A Computer-Assisted Analysis of Rhythmic Periodicity Applied to Two Metric Versions of Luciano Berio's Sequenza VII

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In a computer-assisted analysis, a comparison is made between two metered versions of Luciano Berio's *Sequenza VII*: the "supplementary edition" drafted by the oboist Jacqueline Leclair (published in 2001 in combination with the original version); and the oboe part of Berio's *chemins IV*. Algorithmic processes, employed in the environment of the IRCAM program Open Music, search for patterns on two levels: on the level of rhythmic detail, by finding the smallest rhythmic unit able to divide the all of the note durations of a given rhythmic sequence; and on a larger scale, in terms of periodicity, or repeated patterns suggesting beats and measures. At the end of the process, temporal grids are constructed at different hierarchical levels of periodicity and compared to the original rhythmic sequences in order to seek instances of correspondence between the grids and the sequences. As the original notation of consists of a combination of rhythmic and spatial notation, and the section analyzed in this study consists entirely of spatial notation, this analysis of the metric versions of *Sequenza VII* investigates to what extent the rhythms and meters put into place are perceptible in terms of periodicity, or are rather made ambiguous by avoiding periodicity.

1. Introduction: the Supplementary Edition and *chemins IV*

In 1996, the American oboist Jacqueline Leclair drafted a metered version of Luciano Berio's *Sequenza VII* for oboe solo. She showed her 're-notation' to Berio, and obtained his permission to have her metered version published as a supplementary edition.[1] This development in the life of this work prompts me to investigate the rhythmic material particular to Leclair's version, in comparing it to that of *chemins IV*[2], which could be considered to be Berio's own metered version of *Sequenza VII*. This analysis will employ algorithmic processes in the Open Music[3] environment in order to search for patterns of rhythmic periodicity.

2. The Original Notation and the Problematics of its Re-notation

> *The issue of notation comes out, at least in my own musical perspective, when there is a dilemma, when there is a problem to be solved. And that pushes me to find solutions that maybe I was never pushed to find before. That happens, of course, mostly when there is a certain amount of indeterminacy that is needed in order to gain a certain result...the larger issue, the scope of the work, the reason, if you want, both the technical and expressive reason of the work, that justifies the local situation.*[4]

The most original aspect of the notation of *Sequenza VII* is its grid structure: thirteen lines of music are intersected by thirteen vertical dotted lines dividing each line into the same set of subsections with very specific second durations (2.7 seconds, 1.3 seconds, etc.). The notes between these subdivisions are in a freely mixed combination of spatial and 'rhythmic' (notes with specified rhythmic values) notation; the use of rhythmic material increases over the course of the piece. The durations of the unmeasured notes are determined either spatially, in relation to the indicated seconds, or by articulation: there is a vertical line through some of the notes indicating that they are to be as short as possible. Although having the same set of second durations for each line would seem to indicate that each line should have the same duration (22.6 seconds, the total of the thirteen subdivisions), this is not the case, because there are fermatas within many of the subdivisions having their own additional indicated second durations.

The re-notation of *Sequenza VII* by Leclair began as her own personal method of interpreting the notation in order to execute the indicated second durations as accurately as possible. Her re-notation is, therefore, not an exact calculation of rhythms made by measuring the spaces between notes in the unmeasured subsections, but rather a representation of her own rhythmic interpretation of

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[1] Published by Universal Edition (Vienna, 2001), as *Sequenza VIIa per oboe* (1969, rev. 2000), with the original unmeasured notation printed on the back of the supplementary edition. This edition includes a short commentary by Leclair on Holliger's performance notes (warning that they 'have varying degrees of applicability'), as well as some minor notational changes in the score, such as the use of microtones in the "chords" (i.e. multiphonics).

[2] *Chemins IV, su Sequenza VII, per oboe e 11 archi*, Universal Edition (Milan, 1975). As the title indicates, the work is based on Sequenza VII, the solo oboe becoming a soloist accompanied by an ensemble.

