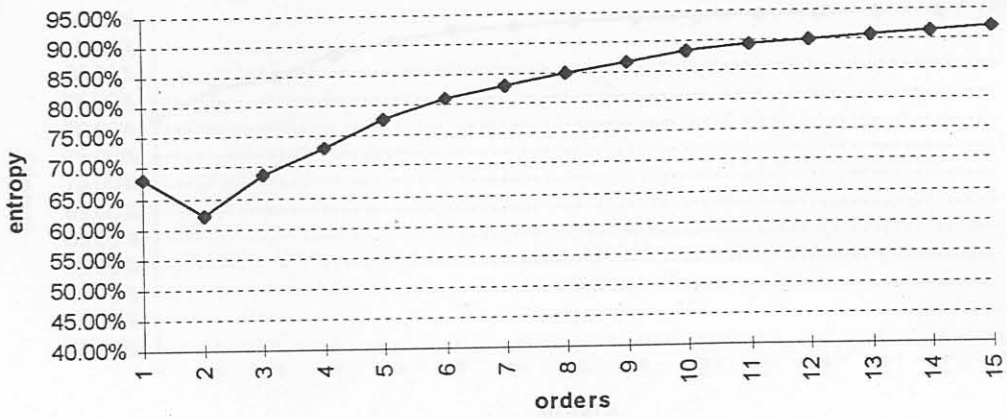

Figure 6-33. Rhythmic entropies for *Sleepy shores*

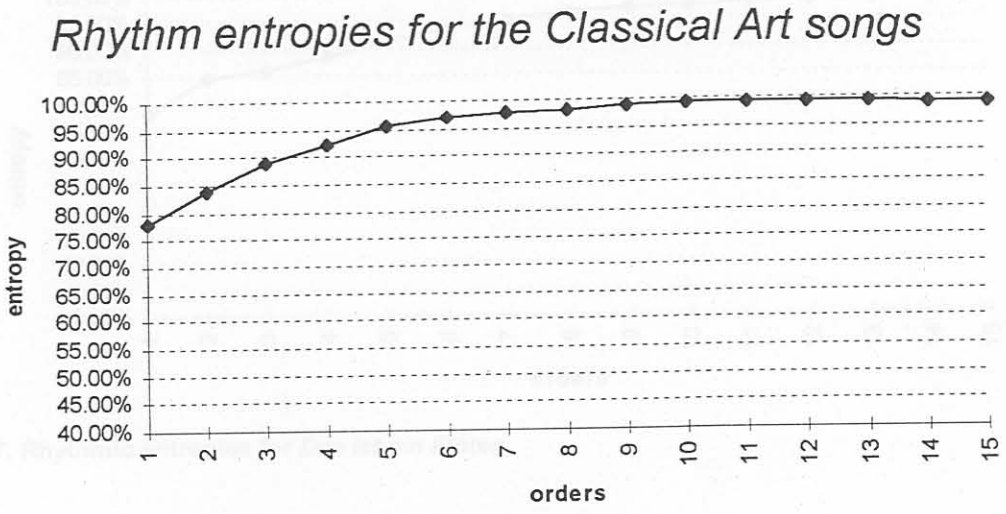

Figure 6-34. Rhythmic entropies for *Ave Maria*

Figure 6-35. Rhythmic entropies for *Nachtigall*

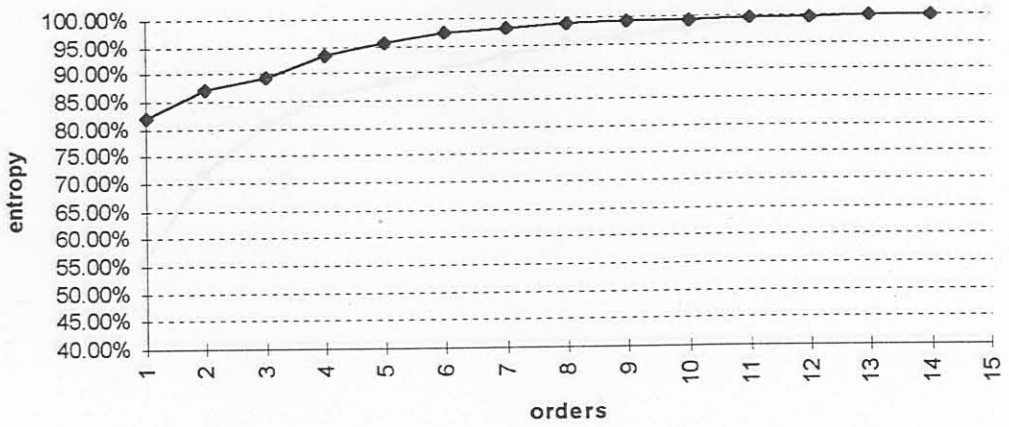

Figure 6-36. Rhythmic entropies for *Ich will meine Seele*

Figure 6-37. Rhythmic entropies for *Das ist ein Flöten*

Figure 6-38. Rhythmic entropies for *Das Wandern*

