The Beat Induction Problem

0. Introduction

When confronted with a tune a listener may assign what is informally known as a beat. Beats are locations on which listeners tend to snap their fingers, clap their hands, tap their feet or choreograph dance steps. While these actions are frequently associated with music having a strong rhythmic pulsation, it is misleading to equate these or any particular gestures with the beat. For rather than showing any physical relationship to the rhythm of what they are hearing, listeners usually show no signs of reacting to the beat. There is a kind of dancing, but it is, in the words of the avant garde saxophonist Ornette Coleman, "dancing in your head."

Just as the beat may be localized entirely in the head and not in the body so too are the beat locations themselves mental phantoms. That is, they are often not associated with musical notes but may be unoccupied, either associated with continuations of notes attacked previously or actual silences. Thus, in the tune "Silent Night", shown in 0.1

0.1.
Si-(beat) i-lent night.(beat beat)
Ho-(beat) o-ly night. (beat beat)

an unoccupied beat occurs within the first syllable of "silent." This beat is, strictly speaking, occupied by a note, namely the continuation of the note assigned to first syllable. But it does not correspond with the *attack* of the note. It is the latter which we are referring to when we say that a note "falls on" a particular beat. Similarly, the two beats following "night" are also unoccupied. Here the positions are silent, or, as they are referred to in musical notation, occupied by rests as the syllable "night" is cut off by the final consonant "t" which occurs on the first of the two silent beats. Whether they are continuations or rests, the empty beats are as significant a part of the tune as those which are occupied by notes. To "know" a tune means to know which locations are occupied and left vacant.

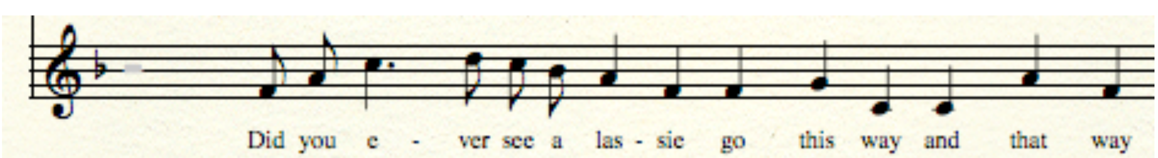
Metrical structure is therefore not a real world object, but a psychological object constructed by the listener upon becoming familiar with the tune. The details of this computation will be the focus of the discussion which follows. Among the factors which the computation takes as its input are pitch, loudness, duration, timbre, harmony and, if the tune is a song, certain characteristics of the text. Preliminary to outlining this computation, however, it will be necessary to specify the character of the output which the computation will be expected to produce. That is, to develop a notation which characterizes precisely the salient aspects of metrical structure as listeners perceive it. Once we have specified the form of the representation, we can then attempt to describe the how a listener comes to assign this particular form when confronted with a given musical input.

1. Metrical description

Looking at the details of metrical structure more closely, it will be seen that the formal description of metrical structure is required to meet two conditions. We can refer to these as periodicity and hierarchy. The former involves the listener's tendency to impart to the raw musical sequence a series of equally spaced temporal locations such that every event falls on one of these positions. This series of pulsations, some but not all of which will be occupied by events, we will call the metrical subdivision. Second each subdivision, whether or not it is occupied, is hierarchically organized in the listener's mind, associated with varying degrees of stress, emphasis or weight compared to others in their vicinity.

The simple children's song "Did you ever see a Lassie" provides a clear instance of these aspects of metrical structure.

1.1



Example 1.1 is intentionally represented in an unfamiliar form in that all indications of metrical structure inherent in musical notation, barlines, beaming of eighth notes and the time signature, have been removed. What remains is an

unorganized sequence of notes giving no indication as to where the beats fall. It this unorganized sequence which the listener initially confronts and assigns the two characteristics of metrical structure just mentioned.

With respect to periodicity, a listener assigns an underlying subdivision so that each note falls on one of these isochronous pulsations. We will represent these subdivisions which occur on each eighth note locations by the sequence of x's in 1.2:

1.2

Secondly, a pattern of relative weights is associated with each position. These are indicated by adding a level above those locations on the subdivision level which are heard as relatively strong. It is obvious that in this passage, strong and weak subdivisions alternate so that "Did", "e-(ver) and "see" occur on relatively strong positions as do all of the final eight syllables. The binary assignment of the quarter note metrical level is indicated in 1.3.

