THE ROLE OF RING MODULATION IN THE FORMAL STRUCTURE OF ROGER SMALLEY'S MONODY FOR PIANO WITH LIVE ELECTRONIC MODULATION

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ABSTRACT
The notated score for Roger Smalley's 1972 work Monody consists of a single line performed by a single performer on piano and percussion. The monophonic nature of the work is ambiguous, however, due to the electronic processing of the live performance via ring modulation. Ring Modulation in this work consists of electronically "multiplying" the audio signal from the acoustic instruments against a sine tone to output the sum and difference tones between their waveforms. In his program notes Smalley claims that by "restricting the piano part to a single monodic line throughout (...) only one set of addition and difference tones is produced and their frequencies can be exactly predicted". However, the timbres of both the piano and percussion (4 Triangles, 2 Congas and 2 Timbales) have complex overtone series, and their interaction with the ring modulation process leads to the production of sounds that arguably have features of both timbre and harmony. This paper seeks to investigate this ambiguity and the role that it plays in the structure of Monody, through the comparison of the notated work and spectral analysis of its actual sound in conjunction with discussion of the psychoacoustic notions of the boundaries between timbral fusion and separation.
1. INTRODUCTION

Monody (1972), for piano, percussion and live electronics was one of the last works Roger Smalley (1943-2015) wrote in England before moving permanently to Australia. For Smalley the mid-sixties had been dominated by the influence of Stockhausen, and the late sixties by his work with Intermodulation, a live electronics ensemble comprising Smalley, Tim Souster, Andrew Powell and Robin Thompson. Monody was written for Intermodulation, an ensemble modelled on Stockhausen’s own live electronics and progressive rock group Soft Machine (Mark 2012: 100). Monody bears influences of both.

In 1974 Simon Emmerson wrote that the interest in “Live-Electronic” processing was “probably a direct consequence of his attendance at Stockhausen’s Darmstadt Course in 1967” (Emmerson 1974). Monody exclusively uses the live processing technique Ring Modulation (RM), a prominent in a number of Stockhausen’s works notably: Mixtur for orchestra and live electronics (1965) and Mantra (1970) for 2 pianists with wood blocks and antique cymbals and live electronics.

Emmerson also notes the work:

- Emerged at a time coinciding with the development of consonance and periodicity in Smalley’s musical language;
- is unitary in form (all sections being derived from a single musical idea in all its permutations);
- uses rhythmic modes and repeated sequences derived from the Fibonacci series. (Emmerson: 18)

The notated score for Monody, consists of a single line performed by a single performer on piano and percussion. The monophonic nature of the work is ambiguous, however, due to the electronic processing of the live performance via ring modulation. RM results in almost no change in the harmonic spectra of pitches of the same frequency, but increasingly inharmonic, noisier spectra in pitches that are more distant in the harmonic series (the process is explained in more detail in section 2). Despite the similarity in instrumentation to Mantra, RM makes a different contribution to the formal structure of Smalley’s work. In Mantra, RM is principally used to differentiate changes in the transposition of the work’s generative series, its use in Monody by contrast is principally timbral/harmonic, (with the same exceptions as discussed below), acting as an additional marker of parametrical variation between the sections.

This paper explores the spectrogram as a means of examining the effect of RM in Monody and its contribution to the formal structure of the work. As I have previously argued (Vickery 2011), the emergence of substrutures from the fabric of musical discourse derives from shifts in the level of continuity from one moment to the next, marked by perceptible changes, discontinuities, between “form-bearing” musical parameters. The spectrogram represents duration and pitch/timbre spatially, and amplitude through colour intensity. These parameters include four of the five “form-bearing” parameters listed by McAdams (1989 p. 195). In general terms the spectrogram is most suited to exploring electronic music where there are difficulties creating a visual representation or score to accurately reflect the sonic complexities of the work. In Monody the degree of parametric disjunction created by the use of RM can be visualised. Tools to measure the spectral attribute brightness, noisiness and amplitude have also been employed.

The recording used for this study was made by Smalley’s then partner pianist Cathie Travers and presumably overseen by the composer. As will be shown, the performance adheres very precisely with Smalley’s intended temporal proportions. It was recorded at the University of Western Australia (where Smalley was professor) during New Music Week in October 1990.
2. THE ELECTRONIC MODULATION

The RM used in Monody consists of electronically “mul-tiplying” the audio signal from the acoustic piano against a sine tone to output the sum and difference tones between their waveforms. Since RM does not calculate logarithmically the resulting frequencies do not necessary conform to equal temperament (which does follow a logarithmic progression). The resulting frequencies in the example below, for example vary from equal tempered pitches by 2 and 5 Hz respectively.