Figure 6-39. Rhythmic entropies for *Halt*

Figure 6-40. Rhythmic entropies for *Liebestreu*

Figure 6-41. Rhythmic Entropies for *Rosamunde*

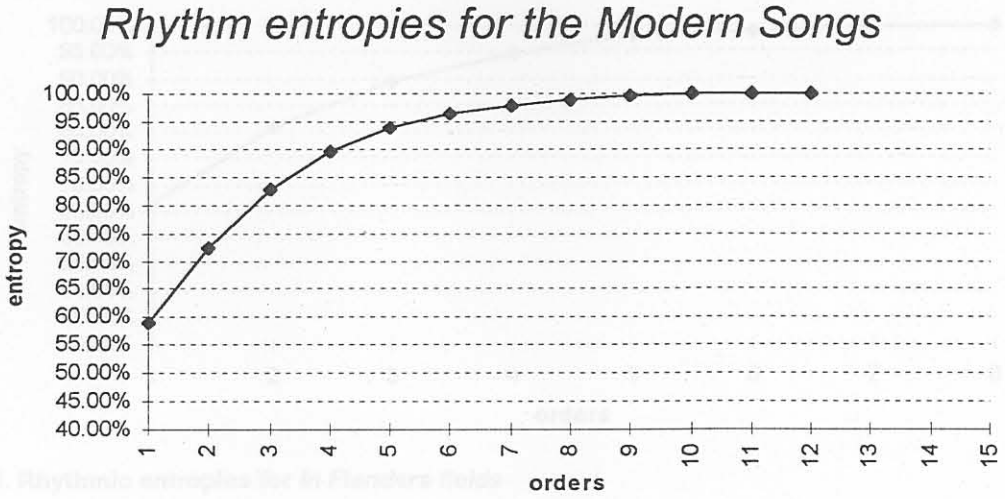

Figure 6-42. Rhythmic entropies for *Since she whom I loved*

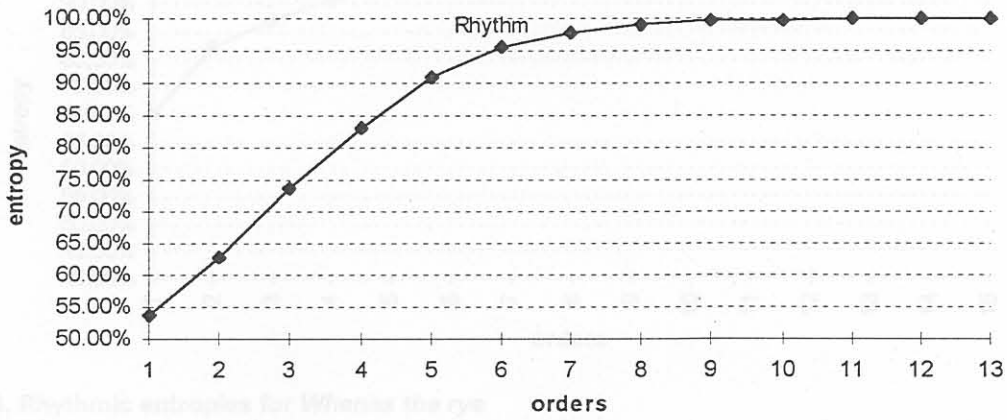

Figure 6-43. Rhythmic entropies for *Cupid and my Campaspe*

Figure 6-44. Rhythmic entropies for *How love came in*