1.3

Example 1.3 does not succeed in representing the complete extent of the beat hierarchy assigned to 1.1. For in addition to a regular pattern of strong and weak positions projected onto the eight note level, the quarter note level just assigned also is heard as alternating weak and strong. In contrast to the binary alternation shown in 1.3, the

next higher metrical level alternates two weak positions to every strong.

1.4

It will be noticed that the ternary pattern is initiated on a relatively weak quarter note location creating what is known as a two note anacrusis, a portion of the musical phrase which precedes the first strong beat. For the moment we will simply make note of this characteristic of metrical form and will have more to say about it later.

The final rhythmic alternation assigned by listeners to 1.1 requires two of the four dotted half note locations to be represented as maximally strong. All things being equal, most listeners will tend to locate these on the first and third of the four positions yielding the metrical grid in 1.5.

1.5

It will be observed that listeners' intuitions for the location of the strongest beats are somewhat unstable in that a small change in the surface structure will cause the listener's assignment of the location of these beats to shift. The German song "Ach du lieber Augustine" is identical to 1.1 save for its omission of the two eighth note anacrusis. The absence of these notes results in the strong beats migrating rightward so that the entire first measure is heard as an anacrusis.

Example 1.6

Finally, it should be noted that the difference between the metrical structures assigned to 1.5 and 1.6 is only significant for some listeners. Indeed, some may have difficulty in perceiving the location of the high level beat at all. The reason for this is that metrical intuitions become gradually less apparent at higher levels of the metrical hierarchy often becoming imperceptible three or four metrical levels above that of the subdivision. Given the relative uncertainty in the location of the two strongest beats, it is reasonable to cut off the metrical representation of this passage at this point, making no attempt to indicate a fifth level which would require the choice of single strongest beat for this passage.

2. Metrical Grids

The pattern of x's we have used for representing the metrical structure of musical form is known as a metrical grid. In a general sense, grids are simply a graphical representation of the changes in a particular quantity, namely perceived metrical stress. They might equally apply to any other quantity measured over periodic time intervals, for example, the monthly of rate of return on a mutual fund, or the temperature fluctuations of the earth's atmosphere. Compared to these and other systems, metrical stress is a constrained hierarchy in that the degree of metrical stress, represented by the height of grid columns varies predictably, with maxima reached every second or third location.

For this reason, organizations such as those in 2.1 while possibly applicable to certain aspects of musical structure-the number of appearances of a particular pitch, the lengths of a sequence of notes, do not represent what listeners take to be the significant aspects of musical time.

2.1

a)

```
        x           L(2)
x       x     x     L(1)
x x x x x x x x x   L(0)
```

b)

```
    x          L(3)
  x x          L(2)
x x x          L(1)
x x x x x      L(0)
```

That the alternations in metrical stress are periodic means that grids which represent musical meter must meet two requirements. First, higher level beats must be sufficiently close together-separated by no more than one or two positions on the immediately lower metrical level. This requirement rules out the structure in 2.1 a) which contains three beats on level L(0) separating the first two strong beats. Secondly, higher level beats must be sufficiently far apart: specifically, they cannot occur on adjacent locations as they require at least one beat interceding on a lower level. Since 2.1 b) contains adjacent strong beat between the first and second and second and third L(0) locations, it is not a possible grid.

All grids which meet these two conditions are possible, or to borrow the terminology of Lerdahl and Jackendoff, well formed. These well formedness conditions allow us to enumerate a catalogue of three level metrical grids.

2.2

a)

```
x
x   x
x x x x
```

b)

```
x
x     x
x x x x x x
```

c)

```
x
x   x   x
x x x x x x
```

d)

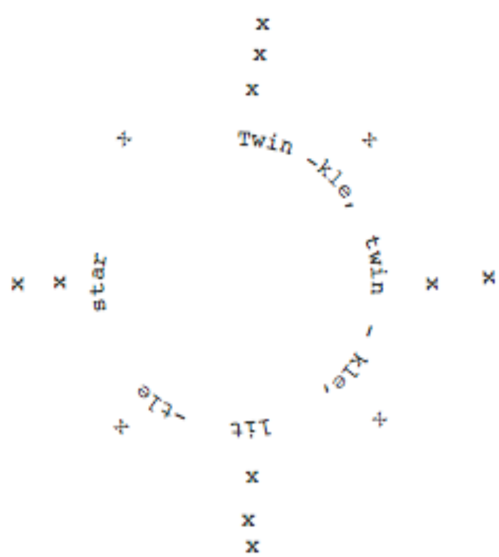
```
x
x     x     x
x x x x x x x x x
```

