Towards a Perceptually–grounded Theory of Microtonality: issues in sonority, scale construction and auditory perception and cognition

Brian Bridges

Thesis submitted to the National University of Ireland, Maynooth, for the degree of Doctor of Philosophy

Volume 2 of 2

Department of Music

National University of Ireland, Maynooth

October 2012

Head of Department: Prof. Fiona M. Palmer

Supervisor: Dr Victor Lazzarini

Table of Contents

List of Figures (main body of thesis) 4

Chapter 7: Commentary on the Portfolio of Microtonal Compositions 10

7.1 Theory, Practice and Compositional Rationales 10

7.2 *Infraction* (2009) for violin, viola and electric guitar 12

7.2.1 *Infraction* (2009): Introduction 12

7.2.2 Initial Microtonal/Structural Rationales in Composition 15

7.2.3 Logistical and Perceptual Rationales in Composition 20

7.2.4 *Infraction* (2009): Conclusion 27

7.3 *Flatlining* (2008) for string quartet 29

7.3.1 *Flatlining* (2008): Introduction 29

7.3.2 Microtonal and Perceptual Rationales in Composition 32

7.3.3 Totalism and Rhythmic Considerations in Composition 37

7.3.4 Performance/Logistical Considerations and Results 44

7.3.5 *Flatlining* (2008): Conclusion 51

7.4 *Angels at the Shotgun Wedding* (2007/08) for 23 electric guitars and tape 53

7.4.1 *Angels at the Shotgun Wedding* (2007/08): Introduction 53

7.4.2 Guitar and Tape Part Tuning Specifications and Sonorous Structure 61

7.4.3 Movement 1: 'Departure' 78

7.4.4 Movement 2: 'Inhalation/Choke' 87

7.4.5 Movement 3: 'Take God out and Show Her a Good Time' 91

7.4.6 Movement 4: 'Pathfinding' 97

7.4.7 Movement 5: 'Return' 103

7.4.8 *Angels at the Shotgun Wedding* (2007/08): Conclusion 109

7.5 *Making Ghosts from Empty Landscapes* (2010) for uillean pipes, pipa, erhu, 2 violins and tape 110

7.5.1 *Making Ghosts from Empty Landscapes* (2010): Introduction 110

7.5.2 Drone-based and Textural Aspects of Composition 114

7.5.3 Melodic Microtonal Aspects of Composition 119

7.5.4 *Making Ghosts from Empty Landscapes* (2010): Conclusion 125

7.6 *A Space for Tension* (2012) for erhu, two violins and tape 128

7.6.1 *A Space for Tension* (2012): Introduction 128

7.6.2 Generating Tuning Schemes and Related Structures 131

7.6.3 Instrumental Articulations and Tuning for Grouping/Segregation and Consonance/Dissonance 147

7.6.4 *A Space for Tension* (2012): Conclusion 162

7.7 Conclusion: Practice–led Insights into Microtonal Composition 163
7.8 Chapter Summary 169
Chapter 8: Conclusion...172
8.1 Summary of Approach and Contributions 172
8.2 Summary of Conclusions: Historical Approaches and Theory................176
8.3 Practice–led Investigations and Extensions of Theory 181
8.3.1 Sensory–based Contexts and the Extension of Consonance/Dissonance Definitions within the Composition Portfolio...181
8.3.2 Extending An Ecological and Embodied Model of Microtonal Relations (Unifying Sensory and Structural Concerns).............................183
8.3.3 Summarising the Final Ecological/Embodied Microtonal Model 190
8.4 Possibilities for Future Development...193
Bibliography 195
Appendix 1: Glossary of Key Terms 222
Appendix 2: Links to online audio examples of compositions discussed in this thesis (alphabetical by composer)...246
Appendix 3: Composition Portfolio Materials (Scores and Charts) 251
Appendix 3.1 *Angels at the Shotgun Wedding* (2007/08) specification charts and scores..252
Appendix 3.2 *A Space for Tension* (2012) specification charts and scores ...304
Appendix 3.3 *Infraction* (2009): score and tuning chart/performance instructions...318
Appendix 3.4 *Flatlining* (2008): score and tuning chart/performance instructions...324
Appendix 3.5 *Making Ghosts from Empty Landscapes* (2010): score...........332
Appendix 4: List of Audio Examples (accompanying DVD–R) 341
Scale examples:...341
Composition portfolio recordings:...342

List of Figures (main body of thesis)

Figure 64, Intervallic materials, cent values and named prototypes/analogues structured around standard practice chromatic divisions. 14
Figure 65: Example of Infraction's *notation form: each semibreve denotes a five–second timeframe within the score. This excerpt shows the opening microtonal variations in the vioin part over drones in the viola and guitar part* 16
Figure 66: The first two thirty-second modules of infraction, testing unison and major second analogues 17
Figure 67: Reduction of Infraction *to a single 12TET interval per part in each 30-second module* 18
Figure 68: Instances of materials which produce the first pronounced grouping/segregation effects in the piece 23
Figure 69: Testing the effect of Pythagorean and just major thirds against a 39th harmonic major/'neutral' third analogue 24
Figure 70: Wide registral spacing leading to significant interaction of a wider range of harmonics at 3'30; comparatively more euphonic case with a more traditional grouped sonority approximating a perfect fifth (hence, to be considered neutral and/or consonant) at 4'00 25
Figure 71: Intervallic experimentation within the range of sixth/seventh interval analogues 26
Figure 72: Concert poster for the Spatial Music Collective presents the Bridgewood Ensemble (Brian Solon/Spatial Music Collective) 30
Figure 73: Chart explaining the derivation of tuning for intervals in Flatlining, highlighting relative importance of various intervals; a tuning track was provided to facilitate ear training for these intervals 33
Figure 74: Prolongation-style functional tendencies in the upper violin part from bars 17–24, eventually defining a compound major third over A 34
Figure 75: Beginnings of more insistent/regular rhythmic material in Flatlining *in bars 55–9* 38
Figure 76: Cross-rhythm–based figures in the opening of the rhythmic materials 39
Figure 77: More closely-related cross-rhythmic figures towards the crescendo of the rhythmic section at bars 78–79 39
Figure 78: Limited intervallic range in early rhythmic parts (bars 45–48) 40
Figure 79: First violin articulations contributing to partial decomposition of the C# *drone in the second violin and viola* 41

Figure 80: A potential case of suppression of perceptual interaction effects due to stream segregation between violin and viola parts 42
Figure 81: Opening bars of Flatlining*, containing seventh-region variants (7th and 31st harmonics)* 46
Figure 82: SPEAR's display of a highlighted 31st harmonic analogue in performance of the piece, indicating starting frequency of a (low) 629 Hz 47
Figure 83: Early section which displays more accurate intonation 48
Figure 84: Pythagorean major sixth (providing cadential figure) at bars 23–4 48
Figure 85: complex rhythmic figures exhibit poor intonational accuracy but with less effect on composite sonority in cases of pizzicato articulations 49
Figure 86: section towards conclusion (bars 99–103) with particularly problematic intonation (with microtonal/alt. tuning effects bracketed out) 49
Figure 87: Section containing more successful intonational rendering of 7/4 harmonic seventh intervals (bars 50–54) 50
Figure 88: Perceptual continuity-based timbral decomposition effects 51
Figure 89: Concert poster for Soundings 0402 *(design: Robin Parmar/Soundings)* .. 56
Figure 90: Rehearsal for the Limerick performance of Angels at the Shotgun Wedding*, Daghdha Space, Limerick (photo: Jonathan Nangle)* 57
Figure 91: Conductor Marc Balbirnie cueing entries in rehearsal for the Limerick performance of Angels at the Shotgun Wedding*, Daghdha Space, Limerick (photo: Jonathan Nangle)* 58
Figure 92: Performance of Angels at the Shotgun Wedding *at The Venue, NUI Maynooth* (photo: Brian Bridges) 59
Figure 93(a): Angels at the Shotgun Wedding *guitar section 1 tunings* 66
Figure 93(b): Angels at the Shotgun Wedding *guitar section 2 tunings* 67
Figure 93(c): Angels at the Shotgun Wedding *guitar section 3 tunings* 68
Figure 93(d): Angels at the Shotgun Wedding *guitar section 4 tunings* 69
Figure 93(e): Angels at the Shotgun Wedding *guitar section 5 tunings* 70
Figure 94(a): Angels at the Shotgun Wedding *movement 1 drone part tunings* 73
Figure 94(b): Angels at the Shotgun Wedding *movement 2 drone part tunings* 74
Figure 94(c): Angels at the Shotgun Wedding *movement 3 drone part tunings* 75
Figure 94(d): Angels at the Shotgun Wedding *movement 4 drone part tunings* 76
Figure 94(e): Angels at the Shotgun Wedding *movement 5 drone part tunings* 77
Figure 95: specification chart for the opening minute or so of the first movement 79
Figure 96: Specification chart for the second minute or so of the first movement 82
Figure 97: Textural and melodic microtonal cases from 2'00 to 2'55 84

Figure 98: Cadential-style figure closing the first movement (trajectories of individual intervals follow guitar parts) *86*
Figure 99: Opening of second movement *87*
Figure 100: More complex chordal/textural tonal materials from 1 minute into the second movement..... *89*
Figure 101: Melodic and cluster-based materials from 2'00 to 2'55 of the second movement..... *90*
Figure 102: Closing materials of the second movment *91*
Figure 103: Opening of third movement with melodic variation around tritone analogues *92*
Figure 104: Second minute of movement three, outlining progression from tritone and fifth-region clusters to seventh-region clusters..... *93*
Figure 105: Third minute of movement three, with significant activity in the seventh region leading to activity which extends from tonic/second/minor third regions to major third regions, with the addition of a fifth–region cluster (97th/3rd/37th harmonics)..... *94*
Figure 106: Tonic-region and major-third-region clusters highlighted..... *95*
Figure 107: Melodic microtonal variations around tritone region at the close of movement three, against cluster based on semitone, whole-tone and minor third analogues (69th/9th/19th harmonics) alongside 27 cents offset from tonic 65th harmonic..... *96*
Figure 108: Opening of the fourth movement, featuring tonic-region cluster and melodic and textural variations from this region to the third-region and more solely texturally-based variations in the sixth/seventh region..... *98*
Figure 109: Majority of instrumental parts broadly coincident with drone parts in the second minute of movement four..... *99*
Figure 110: Seventh–region materials producing perceptual interaction effects during the third minute of movement four.....*100*
Figure 111: Pairing of the 39th and 19th harmonics in the fourth minute of movement four.....*101*
Figure 112: Close of movement four with melodic microtonal movement between various major third analogues.....*102*
Figure 113: Opening of movement five; melodic microtonal variations around the third-region and the filling of a gap in the drone part between the fifth and seventh region by 57th/27th/13th.....*104*
Figure 114: second minute of fifth movement, featuring sparse intervallic materials

creating an open texture through their general avoidance of drone parts 105
Figure 115: Third minute of fifth movement, featuring dissonant grouping of 65th/7th/57th before extended composite clusters of 93rd/45th harmonics and 57th/27th/13th harmonics..........106
Figure 116: Energetic statement of third-based cluster dominating fourth minute of movement five 107
Figure 117: Collapse in perspective of instrumental materials towards unison in the final section of movement five..........108
Figure 118: the TiMi Ensemble with Paul Harrigan performing Making Ghosts from Empty Landscapes *at La Plantation* (photo: Benoit Granier/TiMi Ensemble) 111
Figure 119(a): Pitch materials near opening which are generally derived from prominent components in tape part..........116
Figure 119(b): SPEAR partial-tracking results for the opening bars of the piece, highlighting partials corresponding to the pitched materials of bars 15–18 (approximations of A–D-E–G#/Ab–A alongside an upper glissando around D5) 116
Figure 120: Erhu tracing microtonal materials foregrounded in tape part 118
Figure 121: Microtonal melody in erhu occupying parallel chromatic/diatonic level (constant quartertone offset)..........120
Figure 122: Gestural microtonal ornamentation occurs during bars 17–19 due to standard idiomatic conventions, but is not directly notated in the score (contribute to individuation of this line)..........121
Figure 123: Notated gestural microtonal variations in pipes part..........122
Figure 124: Textural delineation in pipes and violin part contributed to by pitch modulation (bars 83 and following) 123
Figure 125: The first more extensively microtonal melody in ehru part which moves beyond the case of constant microtonal offset (with chromatic/diatonic divisions preserved in melodic steps) to free usage of microtonal intervals between melodic notes..........124
Figure 126: Second example of freer microtonal melody (i.e. with microtonal intervals between melodic notes) at close of the piece..........125
Figure 127: A Space for Tension *in performance at the Bejing Central Conservatory of Music Concert Hall by the TiMi Ensemble (photo: Enda Bates)*..........129
Figure 128: Tape part reduction for A Space for Tension, *highlighting generative tuning bases*..........132

Figure 129: Basic harmonic clock representation for the simplest harmonic-generative relationships in its tuning structure (with the first interval in each functional direction providing a rough indication of relative interval size in cents) *133*
Figure 130(a): Harmonic clock indicating generative relationships for 5-denominated drones (5 as highest common factor or centre) *135*
Figure 130(b): Outline of generative process for 5-denominated drone part *136*
Figure 131(a): Harmonic clock indicating generative relationships for 7-demoninated drones (5 as highest common factor or centre) *137*
Figure 131(b): Outline of generative process for 7-denominated drone part *138*
Figure 132(a): Harmonic clock indicating generative relationships for higher harmonic intervals *139*
Figure 132(b): Outline of generative process for higher harmonic intervals *141*
Figure 133: Partial-tracking representation of opening two minutes of drone, indicating progressively increasing harmonic density *143*
Figure 134: Partial-tracking view of entry of 7–denominated drone part with 77th harmonic (uppermost highlighted partial, minor third analogue) providing an example of a somewhat dissonant relationship with earlier harmonic materials in similar pitch regions (such as the 5th harmonic) *144*
Figure 135: Opening of the instrumental parts of A Space for Tension *on harmonic sevenths before rapidly increasing distance within the harmonic series* *148*
Figure 136: Opening of the instrumental parts of A Space for Tension *as analysed by SPEAR, illustrating divergence from specification (after initial convergence of two of the instruments)* *149*
Figure 137: Transition from 5/4 to 81/64 major thirds in the first violin part demonstrates more accurate rendering of the latter major third variant in comparison with earlier in the piece *151*
Figure 138: Introduction of higher upper harmonic (121st) in erhu part with significant vibrato articulation *153*
Figure 139: Erhu part engaging with the seventh–to–octave region (mirroring a vigorous seventh region in the tape part) *154*
Figure 140: Vibrato articulations within the seventh region (7th and 57th harmonics) in the instrumental part potentially draw attention to the harmonic seventh region in the tape part *154*
Figure 141: Sul ponticello *articulations contributing to a more euphonic perceptual segregation effect, contributing to a 'textural' cadential point of rest* *155*

Figure 142 (recap of score excerpt from figure 134): The opening bars of the piece contain extensive activity in the seventh-to-octave region which may be treated in hierarchical terms as closer to the tonic 'level', even in cases of high harmonics such as 121st/125th 157
Figure 143: Microtonal harmonic materials which potentially exhibit significant perceptual complexity and, hence, dissonance 158
Figure 144: Progression from 5th to 81st harmonics, potentially highlighting their distinctiveness (in terms of sequential melodic distinction and resulting sonority); also, the poccurence of the 121st harmonic potentially registered as an 11th harmonic of an 11th harmonic 159
Figure 145: 55th/77th/11th harmonic intervals resolve as 5:7:1 ratios with respect to the 11th harmonic and hence form a point of sonorous stability 160
Figure 146: 35th/7th/49th harmonic intervals resolve as 5:1:7 ratios with respect to the 7th harmonic and hence form a point of sonorous stability 160
Figure 147: Higher harmonic materials towards the conclusion which may resolve as lower harmonics of secondary centres 161
Figure 148: Revised embodied/ecological model of consonance/dissonance, incorporating a diffuse/point source schema as another consonance/dissonance axis 186

Chapter 7: Commentary on the Portfolio of Microtonal Compositions

This chapter discusses the enclosed portfolio of microtonal compositions based on perspective of the theoretical frameworks presented in previous chapters, leading to a refinement of these models in the light of my own compositional practice.

7.1 Theory, Practice and Compositional Rationales

The previous chapters have outlined a theory of how microtonal music's 'perceptual coherence'—to borrow a phrase from Handel's (2006) account of multimodal perception—may relate to a framework which is based on a combination of bottom–up perceptual processes with top–down cognitive models (which are nonetheless based on ecological and embodied structures). They have done this on the basis of commentary on the theorisation and related practice of early microtonal practitioners (chapters one to four), which has informed the developing theory discussed in chapters five and six. However, some aspects of the theory being advanced here also relate to insights developed from direct experience with microtonal compositional practice, leading to the creation of a composition portfolio which has contributed to the development and refinement of the theories contained in the body of the thesis. This type of process is a bi–directional interaction, with some of the developing theoretical ideas in the thesis informing new creative approaches and working methods, which then may be the subject of further theoretical exploration. As such, the discussion of the included compositional portfolio presented herein will be treated in terms of a more broadly thematically–based rather than directly chronological order.

Five compositions are included in this portfolio. The first is *Infraction* (2009), which investigates various microtonal dyads and triads for their different sonorous potentials through a somewhat singular mode of presentation which favours monotonic five–second note materials, providing relatively coherent conditions for the highlighting of sonorous effects. An earlier piece, *Flatlining* (2008), is a microtonal/alt. tuning string quartet which utilises a smaller range of microtonal variants on standard chromatic intervals in an attempt to facilitate a performance practice which enjoys relative compatibility with those of more typical Western art music practices. In contrast to *Infraction*, this piece features a greater degree of rhythmic articulation.

One of the most exploratory pieces in the portfolio, the multi–movement *Angels at the Shotgun Wedding* (2007/08), comprises a combination of microtonal instrumental parts performed by electric guitars with a microtonal/alt. tuning drone part which is designed to encourage perceptual interference effects due to parallels between its materials and materials highlighted in the guitar parts themselves. Like *Infraction*, this piece's primary aim is to investigate the potential for sensory–based distinctiveness between microtonal interval cases, based on the assumption that the efficient cognition of microtonal structures may be aided by particularly salient cases of sensory distinction.

Following this piece, two collaborations with the Beijing–based TiMi Modern Music Ensemble are discussed, both of which engage with methodological issues for using microtonal materials in contexts where rehearsal time may be constrained and/or musicians' familiarity with microtonal materials may be limited. The first of these pieces, *Making Ghosts from Empty Landscapes* (2010), is a notable exception to the microtonal practice in the rest of this portfolio in that it favours quartertone–based microtonality. The second of these pieces, *A Space for Tension*, places a Chinese traditional instrument (the erhu) in combination with two violins outlining microtonal intervals and glissandi, in combination with a drone part which is more extensively microtonal, progressing broadly from relative simplicity and wide spacing to complexity/density. A concern which is common to both pieces relates to the contribution of their signature instrumental articulations to perceptual grouping and segregation/individuation effects, suggesting a hybrid practice between more strictly static drone–based musics and the more dynamic soundscapes which are more typical of the compositional combination of instrumental and electronic sources.

7.2 *Infraction* (2009) for violin, viola and electric guitar

7.2.1 *Infraction* (2009): Introduction

Infraction was premiered at the 2009 Ergodos *Off–Grid* Festival (at a concert of other amplified works entitled 'Expressway to Yr Skull'[1]) at the Unitarian Church, St Stephen's Green, Dublin on Thursday 23rd April by Benedict Schlepper-Connolly (violin), Garret Sholdice (e–bow electric guitar) and Francis

---

[1] Concert details can be found at http://www.brianbridges.net/Brian_Bridges/Performances/Entries/2009/1/18_Upcoming_performances_-_Spring_09.html. The live recording was produced by Jonathan Nangle of the Royal Irish Academy of Music, Dublin.

Heery (viola). The piece explores harmonically–derived intervals (with respect to *E*) and relatively extended durations for their potential in the generation of perceptual segregation/decomposition effects. As the programme note puts it:

> *Infraction* is a transgression on the basis of changing fractions by fractional amounts, deviating from certain norms and being carefully playful with the system of musical morality known as just intonation.

This refers to the fact that the electric guitar will produce intervals which are related to 12TET divisions rather than just intonation; however, in the context of the piece's sonorous logic, this minor deviation actually encourages the potential for perceptual decomposition from beating effects, through the interaction of upper partials, which are particularly salient in the guitar tone (and thus, subject to potential interactions with components from other sources) through the use of an e–bow.[2] It also refers to the possibility that the string players will need to fine–tune their intonation as each note is sustained. Although the basic notation of the string parts incorporates quartertone–based directional indications, these are present to aid performers in grasping the overall pitch–contour shape rather than indicating accurate tuning. To more accurately indicate details of tuning, interval ratios are provided above each note. These ratios are, as noted above, derived from the harmonic series and are not structured on the basis of prime–limit constrains (*a la* Partch/Johnston) but are rather based on taking select harmonic intervals from within the first 128 divisions of the harmonic series (up to the 81st harmonic). Twenty–eight intervals are so chosen (see figure 64, following page).

---

[2] An electromagnetic device used to excite a single string at a time, invented by Heet, cf. (Heet, 2012).

Ratio	Cents	Function/Analogue
1/1	0	Root
65/64	27	Root-minor offset/analogue
33/32	53	Root+/Quarter-tone
67/64	79	Minor second offset/analogue
17/16	105	Minor second (+) (a)
35/32	155	Minor second (++) (b)
71/64	180	Major second offset/analogue (–)
9/8	204	Major second
19/16	298	Minor third
39/32	343	Minor third (+) (a)
79/64	365	Minor third (++) (b)
5/4	386	Just major third
81/64	408	Pythagorean major third
11/8	551	Perfect fourth analogue (+)/harmonic 11th
45/32	590	Augmented fourth (a) -
23/16	628	Augmented fourth (b)
25/16	773	Augmented fifth
13/8	841	Minor sixth analogue (+)/harmonic 13th
27/16	906	Pythagorean major sixth
55/32	938	Major sixth analogue (+)
7/4	969	Harmonic seventh/minor seventh (–)
57/32	1000	Minor seventh analogue (a)
29/16	1030	Minor seventh analogue (b) (+)
59/32	1059	Major seventh analogue (a) (-)
15/8	1088	Major seventh
61/32	1117	Major seventh analogue (b) (+)
31/16	1145	Major seventh analogue (c) (++)
63/32	1173	Major seventh/diminished octave analogue

Figure 64, Intervallic materials, cent values and named prototypes/analogues structured around standard practice chromatic divisions.

The particular intervals used are chosen on the basis of their forming unfamiliar *analogues* of more familiar chromatic divisions or inflection–like deviations from these divisions. The concept is that such intervals may possess a dual function. On one level of examination/articulation, they may perform a role as alternate tunings of familiar interval prototypes (i.e. they may be considered to be functionally–equivalent analogues in certain circumstances). On the other hand, these intervals may be perceived in some circumstances as evoking distinct inflectional and/or textural differences from these interval prototypes. The circumstances of presentation within the piece are such that the latter perspectives should dominate over an interpretation based on the traditional chromatic/equal–division scale template, due to the predominant deployment of adjacent microtonal changes (highlighting microtonal melodic effects) and extended articulations (highlighting sonorous distinctiveness) in the note materials. As such, the piece is designed as a case study of configurations which prioritise the perceptual distinctiveness (salience) of its microtonal materials.

7.2.2 Initial Microtonal/Structural Rationales in Composition

Infraction is broadly structured around harmonic series intervals in its violin and viola parts. These instruments perform a number of microtonal variations in adjacent contexts (for which, as noted in the theory chapters above, the perceptual system should be significantly more sensitive than is the case for non–adjacent context). Furthermore, as will be discussed below, the investigation of these intervals using sustained tones is designed to highlight the contrasts in sonorities which are engendered through higher-order interactions of upper–partials. The materials are derived from the harmonic series on *E* and the microtonally–offset violin and viola lines begin by investigating harmonic intervals in close proximity to this note (figure 65, below, next page). However, the resulting sonority is further complicated by the presence of the bright, sustained, e-bow guitar, which articulates harmonic materials a fourth below[3] (in the manner of the characteristic upper interval of a guitar *power chord* with its texturally–based stacked fifth plus fourth—the piece had originally intended to use such structures to thicken the guitar part, but this was incompatible with the single–string articulation of the e–bow).

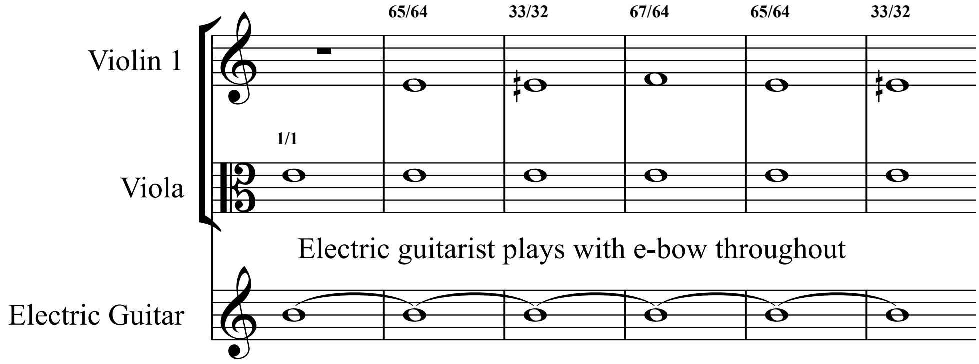


Figure 65: Example of Infraction's *notation form: each semibreve denotes a five–second timeframe within the score. This excerpt shows the opening microtonal variations in the vioin part over drones in the viola and guitar part*

The guitar part does not maintain a steady intervallic offset from the other materials, but is placed at points along a continuum from relative perceptual stability (through relatively large offset in pitch–chroma terms) to relative instability (through smaller pitch–chroma offsets, resulting in more salient beating of harmonic partials, and hence, perceptual decomposition effects). As such, the guitar has a somewhat subsidiary role in the piece's generative logic as a 'perceptual provocateur' (see figure 66, below). Based on this approach, the

---

[3] The guitar part is notated a standard octave above articulation to minimise the use of ledger lines.

guitar part was written after the microtonal violin/viola figures were first completed. When this is borne in mind, the piece's broad process becomes quite clear: a variety of just intonation microtonal analogues of standard chromatic divisions are tested against each other in adjacent contexts in each thirty–second module, with elements of suspension/retardation in the introduction of new interval variants.

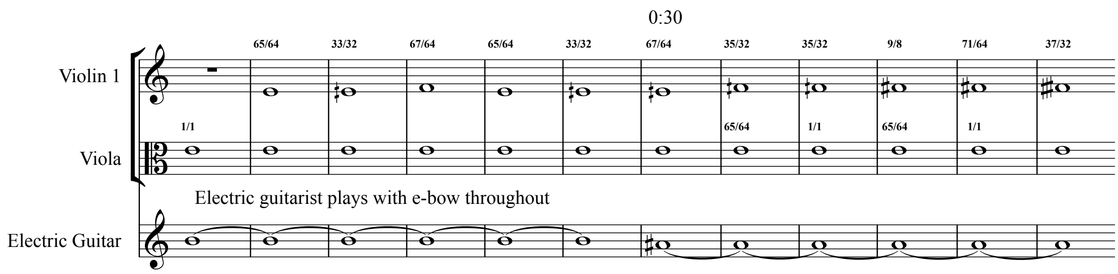


Figure 66: The first two thirty-second modules of infraction, testing unison and major second analogues

A reduction of all of the microtonal analogues in the piece to the nearest-equivalent 12TET category is provided in figure 67, below, next page.

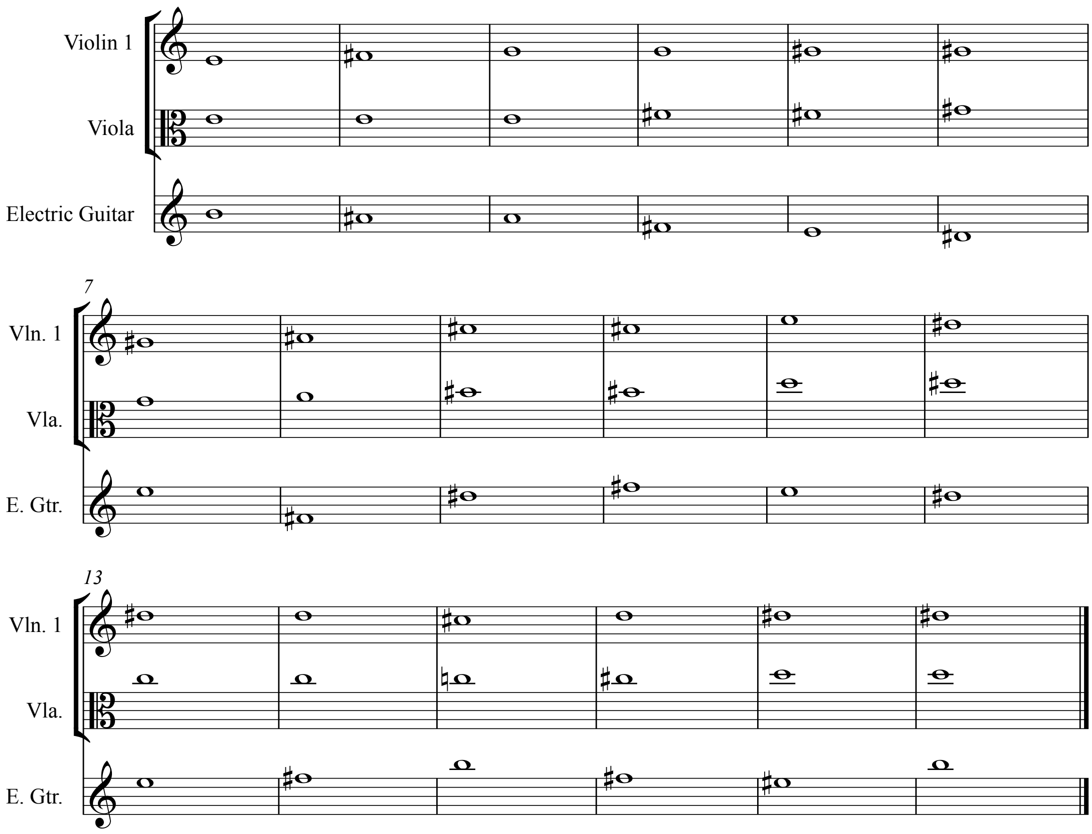


Figure 67: Reduction of Infraction *to a single 12TET interval per part in each 30-second module*

As can be seen, the intervallic movements generally occur within a very limited range, with the minimal leaps in the upper two voices in particular highlighting a microtonal perspective on these intervals; as the materials are in adjacent contexts, these are more likely to draw attention to microtonal aspects and be heard as melodic/sonorous variations on more established 12TET interval categories. The more established larger divisions are more likely to be relevant in the context of melodic leaps (where the outlining of the interval in broad/coarse terms is more likely to be considered notable by the perceptual system than any niceties of intonational or sonority–based variation). The manner of presentation (long, sustained and relatively bright component tones) further draws attention to the sonority–based aspect of the microtonal variations. As such, *Infraction* provides something of a contemporary update to what Tenney (1988, pp.17–31) identifies as the second historical consonance–dissonance concept in Western music, CDC-2, which prioritises concern for sonorous effect, reinforced by some voice–leading prescriptions and growing awareness of registral spacing issues from the later CDC–3 (*ibid.,* pp.39–58). However, the perceptual basis of *Infraction's* concept of harmony does not directly parallel these consonance–dissonance definitions, as it moves beyond the sensory–based concern for tonal fusion to an axis of tonal coherence/grouping to perceptually novel cases of decomposition. As discussed in chapter four, the latter is Tenney's implied (and more generally applicable to contemporary music) successor to the previous Western consonance–dissonance concepts, with the novel cases of perceptual decomposition almost providing an *opposing–consonance*[4] through the extra degree of harmonic clarity which is engendered. (As such, the dissonant cases, from this perspective, are more considered by this definition to be more consonant than more typical grouping–based cases which do not evoke this type of perceptual decomposition.) In addition, as asserted in previous chapters, these distinctive perceptual cases also have the potential to contribute to the memorisation (and hence, structured perception/cognition) of a range of microtonal intervals which include even very small intervallic variations.

[4] Or, perhaps, *anti–consonance* in the manner of an opposite-polarity consonance.

7.2.3 Logistical and Perceptual Rationales in Composition

As *Infraction* requires very accurate intonation to differentiate between intervals within a very small range (frequently as little as an eighth–tone apart), certain logistical aspects dominated the piece's performance practice. Firstly, the microtonal materials are articulated through rhythmically invariant five–second held/single articulation tones (allowing for a degree of fine–tuning once a note was in progress). The piece assumes that a time span of this order is required to ensure tuning accuracy. In addition, there is the listener–centred logistical aspect of allowing time for periodicity–based and grouping/segregation aspects of the sonority to dominate. Both aspects thus necessitate a degree of tuning accuracy and consistency which increases as a single tone progresses. Based on this requirement, enveloped tuning tones were provided for the violin and viola parts, available either from a CD player or computer's audio interface output[5], with left and right channels split to separate channels on a headphone amplifier.

This method resulted in extremely accurate tuning on the parts of the performers and could be adapted to less rhythmically–static materials through a live presentation of certain key intervals to performers through a multichannel headphone output, presenting sampled or synthesised reference tones from programmable digital audio environments.[6] However, such an approach would necessitate the development of a more specialist performance practice whereby performers become acclimatised to such interventions (which have the potential

---

[5] However, a computer–based presentation is simple to implement and has the advantage that a large timecode display can be made available to all performers via a Digital Audio Workstation or custom-designed performance setup via a digital audio environment.
[6] E.g. Max/MSP, Pure Data, Supercollider, Csound etc.

to be both musically disempowering and distracting in the manner of the studio *click track*[7] if they were to enter suddenly in more complex pieces), necessitating a significant amount of rehearsal time.[8] Based on these factors, the present piece develops a distinct aesthetic of sustained, slowly–changing sonorities and invariant rhythms which is related to both performance and perceptual logistics, mirroring the performance practice of many previous microtonal just intonation practitioners. In addition, as will be discussed further below in relation to *Flatlining* (2008), the use of rhythmic materials which are less extensively based on sustained tones provides conditions which are less suitable to engendering distinct perceptual grouping/decomposition effects.

Various sections of the piece illustrate the distinct perceptual results produced by relatively small structural changes for intervallic materials within the context of these broad prescriptions for their presentational circumstances. For example, the opening modules (up to 1’00, see figure 65, above) produce fused and generally perceptually simple/coherent cases based around the perfect fourth. A single heard–out (i.e. subject of perceptual decomposition) third harmonic (perfect fifth) at 5–10 seconds is due to the interaction of the string parts (at 65/64 offset) with the e–bow guitar part. This provides an early (if relatively tame) indication of the perceptual segregation effects to be expected later in the piece, lending the opening a relatively neutral sonorous effect (in retrospect) in comparison with the more novel melodic and sonorous effects which are the

---

[7] A rhythmic guide track which contains regular audible timing cues, frequently employed in studio recording and some live contexts for music which prioritises a significant degree of rhythmic consistency over expressive nuance in this domain.
[8] Furthermore, the development of new performance systems for microtonal music was considered to be beyond the main scope of the present research project.

result of more significant microtonal deviations later in the piece. In this regard, the interplay between various major and minor second analogues found in the second module (0’30 to 1’00) demonstrates contrasts in the beating of lower harmonic materials (with striking difference between salient beating effects within minor second ranges and more coherent grouping above these ranges), in addition to the leading–tone–style melodic function of the step–wise increase in size of microtonal intervals which are analogues of traditional major/minor seconds.

The melodic variations upon interval analogues quickly enter much more distant harmonic territories, transitioning from the lower–order 19th harmonic and just major third at the end of the 1’00–1’30 module to the shimmering spectral/perceptual effects produced by the 79th and 39th minor third analogues against the 9th and 35th harmonic major/neutral seconds from 1’30 (figure 68, below, next page). What is particularly striking about this configuration is that in contrast to those of earlier materials, much more significant upper harmonic interaction is happening, leading to partial perceptual decomposition of the instrumental tones, providing a particularly salient perceptual case.

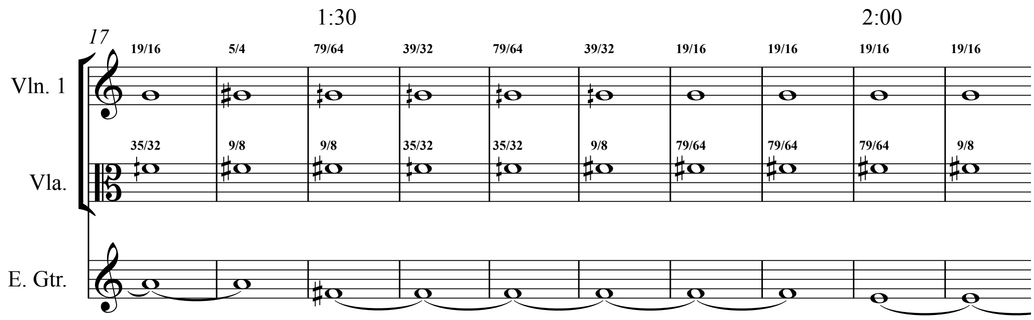


Figure 68: Instances of materials which produce the first pronounced grouping/segregation effects in the piece

These pronounced perceptual interaction and segregation effects are still observable in the next module (2’00), which reinstates the grounding *E*, with the more strident guitar e–bow articulation highlighting more upper partials alongside an active (and, in context, more euphonic–seeming) major second/minor third cluster. An even more euphonic and, in context, open–seeming section which follows (2’30) incorporating major third/minor third variation (including Pythagorean and just major thirds and a 39th harmonic) demonstrates a clear difference in coherence of the resulting sonority in spite of the relatively small distance of 22 cents (less than an eighth–tone) between the two major thirds (see figure 69, following page).