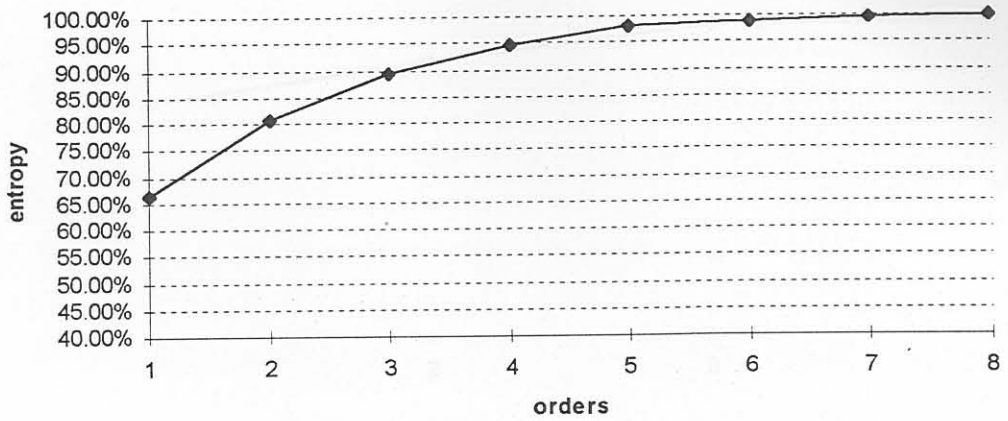

Figure 6-45. Rhythmic entropies for *In Flanders fields*

Figure 6-46. Rhythmic entropies for *Whenas the rye*

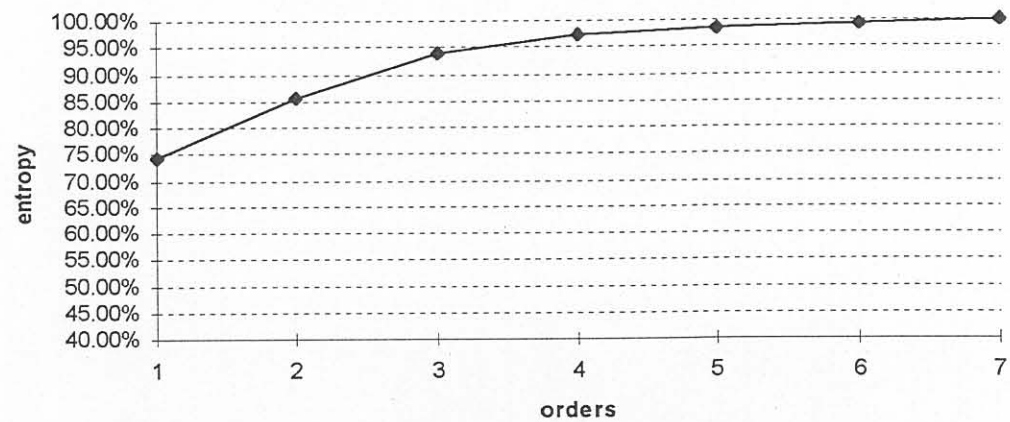

Figure 6-47. Rhythmic entropies for *Being young and green*

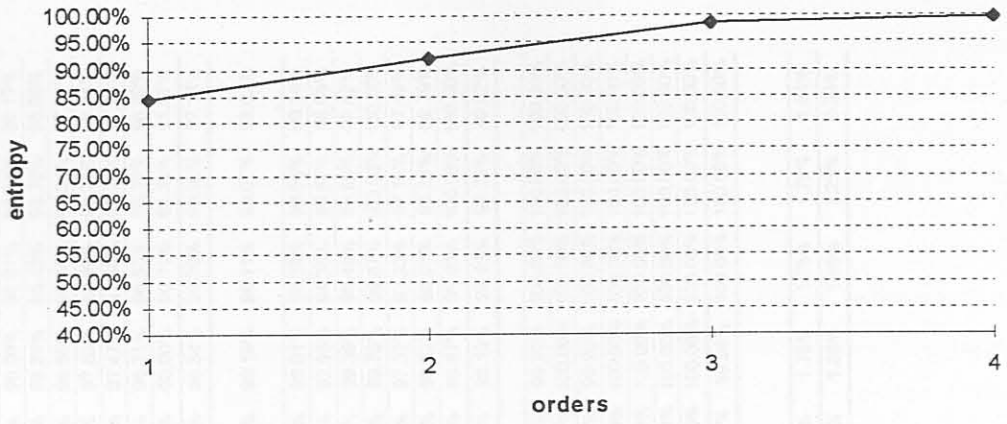

Figure 6-48. Rhythmic entropies for *Nun ich der Riesen*

The first 15 orders of the rhythmic entropies are shown on the following page:

Orders	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Thank you for the music	48.24%	63.44%	76.14%	84.49%	89.93%	93.09%	95.16%	96.36%	97.07%	97.54%	97.89%	98.00%	98.07%	98.14%	98.17%
Summer love	50.85%	65.35%	75.31%	83.59%	88.81%	90.80%	91.75%	93.11%	94.70%	96.43%	97.85%	98.24%	98.48%	98.70%	98.96%
Love letters	57.66%	71.02%	80.49%	87.47%	91.48%	92.71%	93.46%	94.08%	94.91%	95.51%	96.06%	96.56%	96.95%	97.34%	97.62%
Annie's song	61.57%	74.31%	81.93%	87.04%	89.95%	92.06%	92.91%	93.68%	94.67%	95.72%	96.84%	97.80%	98.49%	98.74%	98.74%
One more night	64.11%	80.33%	88.98%	93.49%	95.04%	95.76%	96.04%	96.36%	96.67%	97.01%	97.31%	97.47%	97.66%	97.72%	97.78%
You are the sunshine	68.07%	81.32%	90.14%	93.48%	93.88%	94.74%	95.50%	95.62%	95.76%	95.92%	96.11%	96.31%	96.53%	96.75%	96.99%
Sleepy shores	68.30%	62.30%	68.80%	73.16%	77.87%	81.05%	83.15%	85.19%	86.85%	88.31%	89.31%	90.00%	90.71%	91.34%	91.97%
Average	59.83%	71.15%	80.26%	86.10%	89.57%	91.46%	92.57%	93.49%	94.38%	95.20%	95.91%	96.34%	96.70%	96.96%	97.18%
Ave Maria	77.89%	83.89%	89.17%	92.45%	95.44%	97.04%	97.64%	98.26%	98.85%	99.09%	99.14%	99.19%	99.11%	99.07%	99.02%
Halt	54.71%	70.97%	80.01%	85.27%	87.66%	90.08%	92.61%	94.65%	96.09%	97.41%	98.54%	99.01%	99.39%	99.56%	99.74%
Liebestreu	65.78%	80.01%	78.26%	80.10%	82.50%	84.05%	85.65%	87.06%	88.60%	90.11%	91.48%	92.93%	94.35%	95.51%	96.69%
Das Wandern	68.33%	81.86%	90.36%	94.57%	95.87%	95.99%	96.35%	96.93%	97.70%	98.55%	99.10%	99.36%	99.49%	99.65%	99.82%
Nachtigall	71.84%	80.00%	84.94%	90.37%	93.71%	95.39%	96.94%	97.73%	98.39%	99.00%	99.54%	99.76%	99.87%	100.00%	100.00%
Rosamunde	73.63%	87.47%	93.65%	95.90%	96.85%	97.46%	97.78%	97.93%	97.73%	97.56%	97.43%	97.32%	97.23%	97.15%	97.09%
Das ist ein Flöten	78.08%	84.78%	85.99%	88.80%	91.35%	93.66%	95.15%	96.68%	97.20%	97.85%	98.31%	98.62%	98.97%	99.36%	99.79%
Ich will meine Seele	81.90%	87.36%	89.41%	93.46%	95.62%	97.40%	98.34%	98.84%	99.15%	99.39%	99.53%	99.67%	99.83%	100.00%	100.00%
Average	70.61%	81.78%	86.09%	89.78%	91.94%	93.43%	94.69%	95.69%	96.41%	97.13%	97.70%	98.10%	98.45%	98.75%	99.02%
Cupid and my Campaspe	53.73%	62.78%	73.84%	83.19%	90.94%	95.68%	97.95%	99.08%	99.57%	99.74%	99.87%	99.93%	100.00%	100.00%	100.00%
Since she whom I love	59.12%	72.17%	82.58%	89.45%	93.74%	96.49%	98.01%	99.04%	99.69%	99.89%	99.95%	100.00%	100.00%	100.00%	100.00%
How love came in	63.38%	75.60%	84.58%	90.78%	93.65%	95.72%	97.28%	98.63%	99.29%	99.53%	99.80%	99.90%	100.00%	100.00%	100.00%
In Flanders fields	86.02%	94.78%	98.05%	99.36%	99.66%	99.79%	99.93%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Whenas the rye	87.78%	93.91%	97.26%	99.09%	99.45%	99.62%	99.80%	99.90%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Nun ich der Riesen	88.63%	97.63%	99.79%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Being young	89.59%	97.90%	99.57%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average	75.46%	84.97%	90.81%	94.55%	96.78%	98.19%	99.00%	99.52%	99.79%	99.88%	99.94%	99.98%	100.00%	100.00%	100.00%
								Differences							
Difference P-Group - S-Group	10.78%	10.63%	5.83%	3.68%	2.37%	1.98%	2.12%	2.20%	2.03%	1.92%	1.79%	1.75%	1.75%	1.79%	1.84%
Difference S-Group - M-Group	4.85%	3.19%	4.72%	4.77%	4.84%	4.75%	4.31%	3.83%	3.38%	2.76%	2.24%	1.88%	1.55%	1.25%	0.98%

Table 6-9. Combined rhythmic entropies for orders 1 - 15

Compared to the stochastic analysis of the interval sequence, the entropies for the rhythm sequences generally begin much lower. Most of the compositions also indicate a shallower curve toward 100% entropy. It is also noteworthy that, with some exceptions, the S-group's curve is even shallower. This is supported by the differences of the values of the P-group and the S-group (see Table 6-9). The difference starts with 10.78 points, decreases to 2.37 points at the 5th order and then gradually decreases to 1.92 points and 1.84 points at the 10th and 15th order respectively.

Two of the gradients of the M-group are very similar, although they begin with different 1st order entropies. Both reach maximum entropy at the 13th order. However, all seven compositions belonging to the S-group have steeper curve gradients than any of the other songs under scrutiny. Compared to the S-group, their average is lower with a difference of 4.85 points at the first order. In fact, their beginning entropies are very close to those of the P-group. At the 5th order their average is above that of the S-group with 4.84 points. It reaches a difference of 2.76 points at the 10th order and a difference of .98 points at the 15th order.

As was mentioned earlier in this chapter (see page 6-10), and as is now again evident, the greatest differences in the entropy of the songs are in the rhythmical characteristics of the music. The stochastic entropies of the rhythm are also directly related to aspects of the formal structure of the music, such as rhythmic units, motifs, sub-phrases, phrases, periods, as well as larger sections. Lower entropies with shallower curves indicate a greater rhythmic coherency. Repeats, sequences and similar devices—even though the pitches and intervals may differ—all contribute to a greater predictability (greater redundancy and lower entropy) of a composition.