With the exception of 2.2 d) which is somewhat uncommon in the musical literature and rarer still in well known songs, numerous familiar songs attest to all of the other metrical types. 2.2 b) will be seen to correspond to the upper levels of the grid assigned to "Did you ever see a lassie" in in 1.4. 2.2 c) represents the lower levels of the same grid. 2.2 a) which imparts binary subdivisions to both metrical levels represents musical "common time" familiar in songs such "Twinkle, twinkle little star."

In addition to these observations with respect to the structural aspects of grids we need to make two additional qualifications. First, while the grids shown in 2.2 indicate a finite sequence, varying from a minimum of four units in the strict binary grid 2.2 a) to nine in the 2.2.d) grids are understood to continue their pattern indefinitely, without variation. This is particularly true for simple songs which are highly regular-avoiding irregular meters as well as irregular phrase lengths which would require an alteration in the type of metrical grid. For example, "Twinkle, twinkle" maintains the pattern in 2.5a repeated twelve times while "Did you ever see a lassie" requires sixteen iterations of 2.2 b). Other improvised songs, such as "Ninety nine Bottles of Beer on the Wall" are potentially much longer but are characterized by a rigorous maintenance of the underlying metrical pattern.

These repetitive structures pose a problem for linear grids. Because they contain a beginning and endpoint, they are not adequate for representing the unbounded, continuing character of meter as it is intuitively understood. What is suitable for the task is the radial grid in 2.3

2.3 radial grid (will fix later)



Among the melodic structures which are distorted by a linear representation are those whose melodic structure is out of phase with the grid. These, as previously discussed, contain anacruses-portions of the phrase which precede the first strong beat. It is important to recognize that unlike poetic meters which differ in kind depending on the presence or absence of the anacrusis-the iamb is differentiated form the trochee on these grounds -musical meters are not altered by the presence or absence of an anacrusis. For example, the binary grid in 2.4 a) can accommodate the following anacruses:

2.4.

```
               x               x
       x       x       x       x       x
   x   x   x   x   x   x   x   x   x   x   x
a)            Twinkle, twinkle li  tle star . . .
b)     Ov  er hill     ov  er dale     as  we . .
c)         A  tis     ket  a  tas     ket  a. . . .
d) You are my  sun    shine        my   on  ly . . .
```

Applying linear grids to out of phase structures is problematic in that it is not clear what constitutes the beginning of the grid. If we choose to indicate all available anacrusis positions so that 2.4 d) can be represented at the left edge of the grid, the initial three position of 2.4 a) will be represented as present but unoccupied. But is not apparent that, unlike other unoccupied positions within the song proper, these initial vacancies are a component of the listener's mental image of the song.

The radial grid does not require that we choose to represent any position as initial or final. As such, as can be seen in 2.5, the radial grid can naturally accommodate the entire family of binary grids in 2.4, requiring only that the texts for songs having anacruses be rotated counterclockwise along the circle. Thus, the representation of 2.4 b) requires that it be rotated 90 degrees counterclockwise compared to 2.4.which, as an in phase structure is initiated at twelve o'clock. Other rotational possibilities of 180 and 270 degrees are indicated in 2.4 c) and d). The anacrusis, within the radial grid involves moving the hand of a clock backwards to positions which are made available in the radial structure, but not the linear grid.

2.5 (will create these later)

For convenience, we will continue to make use of linear grids with the understanding that these offer a truncated representation of metrical reality compared to the accurate description of the temporal reality of metrical structure in the radial grid such as that in 2.3.

3. Metrical computation

It is important to recognize that the above discussion only goes part way in accomplishing the objective we defined at the outset. For what we have done so far only succeeds in characterizing the type of structure assigned by listeners when they perceive a beat. It says nothing about how the listener comes to make a particular grid assignment as opposed to many other logically possible candidates when encountering a raw musical surface. It turns out that the computation which listeners effect in making this judgment is, as is often the case when we attempt to model human cognitive capacities, quite complex. The following discussion is not intended to provide a comprehensive solution, but rather an introduction to what the sort of computational machinery the solution requires.