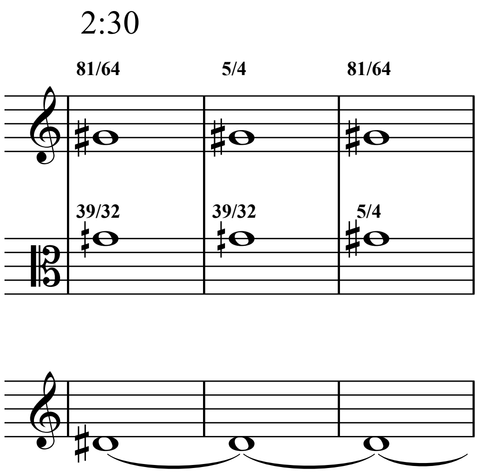


Figure 69: Testing the effect of Pythagorean and just major thirds against a 39th harmonic major/'neutral' third analogue

A further perceptual case is to be found when the piece tends towards wider registral spacing, such as at 3'30, where upper harmonic interactions are clearly perceptible towards the end of the module (figure 70, next page). Although (in more traditional terms) wider spacing may be expected to increase consonance through lack of more audible beating (of lower components), here, the strongly salient upper components of the e–bow guitar timbre provide a range of interaction/beating possibities for various configurations of microtonal materials to initiate. This is one clear instance where the conventional wisdom of common practice is problematised in perceptually–informed exploratory microtonal practice.

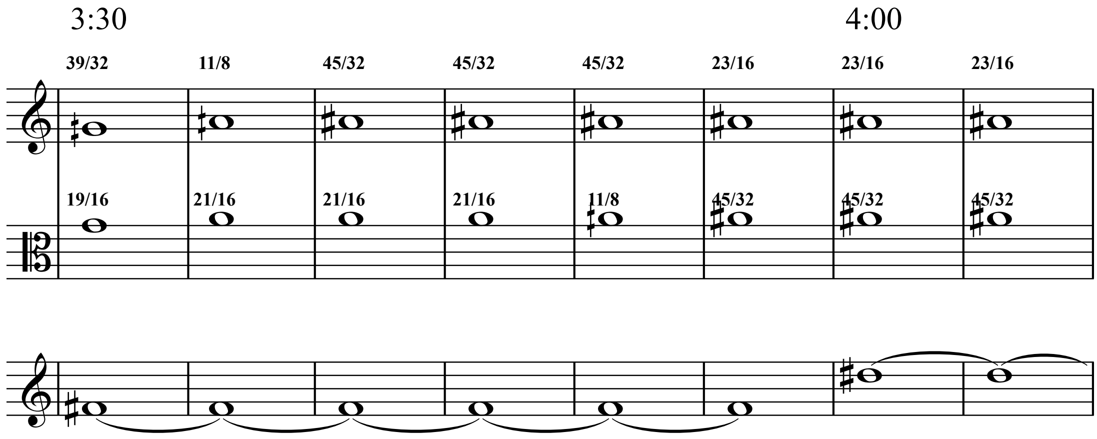


Figure 70: Wide registral spacing leading to significant interaction of a wider range of harmonics at 3'30; comparatively more euphonic case with a more traditional grouped sonority approximating a perfect fifth (hence, to be considered neutral and/or consonant) at 4'00

In contrast, the section at 4'00 (see end of figure 70, above) provides a much more stable (and, in terms of pitch–chroma distance, 'open') sonority approximating a perfect fifth; a cadential–style counterpart to the opening perceptually–stable/grouped fourth. These relatively euphonious (and non–microtonal) cases provide a parallel with the second section of Tenney's *Critical Band* (Tenney, 1988), in which the piece's signature early microtonal intervallic spans give way to a symmetrical opening into a *macrotonal* (i.e. non–microtonal) intervallic territory of dyads based on seconds, thirds and larger intervals. However, in the present piece, a recapitualation towards more typical microtonality happens within its last third (after 6'00), which tends towards more densely–packed intervals which are combined with a greater range of intervallic experimentation/exploration, especially in the extended (mostly downward) run from 7'00 to 8'00 (see figure 71, next page).

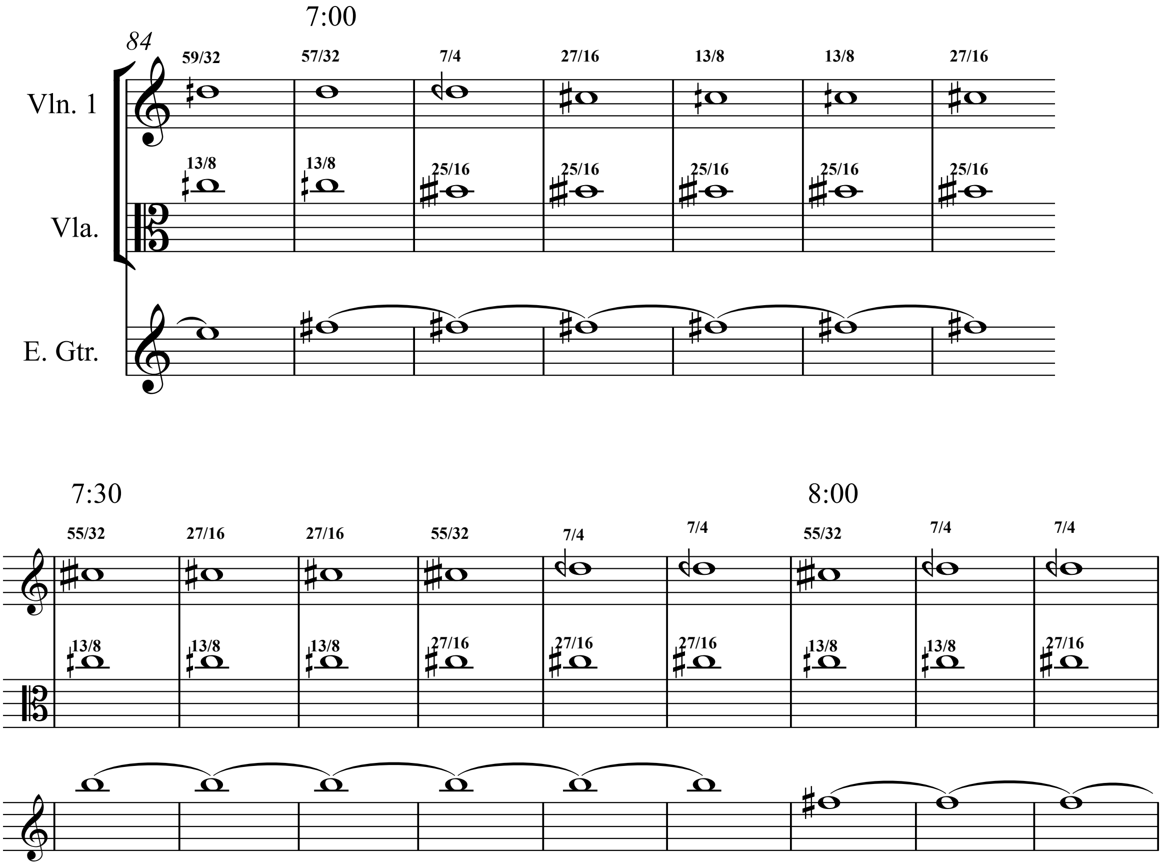


Figure 71: Intervallic experimentation within the range of sixth/seventh interval analogues

The sonorities produced throughout this run are broadly similar, if subject to some more audible beating of lower components in the middle three intervals of the 7’00–7’30 module (at their most audibly rapid with the 7/4 and 25/16 combination with the *F#* on the guitar). Whilst the sonorous results are still relatively stable in terms of grouping/segregation, even these relatively less dramatic perceptual effects appear to contribute to the extremely clear perceptual definition of microtonal interval changes of the order of 31 cents for the 7/4 to the 55/32 (969–938 cents) and 32 cents for the 55/32 to 27/16 (938–906 cents), incidentally producing roughly equal step sizes. Although these are somewhat larger than some of the smaller intervals used in, for example, Partch’s 43–tone scale, they are significantly smaller than the quartertone which some commentary on microtonality (see chapters five and six) has tended to favour as the smallest structurally salient division.

7.2.4 *Infraction* (2009): Conclusion

Based on the factors discussed above, *Infraction* highlights the distinctiveness of many relatively small microtonal intervals through their presentation in both direct sequential proximity (microtonal variations of different larger interval analogues) alongside their simultaneous combination with harmonic intervals using bright sonorities to encourage salient perceptual effects from upper harmonic interactions. The piece therefore contributes to a microtonal consonance–dissonance concept through its microtonally–specific voice-leading rules, favouring adjacent presentation of microtonal interval variations within limited ranges (i.e. making use of any perceptual attention–band effect) over more frequent leaps beyond these ranges (which might be more likely to be perceived as non–microtonal interval types, even if these arrive at microtonal variants on standard intervals). This is framed alongside an exploration of cases of perceptual grouping (relative perceptual stability and hence, considered to be consonant) and perceptual segregation whose relative dissonance may be evoked through perceptual instability, which, in some cases, possesses such an evocative perceptual distinctiveness that it might be better termed *opposing–consonance*.

The performance practice proposed for the piece proved to be both logistically feasible and appropriate to the aesthetic results intended. The use of relatively long (five–second) durations to articulate notes in the string parts allowed for effective fine–tuning of intervals to take place and for the full effects of these tunings to be heard. The use of earphone–based tuning tones proved appropriate to the interest–profiles of the performers involved: they were contemporary music specialists, composer–performers with strong interests in textural/sonority–based effects (and so had an interest in focusing their technical ability on subtle tuning effects rather than more obviously virtuosic elements). One logistical problem with the piece related to the e–bow's articulation, which sometimes resulted in uneven dynamics over these extended periods: a compressor or volume pedal would have alleviated this situation and improved the the consistency of the result, although the increased dynamics sometimes corroborate a peak of tonal activity, such as the transition to significantly higher harmonic materials at 1'30 (see figure 68, above).

An approach based on this type of fixed media guide track might not be as broadly applicable to performers grounded in musical styles which place less relative emphasis on such subtle tuning/sonority effects and which prioritise more obvious demonstrations of virtuosity (as may sometimes be the case for performers grounded in Western common practice music). As such, the findings in relation to optimum performance conditions for pieces such as this suggest that performers need not necessarily be singular performance specialists (in the context of what this implies in the the performance of Western art music, for which the requisite practice required for overtly virtuosic feats can lead to the exclusion of other parametric bases of musical activity). However, the performers do require a significant degree of focus and attention to small details (which is also common to the demands of pulse–based minimalism) which is certainly demanding. Thus, the performance practice provides a demonstration of how engaged non-specialists who possess a high degree of focussed attention in performance can reproduce the piece's intervallic materials with accuracy.

The significant perceptual distinctiveness of some of these interval cases suggests that a technologically–unencumbered version of this performance practice could be feasible, given sufficient rehearsals to embed this more specialist performance practice (in the manner of La Monte Young's Theatre of Eternal Music), although this would require a significant time commitment. For the present purposes, it is most significant that *Infraction* corroborates a basic compositional and performance–based methodology which efficiently supports engaged non–specialists in accurately demonstrating the effects of relatively small microtonal variations in a context which is not dependant on fixed–tuning instruments (in contrast to Partch's general performance practice). However, it also poses questions as to whether microtonal details can be presented with relative accuracy in circumstances which are less significantly reliant on extended duration.

7.3 *Flatlining* (2008) for string quartet

7.3.1 *Flatlining* (2008): Introduction

Flatlining (an early sketch was composed in 2004/5, revised and performed in 2008) is a microtonal string quartet which utilises microtonal harmonic–series materials. It was premiered at a Spatial Music Collective concert on June 26th 2008 by the Bridgewood Ensemble at the former Cultivate Centre (SS Michael and John, now the Smock Alley Theatre) in Temple Bar, Dublin, see event poster in figure 72, below.[9]

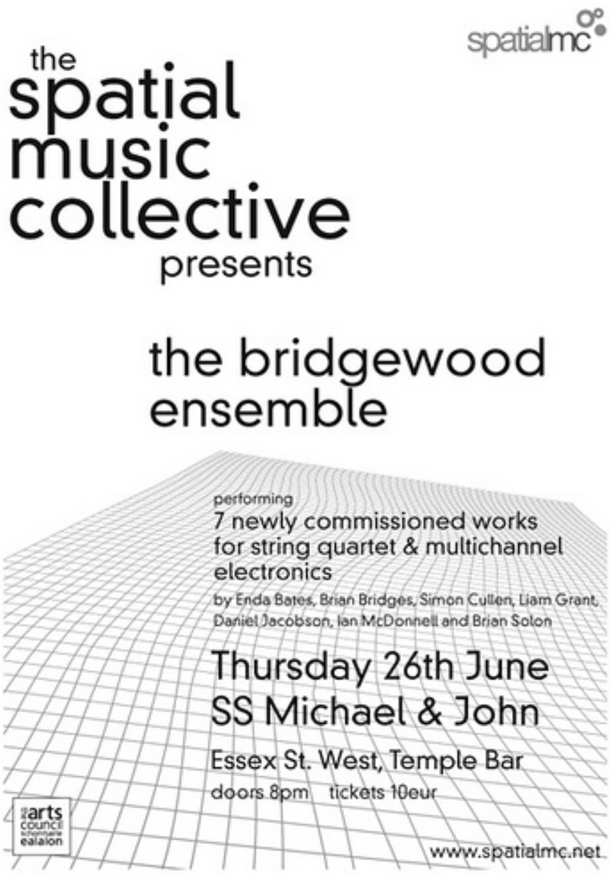


Figure 72: Concert poster for the Spatial Music Collective presents the Bridgewood Ensemble (Brian Solon/Spatial Music Collective)

The piece utilises harmonics up to the 31st harmonic as intervals, featuring microtonal analogues of intervals based around the pitch–chroma regions of standard sixths and sevenths. Tuning of the intervals is indicated through

---

[9] Concert details can be found at http://www.spatialmusiccollective.com/events/. The live recording enclosed is the one produced by the Spatial Music Collective to document the above-mentioned concert and, as such, is a straightforward mixdown of the live speaker feed, rather than a more polished 'listeners' mix'.

quartertone notation on the score, which is deployed to indicate direction (and the presence of a tuning deviation from standard) rather than exact tuning; the scale is taught in advance to the musicians using tuning tones. Consultation with the performers produced the suggestion that the harmonic number notation be removed from the score itself for the sake of greater clarity. Since the range of intervallic variations in this piece was relatively small, this proved to be feasible in this particular instance.

Similarly to the previous piece, the harmonic intervals are derived relative to *E* and the piece tends to remain modally/tonally centred around this region. The primary compositional motivation was the exploration of more 'primitive' cognitive–perceptual attributes than complex functional/modulatory schemes, instead focussing on investigations of the perceptual grouping/segregation potential in various articulatory contexts. Performance indications include a general prescricption for *senza vibrato* articulations to bring out the details of the tuning, along with textural variations provided by directions for vibrato, extended glissandi and, occasionally, *sul ponticello* articulations. The latter effect, common in some spectral musics, is designed to contribute to perceptual decomposition of component tones through the brighter (and more inharmonic) spectrum which results, which may contribute to perceptual decomposition or tones, including individually salient partials. Ideally, the piece is intended to be heard to best effect through a significant degree of amplification applied to the quartet (following the example of George Crumb's *Black Angels* (Crumb, 1971) or, to a lesser degree, the early string–based Theatre of Eternal Music which realised many of La Monte Young's earlier works), producing bright, strident sonorities which are both more abrasive and more potentially subject to perceptual decomposition through the interaction/interference potentials of more salient upper harmonic partials. However, in the performance enclosed here, such a degree of individual control over the timbre and levels was not possible in the context of a mixed concert programme.

7.3.2 Microtonal and Perceptual Rationales in Composition

Flatlining is, perhaps, a relatively conservative example of microtonality. The microtones are not used as frequently in adjacent melodic contexts as is the case in *Infraction*. Indeed, the range of microtonal intervals available as 'variations' or analogues of standard chromatic divisions is much smaller than that in the previous piece, with thirteen within–octave intervals. The relatively small number of microtonal variants are designed to facilitate the incorporation of these materials into a performance practice which is more compatible with common practice approaches; the fact that the piece possesses more significant rhythmic articulation than more singularly drone–based approaches (exemplified by *Infraction*) was a further factor in this decision. Indeed, the piece's performance directions prioritise some intervals over others to further aid the performer in acclimatising to microtonal/alt. tuning practice: the thirteenth harmonic and the various sevenths are highlighted as particularly significant; see figure 73, below (next page).

E - no change

F - no change

F# - no change

G - 19/16 - 19th harmonic / minor 3rd - the change is not very significant

G# - no change - I'm presuming that string players play fairly 'just' thirds

A - no change - using standard fourth

A# - not used

B - no change - the fifth is fine in standard tuning

C - 13/8 - 13th harmonic / minor sixth - a little flat

C# - 27/16 - Pythagorean major sixth

D - 7/4 - 7th harmonic / minor seventh - this interval has quite a strong identity and will become quite familiar once you've heard it, La Monte Young has called it 'bluesy'

D# - 15/8 - Just major seventh

D#+ - 31/16 - 31st harmonic / large major seventh

The most significant intervals are the different types of sixth and seventh.

Figure 73: Chart explaining the derivation of tuning for intervals in Flatlining, highlighting relative importance of various intervals; a tuning track was provided to facilitate ear training for these intervals

With this in mind, the piece’s approach might alternatively (and more comprehensively) be described as *alt. tuning (modal) chromaticism* which provides a set of modal and textural variations with respect to *E* as a tonal centre, with the occasional apparent recourse to more traditional activity related to functional harmony (e.g. the prolongation of the definition of a function–defining compound major third over *A* from bars 17–24; see figure 74, following page).

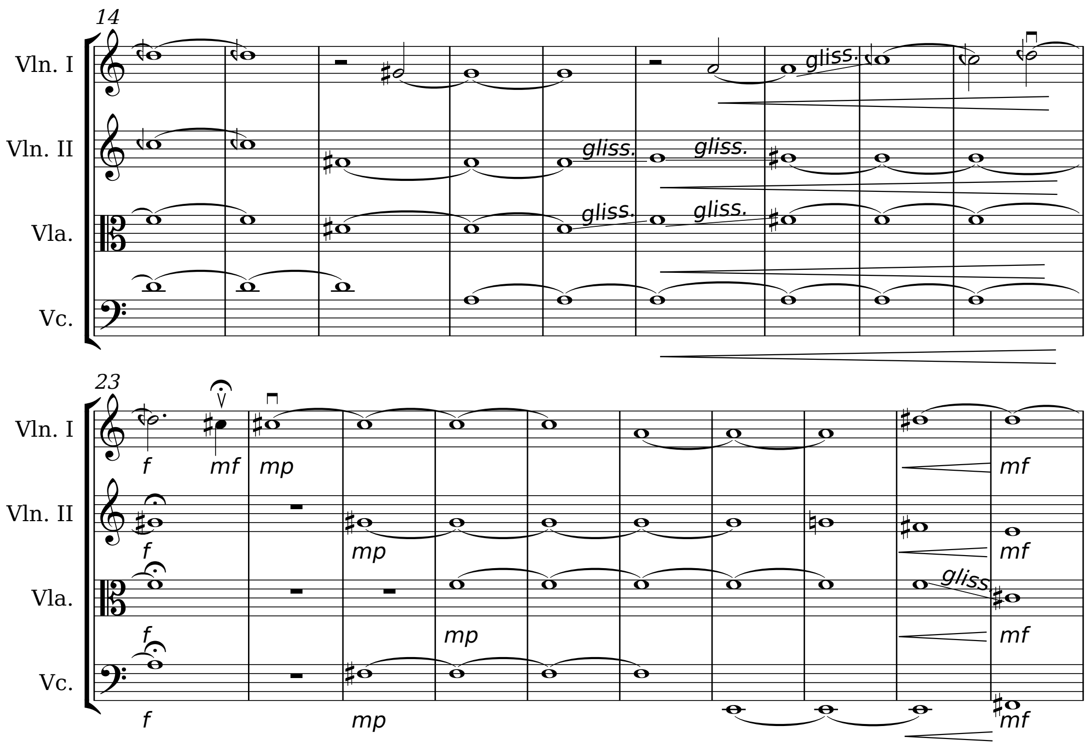


Figure 74: Prolongation-style functional tendencies in the upper violin part from bars 17–24, eventually defining a compound major third over A

However, this type of prolongation/functional tendency could be more fruitfully thought of as being emergent based on two factors, rather than being derived from functional conventions *per se*. The piece's primary axis of investigation is the perceptual grouping/segregation potential of various types of microtonal materials (and articulatory/presentational conditions). This is the first factor: the sonority/perceptual configuration factor. The second factor is derived from a broad adherence to more traditional voice–leading practice, with relatively larger leaps outwards apparently resolved by additional smaller movements inwards, as in the case above. As such, the piece's mode of articulation has more in common with contrapuntal–style CDC–3 (Tenney, 1988, pp.39–58)—thus balancing a concern for sonorous properties with relatively simple functional imperatives of voice leading—rather than the more extensive primacy of functionalism within the Classical/Romantic era CDC–4 (Tenney, 1988 pp. 65–86), even as it modifies the definition of sonority within its consonance/dissonance concept to include foregrounded perceptual grouping/segregation effects which are a by-product of microtonal configurations.

Indeed, during the composition process, it was intended that the textural/sonority–based effects which some of the microtonal materials are designed to produce would provide the degree of relative novelty within an overall context which tends towards the partial familiarity provided by the treatment of these materials as rarely–adjacent intervallic analogues of chromatic divisions. The tonal materials tend to be predominantly based on either rooted or unrooted *E* major seventh chords with added $7^{th}/31^{st}$ harmonics to investigate functional and textural effects of microtonal/alt. tuned interval variations. The focus on textural/sonorous aspects as the primary aspect of articulation is further reinforced through a preference for relatively *senza vibrato* articulation, in addition to gradual glissandi and some *sul ponticello* bowing for heightened spectral effects. As such, the piece's conception of 'harmony' is primarily a textural exploration of perceptual fusion versus individuation. This definition is combined with further axes of distinction between (relatively) slow versus rapid rates of articulation.

In relation to its resultant sonority, the piece originally envisaged a degree of amplification to further heighten the potential for perceptual effects as a by–product of the interaction of the piece's parts. Whilst this is optional (some of the aforementioned perceptual effects will occur even in unamplified context) and was not possible in the premiere of the piece, a bright, amplified timbre would provide more salient upper harmonic materials which may therefore be more likely to become individually audible through beating and continuity–based perceptual segregation. In addition, the preference for a harsher effect to complement the piece's overall exploration of various types of configuration with 'dissonant' associations, follows the sensibility of Crumb's *Black Angels* (Crumb, 1971).

However, these issues of foregrounding sonorous structure do not define the configuration of other structural domains as much as is sometimes the case in microtonal musics which focus on fine degrees of periodicity–based assessment of consonance/dissonance via integer-based tunings and sustained tones. Specifically, the piece tends to have a faster rate of change (even with semibreves at 88 BPM) than many just intonation practitioners would favour. Although its pacing is slow enough in some sections to highlight periodicity–based dissonance and related grouping/segregation effects and such materials are sometimes held for a number of bars, the overall pace is the less languid one which is arguably more typical of common practice Western music; cf. Terry Riley's maxim that 'Western music is fast because it's not in tune' (Riley, quoted in Young 2002, p.76). In this regard, the piece is an attempt to investigate whether microtonal materials like this can engender clearly salient sonority–based effects even with relatively more complex progressions of material, thus referencing a generalised influence of American *totalism*: cf. Gann (1997, pp.352–386). This rubric is used by Gann to describe the overtly postmodern stylistic juxtapositions of materials of relative novelty or complexity alongside presentational circumstances which favour a more 'democratic' (post–minimalist) immediacy. In the present piece, the foregrounded sensory effects of drone-based just intonation minimalism find a counterpoint in more aggressively directional structures derived from voice leading and rhythmic grouping.

7.3.3 Totalism and Rhythmic Considerations in Composition

In contrast to many other pieces contained in the present portfolio, *Flatlining* foregrounds shorter–duration rhythmic articulation in some of its measures in its central section. The *totalism*–derived impulse towards insistent rhythms is a key factor in this decision.[10] This piece therefore embodies an interest in testing microtonally–derived sonorities (including grouping/segregation effects) alongside insistent rhythmic figures. However, its frequent dissonances and use of cross–rhythms undercuts the potential for associating its propulsive/motoric stylistic elements with popular music forms, in contrast to some totalist music. An example can be seen in figure 75 below (next page), where bars 55–59 highlight various configurations of insistent quaver/triplet rhythms in the middle parts alongside dynamic increases and an upper part whose rising melodic figure is also designed to evoke an increase in tension.[11]

[10] As Gann (1997, p.355) notes, 'totalist composers […] admired minimalism's ability to communicate to large audiences, yet also admired serialism's ability to yield more and more information on further hearings, and who also appreciated the inherent [rhythmic] complexity of non-Western musics.' This piece seeks to combine relative microtonal complexity (resulting in sonorous and step–size distinctiveness) with punctuating propulsive rhythmic figures for similar composite effect.
[11] A similar configuration of materials is also to be found at the piece's final crescendo from bars 72–85.

Figure 75: Beginnings of more insistent/regular rhythmic material in Flatlining *in bars 55–9*

The piece therefore embodies a temporal axis of difference from relatively slow held semibreves (or semibreve–based glissandi) to much more rapid quavers, semiquavers and triplet–based quavers in alternately *pizzicato* and *arco* articulations. The generally small intervallic range between these rhythmic parts is intended to contribute to the integration of the materials into a single perceptual stream (or, in performance conditions permit clear spatial individuation between instrumental lines, into two apparently causally-related streams**).** This aspect of cohesion helps create an impression of quasi–heterophonic rhythmic (and pitch–based) offsets which add a degree of non–metric/cross–rhythmic gestural delineation (not always fully clear in the enclosed performance, see later discussion). For example, the frequently off–beat cross–rhythms between violin and viola parts, as is most clearly illustrated in the opening of the more rhythmic section at bar 37 (figure 76, below), contribute to this type of effect. More closely inter–related cross–rhythmic figures are also found towards the crescendo of the rhythmic section (figure 77, below).

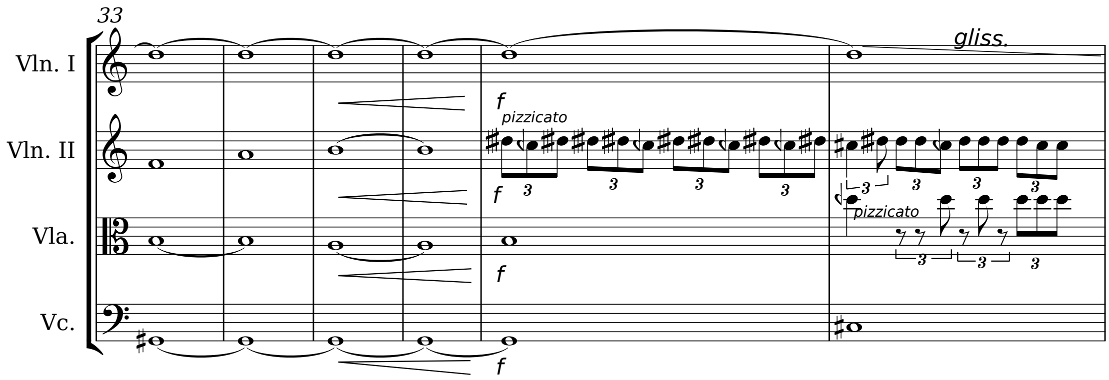


Figure 76: Cross-rhythm–based figures in the opening of the rhythmic materials

Figure 77: More closely-related cross-rhythmic figures towards the crescendo of the rhythmic section at bars 78–79

The presence of these rhythmic materials contribute to a temporal axis of difference (offering another potential axis of consonance–to–dissonance definition). At these points in the piece, the rhythmic/temporal aspect is highlighted over pitch materials in general, with the opening rhythmic section being particularly dominated by single analogues of major sevenths and minor sixths before a chromatic *arco* section (bar 48), leading back to a partial cadence of semibreve materials, providing a greater degree of both tonal/textural and rhythmic resolution (figure 78, below).

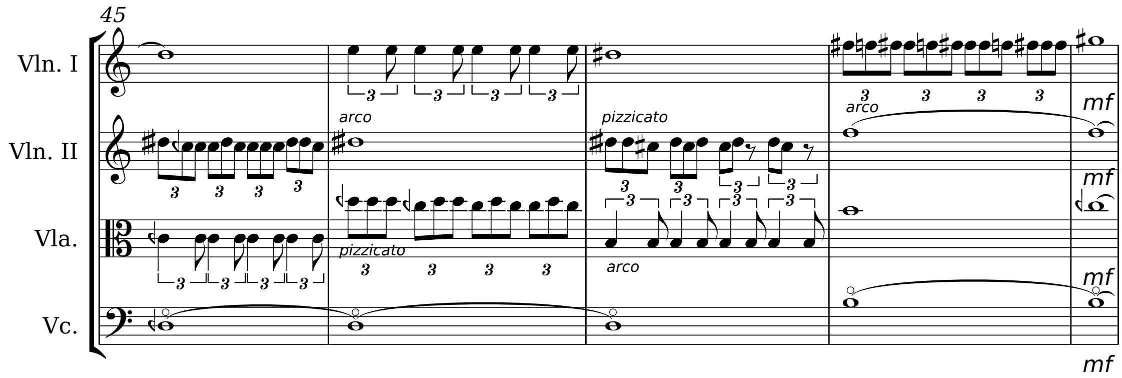


Figure 78: Limited intervallic range in early rhythmic parts (bars 45–48)

In addition to providing a rhythmic analogue for (micro)tonal consonance/dissonance definition, some of the rhythmic materials (with *arco* articulation) were originally intended to contribute to perceptual segregation effects through possible interactions with the upper partials of more sustained tones (through beating effects and perceptual assumptions regarding Gestalt–style good continuation). However, this particular aspect of their usage had limited success in terms of salient effects when presented without significant amplification. Some upper partials are occasionally heard as a direct by-product of the *sul ponticello* articulations, but not as a direct result of the combination of rhythmic interventions and sustained notes. Nonetheless, a delicate case of this effect may be found towards the end of the piece (see figure 79, below) in the violin figures in bars 94 and 95 highlighting beating effects (and contributing, to the author’s ear, to perceptual decomposition effects in the *C#* in the second violin part).

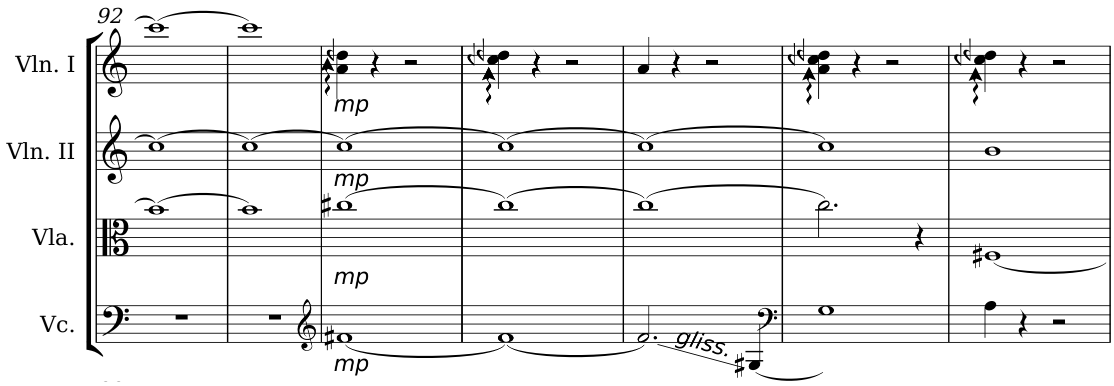


Figure 79: First violin articulations contributing to partial decomposition of the C# *drone in the second violin and viola*

It may be assumed that the role of auditory stream segregation processes might also have influenced the suppression of beating and related perceptual by–products of proximity of some of the microtonal intervallic materials, as in Bregman and Rudnicky (1975, cited in Bregman, 1990, pp.213–15), who found that relative asynchrony in component tones contributed to the formation of separate streams. Although such segregation was found to be clearer when frequency distance was greater (*ibid.*), other cues such as, in the present case, spatial placement, may contribute to their segregation in the absence of significant frequency distance. Crucially, for the present purposes, when the streams were formed, Bregman and Rudnicky (1975, cited in *ibid.*, p.215) found that the sensory phenomena associated with the interaction of frequency components was suppressed when separate streams were formed, or, as Bregman (*ibid.*) puts it ‘when the contributing tones were assigned to separate perceptual objects. Such a case appears to occur at bar 68 and also bars 78–9 (figure 80, below), where the interaction effects of such close combinations are not perceptually tracked (even if their proximity within a critical band is registered as somewhat dissonant in sensory terms).

Figure 80: A potential case of suppression of perceptual interaction effects due to stream segregation between violin and viola parts

Bregman (*ibid.*) further questions why such sensory interaction phenomena are heard at all, if they can be suppressed and surmises that they are 'available' to perception for cases when they are based on interactions which occur within single real–world sources.

If this is the case, then for such interactions to be audible, the presentational circumstances should include conditions which highlight an apparent coherence of origination. In contrast, timbral and spatial location differences may contribute to the judgement that sources are different, hence contributing to a stream segregation process which is so successful that each component stream is accurately parsed for cognitive–perceptual modelling/representation with recognisable timbre (i.e. the stream segregation process appears to leave the timbre of the streams perceptually unaltered). If these types of ecological cues and circumstances contribute to the suppression of what might be termed *unecological* perceptual phenomena, then the opposing corollary is that particularly unusual conditions are needed to engender the false positives of perceptual decomposition of what should be heard as unified timbres into component partials. This is, of course, consistent with the previous commentary with regard to the importance of extended duration (and, in the case of La Monte Young, amplification) to engender conditions of salience between different microtonal configurations. However, in the present case, the strength of the opposing perceptual dynamic of ecologically-accurate perceptual parsing was something of a surprise: the piece had originally been sketched with the aid of computer–based enveloped sawtooth waves in place of the string quartet parts, producing salient interactions of upper partials at various points, including the bars above. Although this was originally designed to simulate the effect of more salient upper partials in amplifying the string quartet, it was assumed that at least some of these interactions would produce noticeable perceptual segregation/decomposition effects. However the strength of perceptual parsing processes in producing ecologically accurate results won through to a much greater extent in this case.

The combination of rhythmic complexity alongside unusual and potentially unstable perceptual conditions was designed to produce a hybrid microtonal form which exploits a combination of novel sonorities and perceptual conditions for more insistently dramatic ends even with acoustic instrument timbres. This aspect of the experiment that is this piece may be judged only a partial success due to the aforementioned relative lack of perceptual decomposition. If this type of sonorous effect is the aesthetic goal, the microtonal just intonation orthodoxy of more significantly extended durations is corroborated. However, the testing of such materials in more significantly amplified contexts might yet produce a hybrid form which balances this type of relative rhythmic complexity with perceptual decomposition effects. The present piece stands as something of a caution that the perceptual system's ecologically–based processes are quite robust and require more significantly disruptive interventions to produce perceptual false positives (as is borne out by the extremes of materials in terms of duration and/or amplification in the microtonal practices of others). In addition, as will be discussed in the next section, the presence of relative rhythmic complexity may have worked against the prioritisation of microtonal intervallic/intonational accuracy in performance.

7.3.4 Performance/Logistical Considerations and Results

The particular combination of working method and materials for this piece did not always lead to an accurate reproduction of the specified microtonal materials. Although tuning references for the main microtonal deviations had been provided in advance and in rehearsal, these proved difficult to sustain for the actual concert. The provision of a tuning reference part on earphones for the opening might have provided one option, but this is arguably a somewhat unwieldy approach for providing an initial tuning reference. A more significant factor may well have been the *relative* rhythmic complexity[12] of the piece, which exercised more attention than the more (apparently) subtle microtonality. However, in the context of less constrained rehearsal time being available (this piece was premiered during a concert of six other new works, with just over one full day of rehearsals) or given an ensemble which specialises in such tunings, issues such as these may not prove to be as significant.

Listening to the opening moments (see figure 81, following page), the intonation appears a little uncertain, undermining the *senza vibrato* indication and consonance–dissonance concept based on an axis between (stable) grouping/stream integration and perceptual segregation effects.

[12] In comparison with the relatively monotonic/sustained sonorities which are frequently the mode of subtle just intonation–based microtonal articulations, as discussed in previous chapters.