Some significant rhythmic characteristics need specific mentioning. *Sleepy Shores* (P-Group, Figure 6-33 on page 6-30) has an interesting curve in which the second order entropy is more that 5 points lower than the first order, after which it begins its gradual upward curve. This indicates a high degree of rhythmic unity of consecutive rhythmic values. A similar deviation from the general shape of the curves is found in *Liebestreu* (Figure 6-40, page 6-32) where the entropy drops by nearly 2 points at the 3rd order and then gradually rises. The score supports this tendency by the frequently repeated pattern of two eighth notes followed by a quarter note. Also note the virtually stagnant entropy values of *Rosamunde* (Figure 6-41, page 6-32) which, after levelling off at the 7th and 8th order, decreases slightly in entropy, before it gradually rises again toward maximum entropy at the 50th order (see complete listing of entropies in Appendix II). Another song which shows a similar tendency is *Ave Maria* (Figure 6-34, page 6-30), in which there is a gradual rise to an entropy of about 99 points at the 10th order, with a gradual decrease up to the 30th order and then a very gradual rise to maximum entropy beyond the 70th order. In this case, however, the curve evens out at a higher entropy level than that of *Rosamunde*. It is interesting that these two songs are amongst the best known songs of the Classical period (S-group).

The results obtained with the stochastic analyses of the compositions indicate that a major factor in all the songs is the rhythmic coherency. The P-group shows a more pronounced and consistent redun-

dancy pattern than the other groups. Because the P-group and the S-group were both chosen from lists that indicate their popularity, it may be argued that the rhythm, or its predictability may be a contributing factor—if not the most predominant factor.

As with all the other analyses demonstrated in this chapter, each of the compositions also has its own unique graphs, confirming that each of the songs has unique rhythmic characteristics.

6.4 Stylistic models of music

The typical entropy characteristics of the three groups of compositions were alluded to in the discussion of the entropies of the individual songs. It was shown that each of the individual songs of each of the three groups generated minimum and maximum values that lie within broad limits for the group to which they belong. This means that graphical models for each of the groups can be developed to illustrate the general characteristic and stylistic features of each group. An example of such a model is shown as Figure 6-4 on page 6-14 and illustrates the average minimum and maximum entropy values for all the 1st order calculations for each group. The same principle may be applied to create composite models containing the averaged extremes of all the analyses that were done.

All the calculations discussed in this chapter are summarized in the three graphical models that follow, one for each of the groups. The average maximum and minimum entropy values for the stochastic processes (intervals and rhythm) are indicated by the curves, while the single order entropy limits are represented by the rectangles. The horizontal positions of the latter are of no consequence and do not indicate any information pertaining to orders; they are merely placed in a clear horizontal area for the sake of visibility. Note that the number of orders shown are different in each graph; but that the horizontal axis of each graph has a maximum of 70 to maintain equal visual proportions of the curves.