Input frequency fundamental = 261 Hz (C3)
Modulation Frequency = 110 Hz (A1)
Result: 371 (261+110) Hz and 151 (261-110) Hz
(F#3 [369 Hz] and D2 [146 Hz]).

Figure 1. Smalley's schematic for the RM setup for Monody.

In his program notes Smalley claims that by “restrict-ing the piano part to a single monodic line throughout (...) only one set of addition and difference tones is pro-duced and their frequencies can be exactly predicted”. However, the timbres of both the piano and percussion (4 Triangles, 2 Congas and 2 Timbales) have complex overtone series, and their interaction with the RM process leads to the production of sounds that arguably have features of both timbre and harmony.

In Audio Scene Analysis (Bregman 1990) suggests that the virtually simultaneous onset and envelope of the piano sound and the RM output, would encourage fusion of the resulting complex of sound into a timbre, but working against timbral fusion is the fact that the pitches produced are often significant intervals from the source pitch and that the frequencies produced are often inharmonic and unlikely to be processed by the human auditory system as belonging to the same harmonic series. The human auditory system is also more responsive to mid-range frequencies (200-5000Hz) and therefore RM outputs that fall outside that range contribute less to the perceived sound.

All acoustic instrument notes are comprised of a fundamental frequency and a number of overtones of varying weights that contribute to the human perception of instrumental timbre. These overtones, although not as strong, are also ring modulated producing a more complex timbre than implied by simply calculating the output of just the frequency of the piano note. Figure 2 shows the overtone weights of a typical piano note (left) and the RM products the fundamental and the first two overtones of an acoustic piano’s C3 and a modulation frequency of F#2 (right). For the sake of clarity in the examples that follow, however only the RM outputs from the fundamental frequency will be shown.

Figure 3 shows the principal pitches and the RM frequency outputs (rounded to the nearest equally tempered pitch) of the first four sections of Monody. The wide variation in RM outputs that
result from changing relationships between the piano pitches and the RM frequency are clearly evident. RM at the same frequency as the piano pitch creates a very consonant octave, while RM at the semitone (for example B4 and G5 in figure 3) creates a highly dissonant cluster. The reason for this is that RM outputs become more dissonant as the relationship between the input and RM frequency becomes more distant in the overtone series. (The implication of this phenomenon on Smalley’s note choices is discussed below).

Section 2 the same eight pitches are repeated with a different RM frequency on each repeat. In this instance, the same piano pitches are heard in a changing halo of RM outputs. Since each of the eight piano pitches is also used as a RM frequency the level of consonance rises and falls according to the relations between the ring modulating frequency and the piano pitches.

Figure 3. Principal pitches and RM frequency outputs in the first four sections of Monody.

3. MONODY’S STRUCTURAL PRINCIPLES

Christopher Mark in his monograph on Smalley notes that in using both the Fibonacci series and Live Electronics, Smalley was following the example of Stockhausen, with whom he worked in the late 1960s. Two of Stockhausen’s works in particular loom as Monody’s forebears: Klavierstück IX (1961) (The fibonacci series) and Mantra (1970) (RM). The similarity between section 2 of Klavierstück IX and section 1 of Monody is illustrated in Figure 4.

In the discussion of the pitch structure of Zeitenbungen (1973) written a short time after Monody, Smalley states:

The pitches are drawn from a seven-note mode which consists of the first seven different notes of the harmonic series (C - E - G - B flat - D - F sharp - G sharp); the rhythmic structure is based on the Fibonacci series (1, 2, 3, 5, 8, 13 etc) which is also a “law of nature” (it can be found in the structures of flowers, pine-cones, shells etc). (Smalley 1973: 99).

Monody utilises a similar principal, although the work is fully chromatic, pitches are introduced in the order of their appearance in the overtone series (Figure 5), albeit rounded to the nearest equally tempered pitch. Because of the relationship between RM and the overtone series discussed previously, this approach allowed the first three sections to introduce successively more dissonant electronic modulation.

The Fibonacci sequence plays a fundamental role in the organization of musical materials in Monody. The Fibonacci sequence is an additive series where each successive value is the sum of the previous two (1, 1, 2 (1+1), 3 (1+2), 5 (2+3)...). The rhythmic material is restricted to values and accent groupings of 1, 2, 3, 5, and 8 rhythmic units. The length of each section of Monody is also based on Fibonacci related values: 19 (1+2+3+5+8), 34, 42 (34+8), 55, 89, 102 (89+13), 144, 110 (89+21), 165 (55x3), 168 (8x21), 170 (34x5) and 178 (89x2). In this approach Smalley adopts

Figure 4. Comparison of Stockhausen’s Klavierstück IX Figure 2. (above) and Monody Figure 1.
Stockhausen's concepts of structural unity (Stockhausen 1957), and the continuum (Coen 206).