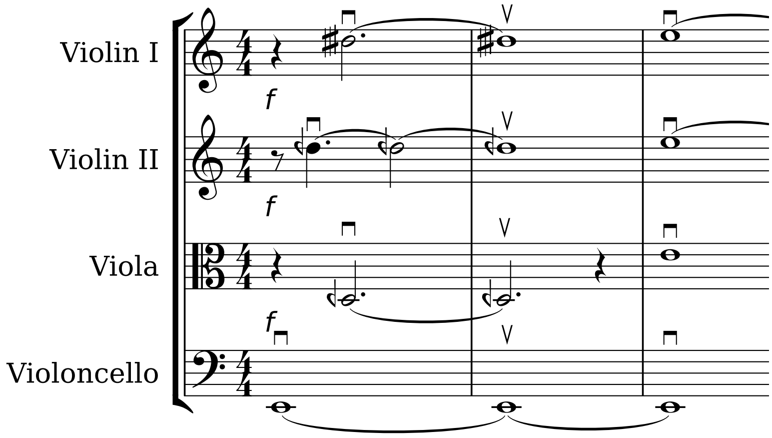


Figure 81: Opening bars of Flatlining*, containing seventh-region variants (7th and 31st harmonics)*

Listening analysis, corroborated by an analysis using SPEAR—Sinusoidal Partial Editing Analysis and Resynthesis (Klingbeil, 2009)—indicates that the first violin begins with an approximation of the more familiar standard (12TET) major seventh, before the pitch trajectory edges upwards in search of the microtonal interval requested (figure 82, next page). However, the approximately 635 Hz expected for a 31st harmonic appears to be lost in favour of a more standard major seventh variation: the frequency of the first violin appears, on analysis, to waver from a relatively low 629 Hz to a more stable high of approximately 645–650 Hz, indicating that there is lack of positive possession of a clear interval reference.

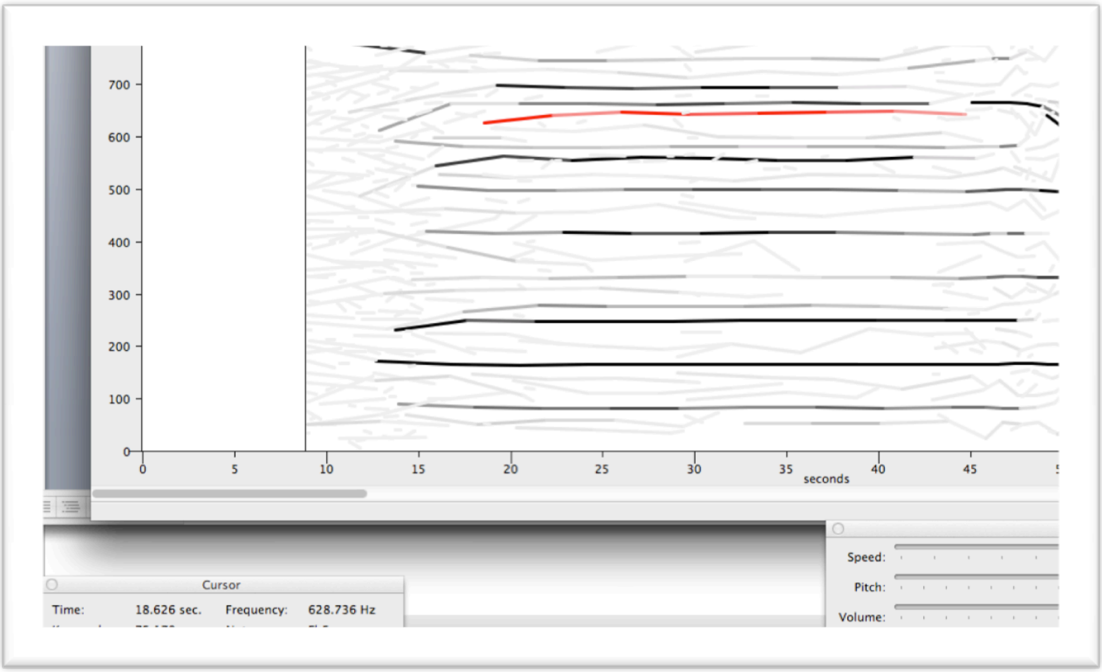


Figure 82: SPEAR's display of a highlighted 31st harmonic analogue in performance of the piece, indicating starting frequency of a (low) 629 Hz

This results in a cent-based deviation of around a quarter-tone from specification (more accurately, 27 cents from specification, if the 645 Hz figure is taken), which is relatively significant for the present purposes and robs the opening of some of its intended sonority–based structural coherence. The harmonic seventh (7/4) is also sharper and uncertain in performance. In general, as noted above, such issues could be ameliorated with a longer period to refine the tuning of intervals (or with less potentially distracting rhythmic articulation in the piece as a whole); as an exercise in relatively more brisk microtonal progressions, this piece corroborates the utility of the more widespread microtonal just intonation practice of utilising more slowly-evolving materials.

In contrast, the sections leading up to glissandi (figure 83, below) have a more seamless quality (with a relatively more accurate harmonic seventh) and are more confident in terms of articulation, aided by the presence of wide vibrato, which is performed fluently according to score and performance directions. However, as the glissandi at bar 10 proceed, the harmonic seventh is still lacking its characteristic neutrality/relative stability.

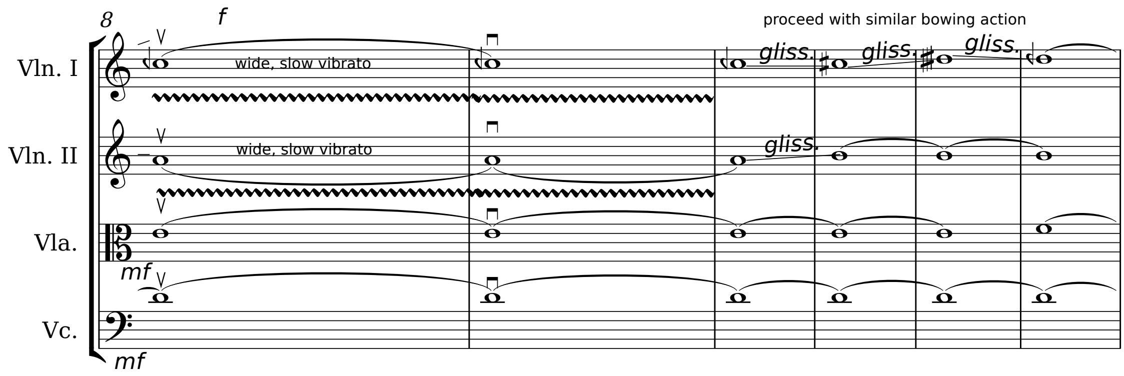


Figure 83: Early section which displays more accurate intonation

The interval is performed consistently with this (more standard) articulation for the rest of the piece, but its presence in this form is sometimes offset by the relative accuracy of other intervals, such as the relatively true Pythagorean major sixth at bars 23–4 (figure 84, below).

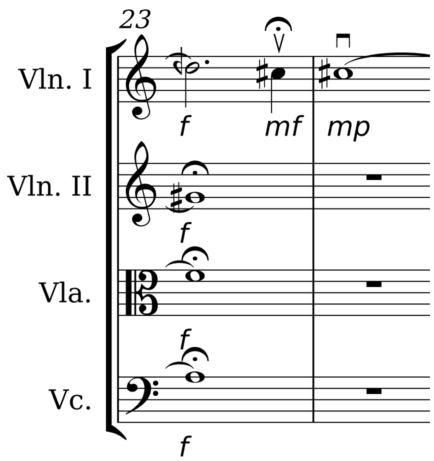


Figure 84: Pythagorean major sixth (providing cadential figure) at bars 23–4

The issue with accuracy of microtonal intonation is also to be found in the more rapid/rhythmic articulations from bar 39 (see figure 85, below), although this is not as significant in terms of the effect on composite sonority (due to the rapid pizzicato articulations).

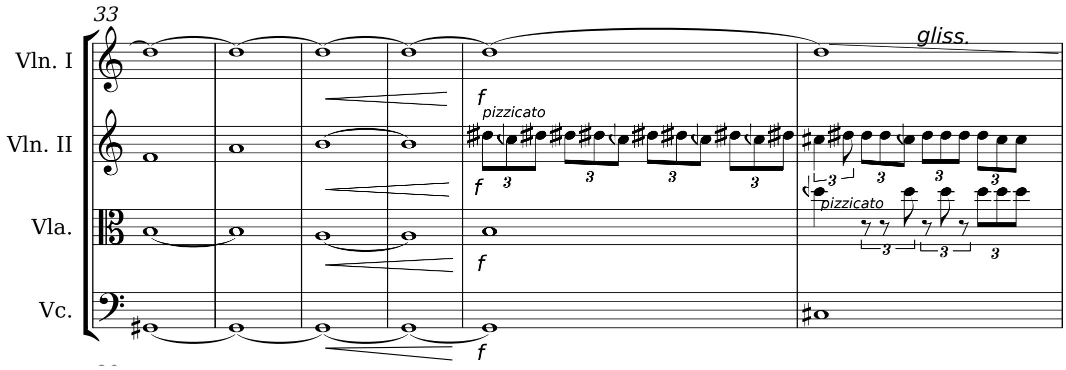


Figure 85: complex rhythmic figures exhibit poor intonational accuracy but with less effect on composite sonority in cases of pizzicato articulations

This type of interval choice/intonation problem is to be found towards the end of the piece (figure 86, below), as the two major seventh analogues are reduced to one, with the more dissonant 31/16 bracketed out, robbing the ending of a little of the texturally–based tension which had been intended.

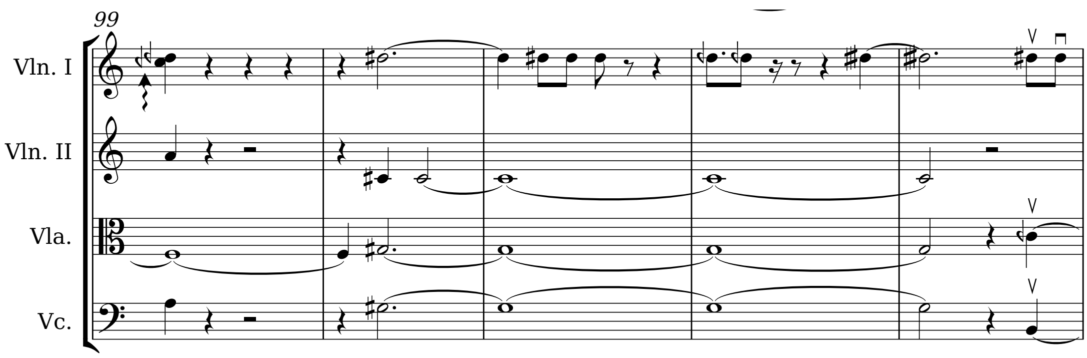


Figure 86: section towards conclusion (bars 99–103) with particularly problematic intonation (with microtonal/alt. tuning effects bracketed out)

However, at some points throughout the performance, the intonation is more successful. For example, the intonation of the harmonic sevenths after bar 50 appears to progressively improve, contributing to the stronger timbral-style fusion of the chords in this section.

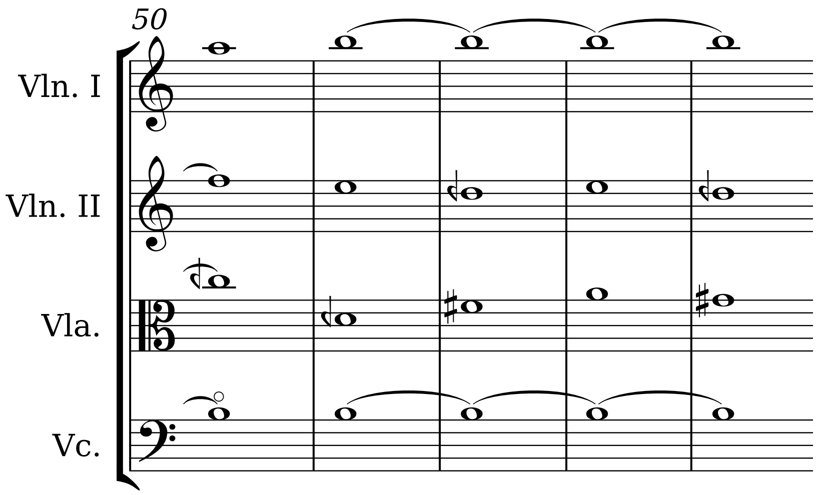


Figure 87: Section containing more successful intonational rendering of 7/4 harmonic seventh intervals (bars 50–54)

At certain moments, the combination of presentational circumstances contributes to clear perceptual decomposition (which had been intended to be more broadly present throughout the piece). This individuation of harmonic partials through the exploitation of the Bregman *old–plus–new heuristic* can be found in bars 94 and following, providing a textural rationale for the microtonal materials through making the seventh and thirteenth harmonics perceptually salient both as pitches in themselves and as inducing/encouraging a distinct listening condition of perceptual segregation, providing another consonance/dissonance concept: that of the apparent perceptual transparency for the hearing of harmonic partials (figure 88, next page).

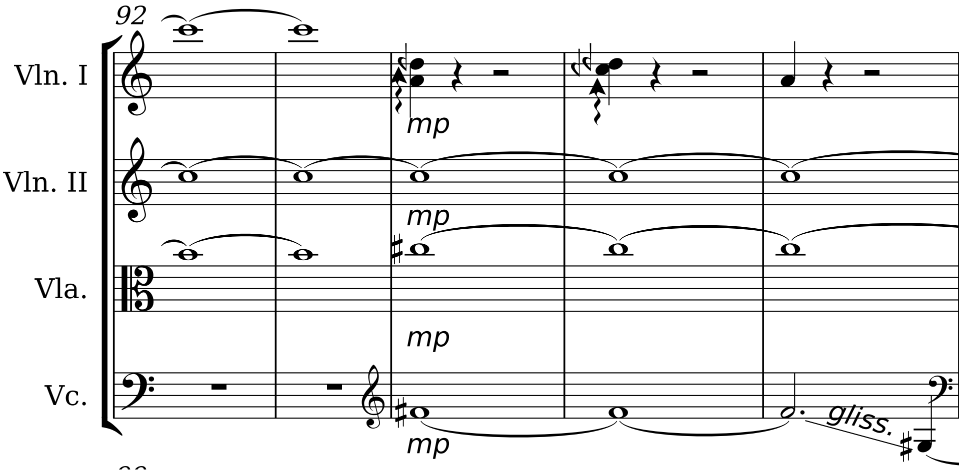


Figure 88: Perceptual continuity-based timbral decomposition effects

As previously discussed, this piece tested various microtonal configurations which are sometimes associated with distinctive perceptual decomposition effects, but which are often presented with facilitating conditions such as relatively sustained articulations and the presence of amplification. In this regard, the piece, when considered as an artistic experiment, acted as more of a negative than a positive finding. These effects were found to be somewhat more delicate and more difficult to engender than was assumed at the outset. Furthermore, beyond the perceptual factors at play, the presence of material of relative rhythmic complexity appeared to contribute to less attention being paid to intonational accuracy.

7.3.5 *Flatlining* (2008): Conclusion

Flatlining is a piece which attempted to investigate microtonal possibilities within a structural context which generally deployed them as alternate tuning analogues of standard chromatic divisions, rather than in directly adjacent microtonal contexts. The distinctiveness of these microtonal materials was invested more in their textural/sonorous result rather than in their scalar/melodic quantisation role. Due to a variety of performance conditions and circumstances, however, this sonorous distinctiveness was less evident than expected and the microtonal materials were only occasionally more clearly evident in the scalar/melodic quantisation context and in this context primarily as an awareness of the occasional deviation from standard (12TET chromatic) scale step positions.

The articulation of the materials is primarily defined by relatively slow, sustained chordal progressions, interspersed with more propulsive rhythmic sections (somewhat influenced by American post–minimal totalism) which provide for an axis of differentiation in addition to the microtonal sonority–based framework of consonance/dissonance. In general, the intonation tended towards some adherence to directional deviation from standard scale steps, although the degree of deviation was inconsistent between intervals. Based on these factors, the more commonplace approaches of microtonal performance practice which expects intonational accuracy are corroborated: focussing on tuning to the exclusion of relative rhythmic complexity appears to be advisable, even in the presence of smaller numbers of microtonal intervallic variations, unless a significant amount of rehearsal/acclimatisation time is available.

7.4 *Angels at the Shotgun Wedding* (2007/08) for 23 electric guitars and tape

7.4.1 *Angels at the Shotgun Wedding* (2007/08): Introduction

One of the initial motivations for the present project was the search for an explanation for the distinctive results of microtonal interval combinations which frequently engender the perceptual segregation of upper harmonic partials when using bright, amplified sources, epitomised by the electric guitar ensemble music of New York composer Glenn Branca, discussion of whose work can be found in my earlier MPhil thesis (Bridges, 2003). The present thesis has evolved beyond this initial genesis to attempt a somewhat more comprehensive and broadly–applicable theory of microtonal music; nonetheless, the focus on microtonality which engenders novel (and/or particularly salient) sensory conditions is a perspective which underpins most of the present work. *Angels at the Shotgun Wedding* was intended to contribute to an exploratory engagement with the perceptual implications of microtonal materials when articulated through amplified timbres and conditions using a relatively large (approximately twenty-piece) guitar ensemble drawn from the undergraudate and postgraduate music community at NUI Maynooth during the 2007/08 academic year.[13] The intention with this piece was to refine a microtonal practice for this type of ensemble which could then contribute to an understanding of conditions which may be

[13] The rehearsal and performance process was aided by the assistance of Marc Balbirnie, a final year undergraduate composition student at the time, who cued/conducted the piece (and acted as copyist for the creation of the tablature–based score from the piece's specification charts). Tablature was chosen due to its clarity as a performance–direction–centric scoring method; in addition, a significant number of the guitarists did not have significant experience with staff notation but did have experience of tablature.

more generally–applicable to a range of sound sources and/or ensemble types, thus contributing to a generalised theory of microtonality. A process of weekly rehearsals during spring 2008 facilitated the early refinement of various drafts of the multi–movement piece.

Angels at the Shotgun Wedding was premiered at the Daghdha Space, Limerick (the former St John's Church) at the *Soundings 0402* concert on April 2nd 2008 (see figure 89, below for concert poster, figures 90/91 for photographs of the ensemble at the venue).[14] Following this, it received a performance at The Venue, NUI Maynooth, on April 8th 2008 (figure 92). The acoustic of the Daghdha Space was that of a former church and produced a somewhat more favourable result through its more significant reverberation characteristics (resulting more obvious perceptual grouping/segregation effects) than in the Maynooth space, which was a basic rock-pop bar-based venue. For logistical reasons, it was decided to record the piece during the Maynooth concert rather than in Limerick (as the journey from Maynooth to Limerick required a significant amount of time, curtailing the amount of setup/sound check time at the venue itself), in addition to a further record of the first movement being derived from one of the rehearsal performances in Maynooth.[15] Additional artificial reverberation was added to these recordings in post–production to simulate an optimum acoustic.

---

[14] This concert was organised by the two co-directors of the Soundings concert series, Jürgen Simpson (University of Limerick) and Robin Parmar; details of the concert programme can be found at the following weblink: http://soundings.eirehub.com/soundings-0402.html
[15] These recordings were assisted by Maynooth graduate Philip Grier, using a stereo pair of Rode NT5s in the performance space.

The piece is scored for a fixed-media/tape drone part and multiple electric guitarists divided into five different tuning-based groups. Following the performance practice of much of Branca's electric guitar ensemble music, each guitarist obtains a sustained sonority through articulating a rapidly repeated plectrum–based *tremolo–picking* effect for each five–second note duration (or compounds of same). The optimum number of performers is four or five guitarists per group (circa 23 guitars), although the piece can be performed with as few as two or three per part if enough apparent uniformity/continuity of sound can be obtained through sustained and rapid tremolo articulation and reverberant diffusion. The guitarists follow a tablature–based score, reinforced by a conductor and timecode display to highlight timing cues.

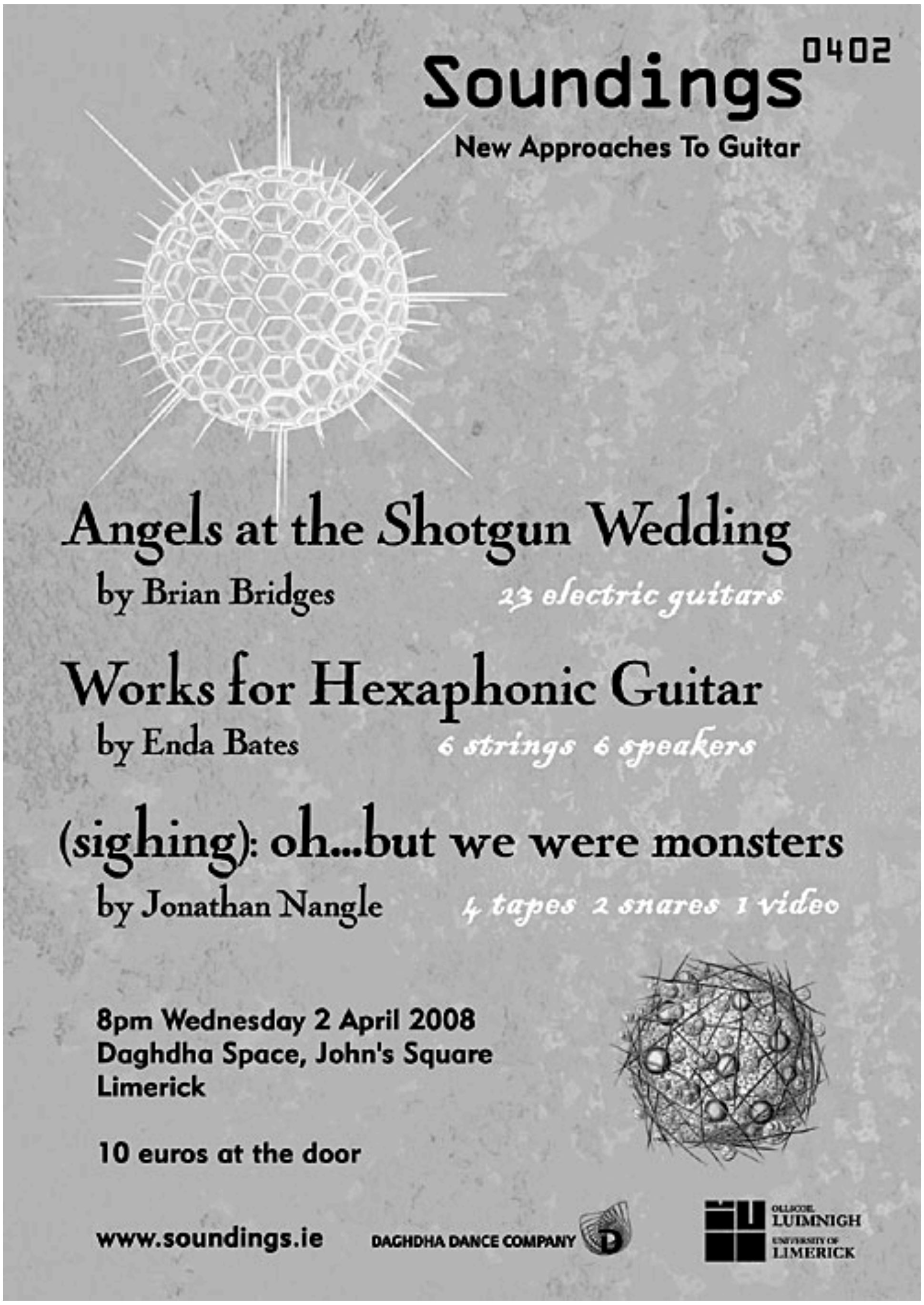


Figure 89: Concert poster for Soundings 0402 *(design: Robin Parmar/Soundings)*

Figure 90: Rehearsal for the Limerick performance of Angels at the Shotgun Wedding**,** *Daghdha Space, Limerick (photo: Jonathan Nangle)*

Figure 91: Conductor Marc Balbirnie cueing entries in rehearsal for the Limerick performance of Angels at the Shotgun Wedding**,** *Daghdha Space, Limerick (photo: Jonathan Nangle)*

Figure 92: Performance of Angels at the Shotgun Wedding *at The Venue, NUI Maynooth* (photo: Brian Bridges)

Angels at the Shotgun Wedding is broadly structured as a multi–movement piece which seeks to explore distinctive sonorities/novel sensory conditions created by the use of microtonal intervals which are broadly derived from harmonic series prototypes. When combined with bright instrumental sonorities and amplification, the use of these intervals tends to encourage the perceptual segregation of upper harmonic partials when these intervals coincide in frequency (or at octave multiples) or are close in frequency to the upper partials of one of the component timbres in a combination. In many cases, these interactions (and resulting perceptual segregation effects) occur due to the extremely close proximity of two or more intervals, resulting in periodic interference patterns (beating) being heard between different pairs of frequency components. As this beating is tracked as an amplitude modulation by the perceptual system, this system may use this as a basis to perceptually segregate these materials into separate auditory streams (the guitars' tremolo articulation may also produce a similar effect in certain cases). As such, dense (and, in some cases, microtonal) clusters may therefore engender a form of perceptual interaction which results in the segregation of single frequency components into different streams, with these frequency components being tracked as single 'pure' sinusoidal rather than multiple–partial complex sources, producing what might be considered to be a relatively consonant form from what would be traditionally considered to be dissonant conditions. (When focussing attention on the lower frequency components, the significant critical band overlap of many components would tend to be tracked by the perceptual system as dissonant; when focussing attention on the upper part of the frequency spectrum, perceptually segregated upper partials might euphoniously 'ring out'.)

The title of *Angels at the Shotgun Wedding* refers, in part, to this phenomenon whereby such perceptual phenomena are sometimes heard as vocal-like in nature; this type of association has frequently been observed anecdotally in responses to the music of composers for amplified forces (Glenn Branca and fellow New Yorker Rhys Chatham, cf. Bridges, 2003). Indeed, my own personal experience attending concert performances of Branca's Symphony No. 13[16] (subtitled 'Hallucination City'—for one hundred electric guitars) tallies with this association. Based on this parallel, the present piece's title derives from the

[16] Branca (2001).

putative form of the perceptual phenomenon/hallucination, alongside a further association with extreme, indeed apocalyptic, conditions which Branca's music is often taken to reference (both in reviews/third–party assessments and, indeed, in the composer's subtitle to Symphony No.6: 'Devil Choirs at the Gates of Heaven'[17]). The present version of *Angels at the Shotgun Wedding* is divided into different movements which, as noted above, are each centred around (indeed, compositionally emergent from) a single, static drone part comprising some of the intervallic materials of the guitar tunings. The movements have the following, loosely programmatic, titles, relating to a sense of an unspecified disruptive event (with the movement titles referencing themes of exodus and/or apocalypse):

Movement 1: 'Departure'

Movement 2: 'Inhalation/Choke'

Movement 3: 'Take God Out and Show Her a Good Time'

Movement 4: 'Pathfinding'

Movement 5: 'Return'

7.4.2 Guitar and Tape Part Tuning Specifications and Sonorous Structure

The piece's materials are divided between the electric guitars and a set of simple tape-based drones which are different for each movement of the piece. The drones are based on the harmonic intervals which are found in the tunings of the

---

[17] Branca (1989).

different guitar parts in the piece; as is the case in the previously–discussed pieces, the similarity of these materials is designed to contribute to the perceptual segregation of upper harmonic partials from the guitar. In addition, the drone–based deployment of these intervallic materials contributes to the definition of distinct sensory (and, more subjectively emotional–affective) 'spaces' based on their signature textures and periodicity–based interaction effects between different frequency components which are a function of the within-octave and registral spacings between materials. The electric guitar parts are somewhat unconventional, in that they are derived primarily from the re–tuning of the guitar strings for various just intonation microtonal intervals which are generally variations on a 'standard' interval type (e.g. a major third), with the six strings divided into two identical, octave–offset, groups of three. Although the piece's intervallic materials are primarily obtained from open strings (to preserve the intonational integrity of its intervals), some supplementary intervals are obtained through fretting major second and perfect fifths, as the 12TET version of these intervals provides a relatively good approximation of just intonation (as will have been observed in the discussions of tuning and temperament in chapters one and two).

Through the combination of five different tuning groups, each comprising three microtonally–offset intervals in open–string (and two further sets of three intervals through fretting the major second and perfect fifth), a relatively wide range of microtonal intervals were obtained which were designed to closely approximate harmonic series intervals. The intervals produced by these means totalled 45 (although there were some duplications and not every secondary interval obtainable by fretting was actually used). Where the same interval could be obtained through both fretted and open–string articulations, the open version was preferred due to the likelihood of brighter/richer harmonic spectra in this case, facilitating greater upper–partial interaction. The microtonal tuning offsets in the different guitar parts facilitate both sequential aspects of microtonal articulation, but more significantly for the present purposes, offers an easy means of accessing dense microtonal clusters on a single instrument, intended to engender a significant degree of perceptual interaction between their frequency components. With the combination of a constant drone part and the more transient but still relatively sustained guitar articulations (almost exclusively based on durations of five seconds or longer), in addition to its focus on the sonorous result of subtle variations in configuration through tuning, the piece could be characterised as bearing a partial resemblance to drone music; although the degree of temporal articulation/differentiation might be anathema to the more purist practice of drone music (such as that found in the early Theatre of Eternal Music, from 1964 onwards). However, even that group's prominent leadership figure, La Monte Young, also composed music which, whilst primarily focussed on pitch/tuning/sonority rather than temporal articulation, still used time-based delineation of different microtonal and/or alt. tuning/sonority–based materials, such as in his *Well-Tuned Piano* (Young, 1964–present). This type of approach is still clearly influenced by the findings of the more singularly drone–based explorations of tuning and could therefore be termed *post–drone music*, which has the benefit of referencing the signature sonorous aspect of the music without misrepresenting it as something which is more generally static in its basic pitch-structure.[18] On this basis, the present piece (and, indeed, much of the present portfolio) may be considered to be post–drone music.

The tuning of the five different guitar sections (along with the *secondary intervals* obtained by fretting major seconds and perfect fifths) can be seen in figures 93 (a–e), following pages. All intervals are normalised on the basis of their origin as harmonic intervals within one octave for the sake of clarity; however, in the case of guitar 1, the actual interval derived from the 125th harmonic is just below the 1/1 root (rather than almost an octave up, as found in the prototypical ratio representation below). The naming of interval analogues below (grouping the intervals obtained by primary or secondary tunings) is designed only as an approximate guide; in addition, some of these *analogue names* are only applicable to a subset of the intervals in a group in certain cases (e.g., guitar 5, which is denoted as providing variations on seconds, but also includes a minor third; thus, the name of each group is weighted towards the majority, which is appropriate in terms of this type of indicative usage, since these intervals are frequently deployed as clusters centering around a clear analogue of the named interval). Secondary (fretted) intervals which are based on harmonic series intervals are indicated in brackets (with the harmonic intervals they are intended to approximate indicated outside brackets). In some of the guitar part, certain of these secondary intervals do not closely approximate harmonic intervals and so are marked as ‘not used’. However, the cent figures provided are the actual rather than nominal cent figures for the approximations of

---

[18] This label also has the convenience of referencing a ‘generational’ distinction between the formative earlier practitioners (Young et. al) and later ones such as Branca (even if Young himself can be viewed as both a drone music and post-drone music practitioner).

these harmonic intervals. Each guitar section is tuned in two octave-offset groups of three intervals (described in descending order from higher to lower). This arrangement facilitates the easy performance of microtonal cluster–chords built on the open string tunings in either single–octave or double–octave configuration, whilst also allowing for the articulation of microtonal melodic variations between different strings. In the case of some guitar parts, the gauge of strings was changed to provide for a relatively even distribution of tension across the guitar's neck.

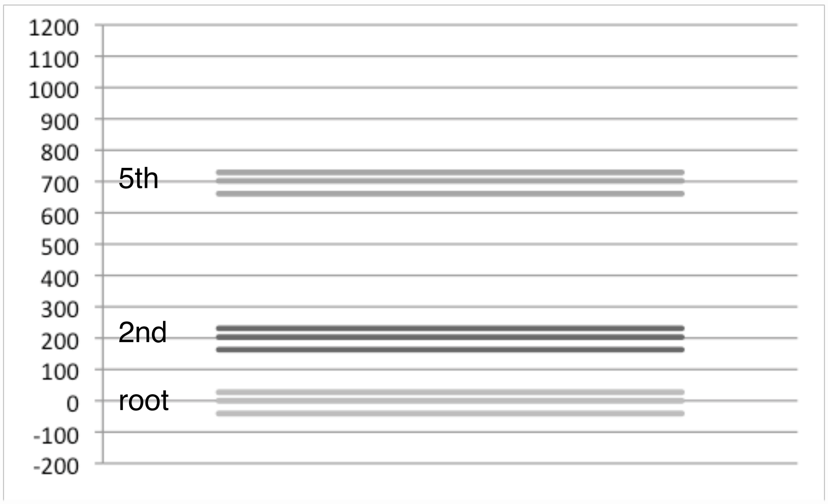
The guitar parts themselves were tuned by ear relative to reference tones provided to the guitarists in advance of rehearsals and then consolidated in a per-part tuning at the start of each rehearsal. Although this process of tuning was somewhat time-consuming, the process also provided a chance to highlight the main intervallic materials which were characteristic of each guitar part, thus providing a degree of ear training which facilitated the guitarists' apprehension of the piece's wider structures (potentially providing for more confident performances as the process of rehearsals and performances continued).