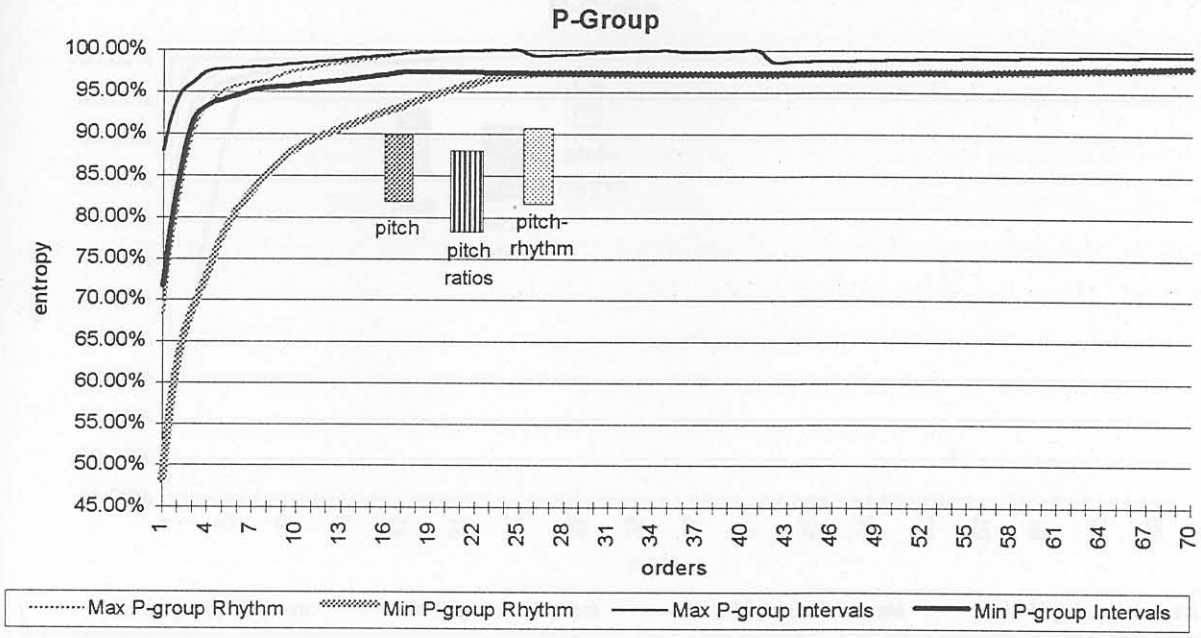

Figure 6-49. Graphical model of the combined entropy values of the P-group

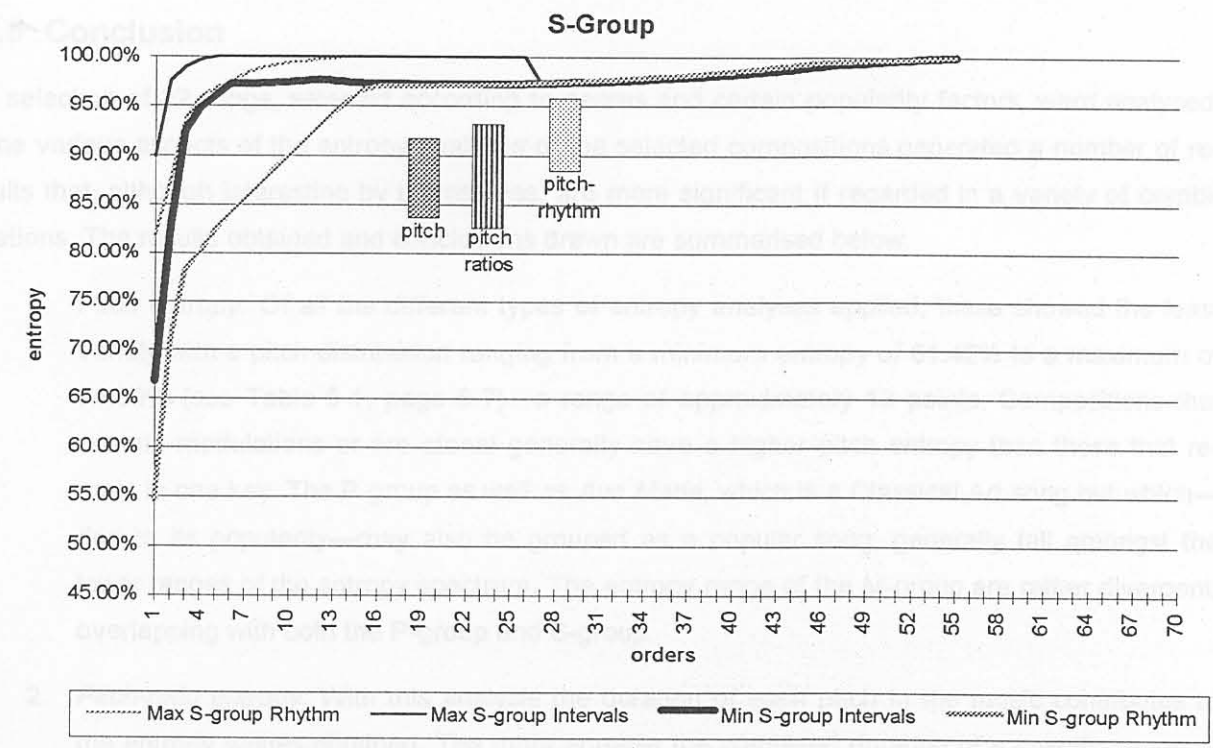

Figure 6-50. Graphical model of the combined entropy values of the S-group

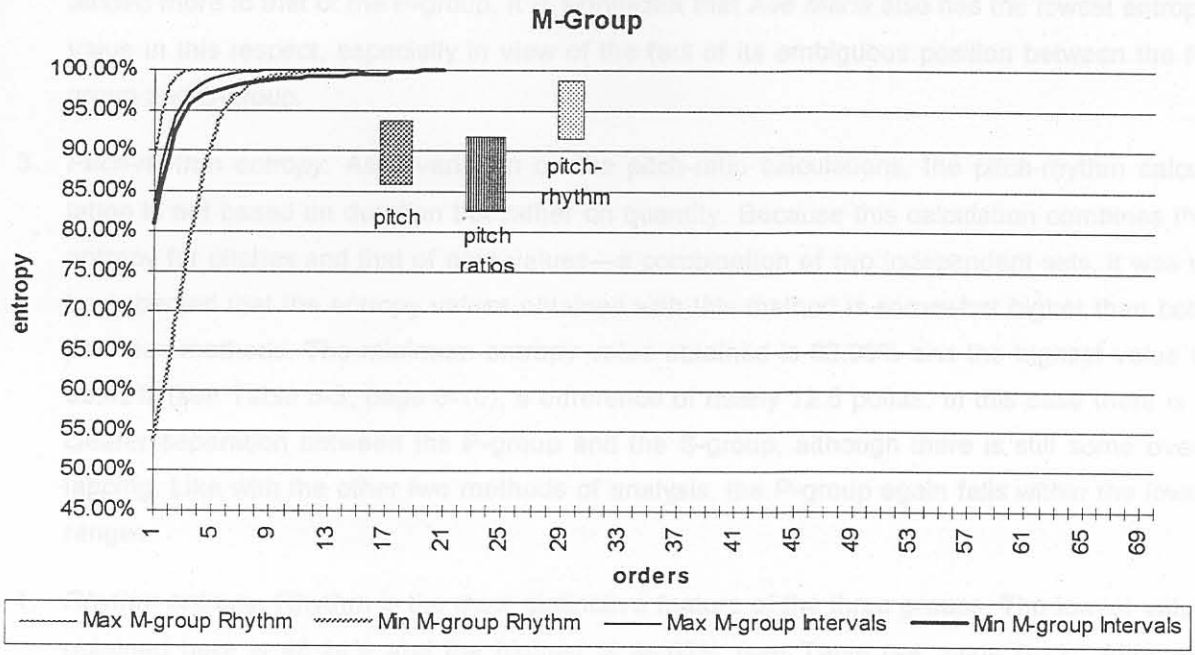

Figure 6-51. Graphical model of the combined entropy values of the M-group

6.5 Conclusion

A selection of 22 songs, selected according to genres and certain popularity factors, were analysed. The various aspects of the entropy analyses of the selected compositions generated a number of results that, although interesting by themselves, are more significant if regarded in a variety of combinations. The results obtained and conclusions drawn are summarised below.

1. *Pitch entropy.* Of all the different types of entropy analyses applied, these showed the least variety with a pitch distribution ranging from a minimum entropy of 81.42% to a maximum of 94.50% (see Table 6-1, page 6-7)—a range of approximately 13 points. Compositions that contain modulations or are atonal generally have a higher pitch entropy than those that remain in one key. The P-group as well as *Ave Maria*, which is a Classical Art song but which—due to its popularity—may also be grouped as a popular song, generally fall amongst the lower ranges of the entropy spectrum. The entropy range of the M-group are rather divergent, overlapping with both the P-group and S-group.

2. *Pitch-ratio entropy.* With this analysis the duration of each pitch in the music contributes to the entropy values obtained. The more equable the combined duration of a specific range of pitches in a composition is, the higher the entropy would be. Lower entropic results would therefore indicate that the composer dwelt longer on some pitches than on others. With a minimum entropy of 75.70% and a maximum of 94.21% (see Table 6-2, page 6-9), the average difference between the P-group and the S-group increased (18.5 points), compared to that of the pitch entropy (13 points). The entropies of the M-group proved inconclusive, and

tended more to that of the P-group. It is significant that *Ave Maria* also has the lowest entropy value in this respect, especially in view of the fact of its ambiguous position between the P-group and S-group.