While the previous discussion did not specify any characteristics of the metrical computation, it does, however, provide us some guidance as to its form. In particular the characterization of well formed grids specifies a limited class of possible output structures. This implies that listeners do not construct a grid from scratch, rejecting those grids such as those in 2.1 which do not meet the binary or ternary spacing condition. Rather the listener chooses the best candidate from a comparatively small number of options dictated by the binary and ternary spacing conditions. Simple arithmetic allows us to be precise as to how many options there are: given two metrical levels one higher (which we will call superordinate) and the other lower (subordinate) there are two in phase arrangements, one binary the other ternary:

3.1 in phase two level grids)

a)

```
x   x   x   x
x x x x x x x . . .
```

b)

```
x     x     x
x x x x x x x . . .
```

In addition there are three out of phase arrangements, one binary and two ternary:

3.2

```
a)
  x   x   x   x
x x x x x x x x . . .

b)
  x     x     x
x x x x x x x x . . .

c)
    x     x     x
x x x x x x x x x . . .
```

A two level grid therefore allows for five possible arrangements, with each additional level increasing the total by a factor of 5. The three level in phase grids shown in 2.1 and the out of phase grids in 2.4 identify seven out of a possible twenty five. The four level grid describing the metrical structure of 1.1 is one of 125 well formed possibilities.

As 1.1 indicates, the set of possible grids is further reduced by the particular character of the passage in question. Among well formed grids, only certain alignments of metrical positions with notes are heard by listeners as viable metrical forms. Thus for example, the following grids cannot be assigned to the texts and tunes in question:

```
3.3
a)

  x                       x
  x           x           x
  x   x   x   x   x   x   x   x
Twinkle twin kle lit tle star

b)

     x               x              x
     x       x       x       x      x     x
 x   x   x   x   x   x   x   x  x   x  x  x
Did you  e          ver see  a las sie
```

What will stand out as most problematic in each of these is what is referred to as the stress mismatch. That is, the words "twinkle" and "lassie" which have stress on their first syllable are assigned to metrical weak-strong positions on the grid.

While the arrangement of text can be decisive in a listener's metrical assignment it is important to recognize that a text is not required for listeners to make metrical judgements. Consider, for example, the pattern of short and long notes, where each non-final long (L) has twice the length as every short (S).

3.4 SLSLSLSLSL

As has been shown in empirical studies, the listener will (all things being equal) tend to assign the out of phase ternary pattern in 3.5 to the raw sequence indicated in 3.4:

3.5
```
  x     x     x     x     x
x x x x x x x x x x x x x x
S L   S L   S L   S L   S L
```

While the addition of a text can effect this assignment, ("The curfew tolls the knell of parting day" will reinforce it whereas "Never, never, never, never, never." will challenge and possibly overturn it), the independent musical structure is by itself sufficient for the listener to have relatively strong intuitions for what constitutes a correct metrical assignment.

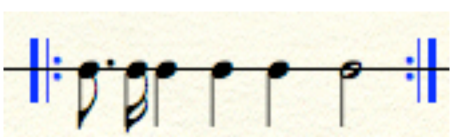
Since independent musical structure can autonomously dictate the assignment of metrical form, we will in the following take for the input musical surfaces which do not contain the complications potentially induced by texts. Furthermore, in addition to limiting ourselves to textless surfaces, we will also simplify the input structures by omitting pitch. As we saw above, the series of pitchless pulses indicated in 3.5 is also sufficient for a listener to assign a relatively unambiguous metrical structure. Just as texts can reinforce or challenge the default metrical assignment, so too can pitch structure. However, that a listener can derive a metrical interpretation in the absence of pitch means that we can accept a purely rhythmic surface as an idealization which will provide insight into the mechanisms according to which rhythmic structure is assigned. Once a computational account of the metrical structure assigned to pitchless, textless surfaces, (hereafter neutral surfaces) is derived we can attempt to incorporate into the computation complicating factors such as pitch, text, dynamics, timbre, etc. These will have an analogous status to the masses of springs and the friction of planes in mechanics. Real insight into the problem requires that we deal with the idealized cases first.