Another important technique employed in Monody is the inversion and rotation of rhythmic groupings. In each successive occurrence of the A material (Figures 1, 5, 9, 15 and 19), the note durations are rotated in a manner that finally inverts their sequence. Similarly in Section 4 sequences of 4 pitches (in groups of 8) are rotated to create varied orderings (left) and rotation of pitch material in section 4 of Monody (right) (Figure 8.).

The increasing values of the Fibonacci series are utilized to emphasise the continuous in temporal levels that transition from rhythm to form.

Figure 6 shows the construction of rhythmic groupings in Section 3 of Monody, in which an overarching structure consisting of 34 semiquavers at the formal level, is subdivided into increasingly smaller Fibonacci values 21 and 13, 5 and 8 and finally 2, 3, and 5 semiquaver groups at the rhythmic level. Smalley emphasises the values through the consistent use of pitches for each grouping.

Similarly in Section 4 sequences of 4 pitches (in groups of 8) are rotated to create varied orderings (left) and rotation of pitch material in section 4 of Monody (right).

4. SECTIONAL STRUCTURE OF THE SCORE MONODY

The emergence of substructures from the fabric of musical discourse derives from shifts in the level of continuity from one moment to the next. These shifts are marked by perceptible changes, discontinuities, between "formbearing" musical parameters. In order for such a shift to imply a boundary between two substructures, the discontinuity must be significant in relation to the preceding substructure, and both the preceding and succeeding substructures must evidence relatively strong internal cohesion.¹

¹ Musical form is constituted through the division of the musical timespan into sections of a certain size; that the individuality of these sections is brought about through a balance between change and continuity; and that this play of variation inside a frame of overall unity is grounded on the tendency of the human mind to create coherence in event structure" (Kuhl and Jensen 2007 p. 266) also see Snyder (2000) p. 194.
Monody is divided into 21 sections. The sections are varied in terms of texture, range, duration, dynamic, RM frequency and use of auxiliary percussion in manner that suggests that they can be categorised into 5 discrete sectional types. Whittall has argued that the section 4 material (what I term a D type section) is the inversion of the Section 2 material (what I term a B type section) (Whittall 342) and Mark goes on to show that the fifth and final interaction of the B material (at Figure 18) is an exact inversion of Section 2. This is further emphasised by the fact that, apart from the 144 semiquaver long Section 2 and Section 18, both the B and D sections always are very similar in length (between 168 and 178 semiquavers). I would argue, however, that the extreme parametrical disparities between the sections (B sections always appear in the middle octave of the piano, whereas D sections are extremely registrally divergent, are more diverse in dynamic range and are always modulated by the same RM frequency), mean that they are heard as dissimilar kinds of materials. This is instead perhaps an instance of “continuum thinking” in Monody, in that the Section B material, in its first iteration a “riff-like” motive of 21 semiquavers repeated 8 times, is extended throughout the work to become a single 144 semiquaver mirror image iteration of the D material and the D material is shortened to match it. Furthermore, the B and D sections have entirely different morphologies: the B sections comprise repeating blocks of 21x8, 34x5, 55x3 and 89x2 semiquavers before reaching a single 144 semiquaver iteration, while the D sections enact a virtual accelerando, using patterns of increasingly smaller note durations (ie 5332-3221-2111) throughout and contain the only demisemiquavers found in the work as the accelerandi climax. Table I describes the parametrical divergence and similarities of each section.

Stockhausen described the concept in the following way:

When certain characteristics remain constant for a while—in musical terms, when sounds occupy a particular region, a certain register, or stay within a particular dynamic, or maintain a certain average speed—then a moment is going on: these constant characteristics determine the moment. And when these characteristics all of a sudden change, a new moment begins. (Stockhausen in Maconie 1990 p. 63).

Smalley first used Moment Form only four years previously in his The Song of the Highest Tower (1968) (Emmerson: 27). However, in the case of Monody there is a stronger cohesion between the five sectional types than would normally be expected in a Moment Form work: only five Fibonacci length durations are used throughout; the sections use either 8 or 12 pitch classes; and only two tempi are employed for example. It might also be noted that disjunction between substructures in Moment Form works must reach a critical point as continuity cannot be maintained across the rupture. Pierre Boulez described this process as “anesthetizing the frontiers” between musical substructures, leading to a situation in which “listening time is no longer directional but time-bubbles, as it were” (Boulez 178). In contrast nu-merous sections (4 to 5, 7 to 8, 8 to 9, 16 to 17, 17 to 18, 18 to 19 and 19 to 20) in Monody are linked togeth-er the marking “upbeat” of “loco” (See Figure 8), suggesting instead a that the work has a typical Block Form structure.