3. *Pitch-rhythm entropy.* As a variation on the pitch-ratio calculations, the pitch-rhythm calculation is not based on duration but rather on quantity. Because this calculation combines the entropy for pitches and that of note values—a combination of two independent sets, it was to be expected that the entropy values obtained with this method is somewhat higher than both previous methods. The minimum entropy value obtained is 82.96% and the highest value is 95.42% (see Table 6-3, page 6-10), a difference of nearly 12.5 points. In this case there is a clearer separation between the P-group and the S-group, although there is still some overlapping. Like with the other two methods of analysis, the P-group again falls within the lower ranges.

4. *Rhythm entropy.* Rhythm is the most distinctive feature of the three groups. The lowest value obtained here is 48.24% and the highest is 84.63% (see Table 6-4, page 6-12). Although there is still some overlapping among the three groups, the separation is now much more marked. Again the P-group ranks predominantly amongst the lower values and the S-group amongst the higher values. Interestingly, where the values of the M-group in the three previous analyses were similar to that of the higher values of the S-group, the rhythmic entropy of the M-group is now similar to the low values of the P-group. This indicates that the predictability of these pieces is mainly due to their rhythmic redundancy. *Ave Maria* that, with the previous types of analyses, ranks amongst the lower values of the P-group, now ranks amongst the higher values of the S-group.

5. *Combined average of the entropy analyses* (Table 6-5 and Figure 6-4, page 6-14). A combination of the pitch-ratio entropy, pitch rhythm entropy and rhythm entropy was used to obtain the average for each of the groups (because of the proximity of the pitch entropies these were not included). Although there is some overlapping between the average entropy values of the three groups, the results clearly indicate that the S-group has the widest range and both its highest and lowest values are higher than the P-group and M-group. The range of the P-group is somewhat smaller and that of the M-group is the smallest.