Guitar 1: ratios

‘roots’	**x 9/8 (analogues of ‘2nds’)**	**x 3/2 (analogues of ‘5ths’)**
65/64	73/64 [585/512]	97/64 [195/128]
1/1	9/8	3/2
125/64	35/64 [1125/1024]	47/64 [375/256]

Guitar 1: cents

‘roots’	**x 9/8 (analogues of ‘2nds’)**	**x 3/2 (analogues of ‘5ths’)**
27	231	729
0	203	702
-41	163	661



Intervals used by guitar one: root (unfretted), fretted major second, fretted perfect fifth

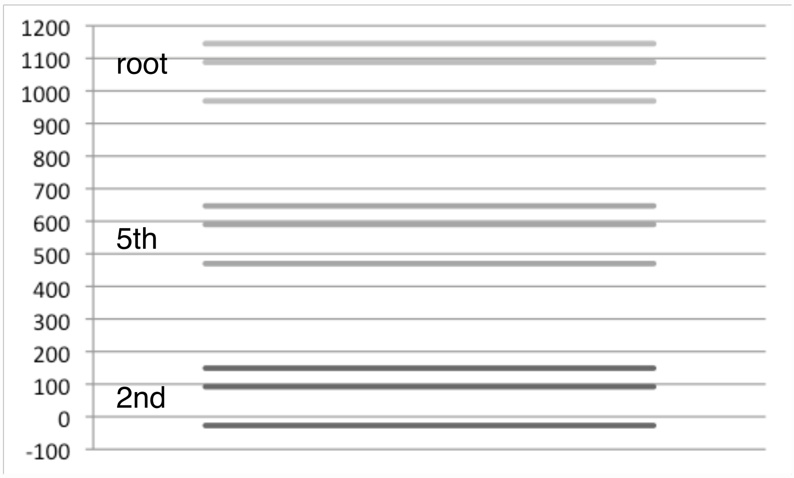
Figure 93(a): Angels at the Shotgun Wedding *guitar section 1 tunings*

Guitar 2: ratios

‘7ths’	x 9/8 (analogues of ‘roots/8ves’)	x 3/2 (analogues of ‘4ths’)
31/16	35/32 [279/256]	93/64
15/8	not used [135/128]	45/32
7/4	63/32	21/16

Guitar 2: cents

‘7ths’	x 9/8 (analogues of ‘semitone/roots’)	3/2 (analogues of ‘4ths’)
1145	149	647
1088	92	590
969	-27	470



Intervals used by guitar two: root (unfretted), fretted major second, fretted perfect fifth

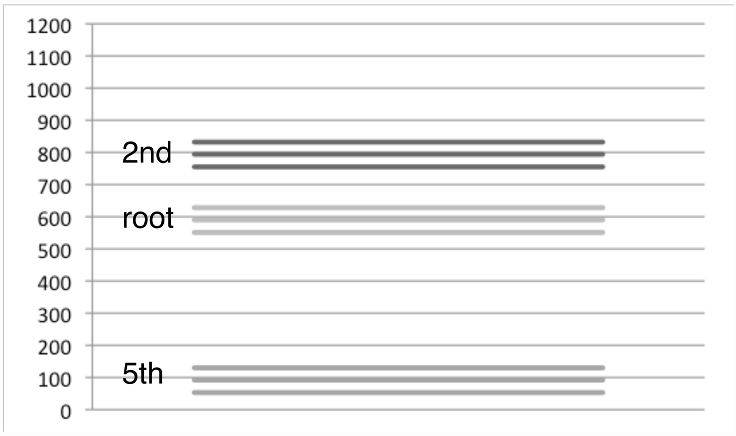
Figure 93(b): Angels at the Shotgun Wedding *guitar section 2 tunings*

Guitar 3: ratios

‘4ths’	**x 9/8 (analogues of ‘6ths’)**	**x 3/2 (‘roots’/’semitones’)**
23/16	13/8 [207/128]	69/64
45/32	101/64 [405/256]	[not used] 135/128
11/8	99/64	33/32

Guitar 3: cents

‘4ths’	**x 9/8 (analogues of ‘6ths’)**	**x 3/2 (‘roots’/’semitones’)**
628	832	130
590	794	92
551	755	53



Intervals used by guitar three: root (unfretted), fretted major second, fretted perfect fifth

Figure 93(c): Angels at the Shotgun Wedding *guitar section 3 tunings*

Guitar 4

‘3rds’	x 9/8 (analogues of ‘tritones’)	x 3/2 (analogues of ‘7ths’)
81/64	69/64 [729/512]	not used [243/128]
5/4	45/32	15/8
39/32	11/8 [351/256]	117/64

Guitar 4

‘3rds’	x 9/8 (analogues of ‘tritones’)	x 3/2 (analogues of ‘7ths’)
408	612	1110
386	590	1088
343	546	1044

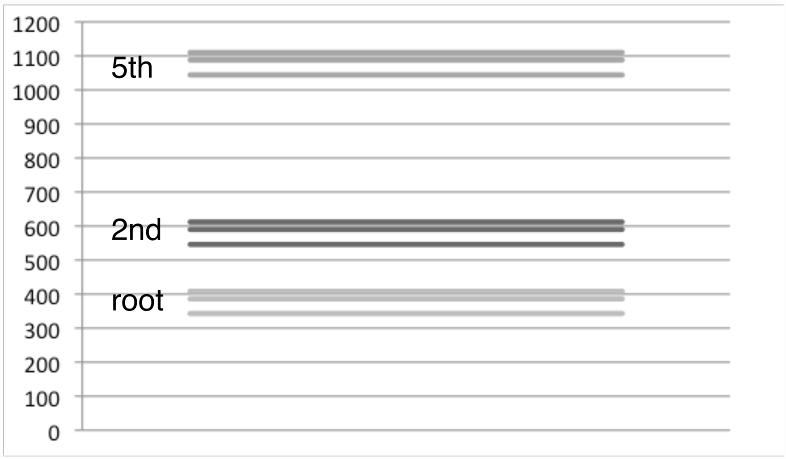


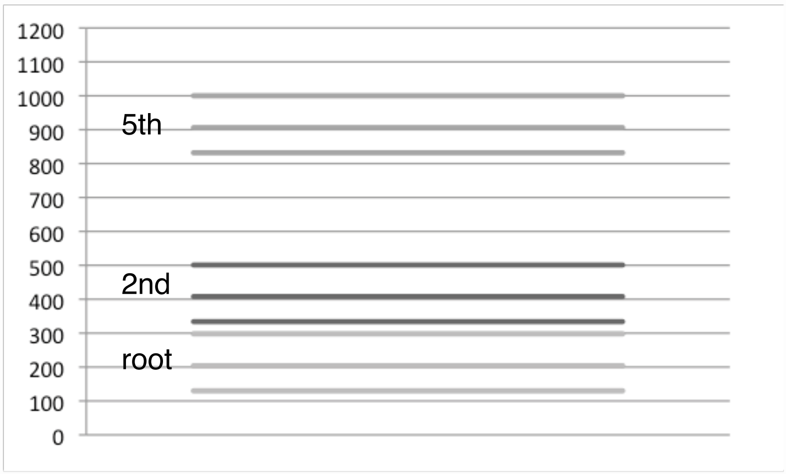
Figure 93(d): Angels at the Shotgun Wedding *guitar section 4 tunings*

Guitar 5

‘2nds[1]’	x 9/8 (analogues of ‘3rds’)	x 3/2 (analogues of ‘6ths’)
19/16	not used [171/128]	57/32
9/8	81/64	27/16
69/64	39/32 [621/512]	13/8 [207/128]

Guitar 5

‘2nds’	x 9/8 (analogues of ‘3rds’)	x 3/2 (analogues of ‘6ths[2]’)
298	501	1000
204	408	906
130	334	832



[1] Also includes minor third (19th harmonic) analogue.

[2] Also includes 1000 cent equal temperament minor seventh.

Figure 93(e): Angels at the Shotgun Wedding *guitar section 5 tunings*

The drone parts—see figures 94(a–e)—are constructed from a simple, static, synthesised tone with eight frequency components (of roughly equal amplitude), resulting in a bright, relatively dense, but band–limited sonority[19] which is designed to contribute to perceptual segregation effects in the instrumental parts. These parts reference broadly emotional/affective spaces related to the thematic resonances associated with the movement titles, with a largely euphonic first movement, dense/explosive second and third movements and somewhat more sombre/funereal fourth and fifth movements. The foregrounded instrumental parts also broadly follow these emotional/affective logics through their selection of individual intervals and/or clusters of intervals which are designed to either avoid the drone parts or be configured in proximity to them, in addition to the deployment of clusters versus more isolated intervals and the use of performance dynamics to articulate textural differences.

Where the instrumental lines align directly with the drones, some of their frequency components may tend towards perceptual segregation (being tracked by the perceptual system as a continuation of the drone). Where they are closely but not completely aligned, they may produce interference/beating effects which may also contribute to perceptual segregation. Further complexities are also added by the spectra of the component tones in both the drone and guitar parts. The drone part contains an eight–part harmonic spectrum, resulting in a variety of harmonic intervals being delineated as second derivatives of each interval of the drone part. Thus, even if, for example, a major third (5/4) is not specifically

---

[19] So that the composite result of the addition of microtonal intervals does not result in too much upper-partial activity before the addition of the instrumental parts.

delineated in the drone part, fifth harmonics will be found within its spectrum, such that the difference between a just major third (5/4) and Pythagorean major third (81/64) in the instrumental part may be apparent in alignment or minor divergence between the foreground note and the background context of the drone. In the electric guitar part, in addition to the additional frequency components resulting from its complex timbre, the relatively light distortion inherent in even settings demarcated as 'clean'/low distortion on the various guitar amplifiers used in the piece may contribute to the creation of sum and difference tones due to nonlinearities within the amplification process. This creates further additional frequency components which may be more likely to cause perceptual interactions between themselves and between the instrumental and drone parts. These distortion characteristics are also likely to be significantly variable with respect to input level; at many points throughout the piece, the audible result of this principle is that the resulting sonorities may change from relative simplicity/coherence/cohesion to relative complexity and greater tendency towards perceptual segregation in the upper components. This aspect is specified in the performance score through the use of standard dynamic notation which, due to the dynamic compression effect of distortion processes, sometimes relates more audibly to this type of timbral change rather than a dramatic change in level (although a brighter, more distorted timbre may be perceived as qualitatively louder than one which is not processed in this way).

Movement 1: ratios (cents)

Oct 5	125/64 (1158)
Oct 4	61/32 (1117), 5/4 (386), 17/16 (105)
Oct 3	9/8 (204)
Oct 1	1/1 (0)

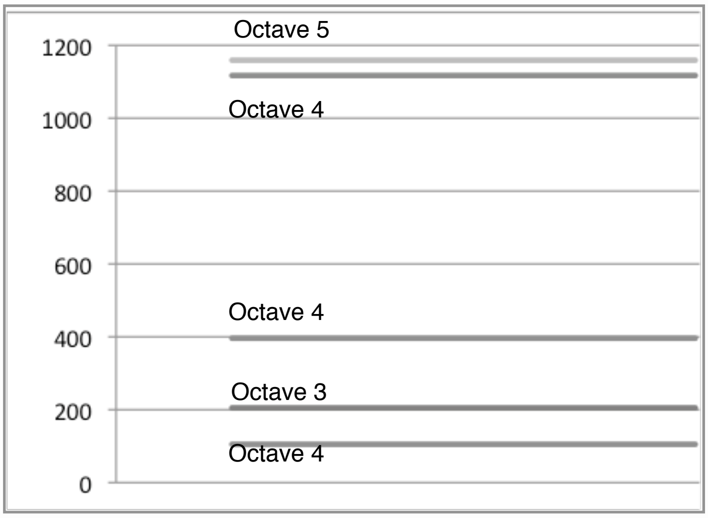


Figure 94(a): Angels at the Shotgun Wedding *movement 1 drone part tunings*

Movement 2: ratios (cents)

Oct 5	31/16 (1145), 59/32 (1059), 7/4 (969), 21/16 (470), 81/64 (408)
Oct 4	61/32 (1117)
Oct 1	65/64 (27)

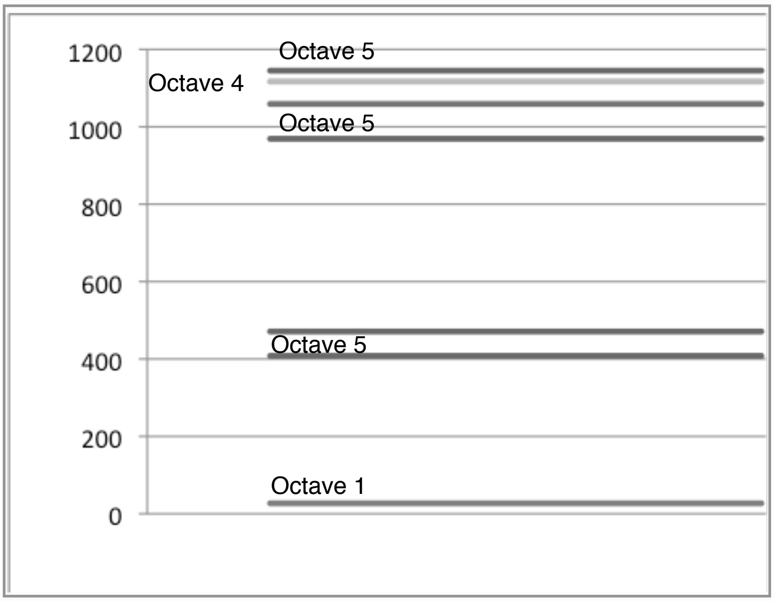


Figure 94(b): Angels at the Shotgun Wedding *movement 2 drone part tunings*

Movement 3: ratios (cents)

Oct 6	65/64 (27)
Oct 5	127/64 (1186), 125/64 (1159), 123/64 (1131), 121/64 (1103) 119/64 (1074),117/64 (1044), 113/64 (984) ,111/64 (953)
Oct 1	no components

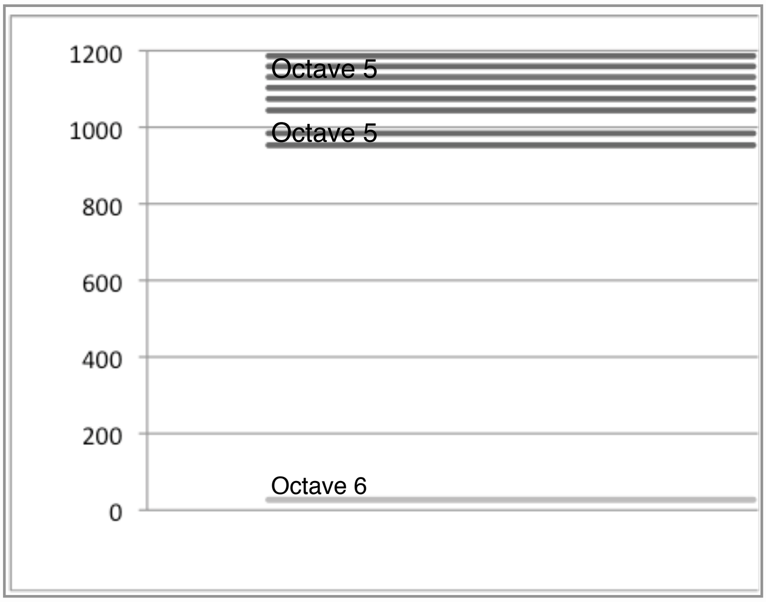
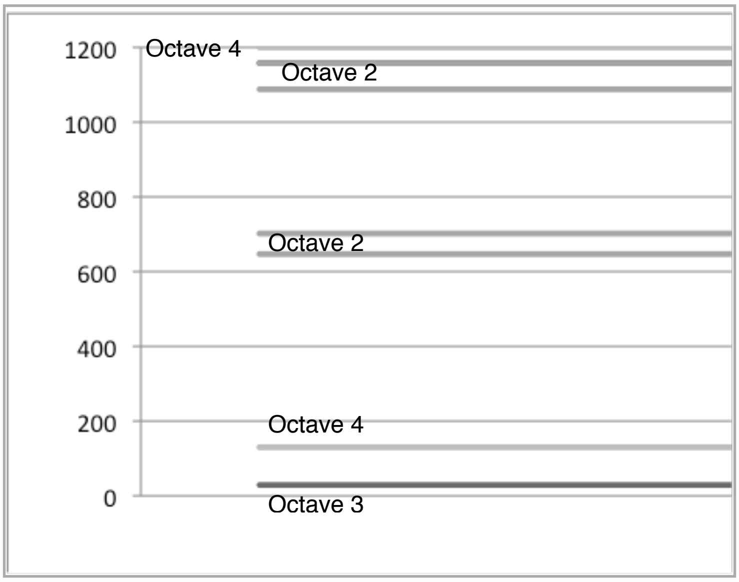


Figure 94(c): Angels at the Shotgun Wedding *movement 3 drone part tunings*

Movement 4: ratios (cents)

Oct 4	69/64 (130), 65/64 (27), 1/1 (0)
Oct 3	125/64 (1159), 65/64 (27), 1/1 (0)
Oct 2	125/64 (1159), 15/8 (1088), 3/2 (702) ,93/64 (647)
Oct 1	no components

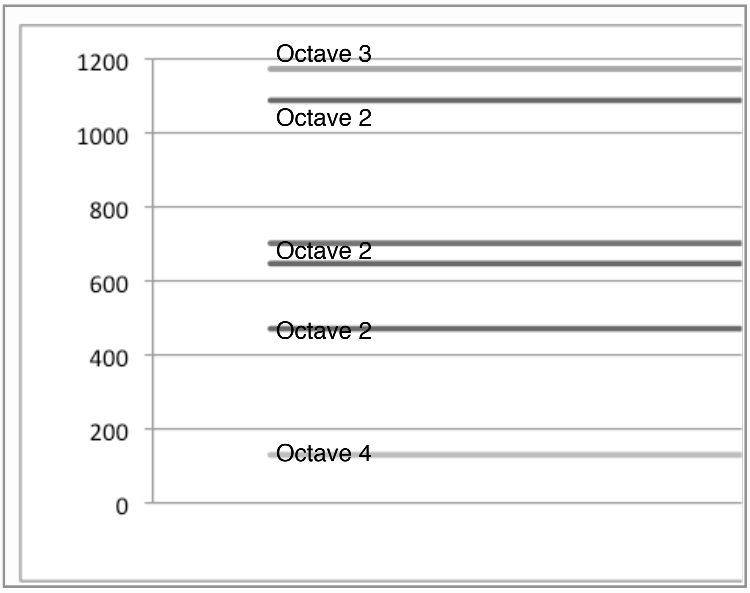


NB: some octave-duplicated components not shown

Figure 94(d): Angels at the Shotgun Wedding *movement 4 drone part tunings*

Movement 5: ratios (cents)

Oct 4	69/64 (130)
Oct 3	63/32 (1173), 69/64 (130)
Oct 2	15/8 (1088), 3/2 (702),93/64 (647),21/16 (471)
Oct 1	no components



NB: some octave-duplicated components not shown

Figure 94(e): Angels at the Shotgun Wedding *movement 5 drone part tunings*

7.4.3 Movement 1: 'Departure'

The first movement's drone is relatively perceptually stable (resulting in a more open/euphonic texture), with interval spacings generally based on standard step sizes (semitone, major second, major third) along with two higher harmonic intervals (61st and 125th) within the major seventh region. As can be seen from tuning of the tape part in movement 1 (see figure n from earlier in this chapter), the drones have sufficient octave spacing in–between their component notes to offset first-order (between lowest harmonic partial) sensory dissonance, contributing to their relative perceptual stability. The majority of the instrumental lines are also based within these regions, offering either single or microtonal variants or relatively dense microtonal clusters within these pitch-areas. The specification chart for the piece (see figure 95, following page) depicts the manner in which these parts either align with or diverge from this drone–based context.

The chart indicates interval size in cents on the vertical axis and position in 5–second intervals on the horizontal axis; the convention in all of these representations is that harmonic intervals in the instrumental part are indicated through the harmonic number in large, boldface text, along with cent values in smaller text throughout greyed lines representing the progression of the instrumental line. These are visualised against the intervals of the drone part, denoted by dotted lines which are represented without direct harmonic number or cent value indications for the sake of graphic clarity; the exact specifications and derivations can be seen in the frequency charts in the section above. Registral shifts are not depicted in these charts (again, for reasons of graphic clarity): these can be found in the tablature–based performance scores found in the appendix.

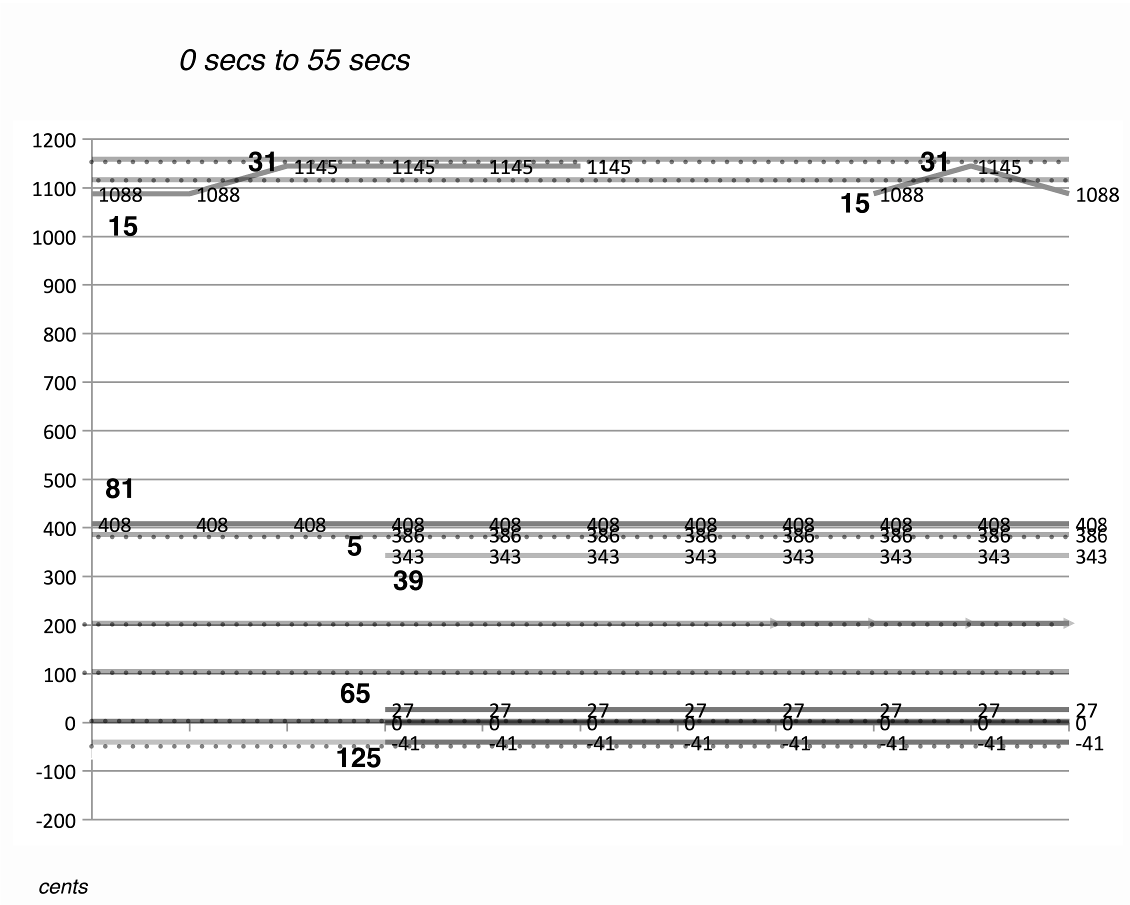


Figure 95: specification chart for the opening minute or so of the first movement

The movement opens with an open and relatively euphonic statement of the 81st harmonic (major third analogue) and 15th harmonic (major seventh analogue), accompanied by the tape-based drone of 61st and 125th harmonics (seventh-region) alongside the 5th harmonic (major third), 9th harmonic (whole-tone) and 17th harmonic (just intonation semitone). This opening thus creates conditions of relative perceptual simplicity whereby the *first–order harmonic materials* (i.e. the intervals as directly specified) are clear alongside some audible beating (and perceptual segregation) effects in the upper partials (which can therefore be considered to be *higher-order materials*). Microtonal distinctions are also directly apparent in more traditional melodic terms during this section: the circa quarter-tone (57 cents) move from the 15^{th} to 31^{st} harmonic is clearly audible with a coherence/lack of ambiguity which may be expected to contribute to structural salience. In addition, the dense microtone–based clusters around the tonic (based on 65^{th} and 125^{th} harmonics) and intervals around the major third (81^{st}, 5^{th} and 39^{th} harmonics) are also within approximately a quartertone of each other and demonstrate the textural effects of microtonal variations both in terms of lower–order density in the frequency region in which the notes are directly specified, in addition to the higher–order interactions which may manifest themselves in perceptually segregated components. The distinction between the relative density of these close microtonal clusters (which are, contrary to expectation, heard as relatively consonant, due to their proximity to key lower members of the harmonic series, i.e. 1^{st} and 5^{th}) and the much wider spacing (and resultant perceptual individuation, most likely contributed to by the tremolo articulation) of the nonetheless qualitatively dissonant chord which follows shortly after at 1'10 (figure 96, page after next), appears to invert turn more traditional sensory–based conceptions of consonance and dissonance. The spacing of components in the latter chord contributes (alongside the more basic perceptual factors noted above) to individuation and, therefore, relative perceptual stability, but in terms of the Terhardt/Parncutt model, it may be treated as dissonant due to the harmonic intervals deviating from a template-based map relating to the lower components of the harmonic series. The intervals (65^{th}, 69^{th}, 9^{th}, 19^{th} and 7^{th}) have no common factors and, as such, cannot be resolved in terms of common factor relationships as lower harmonics around any single centre. Based on these aspects, the tendency is towards a chordal–style group (as opposed to a quasi–timbral–style group) whose harmonic attributes tend towards the upper end of the ambiguous–as–dissonant schema in Terhardt/Parncutt. Thus, the chord may be considered to exhibit two opposing tendencies in terms of consonance/dissonance judgements: (1) related to the basic perceptual clarity of its component materials (with clarity registered as perceptual stability and, hence, being defined as consonant) and (2) based on a more cognitively–related assessment of consonance/dissonance on the adherence (or lack thereof) of its materials to a straightforward harmonic template. The qualitative result of this tension is a chord which arguably combines a cognitive judgement of dissonance with a sensory–based judgement of consonance moderating this dissonance judgement. Thus, the potential of careful specification of microtonal intervals to contribute to such nuanced cases of consonance and dissonance could be suggested as one of its key strengths in terms of a range of musical structuring possibilities.

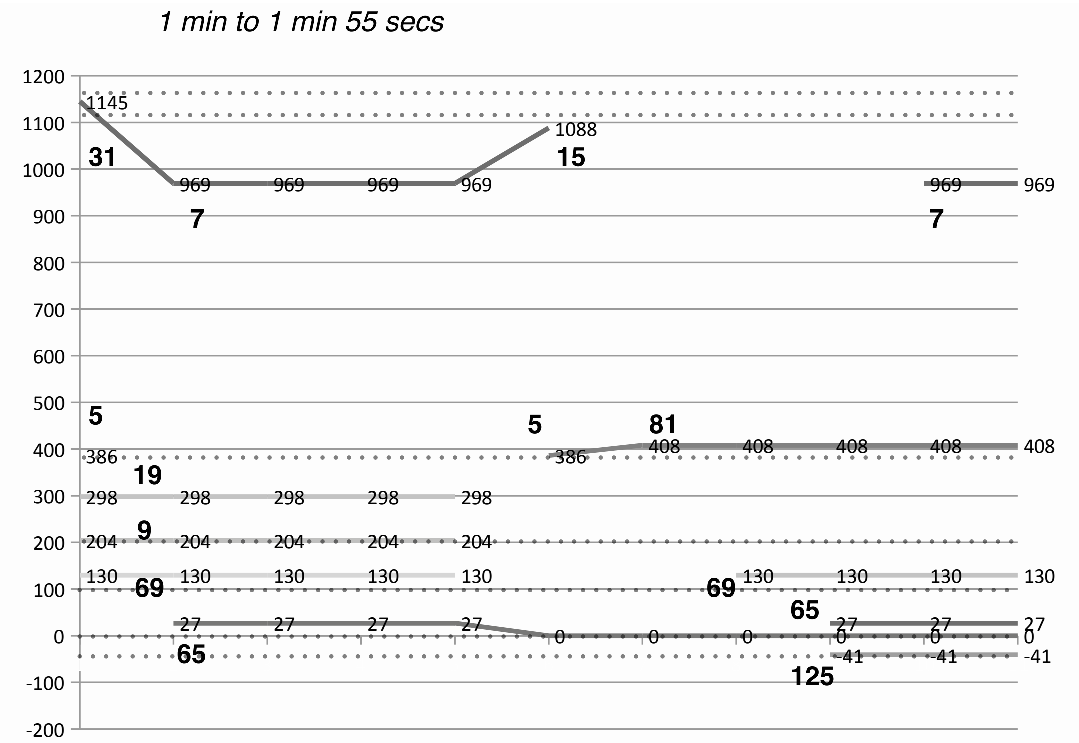


Figure 96: Specification chart for the second minute or so of the first movement

These opposing tendencies of sensory and cognitive consonance/dissonance judgements are also signalled in the point of resolution of this intervallic complex, based on 1st, 5th and 15th harmonics (i.e. with relatively simple relationships between the harmonic materials), although the familiar functional implications of the 15th harmonic as a major seventh may make this cadential–style figure feel somewhat incomplete. This sense of tension is further accentuated as the 5th harmonic widens to the 81st harmonic and is combined with a restatement of what can be termed the *tonic–cluster* of 65th, 1st and 125th harmonics alongside a 69th harmonic (130 cents). These more unambiguously sensory-based aspects of the piece's articulation are joined by the use of register to contribute to a sense of delineation and axes of difference between the materials**.** In the context of the general continuity of the drones (and the highlighting of the significance of microtonal distances, this octave shift may be considered to be more perceptually significant here than might be the case in common practice music. In addition, it prefigures a falling line (see figure 97, following page) in guitar 3 from the 23rd harmonic (tritone analogue) through the 45th to the 11th harmonic (all separated by a microtonal intervals which each comprise just over a quartertone or less), further leading to the highlighting of the entry of the 39th harmonic at 2'15. Perceptible melodic microtonality is also to be found in the implied composite melodic interval between the 19th harmonic in guitar 3 and the 39th harmonic (guitar 4), separated by 45 cents and this entry is further reinforced through the expansion of the 23rd/45th/11th materials to a cluster at this point. As such, both textural and melodic distinctions may contribute to microtonal salience as the increased or decreased/decreased grouping or segregation becomes a point of reference which may be used to aid in the cognitive–perceptual structural of these novel scale divisions.

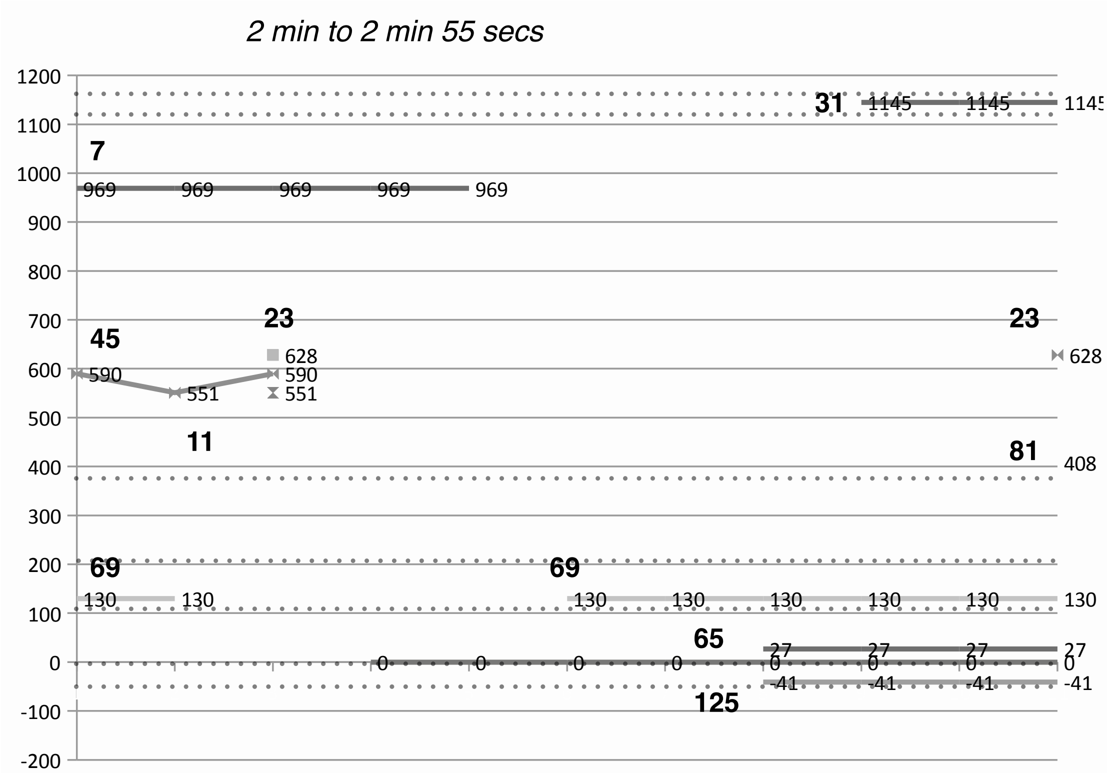


Figure 97: Textural and melodic microtonal cases from 2'00 to 2'55

The clarity of the high 31st harmonic at 2'45 (alongside the statement of the tonic–cluster in guitar 1) may be seen as drawing attention to the empty (save for a drone-based component) pitch–chroma space between it and the 19th harmonic, which is then filled by the 23rd (tritone analogue) accompanied by the high major third analogue of the 81st harmonic (with no common factors between them). This resolves down to a chord on the 9th, 39th and 15th harmonics, a grouping which sounds relatively dissonant in spite of the common factor of 3 potentially simplifying the relationships between these materials. This may be due to the clear tonic implication which is constantly reinforced by the drone (thus resulting in these intervals being treated in relation to the tonic rather than the fifth region) or it may be that the presence of the 39th harmonic as an 'intermediate third' between major and minor registers as diverging from the familiar harmonic template, and hence as dissonance.

The final cadential–style structure of this movement (4’30 onwards, see figure 98, next page) provides a statement of a falling tone in guitars 1 (from $73^{rd}/9^{th}/35^{th}$ harmonics to the by–now characteristic ‘tonic’ of $65^{th}/1^{st}/125^{th}$ harmonics), accompanied by the same movement in guitar group 4 (45^{th} to 5^{th} harmonics), accompanied by a held 11^{th} harmonics (tritone analogues and close to the 45^{th} harmonic), resulting in further sensory–based (and, potentially, cognitively–based/functional) tension being inherent in this figure. The resolution to a chord on 1^{st}, 5^{th}, 9^{th}, 11^{th} and 63^{rd} (7^{th} of 9) provides for comparative perceptual simplicity and cognitive judgements of relative tonal stability (based on the generally low–order harmonic relationships), even if the presence of the 11^{th} and, more particularly, the 63^{rd} harmonics are problematising factors.

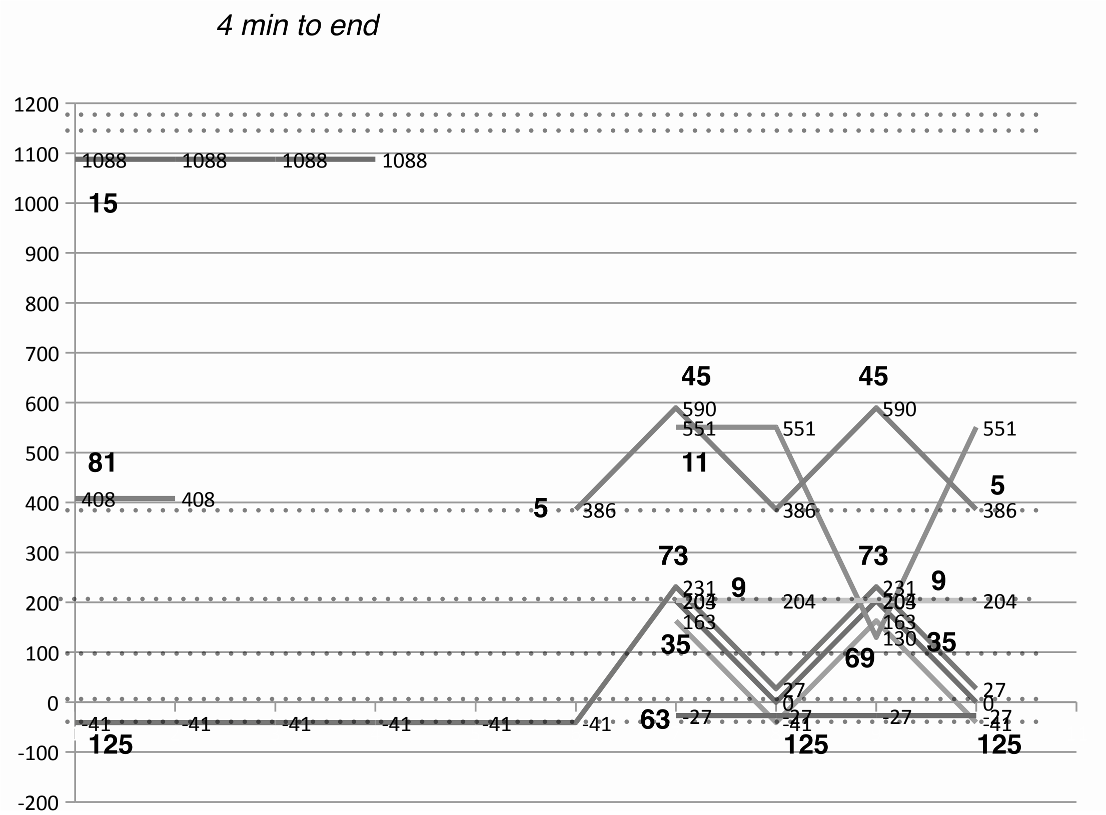


Figure 98: Cadential-style figure closing the first movement (trajectories of individual intervals follow guitar parts)

7.4.4 Movement 2: 'Inhalation/Choke'

The second movement is relatively brief and utilises similar instrumental materials to the first movement. As such, this account will confine itself to an outline of aspects which are reasonably different from the foregoing. One key aspect of distinction is the drone part, which is at a much higher register than that of the first movement (mostly in the fourth and fifth octaves), with significant activity centered around the seventh–to–octave region. Drone parts in this region are present at the 7th, 59th, 61st and 31st harmonics (just below the octave) and the 65th harmonic (above the octave).

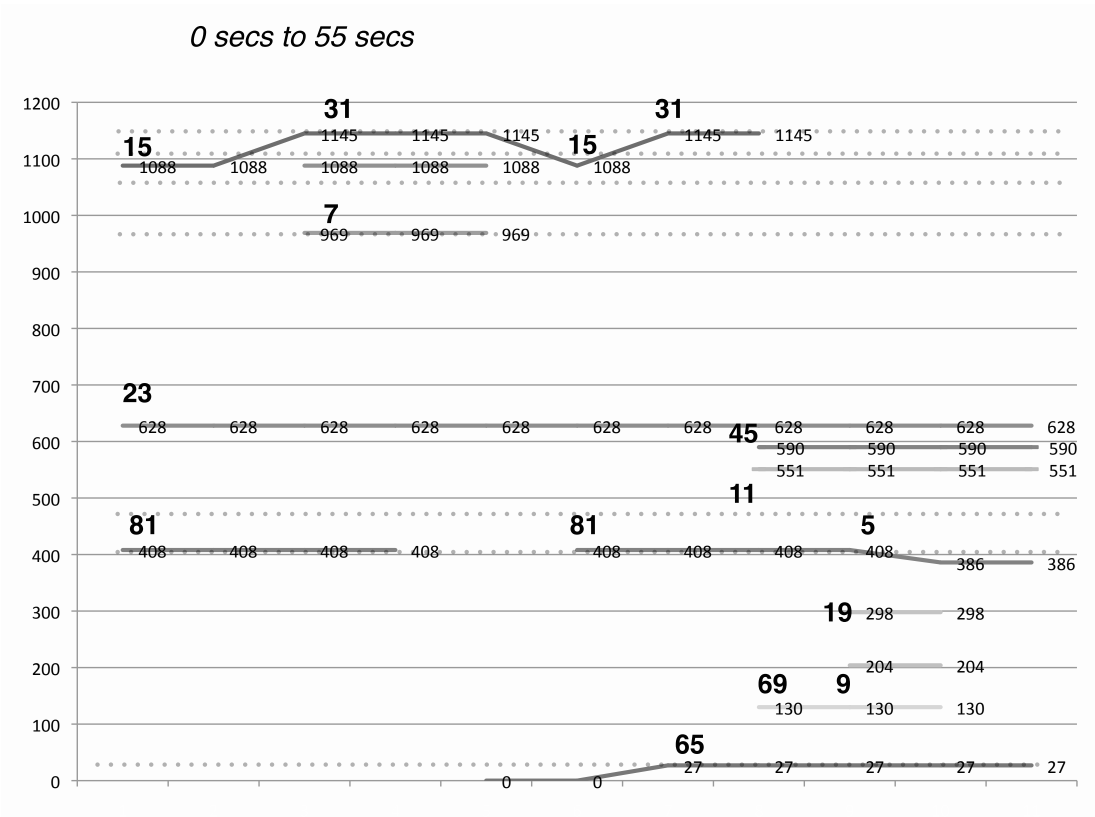


Figure 99: Opening of second movement

The movement opens (figure 99, above) with a strident yet cognitive–functionally ambiguous chord of microtonal analogues of major third (with the relatively more unfamiliar 81st harmonic), tritone (23rd harmonic) and major seventh (15th harmonic), leading to a microtonal cluster of all of the seventh variants, mirroring the similar density of intervals in this region in the tape part. In addition, microtonal melodic movements are in evidence with the widening of the 15th harmonic to the seventh-region cluster, which then links to the tonic (stated at 25 seconds), which is only 55 cents from the upper voice of the sevenths–cluster (7th/15th/31st harmonics). More subtly perceptible (and perhaps less clearly amenable to structural perception) is the 27 cents movement from the tonic to 65th harmonic at 35 second.