4. Outline of the Computation

Our previous assertion that neutral surfaces can be relatively unproblematically assigned a metrical structure does not hold true in all instances. For example, steady streams of eighth or sixteenth notes are frequently encountered in instrumental etudes such as those of Chopin or in the patter arias of Gilbert and Sullivan. Rhythm, in these instances, provides no basis for the attribution of metrical structure thus, other musical factors including pitch, harmony, orchestration and text are required for the attribution of a metrical structure. We can, for the moment have nothing to say about these types of case and we will choose to focus our discussion on neutral rhythmic structures which are easily assigned a meter and to devise the computational machinery required for generating the appropriate output structure.

One such surface is that indicated in musical notation 4.1.

4.1



Again, as in 1.1 above, we have eliminated the barlines, time signature and beaming which would otherwise provide cues to metrical structure. For various reasons to be discussed later it will be useful to go a step further and completely eliminate any potential musical associations from the representation by representing the surface as a sequence of successive attack points as in 4.2:

4.2 ||: 3 1 4 4 4 8 :||

4.2 makes it easier to view what is indicated in 4.1 for what it is: a non-musical sequence of pulses, beeps, or taps. In whatever context they are experienced, a listener will fairly unproblematically assign to 4.2 the metrical structure in 4.3:

4.3

```
        x                       x
x       x       x       x       x       x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
3     1 4       4       4       8
```

Our objective is to account for this competence by determining the computational mechanisms by which 4.3 will be formally assigned to the sequence in 4.2. In short, the computation is required to assign the output 4.3 to the input 4.2.

We begin by assigning to 4.1 the smallest series of isochronous pulsations required so that each event will fall on what will become the lowest metrical level. The second event having a duration of 1 provides us with the subdivision level L(0):

4.4

```
3     1 4       4       4       8
x x x x x x x x x x x x x x x x x x x x x x x x L(0)
```

The next steps in the computation involve the assignment of the remaining levels.

As mentioned previously, each subsequent level allows for five assignments consistent with the binary and ternary spacing conditions, with two in phase and three out of phase options. Four metrical levels will allow for the assignment of 125 possible well-formed grid structures determining a formal process by which the winning candidate successfully competes against the other 124.

We will instead consider a more manageable and probably more computationally efficient approach which is to evaluate only the partial grid structures which result from the addition of a single higher metrical levels.

Thus, the addition of level L(1) will result in an in phase binary and an in phase ternary, referred to as B0 and T0 respectively. It will also allow for the single out-of-phase binary arrangement (B1) and two out of phase ternary arrangements T1 and T2.

4.5

a) B0

```
x   x   x   x   x   x   x   x   x   x   x   x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
3     1 4       4       4       8
```

b) B1

```
  x   x   x   x   x   x   x   x   x   x   x       L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
3     1 4       4       4       8
```

c) T0

```
x     x     x     x     x     x     x     x       L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
3     1 4       4       4       8
```

d) T1

```
  x     x     x     x     x     x     x     x         L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
3     1 4       4       4       8
```

e) T2

```
    x     x     x     x     x     x     x     x       L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
3     1 4       4       4       8
```

We now need a means of determining which of the logically possible grids assigned to the event sequences is consistent with listeners' demonstrable preferences with respect to metrical form. These preferences are positively informed with respect to what we will call hits, events which fall on the metrical level in question and, negatively, by misses, defined as events which do not. In the following hits are indicated by bold faced type and misses by italics.

4.6

a) B0

3 *1* **4** **4** **4** **8**

```
3     1 4       4       4       8
x   x   x   x   x   x   x   x   x   x   x   x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

b) B1

```
3     1 4       4       4       8
  x   x   x   x   x   x   x   x   x   x   x       L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

c) T0

```
3     1 4       4       4       8
x     x     x     x     x     x     x     x       L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

d) T1