6. *Stochastic interval analysis.* Since most music is conceived according to inherent structural patterns (except in the case of intentional aleatoric music), it is to be expected that these could be quantified by stochastic analysis of certain aspects. Interval analysis is important in this respect, and for two main reasons; the dynamics[5] of melodic structures and the dynamics of tonal orientation. It should be stressed that Information Theory cannot show or measure tonality as such, but that it can be used to measure the degree of tonal orientation. Tonality, as

[5] The term 'dynamics' in this context does not refer to its musical connotation of 'loudness' but rather to the movement of the intervals governed by specific conventions and voice leading.

used here, should be regarded in its widest meaning, including dodecaphony, and other synthesised scales. In other words the degree to which the music adheres to a specific sequence of predetermined pitches and, by implication, intervals.

Each composition generated a number of entropy values based on the length of sequences, or orders. The number of orders generated before a composition reaches maximum entropy indicates the structural predictability. Compositions with a lower number of orders are much less predictable than a composition that generates a higher number of orders. Of all the results obtained thus far, the orders of the interval entropy proved the most revealing (see Table 6-6, page 6-16). Except for *Nachtigall* (S-group, 4 orders), the seven pieces of the M-group generated the lowest orders (3) and the P-group the highest (70+). The P-group also showed the largest number of average of the orders (49.29), while the S-group and M-group showed an average of 21.29 and 8.43 orders respectively. Again, *Ave Maria* was an interesting case since it firmly belonged to the P-group with 70+ orders. A graph of the interval entropies of each of the compositions (page 6-17 to 6-23) shows that the rate at which the S-group reaches its maximum entropy of 100% is higher than that of the P-group. The M-group has an even higher increase of entropy with each of the orders. The curves of the graphs also show that each composition has its own unique shape to distinguish it from the other compositions.

7. *Stochastic rhythm entropy.* As for the entropies generated by the intervals, the number of orders generated by this analysis, proved equally significant. The highest orders is found in the P-group where three songs have 70+ orders, while the S-group generated orders between 13 and 54 respectively. *Rosamunde*, which is a favourite for many listeners generated the 54 orders, which is 32 higher than the next highest in the group. The lowest orders were generated by the M-group with a range between 3 and 13. The P-group averaged 56 orders, the S-group 21.43 orders and the M-group 9.43 orders (see Table 6-8, page 6-27). Again except for *Ave Maria* (70+ orders) the three groups are clearly separated. The curves of the entropy values for this analysis show that the rate at which 100% entropy is reached is slower than with the stochastic interval analysis, but as with the latter the rate of change is the highest for the M-group to a significant degree, while that of the P-group is the lowest. The graphs also show the unique character of each of the compositions, even more so than is the case with the stochastic interval analysis.

It would appear that entropic and stochastic analyses of single aspects are not sufficient to indicate the overall characteristic traits of a musical style. The same argument also applies when Information Theory is used to ascertain those factors in music that could contribute to its general popularity with the listener. Music is a complex combination and interaction of, amongst others, a variety of pitches, silences, rhythms, and dynamics. A comprehensive approach is required to identify the entropic and stochastic elements that may contribute to the popularity or acceptance of a piece of music, and

therefore contribute to the style of the music as well.

The elements of the music subjected to Information Theoretical analysis, provided sufficient information to identify specific characteristics and style elements that contribute to the stylistic nature of the music and point to the factors that contribute to its accessibility or even popularity.

Accepting that the P-group of songs are generally amongst the most popular pieces of music today, that the S-group are also popular but among a smaller selection of people, and that the M-group are virtually unknown–accept amongst connoisseurs, some definite tendencies are evident:

1. Music that generally enjoys greater popularity, generates lower entropy values, especially rhythmically.

2. Pieces with lower entropy values generally produce a larger number of orders. Stochastically, the popular pieces reach 100% entropy at a much slower rate than the lesser known pieces. One piece, *Ave Maria*, which shows tendencies of both extremes seems to confirm this argument.

3. The lesser known 20th century pieces essentially have a much shorter order distribution for the stochastic analyses, and may therefore be less palatable to the general public, even though they are more predictable as far as pitch distribution is concerned. This indicates that although pitch and rhythm distribution may be important indicative factors of the acceptance of a piece of music, they are not exclusive factors. The inherent structural dynamics for interval and rhythmic structure, balanced by the careful selection of pitch and note values, seem to be important in establishing whether a piece of music has the possibility of being accepted or even becoming popular or a classic.

The overlapping values between the results of each group tend to support the suggestion that this type of analysis may be done free from period bias. Especially in the 20th century, music has become rather eclectic, and there are many composers who compose in any of the historical styles. Furthermore, much of what today is called 'popular', shows similarities with some of the older styles of music, and is often written with just this purpose in mind. To ignore these facts and maintain the traditional system of historical divisions and classification of music would therefore contradict the aims of entropy analysis which does not claim to provide historical information of any kind. Much of traditional music analysis, is based on comparative methods for which set and preconceived models serve as point of departure. Entropy analysis, in contrast, considers the inherent dynamics of music without any specific reference to outside models. However, entropic analysis is also capable of establishing the similarities in information content of a specific period of music, or even of an individual composer.