A further similarity between the drone part and the instrumental part is that the tension-inducing microtonal density of the seventh region is accompanied by more generally energetic articulations in the guitar parts (which are themselves emergent from the more extensive reliance on cluster-based materials throughout this section). One example of the greater density of the materials in this movement is a dense composite at 1’00 (see start of figure 100, following page), which features the 65th/1st/125th tonic–cluster alongside the full statement of what can be termed the *tritone–cluster* on 23rd/45th and 11th, in addition to the 81st and 15th harmonics in the lower register. This section therefore articulates another clear textural difference in the lower components, but also highlights significant upper harmonic activity (i.e. perceptual segregation of upper components) as the articulations become more energetic. These textural differences can contribute to the highlighting of microtonal distinctions if, as is the case at many points in the piece, they are accompanied by melodic microtonal variations, although in the present case, they primarily highlight a textural stream whilst offering some exposure to a complex perceptual case which may feature upper harmonic activity as a by–product.

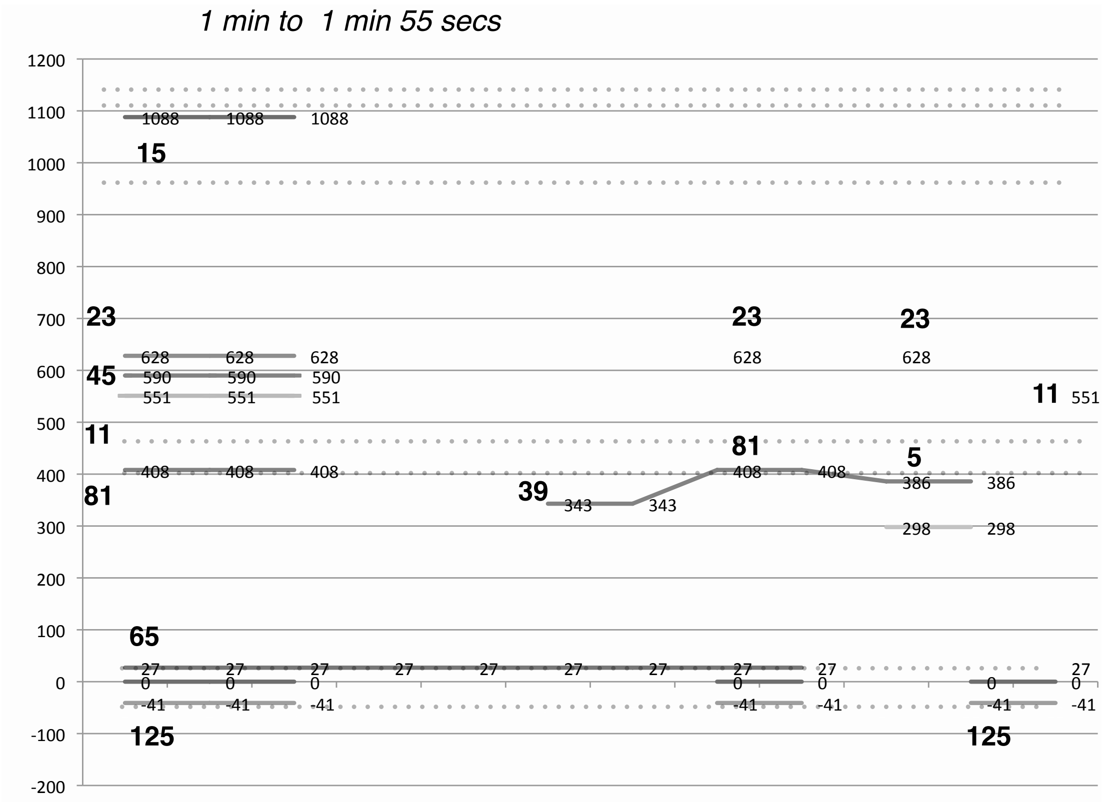


Figure 100: More complex chordal/textural tonal materials from 1 minute into the second movement

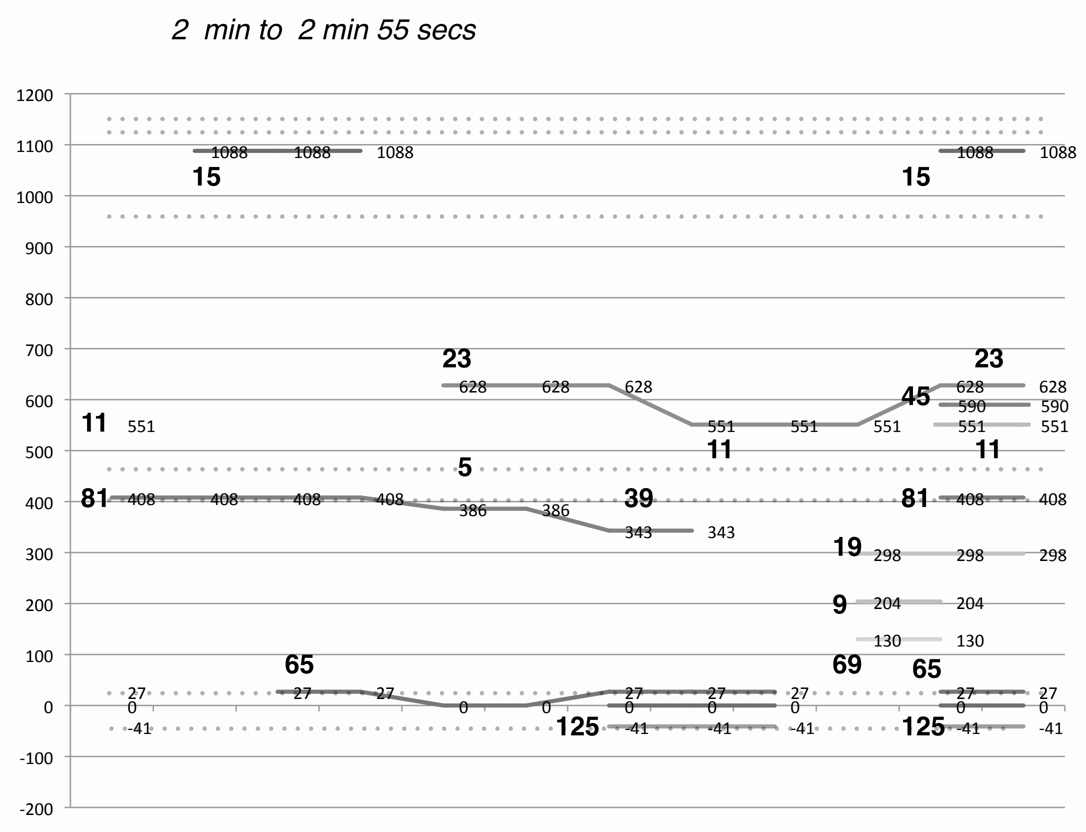


Figure 101: Melodic and cluster-based materials from 2’00 to 2’55 of the second movement

The textural, melodic and harmonic cues are thus combined to distinctly xenharmonic effect in the wider sense. As a further example (figure 101, above), the low 11th (2’35 to 2’45) leads to an octave-up statement of the 19th/19th/69th cluster, which then leads to a restatement of the earlier pairing of the tonic–cluster and tritone–cluster at 2’55 to 3’00, with the movement coming to a close (figure 102, next page) with a restatement of the 69th harmonic against the tritone–cluster, outlining a distance of approximately a perfect fourth, therefore providing a perceptual result which is relatively stable and, thus, providing a cadential point for the movement.

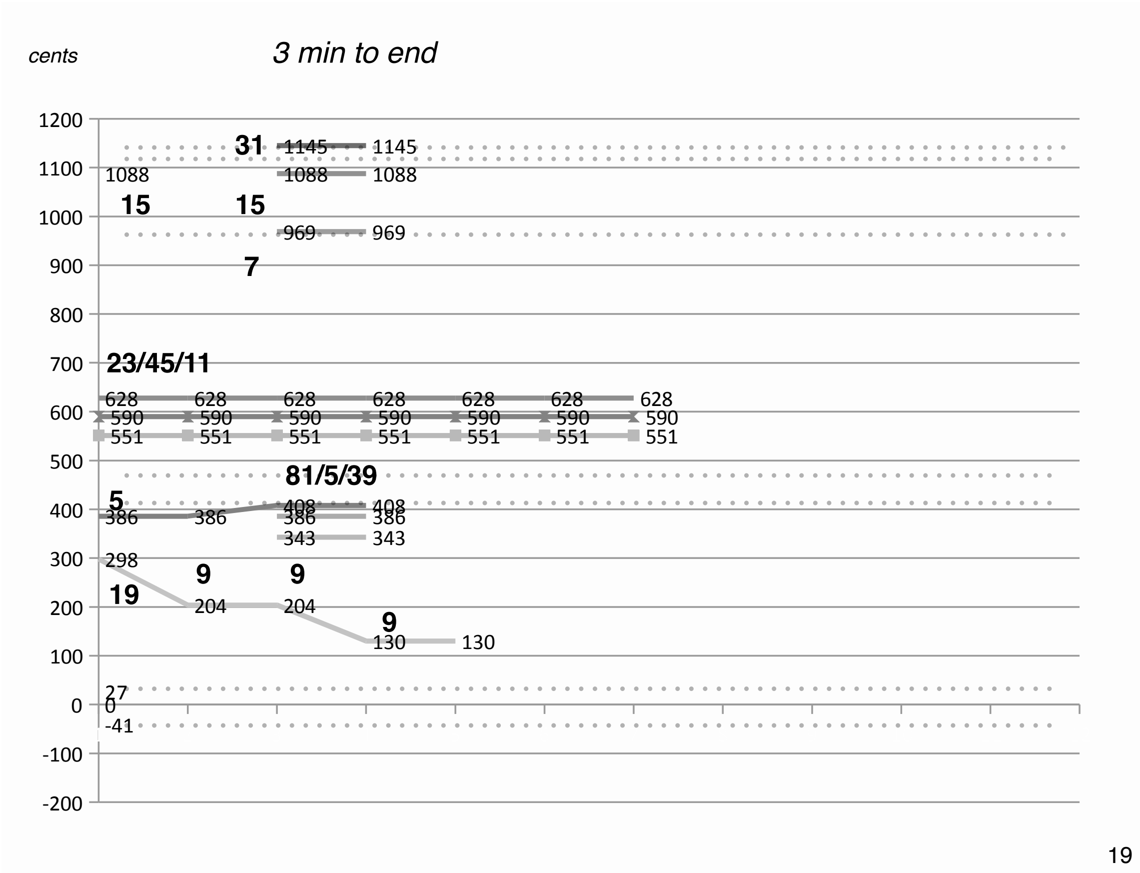


Figure 102: Closing materials of the second movment

7.4.5 Movement 3: 'Take God out and Show Her a Good Time'

As can be seen from the drone tuning/specification chart (see figure 93(c), earlier in chapter), this movement contains a significantly greater density of materials within the seventh–to–octave region, with all of its drone materials centered within this space. In addition, these drones are centred around the transition from octave 5 to octave 6, having a shrill character as a result of the textural weight and density in an already high register. Based on this factor, the higher harmonic drones here contribute a tension-based affective quality to this movement, but, due to their high octave-offset from the materials of the instrumental lines, these drones seem to contribute sensory effects more on the basis of traditional drones (i.e. as providing a background continuity) rather than being significant contributors to perceptual segregation.

The weight within this seventh–region (with all of its functional resonances of resolution–requiring tension from common practice music) therefore lends this movement a similar sensibility to the previous one (although with the affective tension increased due to the factors mentioned above). A strident opening with the tritone analogues (figure 103, below) proceeding through variants— 11th/23rd/45th harmonics— leads to the statement of the third-based cluster from 35 seconds (see tablature-based score in appendix for further details).

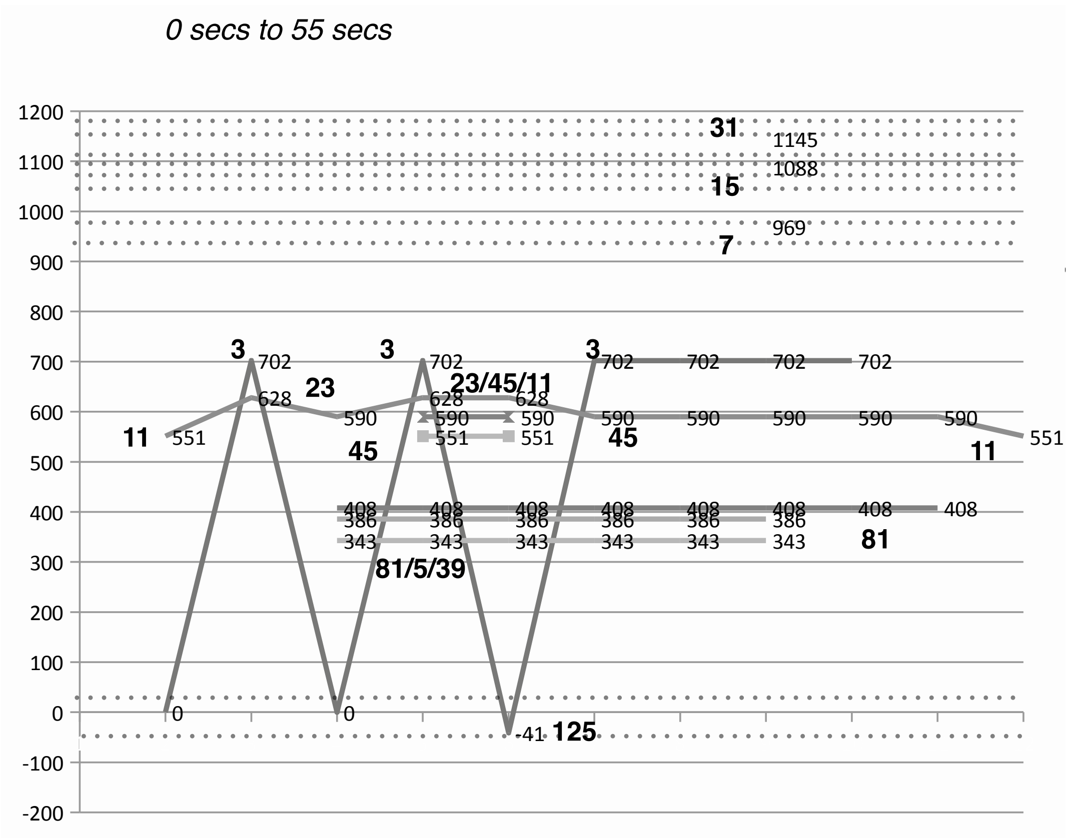


Figure 103: Opening of third movement with melodic variation around tritone analogues

The highlighting of the fifth-region in a cluster (97th/3rd/47th) from around 1'30 (see figure 104, below) allows the 69th harmonic to feature as a tritone offset from this cluster, referencing the prominent occurrences of this interval region with respect to the tonic in foregoing measures.

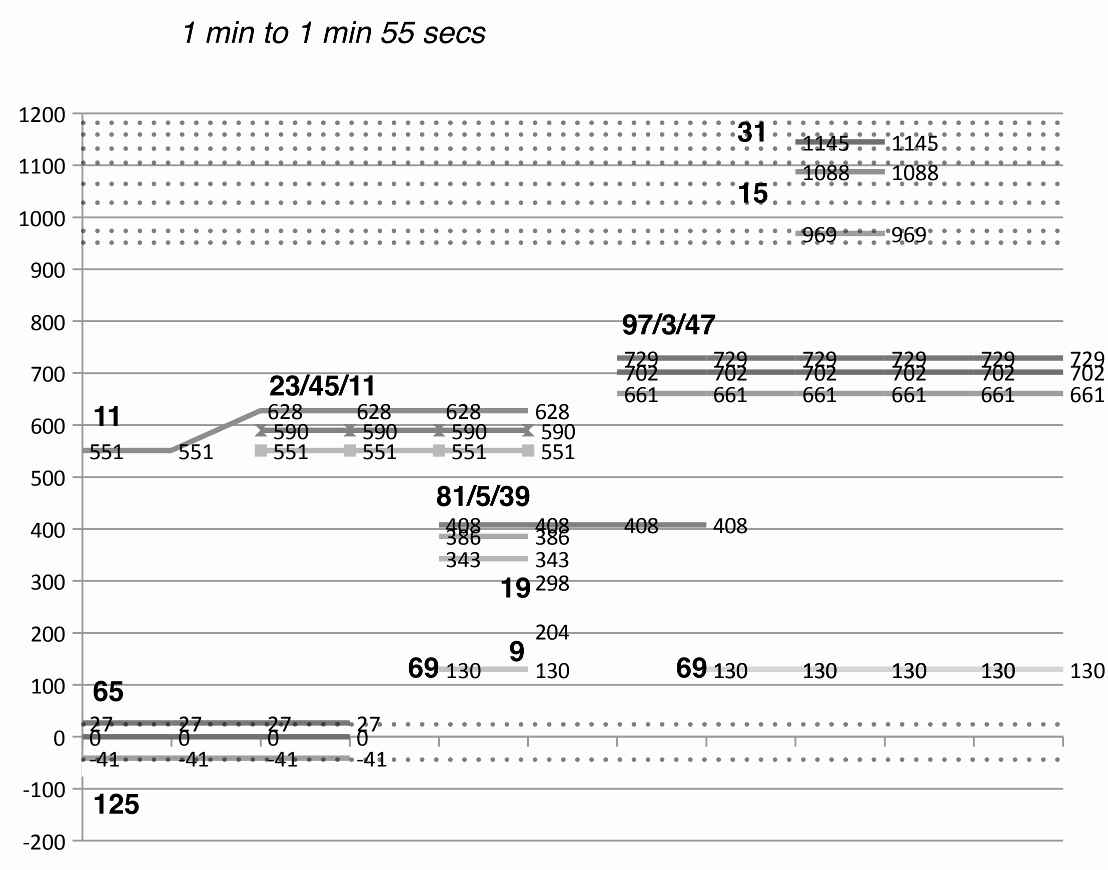


Figure 104: Second minute of movement three, outlining progression from tritone and fifth-region clusters to seventh-region clusters

In addition, the 69th harmonic's solo–voice statement at 2'00 (figure 105, below, next page) draws attention back to the seventh–region drone, which is then referenced again in the instrumental part through the 31st/15th/7th (seventh–cluster), which, after a brief moment of tension–inducing silence, is stated alongside the microtonal offsets of the tonic cluster and the more traditionally chromatic seconds/thirds–based cluster on the 19th/9th/69th harmonics. A 39th harmonic (providing an *intermediate/neutral third*) accompanied by fifth–based variants (with guitar 1 fretting a fifth to obtain 97th/3rd/47th harmonics), provides a directional inward movement at this point. The resting of the fifth-based cluster against the 19th harmonic produces a significantly transparent texture (perhaps due to the minor–third–region 19th harmonic reinforcing relatively fewer harmonics within the fifth–based cluster than earlier harmonic intervals would).

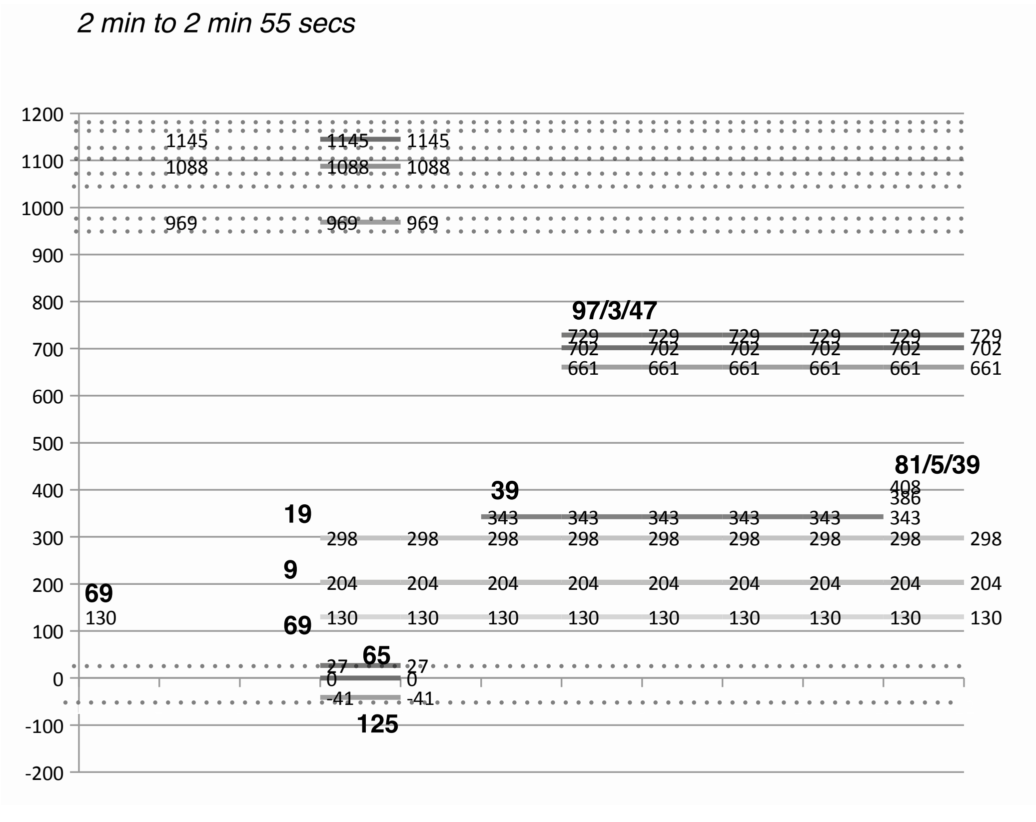


Figure 105: Third minute of movement three, with significant activity in the seventh region leading to activity which extends from tonic/second/minor third regions to major third regions, with the addition of a fifth–region cluster (97th/3rd/37th harmonics)

This then prefigures a tonic/major statement in the move to the clusters in the tonic and third regions (3’20/3’25)—see figure 106, below—which then lead over time (see figure 107, following page) to the melodic/arpeggiated statement of the various tritone analogues[20] (11th/45th/23rd) restated in more rapid succession against the thickening texture of 19th/9th/69th and 65th harmonics as the movement draws to a close.

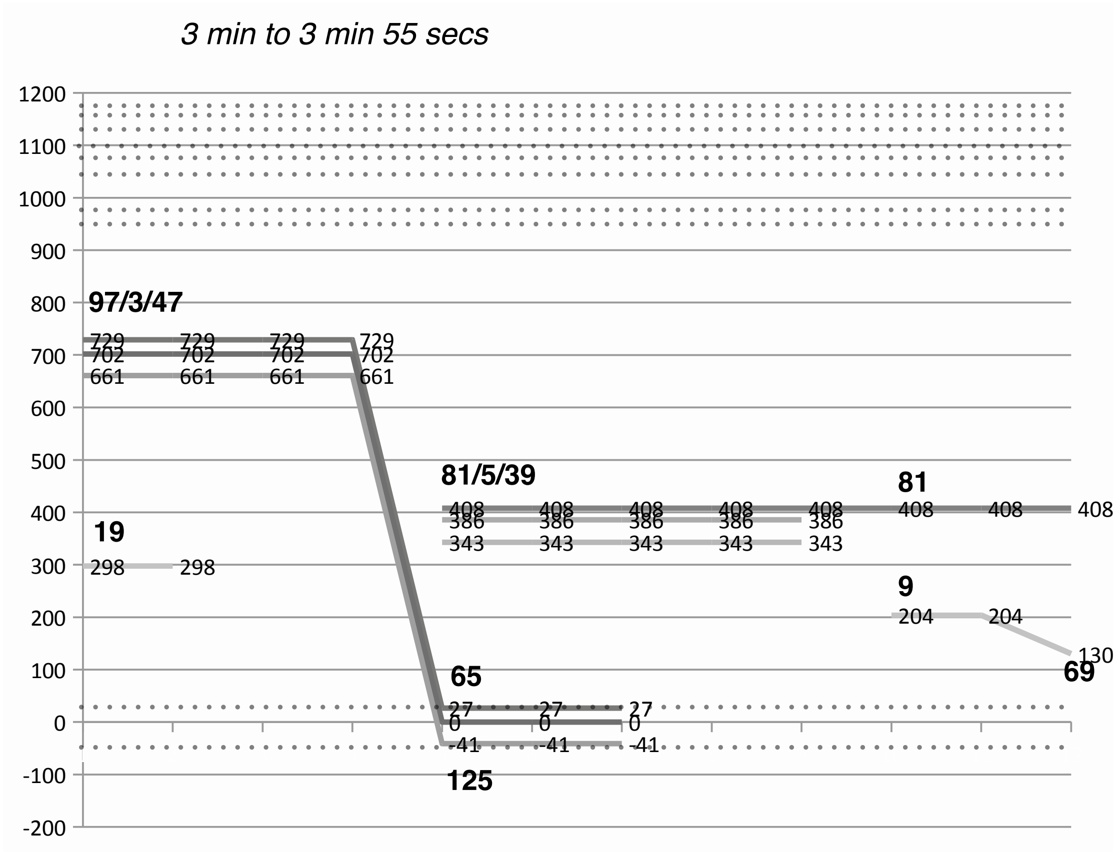


Figure 106: Tonic-region and major-third-region clusters highlighted

---

[20] See tablature-based score in appendix for details of the arpeggiations.

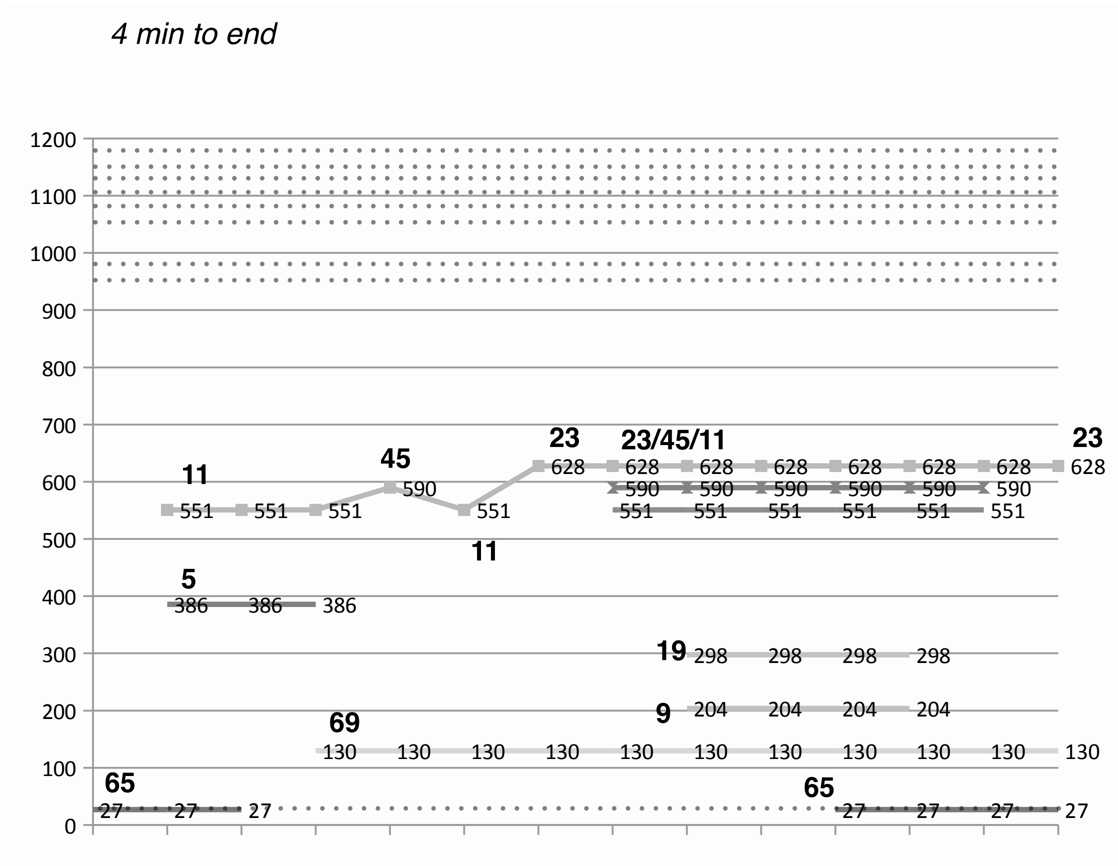


Figure 107: Melodic microtonal variations around tritone region at the close of movement three, against cluster based on semitone, whole-tone and minor third analogues (69th/9th/19th harmonics) alongside 27 cents offset from tonic 65th harmonic

7.4.6 Movement 4: 'Pathfinding'

The fourth movement's drone again has some significant activity in the seventh–to–octave region, but it is less dense and is centred in a much lower register (from the second to the fourth octave). It highlights analogues of sevenths, semitone and tonic and overall provides an emotional/affective context of greater perceptual stability. It also returns to the more established practice within the piece of closer registral spacing between the drones and the instrumental lines to facilitate perceptual segregation effects, which become quite prominent as the drone-cluster around the tonic enters at 20 seconds (see figure 108, following page).

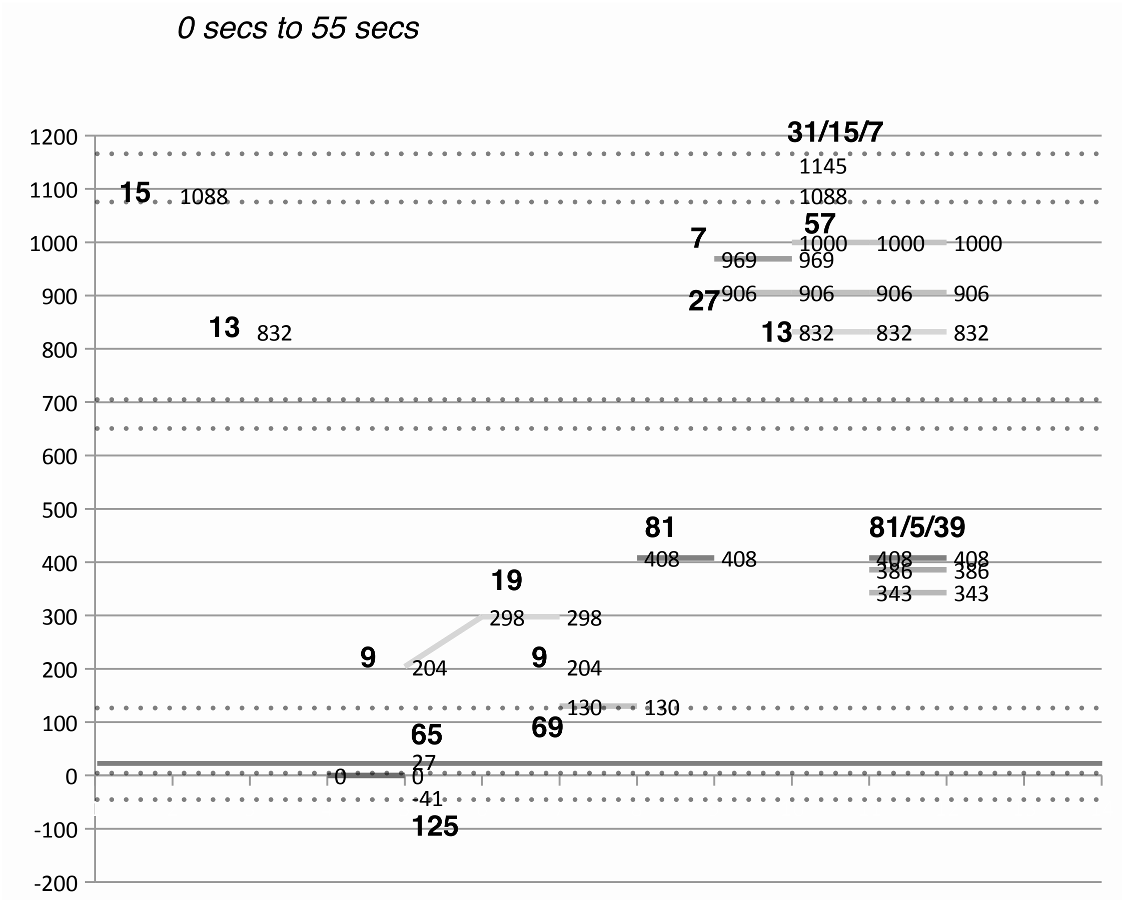


Figure 108: Opening of the fourth movement, featuring tonic-region cluster and melodic and textural variations from this region to the third-region and more solely texturally-based variations in the sixth/seventh region

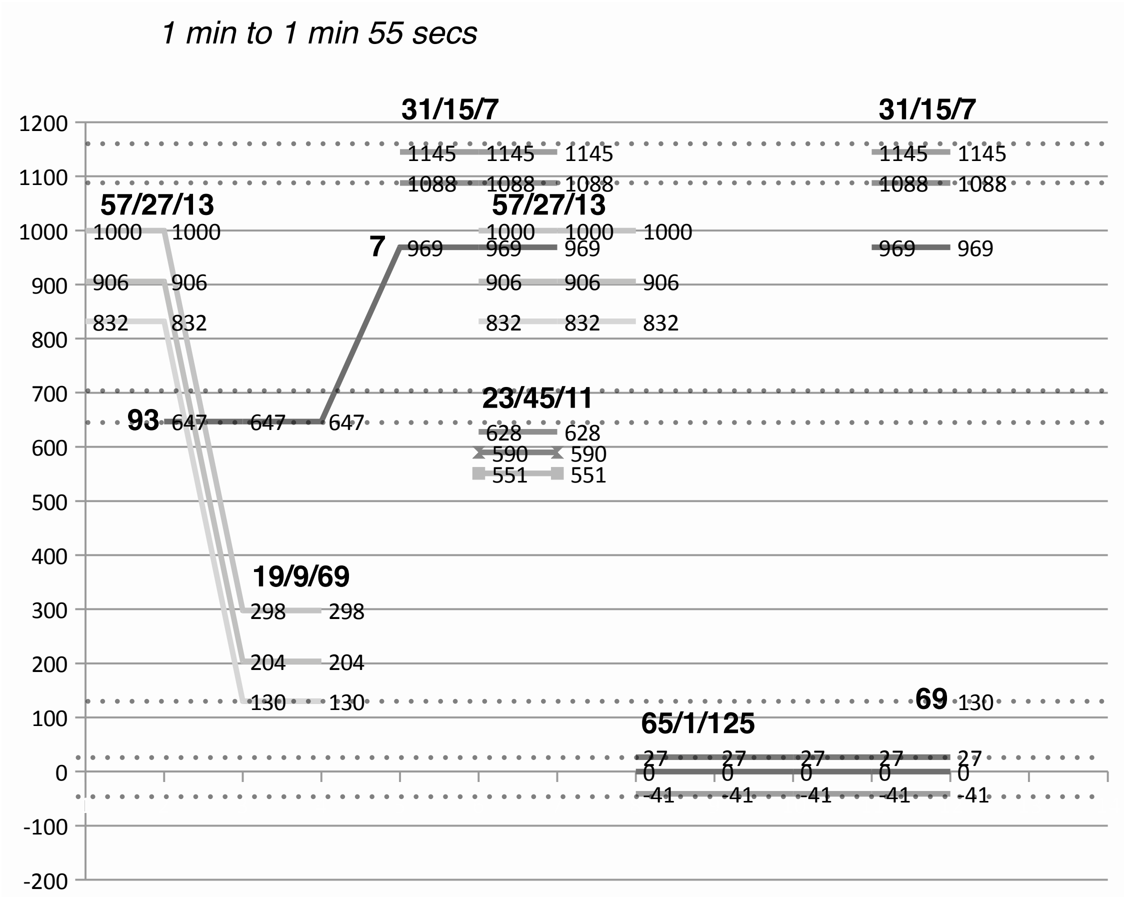


Figure 109: Majority of instrumental parts broadly coincident with drone parts in the second minute of movement four

During the second minute (see figure 108, above), the high 93rd harmonic (low fifth analogue) accentuates the fifth-region which has already been outlined in the drone. A cluster in the sixth/minor seventh region (57th/27th/13th) fills in the gap between the fifth and seventh, before transiting down to the second/minor third cluster of 19th/9th/69th, whilst the 93rd harmonic falls back to a 7th/15th/31st cluster. This is part of a composite figure of clusters in the tritone-to-seventh regions, which then gravitates back to the tonic–cluster, soon accompanied by the sevenths–cluster, which contributes to perceptual segregation through its proximity to the seventh–region drones. This interplay between different cluster–

regions is continued through the alternating of tonic (first in isolation, then as a cluster) and the seventh-based clusters, accompanied by a falling semitone analogue from (74 cents) from 9th to 69th harmonics, with the seventh–region materials producing some of the most striking perceptual interactions of the whole piece at 2’00 to 2’15 (figure 110, below).