```
3     1 4       4       4       8
  x     x     x     x     x     x     x     x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

e) T2

```
3     1 4       4       4       8
    x     x     x     x     x     x     x     x   L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

It is fairly obvious that the most plausible candidate, namely a), is characterized by containining both the greatest hits and the fewest number of misses.

Making this observation explicit requires us to note that the aggregate number of hits or misses is not a decisive indication. This is because binary orientations contain more locations than ternary, thus increasing the likelihood of a hit thereby penalizing the ternary options. We can avoid this potential source of error by choosing as our relevant index not aggregates hits or misses, but the hit ratio, the number of each to the number of locations.

4.7 hit ratio

a) 5/12
b) 1/12
c) 2/8
d) 2/8
e) 1/8

From these results it is clear that the only possible candidate for metrical level L(1) is a). We therefore choose the in phase binary option as our candidate and continue matching the raw surface to the five possible metrical grids which result from a superordinate metrical level L(2) constructed above 4.6 a):

4.8

a) B0

```
3     1 4       4       4       8
x       x       x       x       x       x         L(2)
x   x   x   x   x   x   x   x   x   x   x   x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

hit ratio: 5/6

b) B1

```
3     1 4       4       4       8
    x       x       x       x       x       x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 0/6

c) T0

```
3     1 4       4       4       8
x           x           x           x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 2/4

d) T1

```
3     1 4       4       4       8
    x           x           x           x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 1/4

e) T2

```
3     1 4       4       4       8
        x           x           x           x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio 2/4

Again, the winning candidate is a) in which five of the six L(2) positions are occupied by events.

We now compare the five candidates resulting from constructing the next metrical level L(3) above 4.8 a):

4.9

a) B0

```
3     1 4       4       4       8
x               x               x                 L(3)
x       x       x       x       x       x         L(2)
x   x   x   x   x   x   x   x   x   x   x   x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

hit ratio: 3/3

b) B1

```
3     1 4       4       4       8
        x               x               x         L(3)
x       x       x       x       x       x         L(2)
x   x   x   x   x   x   x   x   x   x   x   x     L(1)
x x x x x x x x x x x x x x x x x x x x x x x x   L(0)
```

hit ratio: 2/3

c) T0

```
3     1 4       4       4       8
x                       x
x       x       x       x       x       x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 2/2

d) T1

```
3     1 4       4       4       8
        x                       x
x       x       x       x       x       x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 2/2

e)

```
3     1 4       4       4       8
```

```
                x                       x
x       x       x       x       x       x
x   x   x   x   x   x   x   x   x   x   x   x
x x x x x x x x x x x x x x x x x x x x x x x x
```

hit ratio: 1/2

Three of the candidates a), c) and d) have a hit ratio of 1, corresponding all L(3) beats with events.

This result is interpreted as predicting that these three metrical structures will be heard as equally viable metrical assignments for the raw sequence in 4.1. While in principle possible-many sequences are, in fact, metrically ambiguous allowing for two or more metrical interpretations, in this instance this prediction is incorrect; it is easily verified, as we noted in 4.3, that the correct metrical assignment is not ambiguous but that of d). While a) is plausible, c) is, all things being equal, quite unnatural, contrary to what is predicted by our computation in its present form.

The basis for the relative preference for d) resides in a factor which is not so far incorporated into our computational mechanism namely event length where length is defined in the sense discussed previously, as the time point between the attack of an event and that of the succeeding event. When rhythmic sequences are composed of events of different lengths there is strong tendency to locate relatively long events (in this sense) on metrically strong positions of the grid.

The numerical code in the time point representation allows us to read off length information and to observe that the most viable metrical interpretations a) and d) do, in fact, both situate the longest unit of the sequence on the metrical level L(3). In contrast, the least viable candidate having a hit ratio of 1, c), assigns the longest event in the sequence to a relatively weak position.

This informal observation can be made precise and predictive by devising what we will refer to as the weighted hit ratio or WHR. The WHR is defined as the sum of the lengths of events occurring on the metrical level in question divided by the total number of positions on this level.

4.9 shows the results of a computation for the WHR for the five candidate grids in 4.8:

4.9 WHR
a) 3+4+8/3 = 5
b) 4+4/3 = 2.7
c) 3+4/2 = 3.5
d) 4+8/2 = 6
e) 4/3 = 1.3

The WHR correctly predicts the range of preferred hearings with d) scoring the highest, a) a reasonably close second and c) a distant third. Furthermore, it will be seen that the WHR can be substituted for the simple hit ratios calculated earlier and will not influence the computation which led us to these results.

Finally, as will be seen, the computation making use of the WHR will yield predictions which are reasonably close to the intuitions of most listeners when they are confronted with neutral rhythmic surfaces.