[3] IRCAM software designed by G.Assayag and C.Agon, and developed by the research team at IRCAM

[4] From an interview with Luciano Berio conducted by Benedict Weisser, April 24, 1997. Transcribed in Benedict Weisser, *Notational Practice in Contemporary Music: A Critique of Three Compositional Models (John Cage, Luciano Berio, and Brian Ferneyhough)* (PhD dissertation, City University of New York, 1997), Appendix A, lines 12-29

these events as a performer, set in a new thirteen-line grid that accurately replicates the second durations in metered form; in her tempo of a quarter-note = 60, (there is of course no tempo marking in the original), the first subdivision of 3 seconds becomes a 3/4 measure, the second subdivision of 2.7 seconds becomes 11/16, etc. . Because her choice of rhythms serves only as the means towards the goal of accurately executing the durations, she suggests that the performer use her re-notation as a guide for study, and perform from the original.[5]

This technique of interpreting spatial rhythms into new measured relationships which are not necessarily exact interpretations of the spaces between each note but nonetheless keep the overall proportions of the piece intact is similar to the process used by Berio in producing a rhythmic version of his *Sequenza I* in 1992[6]. Berio's idea of the function of his metric version of *Sequenza I* is also similar to Leclair's performance idea, in its intention to minimize the loss of rhythmic freedom: '...what's happening is that they are continuing to perform, if they don't learn it by heart, from the older spatial notation, and they use the rhythmical [1992] version as a reference.'[7]

When Leclair sent her re-notation of *Sequenza VII* to Heinz Holliger in 1997 (before Berio had approved its publication), Holliger responded that although it is an 'accurate work', he didn't 'see really the reason for it', because he considers the oboe part of *chemins IV* to be Berio's own measured version. The solo-part from *chemins IV* does not, however, function in the same way as Leclair's re-notation for three reasons: it does not attempt to preserve the overall duration of the original, it does not retain the same subdivisions as the original (but rather introduces new metric divisions), and it does not retain the grid structure of the original. Holliger went on to praise the original notation of *Sequenza VII:*

> I like very much Berio's clever notation: mixing normal and space [spatial] notation. It gives the right balance between precision and spontaneity. It is very precise where it needs to be and leaves some freedom where it has to...[it is] very appropriate and imaginative notation, which is a very exact image of the isometric structure of the piece ...[8]

We will now look at the supplementary edition in finer detail: at the level of local rhythm, in a comparison to the rhythms of the solo part of *chemins IV* with a particular focus on the problematic of periodicity (here defined as rhythmic patterns whose regularity suggests beats and their organization in measures).

In general, Leclair retained the rhythmic portions of the original score in their entirety, the fermatas with their durations in seconds, and the grace notes. As discussed earlier, the second durations of the original grid become their metric equivalents, exact or approximate, in the new grid: in the tempo quarter note = 60, the whole number second values and certain other values are replaced by their exact equivalents (3/4 for 3 seconds, 3/8 for 1.5, etc.), while more irrational values are slightly modified, while preserving their different proportions (11/16 is very slightly – .05 seconds – longer than 2.7 seconds, 7/16 is .05 seconds longer than 1.8 seconds, etc.). The difficulty arises in fitting the spatial notation into the metric structure, while retaining a sense of the un-metered complexity of the original. The relative periodicity of a section will be the measure used here to test its 'metric' feel; for this purpose, a temporal grid will be created and compared to the notated rhythms. This analysis will be applied to the first thirteen measures, corresponding to the first line in the grid notation. As this opening section consists only of the note B4 repeated with different colorations, rhythmic details are particularly discernible.

3. The Creation of a Temporal Grid Based on a Fundamental Unit

> *…very often what happens, there is a temporal grid, maybe static, but the other ones [other temporal organizations] are moving in a constantly mobile way. Sometimes the temporal grid is completely abstract, indifferent...There are always different phases that are important.*[9]

The temporal grid is created by a process using the Open Music environment[10]. An algorithmic function (originally designed to determine the virtual fundamental of a series of frequencies) finds the smallest unit by which all of the lengths of the notes[11] can be evenly divided; this temporal unit will be referred to as the "fundamental unit" in this study. Another function finds the multiple of the fundamental unit corresponding to each note duration as it occurs over time within the overall segment (see Appendix 1). Thus, if the unit equals 500 milliseconds, notes in the grid can only have a duration that is a multiple of 500. The interest of this process is twofold: the primary goal is to

[5] Jacqueline Leclair, correspondence with the author, January 1999-March 2000

[6] Benedict Weisser's study of the1992 version shows that it does not attempt to exactly convert the spatial relationships into equivalent rhythmic proportions.

[7] Weisser, 'Luciano Berio: Notation-as-Play within a Predefined System.' Appendix A, lines 98-100

[8] Heinz Holliger, letter to Jacqueline Leclair, October 3, 1997 (provided by Leclair to the author)

[9] Berio, in Weisser, 'Luciano Berio: Notation-as-Play within a Predefined System' Appendix A, lines 169-180

[10] See footnote 3. I would like to thank former IRCAM researcher Killian Sprottle for his valuable input.