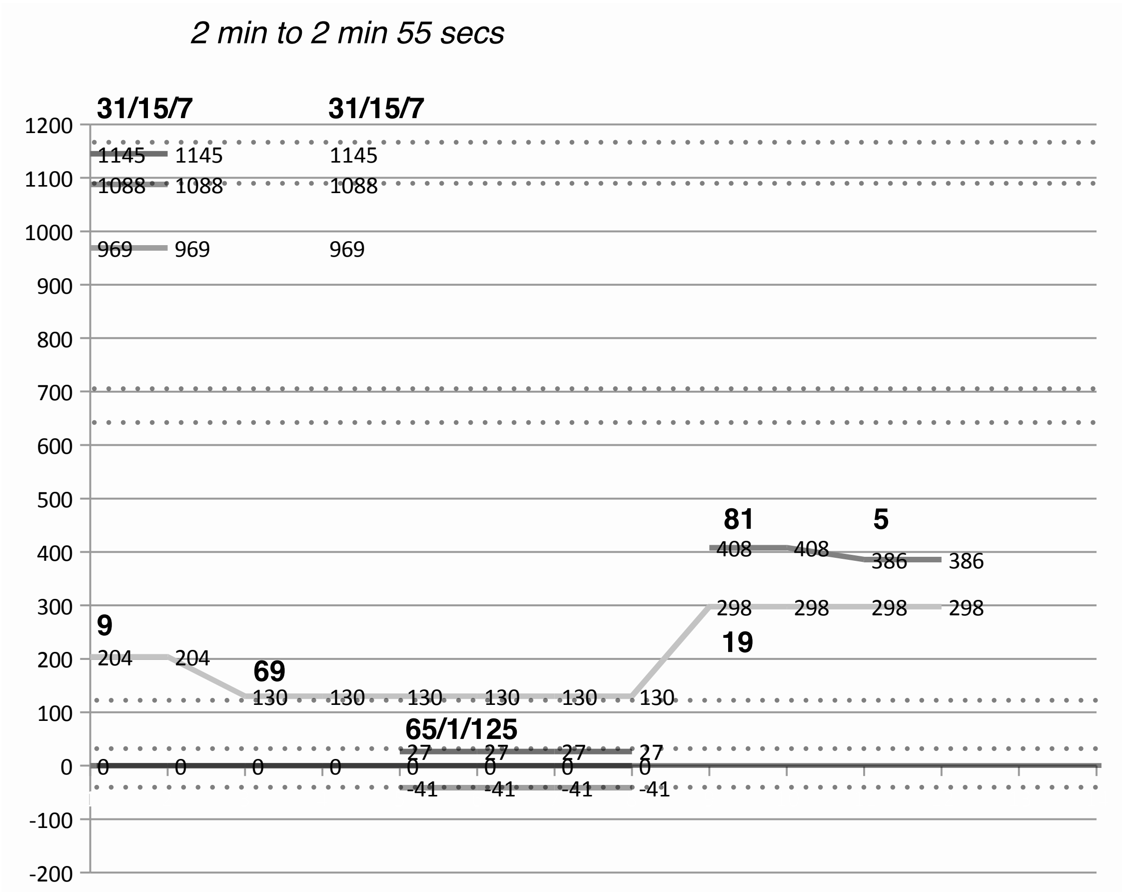


Figure 110: Seventh–region materials producing perceptual interaction effects during the third minute of movement four

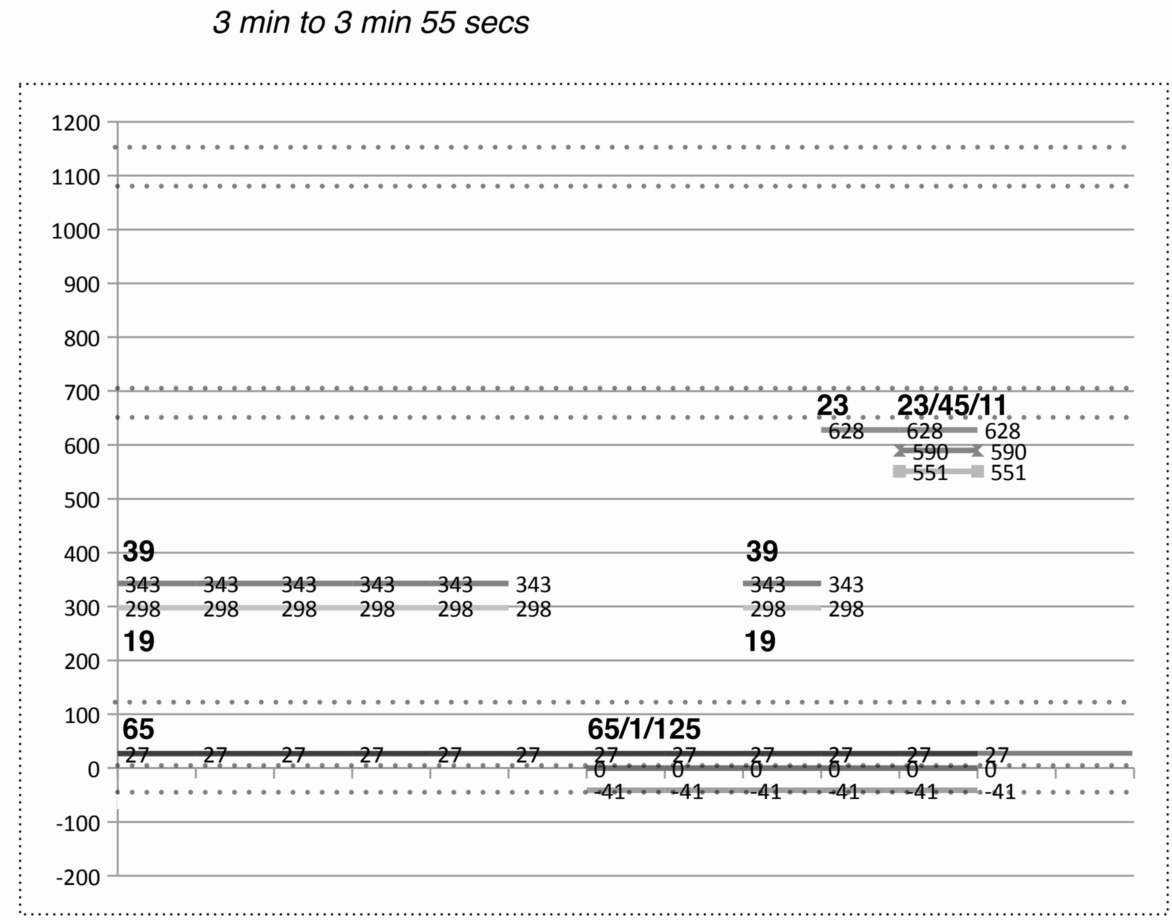


Figure 111: Pairing of the 39th and 19th harmonics in the fourth minute of movement four

From 3’00 (figure 111, above), the 45–cents–offset pairing of the 39th and 19th harmonics serves both a melodic (descending from the 5th harmonic) and clearly textural function when stated with the 65th harmonic which prefigures the higher statement of the tonic–cluster (which in this upper–register statement more clearly exhibits its similarity to the drone materials). The fifth–region is then gravitated towards through a recapitulation of the 39th and 19th harmonics leading to a cluster of the tritone analogues (increasing the apparent tension). This sonority is then added to by the 7th harmonic from 4’00 (see figure 112, below), further reinforcing the impression of competing centres (tonic –region, seventh–region and tritone–region).

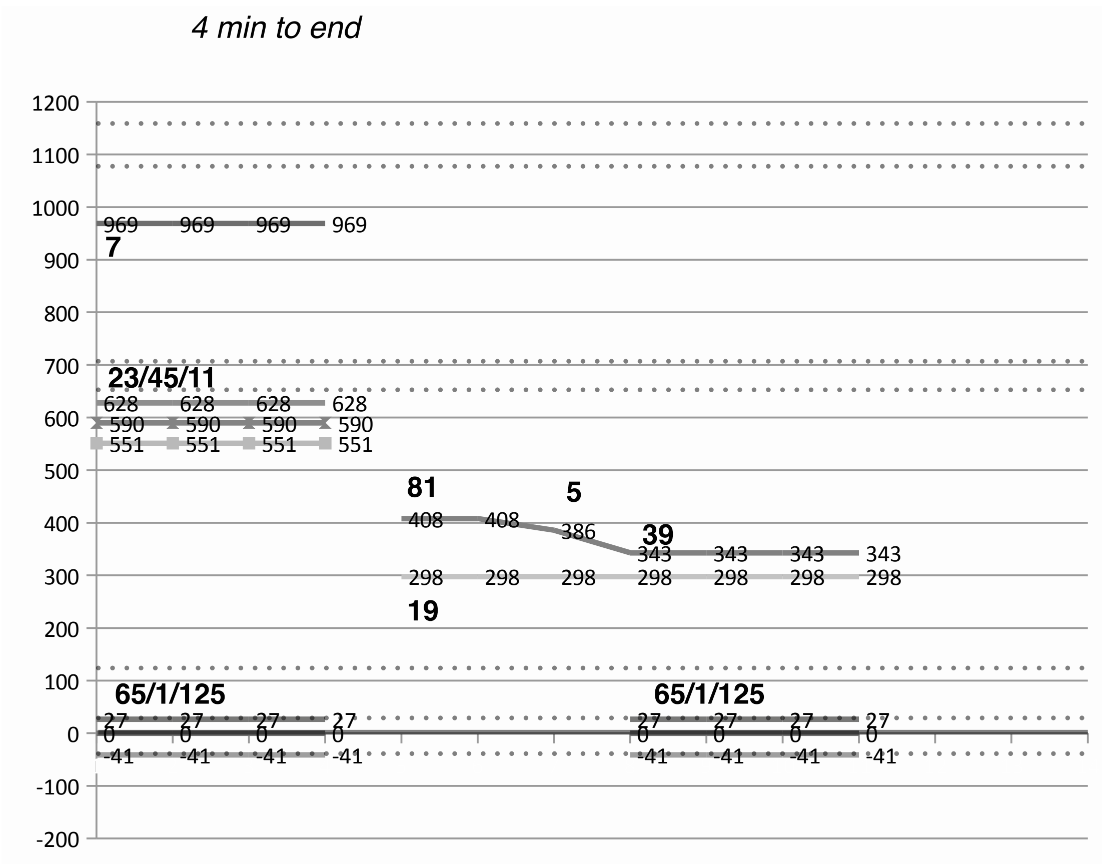


Figure 112: Close of movement four with melodic microtonal movement between various major third analogues

The movement closes (see figure 112, above) with the 81/5th melodic pairing against the 19th harmonic, drawing attention to an inwards movement towards the tonic. This melodic pairing provides one of the smallest microtonal intervals (22 cents, or less than one eighth-tone) before a less–than–quartertone step to the 39th harmonic (43 cents), but the salience of these microtonal steps is highlighted through the textural/sonorous changes they engender. The piece then draws to a close with a recapitulation of the minor and intermediate third analogues alongside the tonic-cluster, providing a relatively dark affective framing.

7.4.7 Movement 5: 'Return'

This movement has drone components which are again in lower octaves (2,3 and 4) than is the case for the second and third octaves. Indeed, most materials are in the second octave and are relatively widely spaced with the exception of the two fifth-region drones (3^{rd} harmonic and 93^{rd} harmonic, or 702 and 647 cents); all other materials which are very close in pitch–chroma distance (less than a semitone) are offset by octaves. This leads to an impression of relative textural openness which is especially apparent in comparison with the density of the drone-based materials in previous movements.

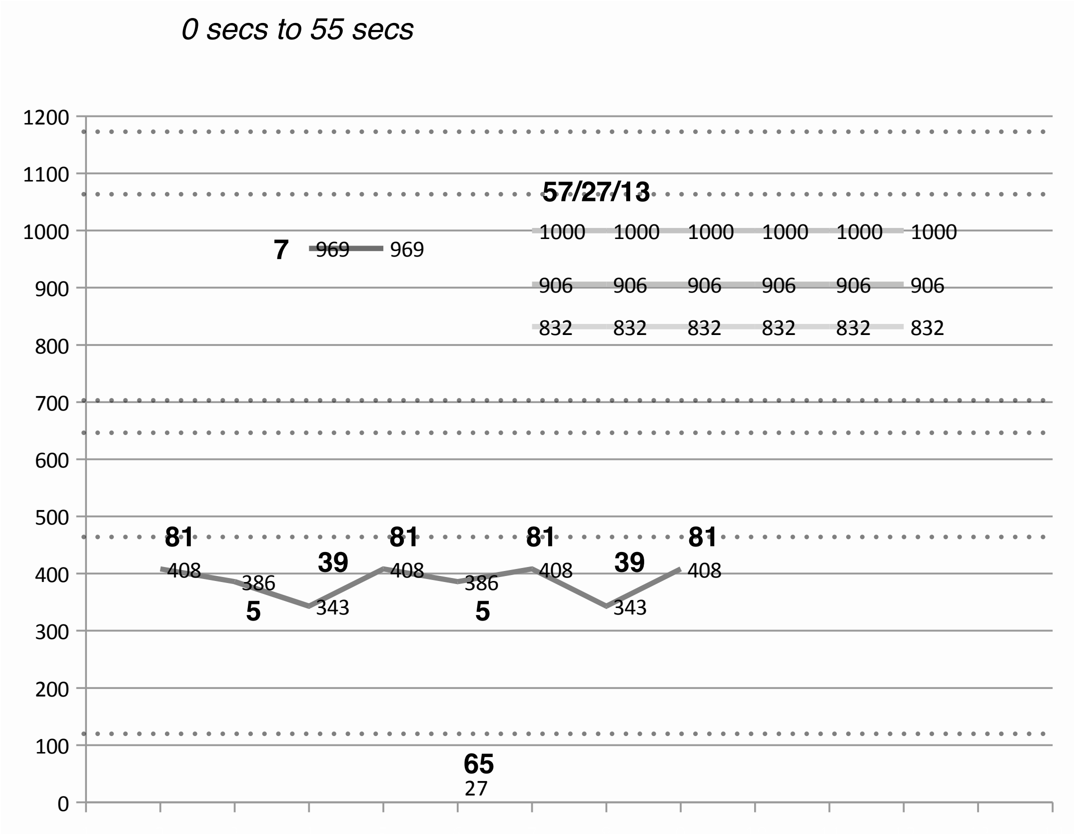


Figure 113: Opening of movement five; melodic microtonal variations around the third-region and the filling of a gap in the drone part between the fifth and seventh region by 57th/27th/13th

As a closing movement, it recapitulates some by–now familiar tropes (see figure 113, previous page), such as the 81st/5th/39th progression accompanied by a 7th harmonic (providing a sense of contrary motion), leading to an upper–octave cluster in the sixth/minor seventh region (57th/27th/13th) with perceptual segregation engendered by these materials quite salient at circa 50 secs.

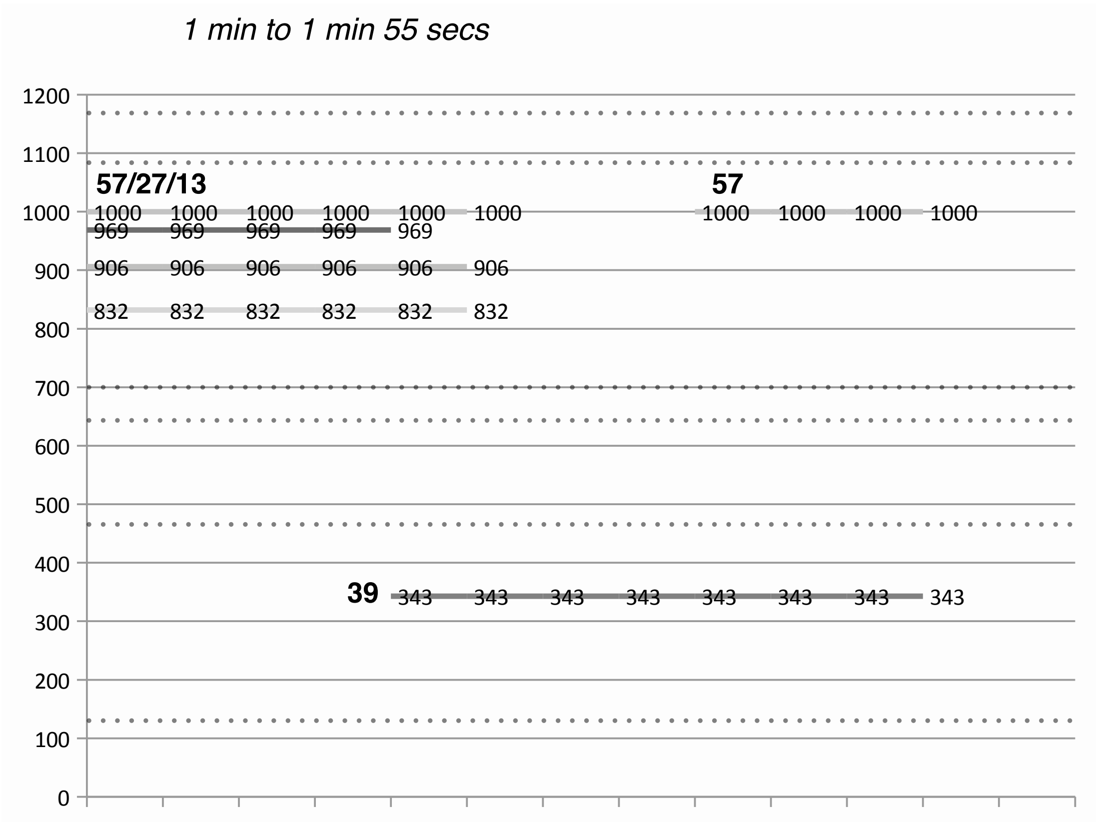


Figure 114: second minute of fifth movement, featuring sparse intervallic materials creating an open texture through their general avoidance of drone parts

The distance of the 39th harmonic and 57th harmonic from the drone parts from 1’20 and 1’40 (figure 114, above) respectively provides a particularly clear sense of xenharmonic perspective, creating an open, but unfamiliar sonority (again, with no commonality in factor-based simplification between the two instrumental tones, although the 39th harmonic relates to the 69th, 63rd, 21st and 15th harmonic in the drone through a common factor of 3 (hence these are 13th, 23rd, 7th and 5th harmonics of the 3rd harmonic/perfect fifth). As such, the addition of the 57th harmonic at 1’40 adds significantly to the ‘reading’ of complexity of the piece’s tonal materials, resulting in a bell–like chord which then proceeds to a solo statement of the 57th harmonic (alongside the drone parts) to an even more strikingly dissonant (in both sensory and apparent cognitive–functional terms) chord of the 65th, 7th and 57th harmonics, producing striking perceptual segregation of a figure which eludes easy resolution with respect to the tonic (figure 115, below).

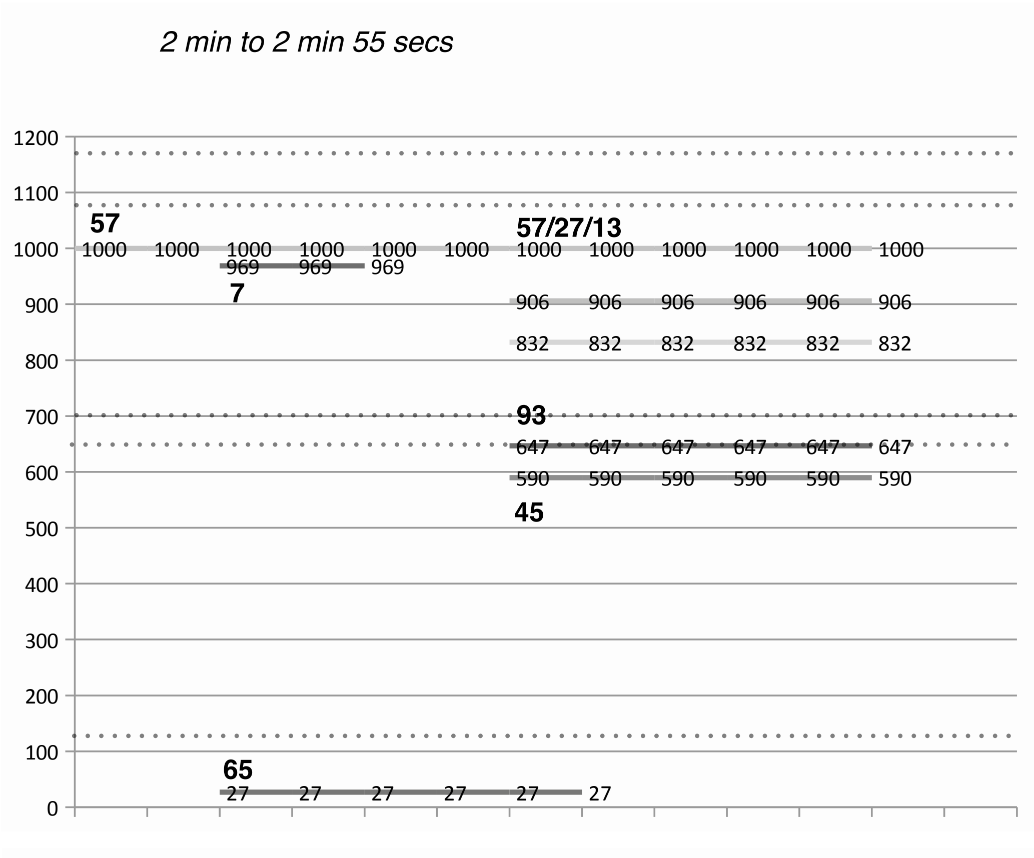


Figure 115: Third minute of fifth movement, featuring dissonant grouping of 65th/7th/57th before extended composite clusters of 93rd/45th harmonics and 57th/27th/13th harmonics

This is followed at 2'30 by an extended upper-octave cluster consisting of the 45th (tritone variant), 93rd (low perfect fifth analogue), 27th and 13th harmonics (major and minor sixth analogues) and the 57th harmonic in the position of a tempered minor seventh, which is initially 'grounded' by the presence of the near–tonic 65th harmonic but whose cognitive–functional balance is changed significantly by its removal.

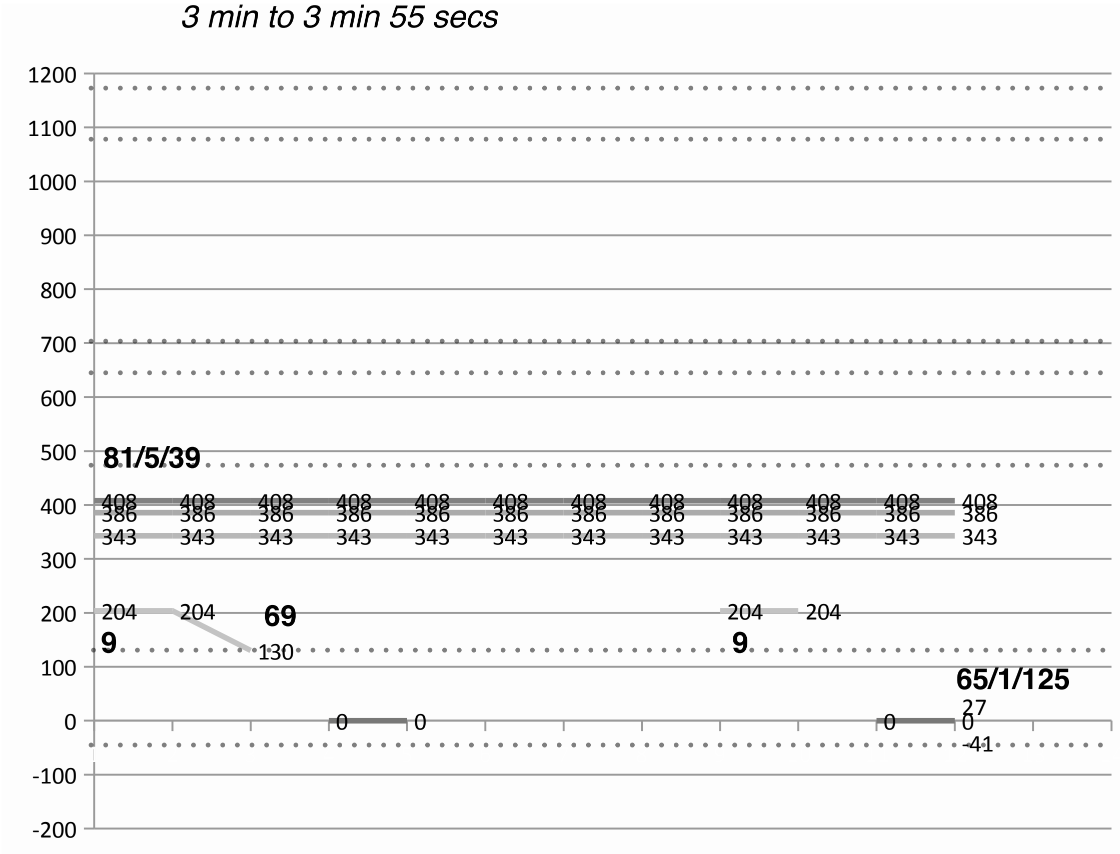


Figure 116: Energetic statement of third-based cluster dominating fourth minute of movement five

Another contrast comes in the transition to a harsh, energetically–articulated (and hence, distorted) statement of the third–based cluster from 3’00 (figure 116, above). This brings the dominant tonal centre further back towards the tonic (reinforced by the 9th harmonic down to the tonic–cluster), which then resolves into the solo statement of the tonic, embellished by the 69th harmonic. This leads, in turn, to a final statement of the cluster on the tonic and a final falling semitone-based melodic cadential figure as the drone fades out and the perspective on the piece's tonal materials collapses to the unison identity (figure 117, below).

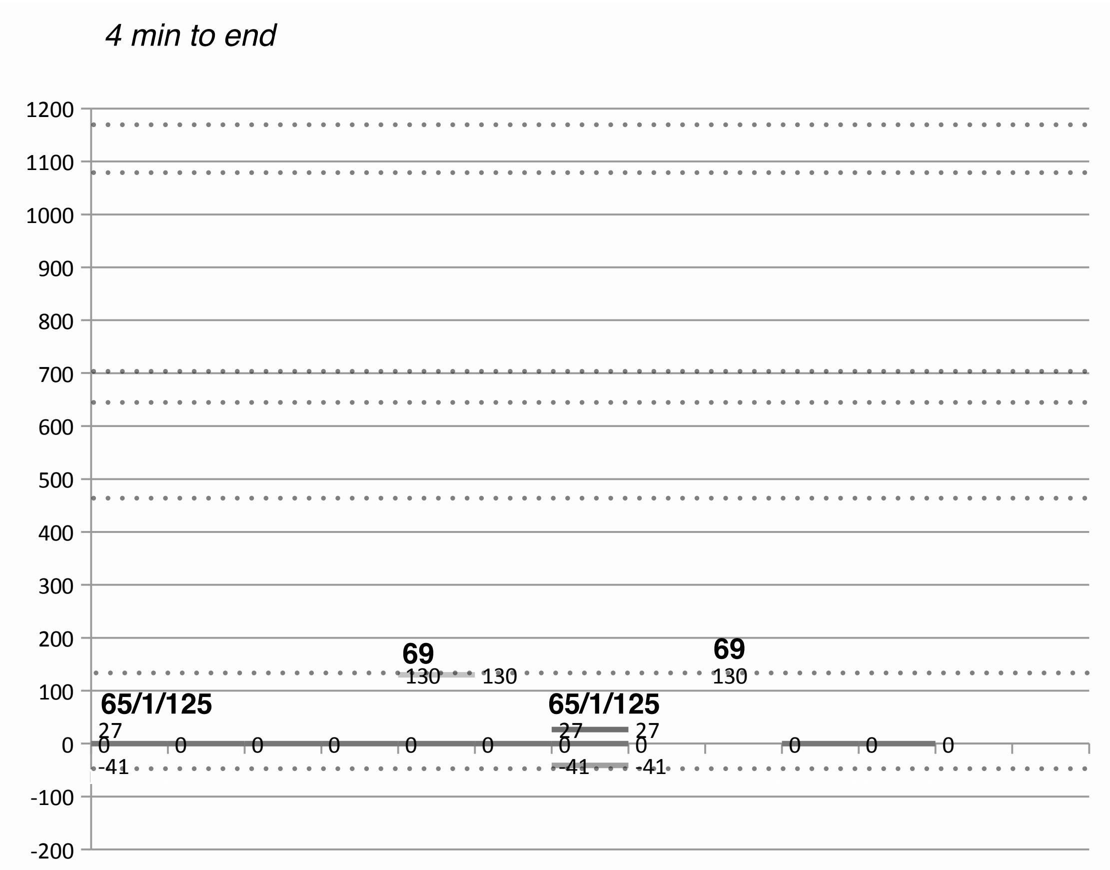


Figure 117: Collapse in perspective of instrumental materials towards unison in the final section of movement five

7.4.8 *Angels at the Shotgun Wedding* (2007/08): Conclusion

Angels at the Shotgun Wedding is an exploratory piece whose materials combine drone–based tape parts and a range of harmonic series intervals articulated by five different electric guitar groups. Its primary locus of articulation is chordal/textural, although the sequential–melodic aspect of microtonality is highlighted in a number of its progressions. However, even in these contexts, its primary goal is the generation of conditions which will allow for sensory distinctiveness to contribute to perceptual and cognitive salience for a range of sometimes very small microtonal intervals or intervallic variants.

The piece's consonance concept is particularly focussed on perceptual segregation effects, with the coincident frequencies between the drones and frequency components within the instrumental parts, coupled with higher–order interactions of partials in the significantly bright (and mildly distorted) timbres of the guitars through beating effects providing the primary means of creating these conditions. Additionally, various aspects of the drones' basic configuration (i.e. without reference to any other materials) also contribute what might be viewed as a range of distinct affective properties to each movement, through their relative spacing/density and through their own internal beating effects. However, a further aspect of the piece's model of consonance/dissonance may be found in some of its other relatively more unusual perceptual circumstances. The guitar's *tremolo picking* articulation (created through rapid alternate–direction picking using a plectrum) appears to contribute significantly to stream segregation of some individual lines in cases where the different rates of articulation are relatively clear. In cases such as this, a somewhat paradoxical dual–assessment of consonance/dissonance may predominate in any judgements which feature materials which may be regarded as more functionally dissonant in tonal–hierarchical terms.

7.5 *Making Ghosts from Empty Landscapes* (2010) for uillean pipes, pipa, erhu, 2 violins and tape

7.5.1 *Making Ghosts from Empty Landscapes* (2010): Introduction

Making Ghosts from Empty Landscapes (pipa[21], erhu[22], uilleann pipes[23], 2 violins and tape) was premiered by the Beijing-based TiMi Modern Music Ensemble[24] and Irish uilleann piper Paul Harrigan at La Plantation Arts Centre, Beijing, 28th March 2010. The concert took place as part of the inaugural Beijing Irish Contemporary Music Festival, organised by Benoit Granier of the Central Conservatory of Music, supported by a grant from Culture Ireland (the

---

[21] The pipa is a four-stringed lute (with frets) which is derived from an instrument design imported from Persia to China during the fourth century C.E.; the instrument was originally most frequently used in a solo context (Randel, 2003, p.266).

[22] The erhu is a Chinese traditional instrument originating in Central Asia whose two stings are bowed (using a horsehair bow) like a violin/fiddle; its relatively small resonating body contributes to a relatively narrow set of resonant peaks within its timbre resulting in what might be qualitatively described as its characteristic 'nasal' timbre (*ibid.*)

[23] The uilleann pipes are a set of reed-based pipes which are articulated by an elbow-operated bellows, comprising three drones (named *bass*, *baritone* and tenor) tuned to octaves of *D*, alongside a *chanter* (which operates on the basis of stopped finger-holes for articulation of notes) which has a register of up to two octaves (with more available using special techniques) alongside three or four *regulators* (which are often described as keyed alternate versions of the chanter) which were added in the nineteenth century, giving the pipes their present form (Ó Canáinn, 1978, pp.81–82).

[24] Included musicians from TiMi Ensemble 2010: Zhou Ling Yan (erhu), Wang Fan (pipa), Wei Wei (violin),Yuan Fangfang (violin)

Irish state agency which supports the international promotion of Irish arts and culture).[25]

A photograph of the TiMi ensemble with Paul Harrigan in performance can be found in figure 118, below.

Figure 118: the TiMi Ensemble with Paul Harrigan performing Making Ghosts from Empty Landscapes *at La Plantation* (photo: Benoit Granier/TiMi Ensemble)

This piece differs from other pieces in the portfolio in that some of its microtonal materials are specified in the score simply as quartertonal variations on standard divisions which are not further qualified by interval ratio notation or similar. A further distinction is its incorporation of a relatively extensive tape part (in contrast to the lack of such additions in *Infraction* and *Flatlining* and the relatively simple drone-based tape part in *Angels at the Shotgun Wedding*). This

[25] Concert details can be found at: http://weliveinbeijing.com/events/main.rails?eid=200003735 (last accessed September 2012). The enclosed live concert recording was mixed by Songming Wu, with additional post-production by Brian Bridges.

combination of relatively spare (and coarse) microtonal divisions alongside a tape part which incorporates spectrally–processed instrumental sources was designed to allow for the exploration of the melodic quantisation and textural aspects of microtonality in separate production domains, facilitating the speedy rehearsal of the piece which was necessitated by a brief visit to Beijing.

The choice of materials and configurations in this piece are based on an integration of this project's interests in microtonality, spectralism and perceptual phenomena. The pipes, being tuned relative to just intonation (and through the presence of their drone on *D*) provide a potential harmonic coherence and stasis (in the sense of basic sensory consonance/dissonance phenomena and auditory scene analysis grouping/segregation effects) which, along with the diffuse[26] spectrally–processed and extended drones in the tape part foregrounds a sense of an environmental–style context. Within this context, the other instruments (and some of the edited partials within the electronic/tape part) move along axes from grouped/blended (with the background 'environment') to individuated/segregated (and thus clearly part of a foreground implication of 'agency'). Indeed, the instrumental parts tend to follow pitch-frequency paths implied by elements of the tape part[27] (as if taking a 'sculptural' approach by following patterns of lesser resistance within the source materials)**.**

To further this aim, they exploit some of the commponplace heuristics of

---

[26] I.e. without obvious attack transients.
[27] Based on this aspect, a solo version of the tape part is included for the reader to compare these salient implications of foregrounded tonal materials with the resulting instrumental lines. This aspect of connections between the parts will also be discussed further below.

auditory grouping, encouraging blending between tape and instrument (through the suppression of attack transients and the favouring of accurate harmonically–related tunings[28]) and segregation/individuation (through devices such as obvious transients/relatively sudden discontinuities in levels, and offset tunings and spatial placements). In a departure from my recent microtonal work, this piece frequently uses quartertone notation without specifically referencing any just-tuned intervals. In this case, the motivation was that the microtonal materials introduced in the erhu part were intended to provide a finer degree of melodic quantisation than the normal 12TET (twelve–tone equal temperament) scale. However, in contrast to my just intonation microtonal work, the quartertone materials presented here do not directly contribute to enhanced grouping with another harmonic tone/complex of tones. Rather, it serves to contribute to the delineation/individuation of a separate voice over the background sound–masses, assigned as a separate auditory object/stream through its distinctive timbral structure, trajectory of glissandi and vibrato patterns[29] and, as will be discussed later, functional concerns. In applying these different microtonal/spectral effects for both melodic and textural purposes, the piece attempts to weld these perceptual concepts to conceptual/programmatic concerns. More specifically, its processed and electronic drones form a background soundscape from which the musicians 'sculpt' animate gestures, just as the mind's natural inclination when confronted with an empty landscape or static scene may be to search for anything which indicates activity, sometimes accidentally producing perceptual

[28] This is especially prominent in relation to the uilleann pipes' relationship with their spectrally-processed 'double'.
[29] A particularly clear example of this role can be found as the erhu clearly emerges from the background tape part and the pipes in the final bars of the piece.