Use of discrete sections in this way points to the influence of Stockhausen’s notion of Moment Form. The actual duration of the sections, ranging from 6 to 37 of less than 40 seconds.

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2 The term Block Form was applied to Stravinsky’s compositional approach as early as 1919, before the composition of his signature Block Form work Symphonies of Wind Instruments. (Henry 1989).

3 Most music is structured in such a way that a formal change takes place every 30–40 seconds or so (...) this innate tendency of human cognition to structure and group musical sound into sections of certain proportions is difficult to explain. It may be tied to the limitations of our working memory as suggested by some; or it could be seen as the product of an attention cycle, that would then be the result of the need of the human brain to perform an attention switch every so often in order to recognize its content. (Kuhl and Jensen 2007 p. 263).
<table>
<thead>
<tr>
<th>Figure</th>
<th>Texture</th>
<th>Range</th>
<th>Temp</th>
<th>Duration (\text{L,\text{r}})</th>
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<th>Dynamic</th>
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<td>42</td>
<td>8-9</td>
<td>pp</td>
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Table 1. Parametrical descriptors for the 21 sections of Monody.
5. SPECTRAL ANALYSIS OF A RECORDING OF MONODY

Two forms of spectral analysis were employed: analysis of the spectral parameters brightness, noisiness and loudness and visualisation of the waveform as a spectrogram. The data for spectral analysis derived from Jehan’s analyzer tools in MaxMSP (Jehan 2001) to record a value for each parameter roughly every 25ms. For the graphs below the average value each section for figures 9 and 10 and each second for table 2. In both graphs data is displayed in a stacked line graph. Values were converted to a percentage of the lowest to the highest value. This is because listeners experience parameterical changes, dynamics for example, in relative terms—in relation to other sounds in the work—rather than absolutes.

Spectral Brightness is a measure of the spectral centroid, that is, how high centre of weight is above the fundamental in the frequencies that are present. In effect it indicates a spectrum’s “center of mass”. For example the Brightness of a sine tone is low as all of its energy is concentrated at a single frequency, whereas a rich, complex sound (such as a ring modulated piano tone, would be expected to have a high Brightness value. It is affected by loudness in acoustic instruments because more harmonics are present at higher dynamics.

Figure 8. Linking figures at the end of section 4 and 8 of Monody.

It may also be affected by piano register as, rather like the human auditory system, machine frequency detection is more precise for higher frequencies. Noisiness is a measure of the “flatness” and inharmonicity of a spectrum. For example white noise has the highest Noisiness value as there is the same energy at every frequency, spectra with complex and non-integer (inharmonic) frequencies would also have a high noisiness value.

Figure 9 shows the variation in the three parameters in each section over the length of the entire work. The parametrical variation between successive sections is clearly apparent. There are significant spikes in Brightness in sections 3, 8 and 11. In these sections the piano is playing in the C4–C5 range and in sections 3 and 11 the triangle is also played, adding to the high frequency overtones. The noisiest sections all correspond to the B type material (Sections 2, 6, 10, 14 and 18) where all the “non-C” RM frequencies are found (including the whole of the chromatic scale). In sections 10 and 14 two Ring Modulators are used and the piano notes have the least consonant relationship to the RM frequency. Even in Section 18 the RM frequency is an octave above the average range of the piano’s pitches: similar noisiness can be found in the C Sections 13 and 21 and D Sections 4, 12 and 20 for the same reason. The significant parametrical variation between shorter sections and their neighbours (Sections 1, 3, 5, 7, 9, 11, 15 and 19) also bears out the theory proposed in my PhD on Nonlinear music that “Substructures shorter than thirty seconds by contrast would be (are) reliant upon (…) disjunction at their boundaries, from external substructures, to establish a sense of discontinuity from the surrounding texture” (Vickery 2013).

Figure 9. Stacked column chart showing the average brightness (bottom), noisiness (middle) and amplitude (top) detected for each section of Monody in score order.
In Figure 10 the results are grouped by section to show the parametrical continuity between section types. The results are evidence that the spectral profile of the sections is cohesive enough to allow the listener to experience them as blocks belonging to the same “family” of material type.

Figure 10. Stacked column chart showing the average brightness-bottom, noisiness-middle and amplitude-top recorded for the five sections groups of Monody.