[11] For the purposes of this study, the length of the note is considered to be the time between one attack and the next. Rests are not taken into account because they cannot be considered articulations in time in the same way as an attack at the beginning of a note.

establish a regular "pulsation" suggested by the rhythmic segment itself, against which it can be compared; at the same time, the calculation of the fundamental unit gives some indication of the rhythmic complexity or variety of the segment, as a smaller value indicates more variety and a larger one regularity. The unit can be multiplied in order to show higher-order periodicity. For example, if a 500-millisecond fundamental unit is the equivalent of an eighth note in the tempo quarter note=60, it may be relevant to double the fundamental unit in order to compare the rhythmic segment to a quarter-note pulsation.

4. A Periodic Analysis Based on Auto-segmentation

In the following section, the calculation of a fundamental unit will determine the initial segmentation relevant to a comparative analysis. Given a minimum segment length (in this case, five notes), a process of auto-segmentation gives the longest possible sequence with the largest possible fundamental unit. In both the supplementary edition and *chemins IV*, the fundamental unit for the first segment of the piece is 250, or a sixteenth note, but the segment length is not the same: the sixteenth note remains the fundamental unit for the first twelve notes, up until the triplet figure in the seventh measure of the supplementary edition, while in *chemins IV* it changes in the course of the fifth and sixth measures, after the tenth attack. Thus, the first comparative analysis using temporal grids will be restricted to the first ten attacks[12], contained in the opening four and a half measures. In both versions, while the fundamental unit is 250, an eighth-note grid is also relevant (the fundamental unit doubled); furthermore, in the supplementary edition, most of the periodicity also occurs on the superior quarter-note level.

Examples 1a and 1b compare the first segment of the supplementary edition (which will be referred to as SE from here on) to two grids, with fundamental units of a sixteenth note and of an eighth note respectively. As the sixteenth-note is the fundamental unit of the rhythmic sequence, the first grid reproduces the sequence entirely; the only difference in the grid version is that there are no rests (see footnote 2) and the time signatures are changed in order to show a possible metric grouping suggested by the rhythm. The eighth-note grid corresponds to all but three notes of the ten-note sequence, while six notes of the sequence fall on beats (although one of these notes is displaced by a grace note), thus reinforcing a quarter-note pulse. On the metric level, in the time signature of 3/4, notes fall on all four downbeats but one.

Example 1 illustrates periodicity on several levels, most strongly on the level of the eighth-note pulsation (7 out of 10 notes, thus 70%), and almost equally on the quarter-note level (60%). Taking the three grace notes into account[13], the selection is in fact 60% periodic on the eighth-note level and 50% periodic on the quarter-note level. The first five notes all fall on beats except for the fourth, which is displaced by a grace note. The first rhythmic rupture of the periodicity (a rupture achieved by a the note values themselves rather than the presence of a grace note) is achieved by the 11/16 measure, which displaces the quarter note pattern by a sixteenth-note; this is illustrated by the eighth-note grid (Example 1b), which is no longer aligned with the original in its third measure of 3/4 time. The syncopated sixteenth notes fall once again into the original quarter-note pulsation, but the last eighth note is outside of it (and is furthermore also preceded by a grace-note), so that the second half of the segment is generally less periodic than the first (Example 1b). As for the notes that would fall on the downbeats in a meter of 3/4, it is important to note that two of these three notes have the indicated dynamic of *P*, while all of the other attacks are marked either *fff* or *sffz*; therefore, the suggestion of a 3/4 meter is relatively weak.[14]

The total duration of all of the notes and rests up until the tenth attack is nearly the same in *chemins IV* (which will be referred to as *chIV*) as in SE: 10000 milliseconds in *chIV*, as compared to 10250 milliseconds in SE[15]. As in SE, the fundamental unit for this section is 250 (a sixteenth-note pulsation - see Example 2a), and the fundamental unit doubled (an eighth-note pulsation) is able to reconstruct most of the rhythmic sequence (60%, as compared to 70% of SE, without taking grace notes into account - see Examples 1b and 2b). However, *chIV* is much less periodic on the quarter-note level: 30%, as compared to 60% in SE, without counting grace notes; it is therefore also more metrically ambiguous, despite the fact that the metric structure chosen by Berio is slightly less complex: where Leclair has a 11/16 measure, *chIV* has a 5/8 measure[16]. As the tenth attack is displaced by a grace note, only the first and third attacks actually fall on a quarter-note pulsation, and the second of these attacks is de-emphasized by the dynamic *P* (Examples 1b and 2b). The fact that the first four notes could be interpreted as being in the tempo of 40=quarter note – as two quarter notes followed by two eighth notes - contributes to the

[12] More precisely, the time between each attack (see footnote 9), up to and including the note falling on the second eighth note of the fifth measure in both versions.