‘phantoms’ (i.e. perceptual *false positives*) in the process.[30]

7.5.2 Drone-based and Textural Aspects of Composition

Making Ghosts from Empty Landscapes appropriates some of the idiomatic conventions inherent in Irish traditional music through its use of drone-based accompanying structures in both the live uilleann pipe part and the tape part (which itself is derived in major part from spectrally–processed uilleann pipe, violin and erhu materials created/processed using SPEAR in combination with multi–track editing and mixing using the Logic Pro digital audio workstation). The pipes are employed with two of the drones engaged at the start of the piece (to illustrate the similarity and interplay between the acoustic drones and the electroacoustic/processed drones of the tape part. The piece also employs the chanter part of the uilleann pipes for the more characteristic melodic/gestural articulation purposes (including significantly sustained notes to interact with the drone–based spectral materials) but eschew the less uniquely identifiable articulations provided by the regulators. As such, the pipes occupy a central place in the piece in terms of the sonorous grouping, embodying an axis between linear/melodic (foreground) and vertical/textural (background) roles in themselves and in their interaction with the harmonic materials of the tape part. For example, when levels are balanced correctly in the mix, the opening gesture of a rising tone to a held *D5* (at bar 9) provides the impetus to hear a component of the tape part (and related harmonics) to be heard (perceptually segregated) as a continuation of this sound event, based on frequency commonality. However,

[30] In doing so, it engages with inspiration drawn from the emptiness of rural landscapes in the west of Ireland, which have been relatively depopulated since the nineteenth century.

there is a similar but opposing tendency (related to the perceptual cohesion potential of the drone) to hear some of the foregrounded instrumental events as something akin to surface details on the overall drone structure through their sustained tones and glissandi (providing an effect more akin, perhaps, to chordal coherence rather than the foregoing timbral fusion/assignment perceptual decisions). This aspect is in evidence in the early violin figures at bars 15–16 (figure 119, next page), which outlines pitched materials which are all prominent (in approximations) in the tape part along side a quarter-tone sharp *D* on the erhu which similarly contributes to a chordal–style cohesion with prominent drone elements of similar frequency whilst being foregrounded through its distinctive timbre and tuning deviation. This engagement with cues for various types of perceptual cohesion is further enhanced by the *sul ponticello* articulation of playing close to the bridge in the first violin (bar 18), creating a more delicate and upper–partial–heavy sound which further contributes to its partial submersion (when articulating intervals derived from near harmonics) into the textural mass of the harmonic tape part.

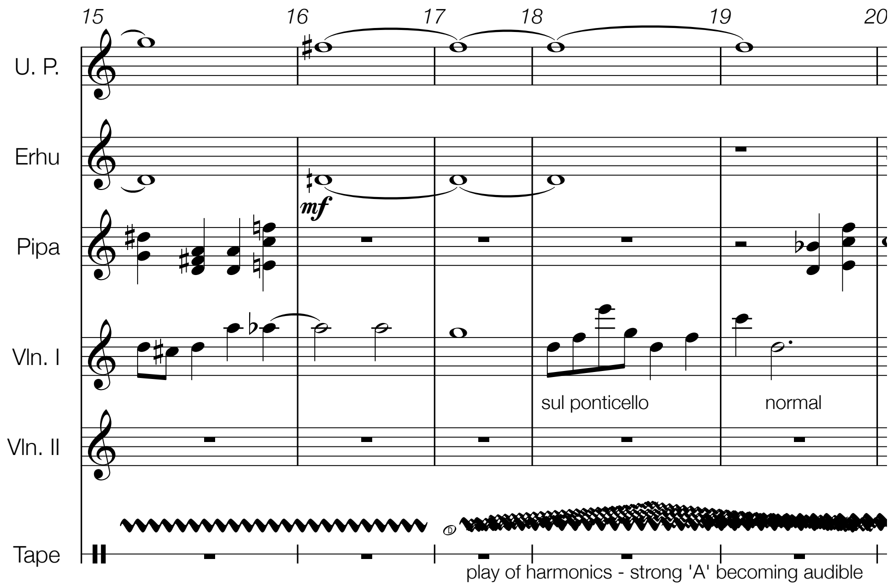


Figure 119(a): Pitch materials near opening which are generally derived from prominent components in tape part

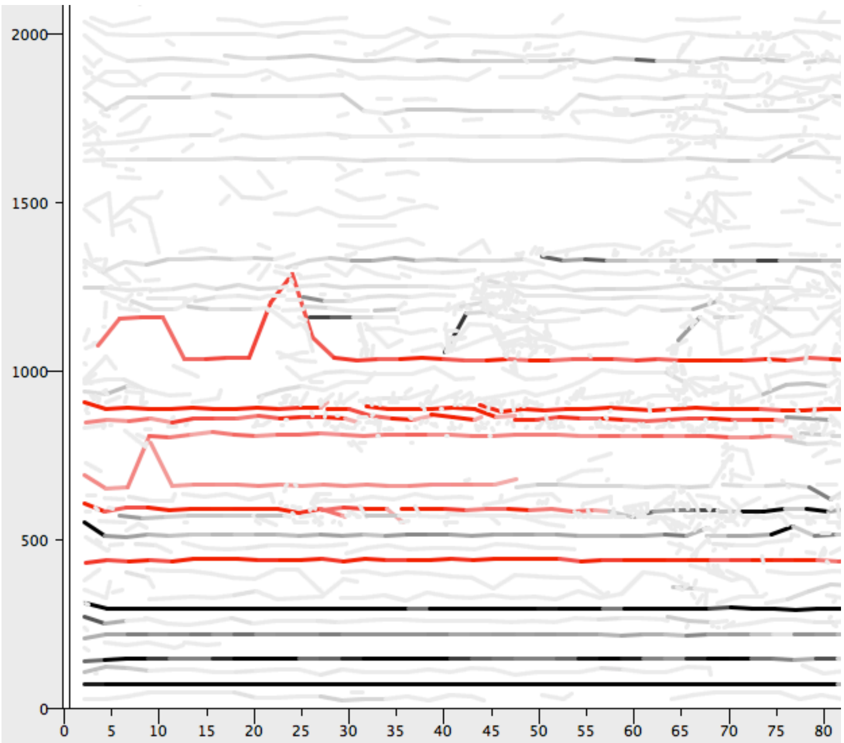


Figure 119(b): SPEAR partial-tracking results for the opening bars of the piece, highlighting partials corresponding to the pitched materials of bars 15–18 (approximations of A–D-E–G#/Ab–A alongside an upper glissando around D5)

These contexts highlight a range of distinct perceptual cases for microtonal materials along a continuum of articulation from exact tuning contributing to stronger timbral–style grouping through to less precise tunings contributing to a more commonplace chordal–style cohesion. Although the latter case is to be expected from more typical musical practice, the presence of such relatively distinct cases with very similar structuring of musical materials highlights the manner in which accuracy of intonation with respect to harmonically–related intervals can engender a degree of subtle contrast within ostensibly more homogenous larger–scale configurations of material. When the erhu traces melodic microtonal variations between *A* and *B* (in bars 33–36), it is foregrounding materials which are already perceptually salient due to differing vibrato rates in comparison with the other element: Bregman's identification of a *common (micro)modulation* grouping effect, cf. (Bregman 1990, pp.252–3, p.575) after (Chowning, 1981). In addition, the erhu's earlier tracing of an approximation of a harmonic minor sixth (figure 120, next page) contributes further to the textural interplay between drone–like elements in the tape part and the perceptual submersion of foreground instrumental materials (bars 31–32).

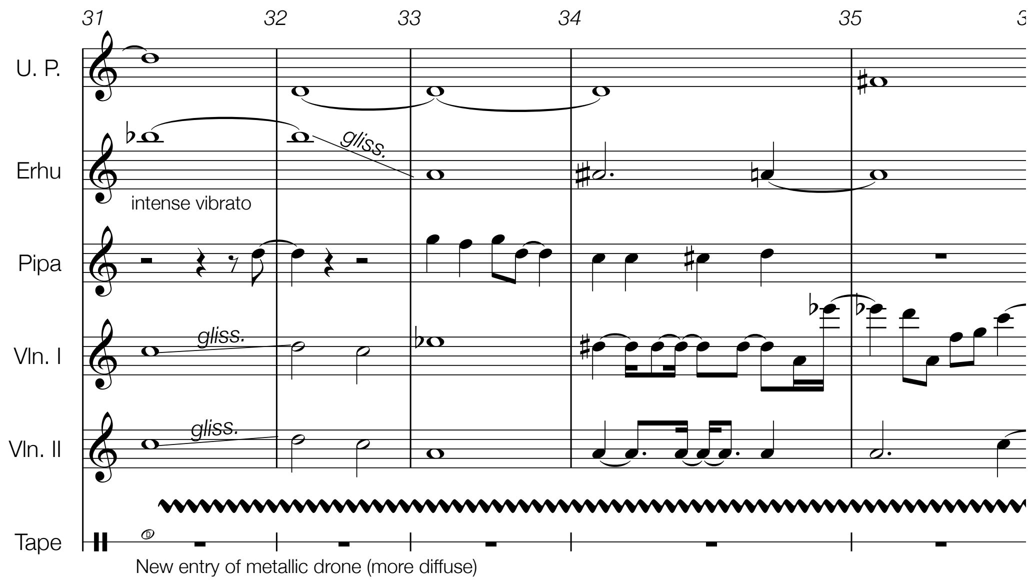


Figure 120: Erhu tracing microtonal materials foregrounded in tape part

The textural grouping/segregation effects within the overall drone–like context of the piece are similar throughout the rest of its length. Although only some of these effects are due to expressly microtonal levels of tuning accuracy in the instrumental materials in question, their perceptual conditions derived from the configuration of the tape part are based on fine–tuned editing of the frequency components of the tape part which often includes microtonal shifts or glissandi to contribute to perceptual segregation, providing intervallic materials for the live parts. Building on these factors, the structure of the piece's instrumental lines develops from the perceptually emergent effects of a perceptually–aware sonority–based compositional approach which includes microtonality as a vehicle for the creation of these conditions.

7.5.3 Melodic Microtonal Aspects of Composition

Beyond the microtonal contributions to grouping/segregation effects, quartertone–based microtonality makes a contribution to the erhu's melodic part (in addition to some un–notated gestural inflections present in the uillean pipes part). As noted earlier, the occasional use of quartertones in combination with a tape part which provided some finer-quantisation microtonal inflectional variations for textural effect was something of a logistical compromise and so the notated microtones were confined to these relatively coarse divisions.[31] This partial segregation of roles (dividing microtonal materials into textural—tape— and (primarily) melodic—erhu—components) proved to be a reasonable compromise for the purposes of the piece such that my concerns about limiting myself by the removal of one of my primary compositional tools (sub-quartertone microtonality) provded unfounded. Indeed, it was useful to reflect that after my exposure to microtonality during the course of the present project, semitone-based melodic quantisation was frequently perceived as too coarse (and felt quite melodically limiting). The presence of quartertone–based inflections in even one part was enough to address this aesthetic concern. Furthermore, the expressive range of erhu vibrato techniques (in addition to the instrument's characteristic nasal/vocal–like timbre) facilitated the clear individuation of this melodic line, allowing the quartertones to act as melodic or chordal rather than more timbre–based perceptual 'agents', such that the coarser/less directly harmonically-related tunings did not prove problematic.

[31] In fact, this concern for the simplification of microtonal materials was probably unnecessary due to the ehru player's grounding in Chinese traditional music: the quartertone–based inflections were executed effortlessly in rehearsal and performance.

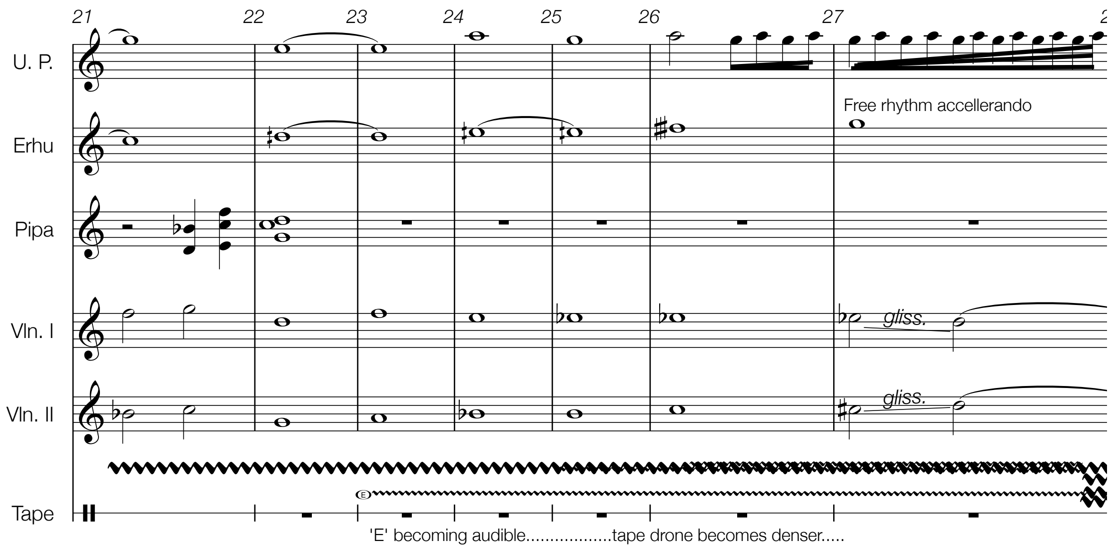


Figure 121: Microtonal melody in erhu occupying parallel chromatic/diatonic level (constant quartertone offset)

As can be seen from figure 121, above, the erhu traces a microtonally inflected melody which could be thought of as occupying a *parallel chromatic/diatonic level* (from bar 22), as seen in the work of some of the early twentieth century quartertone composers, whereby the *quartertone–offset* intervals have non–microtonal intervallic gaps between them (in this case, whole tones). This is a relatively conservative microtonal approach which for those composers sometimes contributed to a functional distinction in comparison with *non-offset* materials (Hába and Wyschenegradsky) and sometimes to a more sonorous/textural logic (Ives). In the present case, the usage is related to the sonority–based logic: the aforementioned contribution to perceptual segregation of the melodic line. However, this type of (somewhat conservative) usage means that what might be termed *melodic microtonality* (i.e. the use of microtonal spaces between melodic intervals) is not employed here. As such, this might be considered as a secondary microtonality, whereby the configuration of microtonal materials intended to contribute to a particular perceptual effect but whose microtonal nature is not highlighted/reinforced through other aspects of presentation. The one exception here is the quartertone inteval between the *F#+* and *G*, but this could be explained simply in the context of inflectional tendencies in leading tones (indeed, it is inspired by such practices).

Some degree of gesturally–based microtonal variation/inflection is to be found in the uilleann pipes part, though this is frequently implied by adherence to standard performance idioms from Irish traditional music rather than notated (e.g. the inflectional ornaments/controlled slow vibrato at bars 17–19/circa 43–48 seconds on recording—see figure 122, below).

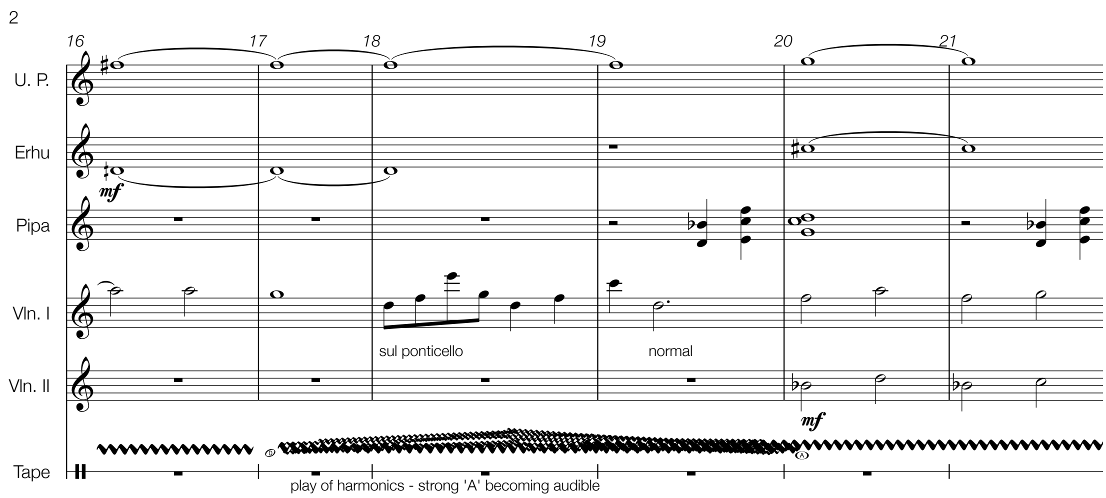


Figure 122: Gestural microtonal ornamentation occurs during bars 17–19 due to standard idiomatic conventions, but is not directly notated in the score (contribute to individuation of this line)

However, this effect is also employed in a specifically notated case in bars 46–52 (see figure 123, below, next page). Although these are effectively perceived as ornamental variations rather than structural microtonality (i.e. they are not categorically treated in the context of a continuous and irregular variation), they nonetheless contribute a similar function to the erhu's quarter-tone offsets in contributing to the clearer perceptual delineation of the instrumental line.

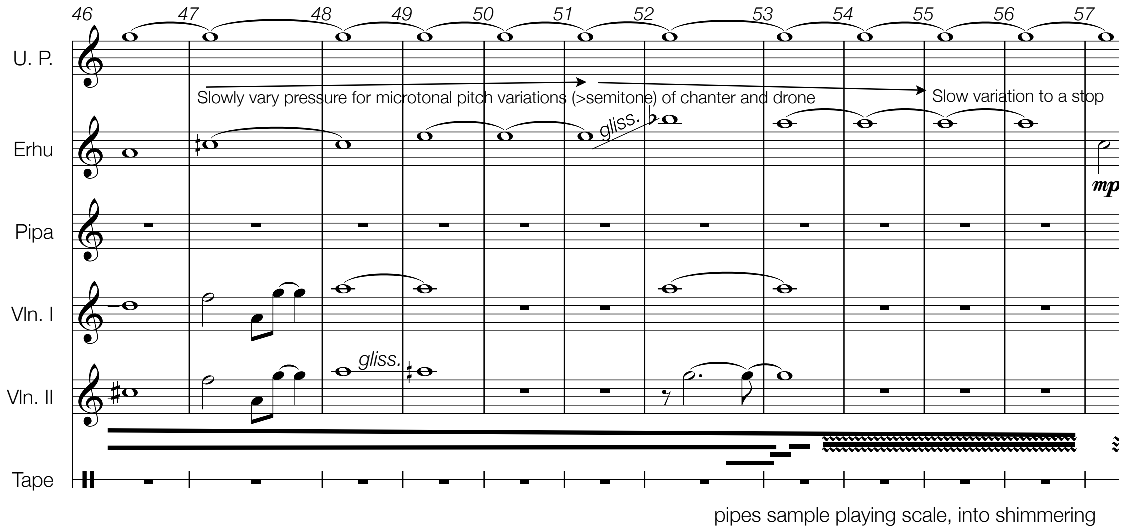


Figure 123: Notated gestural microtonal variations in pipes part

This textural delineation effect is also applied elsewhere as the pipes alternate between a held *A* (varying) and occasional interjecting *F#s* (bars 83 and following/c.2'40 onwards, see figure 124, below) with similar articulations in the slowish vibrato figure of the first violin to aid the perceptual segregation of the instruments from the background drone.

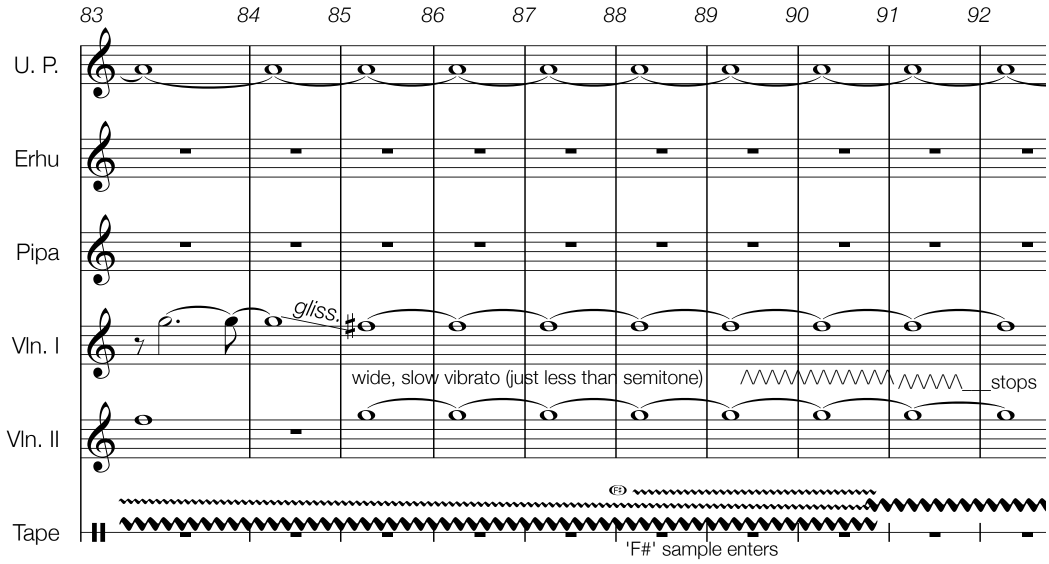


Figure 124: Textural delineation in pipes and violin part contributed to by pitch modulation (bars 83 and following)

This type of articulation (in the pipes alone) is even more prominent at bars 103 and following (figure 124 below, approx 3'35 in recording) accompanied by the microtonally offset erhu line which momentarily rests on a non–offset *A* before trailing off in a movement of ¾ of a tone downwards. This is the first more complete instance of a melodic line which moves beyond the more limiting case of the *microtonal offset* melodic construction[32] discussed above to a more extensive microtonality which cannot simply be described as a diatonic/chromatic melody with a constant microtonal offset applied throughout.

[32] This is with the exception of an instance at bars 26–27, which could be nonetheless be explained as a version of a leading–tone–style logic.

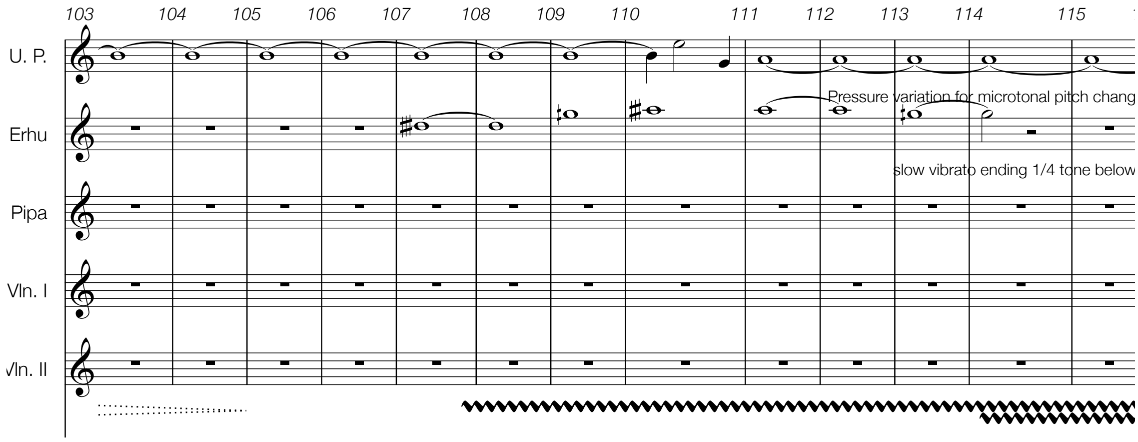


Figure 125: The first more extensively microtonal melody in ehru part which moves beyond the case of constant microtonal offset (with chromatic/diatonic divisions preserved in melodic steps) to free usage of microtonal intervals between melodic notes

These measures therefore act as early precursors for the microtonally freer melodic line from bars 221–224 (figure 126, below, next page; approximately 7’24 in the recording). Placed against a low *E* on the pipes with slow vibrato articulation just as the tape part is fading away it contributes to the clearest perceptual delineation of the instrumental parts which has yet taken place in the piece.

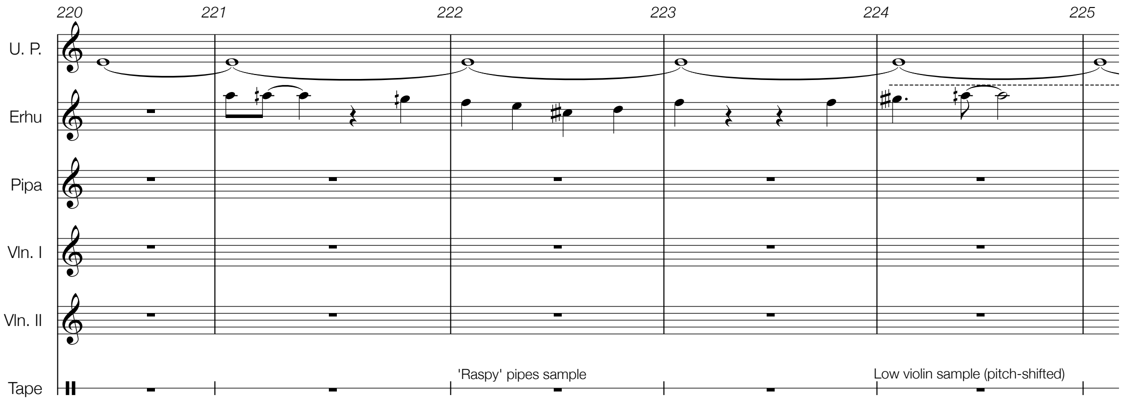


Figure 126: Second example of freer microtonal melody (i.e. with microtonal intervals between melodic notes) at close of the piece

From bar 229, the sense of perspective is further focussed onto ('collapsed into') the live instrumental parts. The slow, broad and irregular vibrato in the pipes is the only accompaniment for the erhu apart from the first case of an isolated and identifiably singular instrumental–style source in the tape part (in the shape of an tubular–bell–like sound). The microtonal melodic cadence of a quartertone downwards in the erhu further collapses the musical perspective into a single held statement of the piece's tonic.

7.5.4 *Making Ghosts from Empty Landscapes* (2010): Conclusion

Making Ghosts from Empty Landscapes is informed by the foregoing theories of microtonal composition in terms of its overall sonorous/textural logic, but also in terms of its role in melodic quantisation and functionally–related aspects. The piece embodies a number of different models of microtonality at various stages in its creation (and articulation). The overall drone–based aesthetic contributes a fruitful space in which to investigate various perceptual cases of (and contributing factors to) grouping and segregation effects. The structure of the tape part itself is informed by the use of factors which are intended to give rise to more salient individual frequency components (and harmonics of same), which then provide tonal materials for articulation in the live instruments, contributing to the fluid interplay between these parts. In doing so, the piece develops an initial working method which is related to the sculptural metaphor—e.g. Harrison (1999, p.125–7)—sometimes employed in relation to electroacoustic composition, seeking to highlight/articulate wider musical structures (or potentials) which may be implicit in the sound structures of the source materials.[33]

The division of roles between the extensively textural tape part and the occasional deployment of relatively coarse quartertone–based microtonality in the erhu elucidates two distinct functions of the use of microtonal materials. Quartertonal inflections in the ehru are considered to contribute to the clearer perceptual delineation of this line at various points. In addition, the inflections obviously have the potential to provide a finer degree of pitch quantisation for the purposes of rendering melodic contours than standard chromatic divisions. However, on analysis, this role appears to be relatively insignificant in the present piece: quartertone intervals between melodic materials are used very infrequently and when they do occur are deployed at points which may be considered to be cadential (either through rising or falling contours), where they

[33] Harrison's invocation of the sculptural model is based on the interpretation of spatial forms from the composed timbral gestures rather than discussing the process of deriving elaborated timbral structures from elements within the source materials.

may be exaggerated versions based on the familiar logics of leading note and suspensions of resolution. The format of the erhu melodies appears to be more significantly based on more functionally–derived microtonal offset for increasing functional distinctiveness/distance (in terms of the cone–based model of tonal hierarchy) of such a melodic contour's materials relative to the rest of the non–offset diatonic/chromatic materials in the piece. Such a usage (which was unpremeditated in composition) may corroborate this aspect of the functional theories of the early twentieth–century quartertone composers such as Hába and Wyschnegradsky. Thus, in its deployment of microtonal materials in both gestural/textural and quartertonal configurations, the piece draws attention to a number of distinct cases/implications of the use of microtonal materials, even if the degree of microtonality within the piece's instrumental part is not particularly extensive. Apart from the potential functional implications of quartertones, the most fruitful avenue for further exploration from this piece is the use of drone–based structures alongside live instruments to investigate the interplay between the two different grouping cases of fused timbres and looser chordal–style (i.e., in ecological terms, *causally–related* rather than *single object*) perceptual judgements.

7.6 *A Space for Tension* (2012) for erhu, two violins and tape

7.6.1 *A Space for Tension* (2012): Introduction

A Space for Tension, for erhu, two violins and tape, was premiered by the TiMi Ensemble at the Central Conservatory of Music, Beijing, on March 18th 2012, alongside pieces by fellow Irish composers as part of the second Beijing Irish Contemporary Music Festival.[34] A performance photograph can be found in figure 127, following page. The piece marks a continuation from the other just intonation pieces in the enclosed portfolio, in addition to incorporating the findings of the previous piece in relation to the perceptual configuration (grouping/segregation) potential found in various types of instrumental articulations and performance nuances. In this regard, *A Space for Tension* sees an interplay between the (generally more foregrounded) instrumental lines and the 'drone–spaces' which constitute the tape part, derived from various formal tuning schemas constructed around a just intonation/periodicity model.

These drones are articulated through sound sources derived from spectrally processed—using SPEAR (Klingbeil, 2009)——and granulated—using a

---

[34] The festival was supported by Culture Ireland and the Irish Embassy in Beijing. The enclosed live recording was co-ordinated by Yang Siyu, supervised by Li Kai, with additional post-production mixing by Brian Bridges.
Further details of the concert programme can be found at the Beijing Irish Contemporary Music Festival website: http://lbdo.net/sites/irlande/schedule/. A preview feature in China Global Times (English language daily) can be found at:
http://www.globaltimes.cn/NEWS/tabid/99/ID/700510/Celtic-charm.aspx.

processing patch created in Max 5 (Cycling '74, 2008)—iterations of either sampled[35] or physically-modelled sound sources.[36] The drones are therefore conceptualised as environments with certain formal acoustic properties (derived from the formal tuning schemas) into which the live instruments are agents which respond/interact by using pitch materials which correspond with the constituents of the relevant drone structures.

Figure 127: A Space for Tension *in performance at the Bejing Central Conservatory of Music Concert Hall by the TiMi Ensemble (photo: Enda Bates)*

These materials do not serve a role which is primarily based on traditional codifications of functional/syntactical harmony, but are much more concerned with the creation of distinct textural–perceptual configurations (based on the grouping/segregation definition of consonance/dissonance elaborated elsewhere

---

[35] A rights-free choral sample had been obtained for use in another project from the Internet Archive at www.archive.org. The sample was taken from a 1916 recording of Handel's *Messiah* (Oratorio Chorus/Edison, 1916) and consisted of the final cadence of the 'Hallelujah Chorus', which was then subjected to spectral processes to thin the texture significantly, producing an abstracted sonority which was considered to have bell-like properties. The materials were derived from a section in which the note *B* (and harmonics of same) were quite dominant (see figure 127, below).

[36] Created in Logic Pro's *Sculpture* instrument (Apple, 2004)

in this thesis). The combination of pure tunings and *senza vibrato* articulations contributes to perceptual blending of materials with the background drones. Conversely, more vibrato–heavy articulations, clear distinctions between amplitude/dynamics levels of sources and *sul ponticello* articulations variously contribute to greater perceptual segregation of elements. In addition, the use of pitch materials which closely match those within the drone-based tape part also contributes to a type of perceptual decomposition, where the similarity of foreground (instrument–derived) materials to frequency content in the drone parts temporarily highlights individual harmonic partials within these drones as potential continuations of the same/similar frequencies in live sources (this is most easily discernible in the cases of the muted instrumental articulations at the mid-point of the piece).

Apart from these perceptual connections, there are many cases throughout where the instrumental lines perform a more standard/traditional role in tracing and, hence, foregrounding the harmonic materials of the drone part (thus performing a perceptually straightforward foregrounding action upon the selected materials). In addition, based on the density of these drone materials and the degree to which their components are related to higher or lower levels within cognitive tonal hierarchies and/or the degree to which they contribute to audible beating effects (hence, providing impressions that range between relative stasis and relatively more energetic activity), these drones may contribute to the delineation of distinct emotional–affective ‘spaces’[37] of varying degrees of consonance/dissonance (thus referencing the piece’s title).

7.6.2 Generating Tuning Schemes and Related Structures

The drone–based tape part of *A Space for Tension* can be considered as a composed environment which foregrounds a variety of formal tuning schemas at different points in the composition. The broad structure of the tape part, based on these tuning schemes, is to proceed from more consonant tunings which are derived from nearer harmonics (and transpositions of these via nearer harmonic intervals) which are articulated through relatively sparser harmonic spectra to more dissonant tunings which are typically derived from more distant (higher) harmonics articulated via relatively dense spectra. Various modules of drone-based materials are thus created centred on 5/4, 7/4 and higher prime-based/microtonal intervals such as 17/16 and 19/16. It should be noted at the outset that these intervals *do not* imply prime–limit figures, but rather denote the lowest (i.e. simplest) harmonic interval upon which other intervals are derived. Thus, the piece sets up a number of competing *seconday tonal centres* in the context of tunings related to a single harmonic series and the relative complexity of these materials increases as the piece progresses. Figure 128 (next page) provides an outline of the broad structure of the progression between these different tunings in the tape part.[38] The names ‘bells’, ‘air’ and ‘steel’ are labels

[37] Providing constant background sound ‘environments’.
[38] Note that for the sake of graphic clarity, the notation of this tape part reduction quantises start and end times of drone sections. In addition, in rare cases (such as the opening ‘bell’ materials), select individual voices from drones have been muted out to thin the texture (resulting in the tuning scheme being root/octave, major third and 45th harmonic/tritone analogue, although this is filled out by the other notes of the inverted *G* minor chord of the source sample), and some of the

relating to the sound source used to generate the drone material. The ‘bells’ source is a qualitative description of the spectrally-processed vocal sample noted in the introduction, with the other two names referring to the manner of excitation or material used in the physical modelling process using Logic Pro’s *Sculpture* instrument (‘air’ referring to the use of a blown string model and ‘steel’ referring to the foregrounding of the string material to a bright, steel-like, setting).

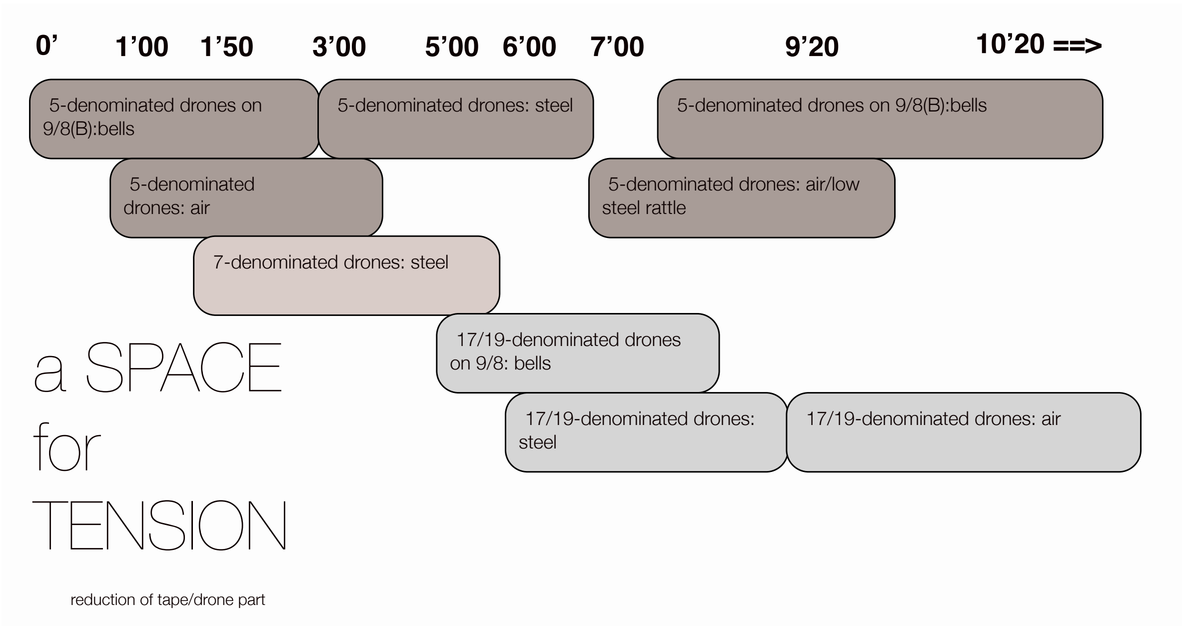


Figure 128: Tape part reduction for A Space for Tension*, highlighting generative tuning bases*

However, as the tuning schemes for each individual interval group encompasses a variety of relationships, the chart above should be read in conjunction with a

---

timbral descriptions above highlight the most significant timbre in a drone-based sound object (although other sources may be audible in the same drone–object provided that the tuning is the same as that which is notated).

further chart (figure 129, next page), which provides a clock-like representation of the harmonic space[39] with the *unitary identities* of root/octave and fifth on the horizontal, with the first–order harmonic intervals traced clockwise from horizontal left in order of size. Following this, any derivative higher–order intervals are graphed as displacements from the centre relative to the angular direction first–generated interval for this factor (i.e. they do not follow the arrangement based on cents size).