The Spectrogram was created using Chris Cannam’s software distributed by Queen Mary, University of London (Cannam et al 2010). The following parameters were used in the generation of the spectrograms: minimum/maximum frequency of 5.8594/9445Hz, Logarithmic scale, and Window Size 8192/93.75%. The images were exported from the software’s spectrogram layer to Portable Network Graphics (.png) file, using the black-on-white spectrum setting: where white indicates frequencies with low energy and black indicates frequencies with high energy.

In Table 2 the spectrogram along with a stacked graph of the continuous brightness, noisiness and brightness data is fitted proportionally against the critical details from the score. The implied duration of each section and the actual duration of the section in the live performance are also contrasted. It is interesting to note that although it retains the proportions of the section to a remarkable degree, Travers performance was consistently 20% slower than the tempi indicated in the score. It is possible that the slower tempi were taken on the instructions of the composer: in Whittall’s review of the first performance he states that the performance, by the composer, was 12 minutes long, a third slower than the indicated tempi. The sectional divisions of the work correlate well both with brightness, noisiness and brightness values and the spectral morphology visible in the spectrogram.

These analyses lead us to the ultimate conundrum of why the sections in Monody are arranged in this particular ordering and the question of whether there is an over-arching logic to their arrangement. Although the work undoubtedly consists of Blocks of parametrically divergent musical materials, in terms of two crucial (particularly at the time it was written) parameters pitch and duration, there is little divergence at all. In this way the work is unlike typical Block form works such as Stravinsky’s Symphonies of Wind Instruments.

On casual listening, it is likely that the A sections are so divergent from the other material that they would tend to be heard as the beginnings of new sections. This would give the work a five-part structure that functioned as a “theme” followed by permutations of its material. Given the importance of the techniques of rotation and inversion at the foreground level of the piece however, (let alone the absence of Fibonacci series structuring) this reading makes little sense theoretically.

Another observation is that Sections 3 through 21, form a palindrome: a fact that can hardly be a coincidence. This interpretation allows for sections 13 through 21 to be read as an inversion of sections 3 through 11, but does not easily admit any connection with the Fibonacci origins of much of the work’s structure.

Because Monody has 21 sections (the 7th number in the Fibonacci series) it is perhaps most tempting to see it consisting of nested 1 and 2, 5 and 3, and 8 and 13 “groups of groups” comprising Fibonacci values. This reading places a full statement of the five sections in order at the centre of the work flanked by groups in which the two sections that are inversions of one another (B and
Table 2. Structural Scheme for Monody showing Sections and their proportions, parametrical variations, spectrogram continuous and brightness (top), noisiness (middle) and amplitude (bottom) graph.
D) are interchanged.

Although this reading is the most logically consistent application of the processes found at the foreground level of the work to the mid-level structure, it is hard to see how it could be apparent to the listener. It is possible that it was intended to remain obscure, however this contradicts the relative clarity of the ideas presented at the foreground level and perhaps also against the spirit of Smalley’s contemporaneous interests which Whittall states had “drawn closer to American experimentalists like Riley, Reich and Glass, who deal, as he has put it, ‘in the actual process of hearing’” (1976, 341). It is perhaps even tempting to see the structure of Monody as ‘field of possibilities’ (Eco 1977) open to a number of interpretations.

\[\begin{array}{cccccccc}
A & B & C & D & A & B & E & D \\
B & A & C & D & C & B & A & D \\
A & B & C & D & E & B & A & D \\
\end{array}\]

Figure 11. Possible formal implications of the sectional ordering in Monody.

6. CONCLUSION

The investigation of Monody using spectral analysis tools reveals very clearly the parametric disjunction employed by Smalley to differentiate successive sections, even when the musical materials are quite similar: as is the case in the B and D sections. The plotting of brightness and noisiness against the structure gives visual evidence of what is apparent to the ear from listening to the work, but cannot be readily deduced from the score alone.

The work is essentially “modal” never venturing from a tonal centre of C and in this respect Smalley’s use of Ring Modulation is rudimentary, given RM’s potential for the augmentation of timbre and dissonance. However, as the analysis shows use of multiple registers for the RM frequency creates a broad range of timbral outcomes.

While Fibonacci-based proportions of note durations (and to some extent pitch relationships) are crucial in the foreground, note-to-note, construction of the work and also to the middle-level sectional durations, its role in the overall formal structure is far more ambiguous. Monody is perhaps an unusual case — a work in which the sectional structure is extremely clear, but the unifying over-arching structure a unique instance, and one that is stubbornly resistant to quantification.

7. REFERENCES