[13] As in the original notation, the grace-notes in the second, third and fourth measures are accented and tied to the notes they proceed, which are articulated only by a change of fingering (indicated as a number above the note in the score). For the purposes of this study, a change of fingering will not be taken into account as a new note, as it does not constitute a true articulation, but rather a change of color.

[14] When a fourth instance of a 3/4 "downbeat" appears later in the first line (measure 7), it has the dynamic *PP*.

[15] The indicated tempo for *ChIV* is eighth note=110-120; the latter tempo is considered in order to simplify comparisons with SE.

[16] This metric difference results in SE being 250 milliseconds longer than the corresponding measures of *chIV*.

metric ambiguity. In general, the rhythmic placement of notes is quite varied, with only three notes falling on beats, three notes falling an eighth note after the beat, two falling a sixteenth-note before the beat, and two falling a sixteenth-note after, without taking grace notes into account (see Example 2a). This diversity is due in part to the 5/8 time signature, but is mainly the result of the frequent use of the dotted eighth note, constituting half of the note values.

From this analysis of the first segment of the two versions, the following observations can be made: first of all, that the irregular time signature of 11/16 chosen by Leclair is, predictably, effective in achieving a rupture of the quarter-note periodicity; secondly, that in Berio's own version of the same material, quarter-note periodicity is largely avoided, mostly due to the numerous dotted-eighth notes. We will now look at the point at which the two versions differ in terms of their respective fundamental units. The tenth (attacked) note, occurring in measure 5 and tied into measure 6, has a total duration of 3000 milliseconds (three beats) in SE, and thus does not vary from the fundamental unit of 250; neither does the distance between the eleventh and twelfth attacks (measures 6 and 7 respectively), which equals 1000 milliseconds. The tenth note in *chIV*, on the other hand, totals 3167[17] milliseconds, or three and 1/6th of a beat, thus necessitating the new fundamental unit of 83, or 1/12 of a beat: the largest possible divisor of both a sixteenth note and 1/6 of a beat.

5. Using a Temporal Grid to Find Patterns of Large-scale Periodicity

By applying the fundamental unit of 83 to the whole first line of SE and its corresponding section of *chIV*, a comparative analysis can be made on a larger scale. More than half (eleven out of 21) of the attacks fall within an eighth note pulsation[18] in SE, as compared to eight attacks occurring on this level of periodicity in *chIV* (see Examples 3a and 4a). The difference is more marked on the quarter note level: nine attacks of the first line of SE are placed on "beats" (in terms of a steady quarter note pulsation), while only five attacks of *chIV* are aligned with "beats" (see Examples 3b and 4b).[19] Eight out of nine of the attacks on "beats" in SE occur either in the first two measures or between measures 7 and the downbeat of measure 9; thus, the time signature of 4/12 of measures 9 and 10 achieves a certain rupture of periodicity, analogous to the periodic displacement occasioned by the 11/16 measure (see Example 3b). The 4/12 measures also disrupt the larger scale (but weaker) three-beat pattern (see Example 3b).

These observations are based on a system taking the first attack as a point of departure for all patterns of periodicity. In the final phase of this analysis, a process will automatically choose the starting point yielding the most instances of periodicity on a given level. In the case of SE, the most relevant levels of periodicity all start with the first attack. The same is generally true for *chIV*, with one possible exception: starting with the seventh attack, three notes fall into a "metric" pattern of three beats, displaced in relation to the first attack by a sixteenth note (Example 5). This pattern is not strong enough to actually suggest a time signature of 3/4 (the first attack is displaced by a grace note, the last of the three attacks has the dynamic *PP*, and the correspondences to the grid are not all consecutive), but rather has the effect of undermining the quarter-note and eighth-note pulsations established by the opening notes.

6. Analytical Applications of a Temporal Grid: Conclusions

In this brief analysis, a temporal grid has been used to find periodicity on several levels: first of all, the calculation of the fundamental unit itself reveals the level of rhythmic complexity on a foreground level, while the process of auto-segmentation indicates where changes take place on this level; secondly, a comparison with a temporal grid reveals levels of periodicity that reinforce a feeling of beats in a given tempo; and finally, this same process of comparison can suggest metric groupings by repeated correspondences to a higher-level multiple of the fundamental unit.

References

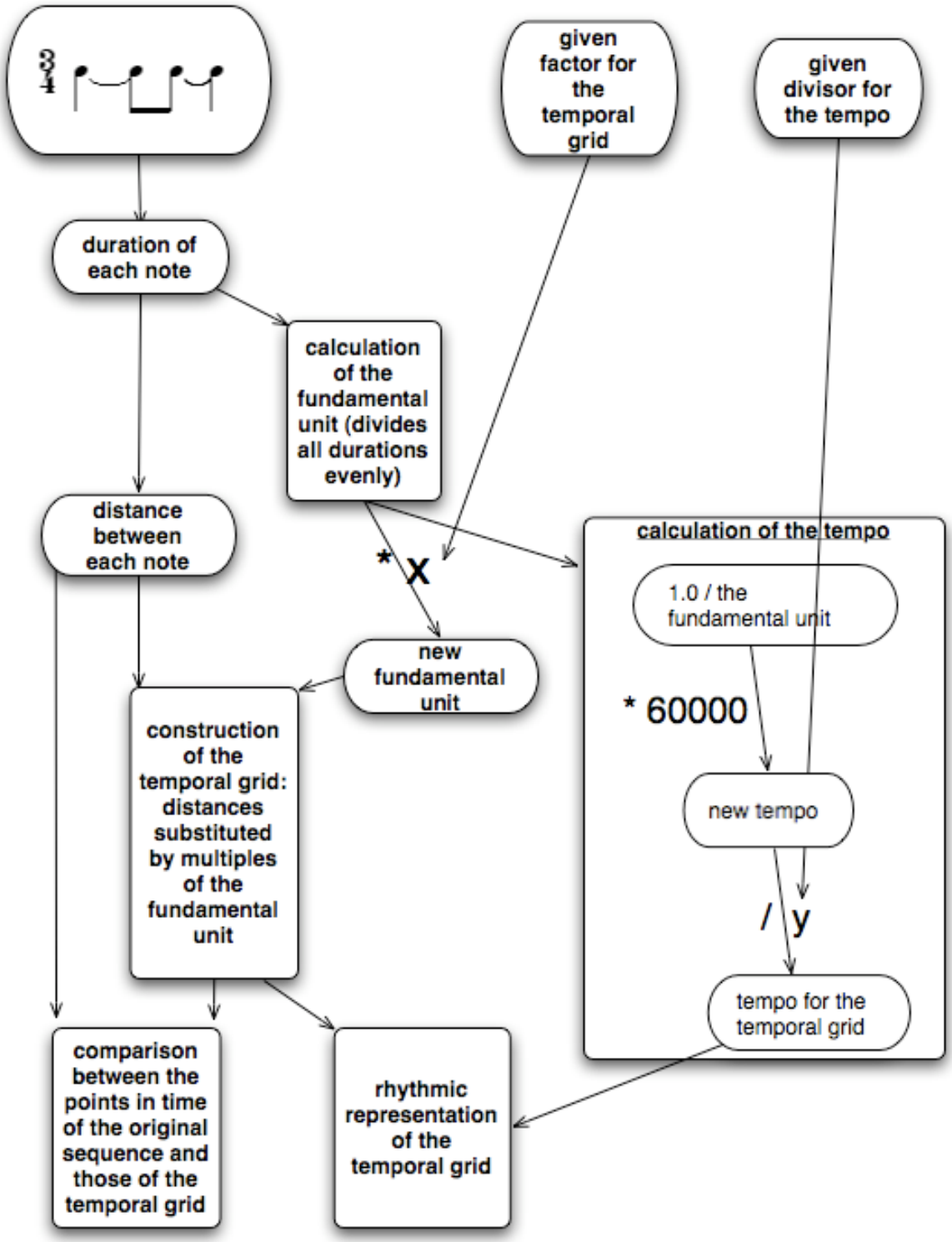
[1] Berio, L. "*Sequenza VIIa per oboe (1969, rev. 2000)*", Universal Edition, Vienna, 2001

[2] Berio, L. "*chemins IV, su Sequenza VII, per oboe e 11 archi"*, Universal Edition, Milan, 1975

[3] Weisser, B. *Notational Practice in Contemporary Music: A Critique of Three Compositional Models (John Cage, Luciano Berio, and Brian Ferneyhough)*, PhD dissertation, City University of New York, 1997

[17] Both millisecond durations and fundamental units are given as rounded figures.
[18] The fundamental unit multiplied by six.
[19] In both versions, one of the notes which falls on a "beat" is preceded by a grace note, as mentioned earlier.

Appendix 1: the algorithmic process



Note: The given factor for the temporal grid and the divisor of the tempo may be determined in relation to the fundamental unit.