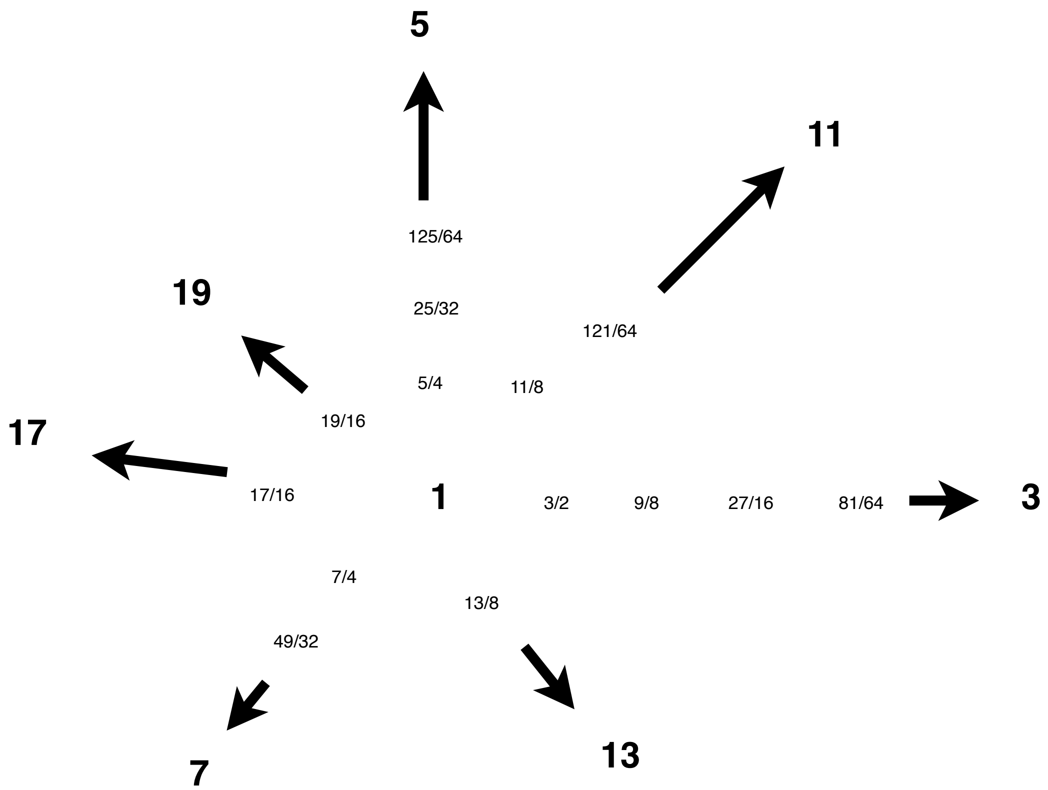


Figure 129: Basic harmonic clock representation for the simplest harmonic-generative relationships in its tuning structure (with the first interval in each functional direction providing a rough indication of relative interval size in cents)

---

[39] Conceptualising the 1200 cents of a pitch-chroma octave as a 360 degree rotation, with first-order intervals obtained through different generative/functional 'directions' (indicated by large arrows) arranged based on cents size.

The illustration above is not an exhaustive representation of the piece's intervallic materials, but rather provides an indication of the secondary centres which are used to develop the drone materials throughout the piece, generally based on the harmonic numbers 5, 7, 17 and 19.

Although the different generative harmonic directions noted above potentially indicate prime–limits, as discussed in the introduction, this does not imply that the drone materials are limited to these prime–limit intervals. Rather, they serve to signify the generative starting point for the tuning materials (i.e. the structural base/root of the drone), whilst being aware that the basis of most of the intervallic material is relative to a harmonic series of *A* (although the modules denoted by 'bells' in the tape chart above are on a major second above *A*). As such, some degree of recognition of the originating harmonic centre may be obvious at some points through lower components of the drone, although the insistence of the materials based on the secondary tonal centres may tend to foreground these alternative centres at certain points/under certain conditions. The generation of materials based on secondary centres is depicted as superimposed onto the formal structures of the 'harmonic clock' diagrams below (figures 130, 131, 132). Again, note that this component of the representation prioritises functional directions rather than providing an accurate indication of relative interval sizes (in cents) for these higher–order intervals.

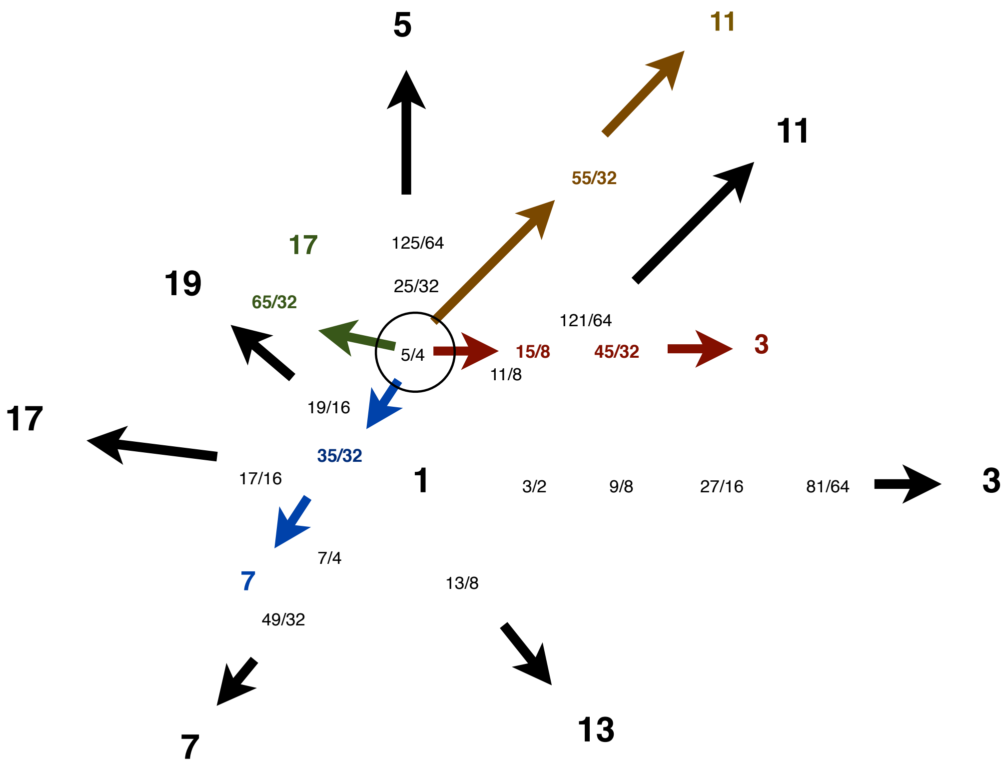


Figure 130(a): Harmonic clock indicating generative relationships for 5-denominated drones (5 as highest common factor or centre)

Figure 130(a) (above) depicts the relationships with 5/4 which are to be found in the 5–based drone materials. The formal/generative relationships are prioritised in this superimposition, rather than adherence to the prioritisation of interval size in the first level of the diagram. Utilising these functional/generative relationships produces the following set of tuning materials (figure 130(b), below, next page).

	x	=
5/4	7/4	35/32
5/4	3/2	15/8
5/4	9/8	45/32
5/4	11/8	55/32
5/4	17/16	65/32

5-space

generative

usage

5-denominated harmonic space

5 as highest common factor to all intervals so generated

note: not the same as 5-limit tuning: other prime-limit intervals expand on 5/4 to produce new divisions.

1/1

65/64=26.84 cents

35/32=155.14 cents

5/4=386.31 cents

45/32=590.22 cents

55/32=937.63 cents

15/8=1088.27 cents

2/1

5-denominated interval identities used in drone parts

Figure 130(b): Outline of generative process for 5-denominated drone part

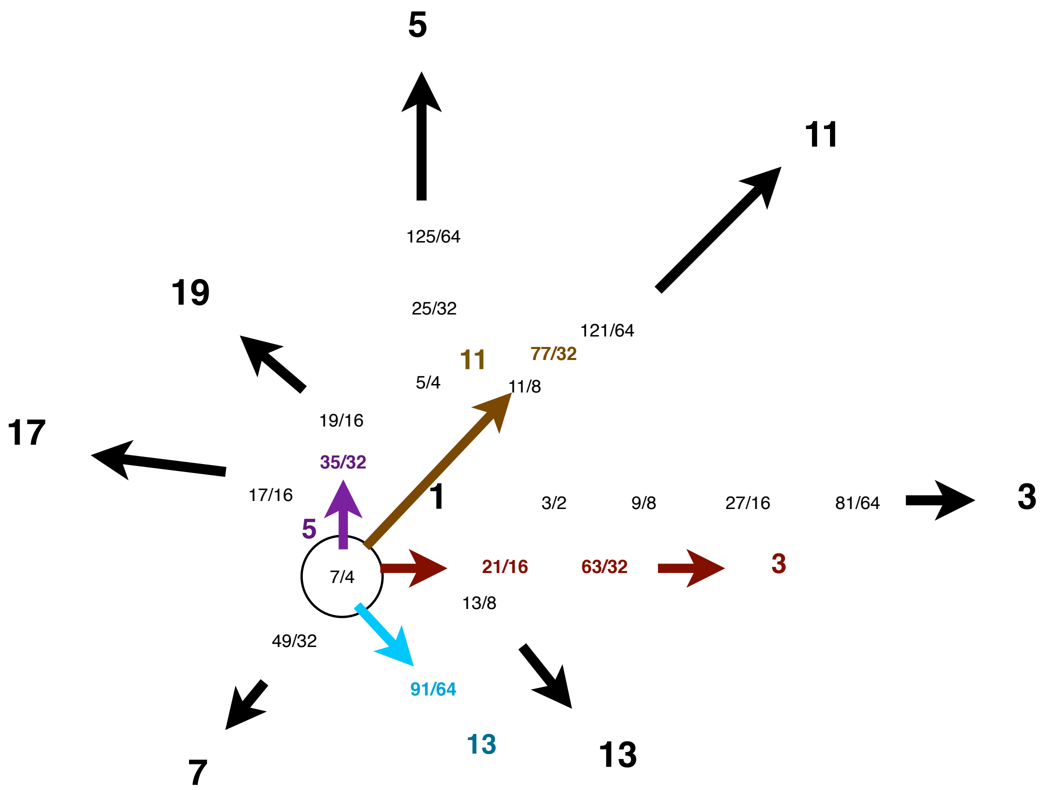


Figure 131(a): Harmonic clock indicating generative relationships for 7-demoninated drones (5 as highest common factor or centre)

The basic formal–generative relationships for the 7-based drones are illustrated in the harmonic clock diagram above and the tuning chart on the following page (figure 131(b)).

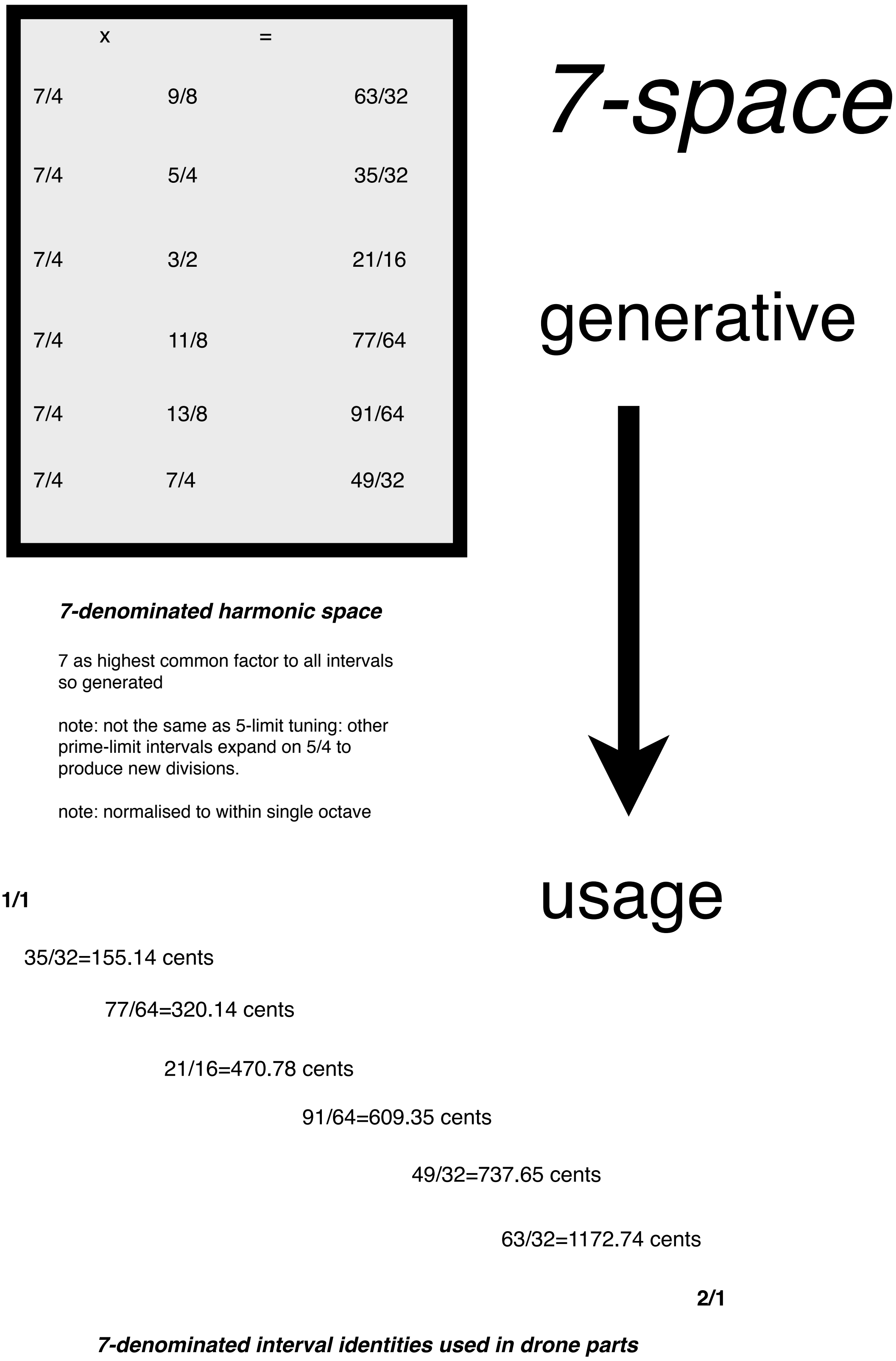


Figure 131(b): Outline of generative process for 7-denominated drone part

Lastly, the relationships which are used to generate some of the higher harmonic materials (relative to harmonic numbers 17 and 19) are illustrated in figure 132(a)—this page—and 132(b)—following page.

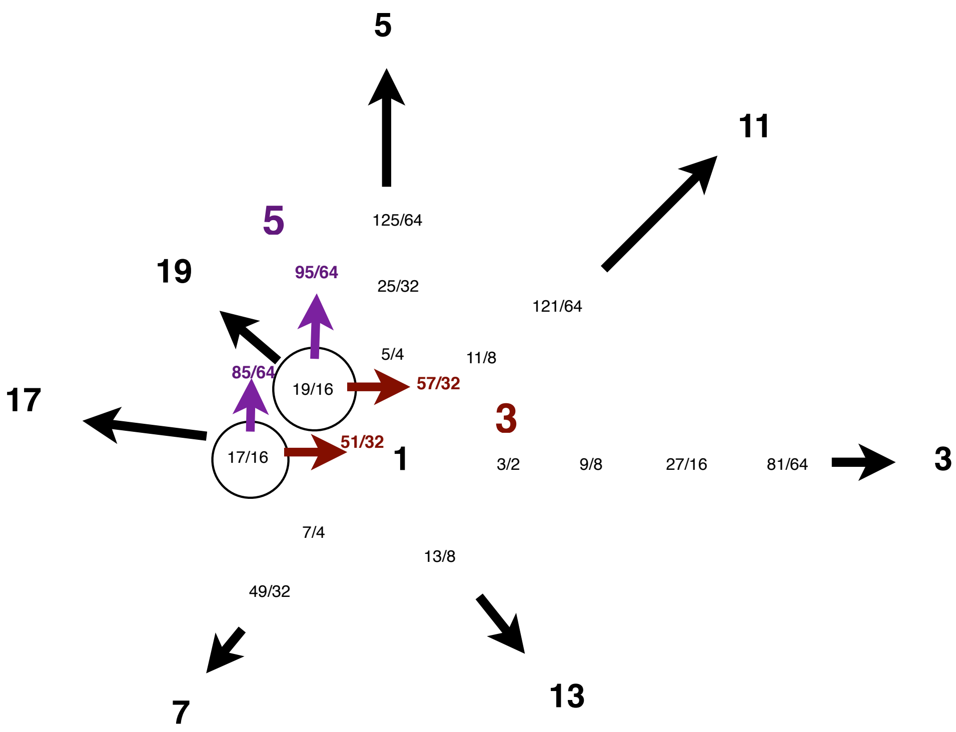


Figure 132(a): Harmonic clock indicating generative relationships for higher harmonic intervals

This drone/space includes the highest (or most distant in the harmonic series) intervals found in the piece. However, it should be noted that these are not completely limited to the materials derived from 17 and 19 (highlighted above), but also include more distant materials from the 3 and 5 generative directions (such as 81/64 and 125/64). In the materials derived from 17 and 19 (and other higher harmonics), this includes the Pythagorean major third (81/64), in addition to a 57/32 (approximately 1000 cents) analogue of a minor seventh (and/or seventh harmonic) and the 125th harmonic (1159 cents) in very close proximity to the octave.

x		=
19/16	5/4	95/64
19/16	3/2	57/32
17/16	5/4	85/64
17/16	3/2	51/32
25/16	5/4	125/64
9/8	9/8	81/64

higher harmonic space (to 17/19)

17–19 space

plus other higher harmonics

generative

usage

1/1

81/64=407.82

85/64=491.27 cents

95/64=683.83 cents

25/16=777.63 cents

51/32=806.91 cents

57/32=999.49 cents

125/64=1158.94 cents

interval identities in higher harmonic space (to 17/19)

Figure 132(b): Outline of generative process for higher harmonic intervals

Assessing the contribution of the different drones to the piece's overall structure, the piece begins with a somewhat deceptive statement of the 5-based drone schema on *B* rather than the piece's (subsequent) main centre of *A*. As can be heard in the initial moments of the piece, the (thinned–out) statement of the 5–based drone, although based on relatively near harmonics (or simple transpositions of same) still engenders a significant degree of beating around its major third division (which is audible and visible as clusters centred between approximately 690 and 650 Hz or *D* and *E* and between around 1170 and 1230 Hz or *D* and *Eb*) which is due to the interaction between the tuning schema and the frequency content of the originating sample (which was chordal rather than monophonic). The actual sonorous result of these tuning schemas is thus clearly dependent on the articulation of the frequency content in the various sound sources. The timbres obtained from the physical modelling process are subject to a more significant degree of tuning irregularity (due to the addition of a degree of *jitter*—randomised variations—to the position of the excitation source on the virtual string), which is clearly observable within the upper harmonic content of these sections when isolated using a partial–tracking application such as SPEAR. In addition, the overall density of frequency components is significantly increased through the use of the aforementioned tuning schemas when applied to timbres with upper harmonic content of significant amplitude (i.e. bright timbres)—see figure 133, next page.

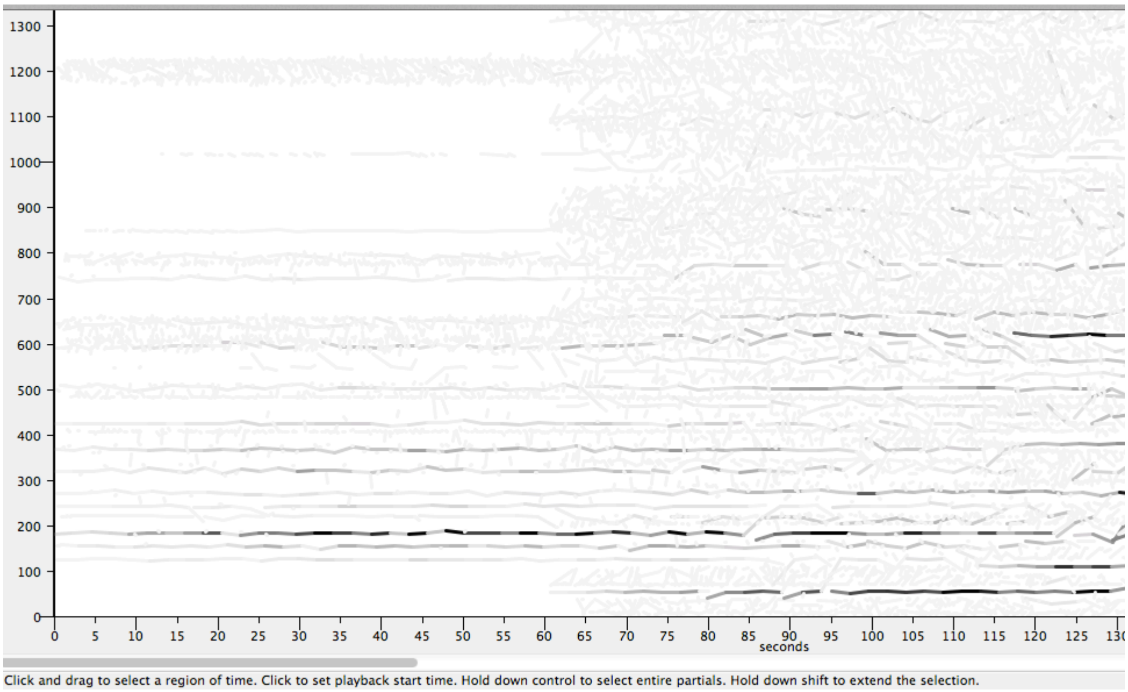


Figure 133: Partial-tracking representation of opening two minutes of drone, indicating progressively increasing harmonic density

A further axis of relative consonance/dissonance within the drones is to be found in the presence of more audible lower–octave statements throughout the physically–modelled materials. This, in spite of its restatement of the piece's overall tonal centre, produces a sense of textural dissonance when stated with significant amplitude against higher harmonic intervals which occur within more typical musical pitch ranges (and thus acquire more perceptual salience, potentially 'amplifying' their dissonant relationships with this sub-octave fundamental/root). However, to return to more straightforward consideration of formal tuning specifications, it is also clear that certain harmonic materials occupy clearly dissonant roles in various components of the tape part, such as the 77th harmonic (minor third analogue) around *C* as the 7-denominated part enters at circa two minutes (upper-most highlighted partial in the analysis from

SPEAR, figure 134, below). This 77th harmonic forms a dissonant relationship with the fifth harmonic (the source of the just intonation major third) in the rest of the harmonic materials.

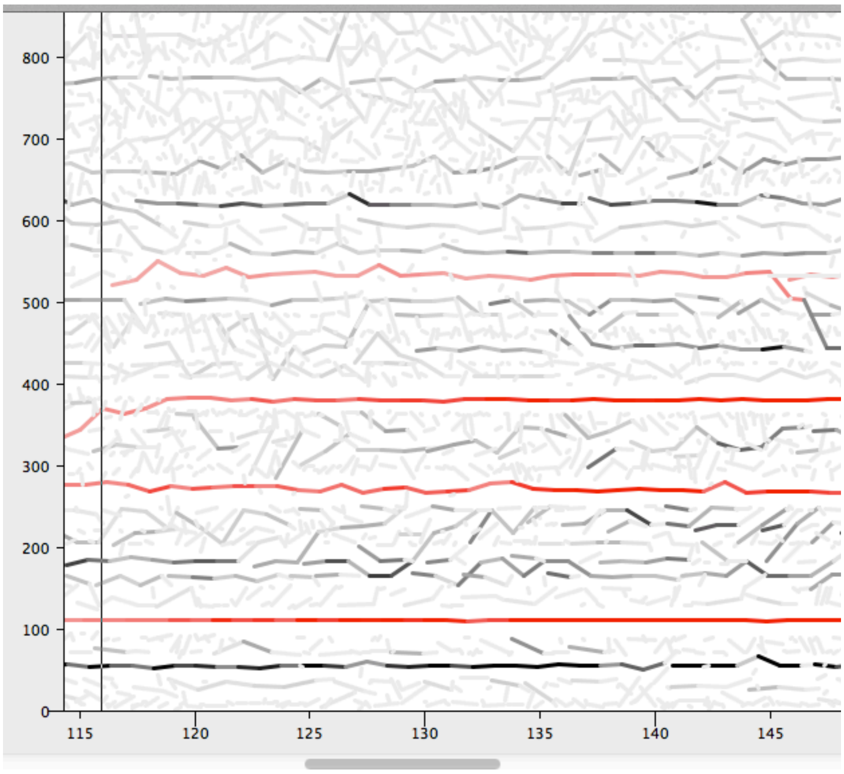


Figure 134: Partial-tracking view of entry of 7–denominated drone part with 77th harmonic (uppermost highlighted partial, minor third analogue) providing an example of a somewhat dissonant relationship with earlier harmonic materials in similar pitch regions (such as the 5th harmonic)

The 5–based materials begin to assert greater dominance at circa three minutes, articulated using a timbre derived from the 'steel' physical modelling source, accompanied by the overhang of the 7–based drones using the same source. As such, the first two minutes of the 5–based drones are characterised by the interaction between these two parts. The microtonal interaction potential inherent in the structure of the 5–based drone, through its microtonal 65th harmonic and quarter-tone sharp semitone in the 35th harmonic, allied with the interaction potential between materials such as the 15th harmonic in the 5–based drone and the 63rd harmonic in the 7-based drone[40] significantly undermines the stability of overall pitch/chordal grouping percepts even in the presence of a relatively clear/high amplitude tonic drone as lowest audible frequency component.

The progression to the materials which are derived from higher harmonic components (notated in shorthand as *17 and 19–denominated*) evokes a different kind of dissonance/tension, even in relative isolation (i.e. without overlap with respect to other drone groups), through its cluster of materials close to the harmonic seventh (7/4 or 969 cents), 15th harmonic and octave, including the 51st, 57th and 125th harmonics. This results in an audible degree of interaction between these intervals and the frequency components inherent within the source's harmonic timbre, resulting in a characteristic audible cluster (with significant beating) which is discernible in statements using both the 'bells' and 'steel' sources. Although these materials are derived from higher harmonics (both in terms of their overall position within the harmonic series and also in terms of the larger pitch–chroma size of intervals lying near the major/minor seventh intervals), the section in which these intervals predominate is, perhaps, less dissonant in overall terms than the section in which 5–based and 7–based intervals overlap. However, the aforementioned cluster certainly produces a

[40] In addition to other pairings such as the 77th harmonic and 5/4 major third and 45th and 91st harmonics.

strong evocation of dynamism through the rapid beating of each of its component timbres (which are themselves perceptually segregated quite successfully, which may be due in part to the commonplace modality of timbral/spectral difference but is also likely to be contributed to by the audible beating effects aiding the perceptual segregation).

Based on the sensory/timbre–related factors discussed above, the drone-based tape part's overall consonance–dissonance schema sometimes proved to be less straightforward than a simple assessment of its formal/generative tuning schema might suggest. However, the numeric descriptions of the drones in the tape part do stand as a shorthand label which can be associated with the more salient characteristics of a particular drone–object, such as the cluster around the seventh degree, discussed above. As is clear from the foregoing discussions, any rigid functionalism which is simply based on ratio–based dimensions/directions may fall short in quantifying sensory consonance/dissonance in more complex timbral cases such as those found in the tape part, where factors such as grouping/segregation and increased critical band overlap and more ambiguous tonal pitch judgements contribute to consonance/dissonance assessment. The effect of timbre (in terms of spectral content) on this latter effect is particularly significant in the section around three minutes, where the re-entry of a 5–based drone–object with the 'steel' sound source dramatically affects the perceived pitch–salience (and dissonance judgement) for the resulting composite in a manner which contrasts with the early statement of this drone-object (alongside the 7–based 'steel' source) using the 'air' sound source. Due to these frequent sensory–based complicating factors, the assessment of the effects of tuning-based structures is best approached through a consideration of the instrumental parts, with the tape part taken as providing a dense and slowly–evolving backdrop for the instrumental figures to interact with in highlighting various harmonic intervals, in addition to providing a larger-scale emotional/affective structure to the piece. This larger–scale axis of organisation is primarily to be found through relatively simplistic density–based consonance/dissonance judgements, whose finer textural details (including certain identifiable timbral-style attributes) are nonetheless dictated by the formal structure and may be perceived as such when the drone–object is perceptable in relative isolation.

7.6.3 Instrumental Articulations and Tuning for Grouping/Segregation and Consonance/Dissonance

The instrumental sources in *A Space for Tension* generally delineate clearly foregrounded activity, although the nature of the tunings chosen and the predominance of *senza vibrato* articulations, leads to their becoming perceptually more submerged into the background drone structures. However, their presence as separate agents is clearly audible in the opening moments (when placed against a sparse statement of the 'bells' source). Figure 135, following page, illustrates how the instrumental parts begin on the neutral/textural/harmonic seventh of 7/4 and proceed to a cluster based on the 13th, 15th and 49th harmonics (i.e. between *E* and *G#*).

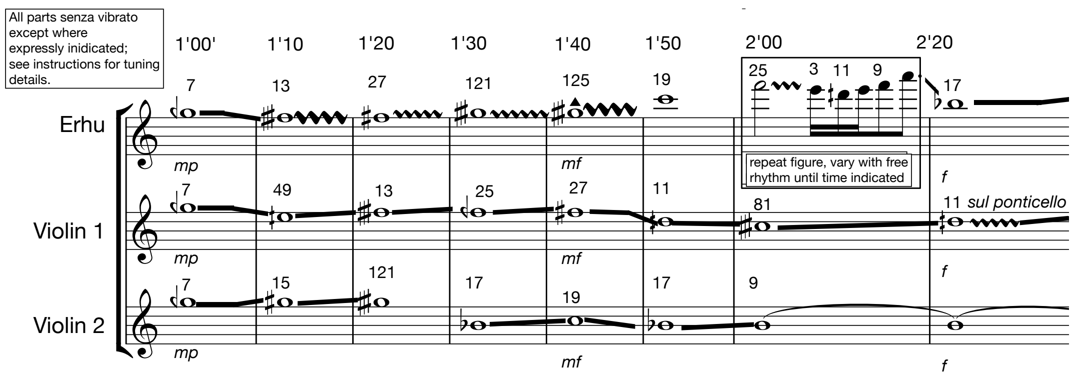


Figure 135: Opening of the instrumental parts of A Space for Tension *on harmonic sevenths before rapidly increasing distance within the harmonic series*

Although the tuning is a little uncertain for the 7/4 (and relative variations between instruments are audible) analysis using SPEAR (figure 136, below) suggests that the instruments converge broadly between 750 and 800 Hz, with one of the instrumentalists in particular tending to err on the low side.

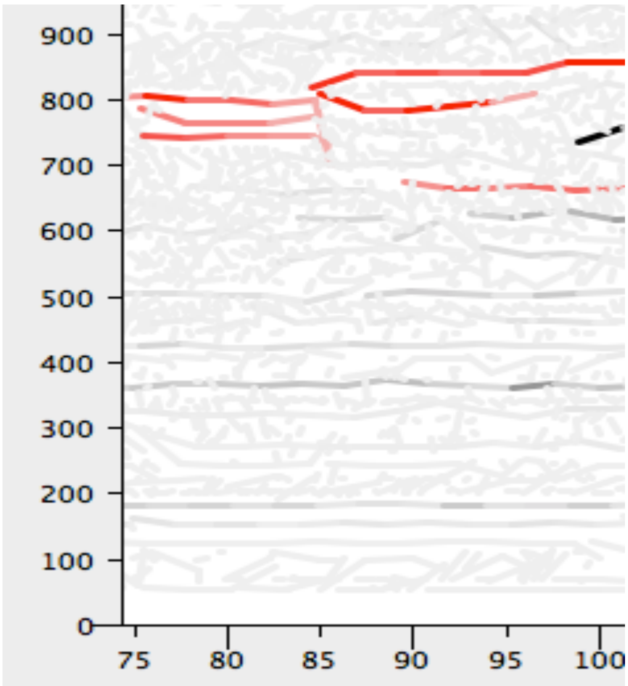


Figure 136: Opening of the instrumental parts of A Space for Tension *as analysed by SPEAR, illustrating divergence from specification (after initial convergence of two of the instruments)*

In contrast, the 15th harmonic (15/8) is confidently articulated (as might be expected, due to its familairity), as is the 49th harmonic. However, the 13th harmonic in the erhu is less sure in its intonation: this may be because the erhu player had less rehearsal time with the piece than other instrumentalists in the ensemble[41]. The directional imperative of the extremely sharp 121st and 125th

[41] Although, as noted in relation to *Making Ghosts from Empty Landscapes*, the experience of performing both Western and Chinese traditional music does appear to have contributed to a

harmonics is also lost somewhat in the erhu (whose individual clarity is, in any case, obscured by its greater distance from a microphone in comparison with the other instruments, due to the vagaries of the live setup for a variety of multi-instrumental pieces). In some cases, the directional notation has also been applied overzealously in the other parts: for example, at two minutes (see score in figure 136, previous page), an 81/64 Pythagorean major third starts close to the intonational specificaiton, but throughout the rest of its length tends to be rendered closer to a *D* than a sharp *C#*. These cases would seem to indicate two distinct, but related, tendencies within performance for materials which are different from standard intonation: (1) a conservative tendency (epitomised by the 121st/125th harmonics), which tends to 'bracket out' more extreme tuning deviations in favour of less marked directional imperatives and (2) a tendency to exaggerate intonational differences from standard (epitomised by the 81/64 discussed above) which may result in tunings which are closer to the next standard chromatic interval rather than providing a microtonal deviation. In this regard, there may be a tendency to gravitate to materials in the tape part which are themselves close to standard chromatic intervals if the interval notated in the score is close to this: the 81/64 which tends towards a *D* could be viewed as an example of this. However, a later statement of this interval (see figure 137, below, next page) in the same part (violin 1) is much more accurately rendered, suggesting that a more dynamic melodic (or, indeed, reherasal–familiarity) logic may also be at play at certain points.

---

strong general awareness of intonation, given more extensive rehearsal time, and rehearsal intonation was often significantly more accurate than that found in the concert performance.

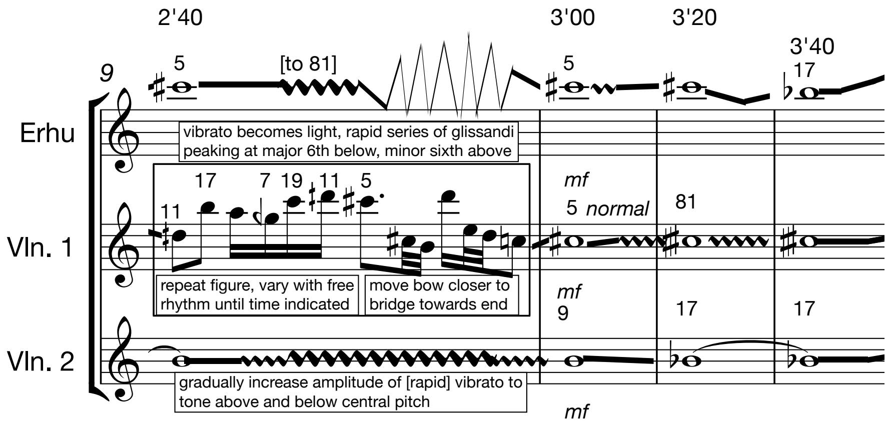


Figure 137: Transition from 5/4 to 81/64 major thirds in the first violin part demonstrates more accurate rendering of the latter major third variant in comparison with earlier in the piece

Based on these cases, it must be admitted that the microtonalist may need to regard some of his/her tuning specifications as something of a Platonic ideal in various performance circumstances where familiarity with these intervals is relatively limited. To some extent, the present piece is structured to anticipate this possibility to some degree, with the pairing of the instrumental part with a tape part in which these intervals are subject to a finer (and more reliable) degree of parametric control. In this model, the instrumental elements are more significant in terms of a more broadly melodic logic (when more perceptually segregated and, hence, foregrounded). As is the case with the previous piece, this delineation of distinct perceptual foreground/background roles is facilitated by timbral differences and vibrato/micromodulation within the instrumental sources, encouraging their individuation at various points. Of these two factors, the vibrato articulations appear to be the most significant contributors to segregation/individuation for instrumental sources. The *senza vibrato* articulations of the string parts are clearly individuated through the sparser backing of the piece's initial moments but become more progressively blended in with the tape part as this becomes dominated by brighter/denser harmonic timbres, as is the case from two minutes, where the two violin parts are perceptually tied to the background elements until the first violin begins a vibrato articulation at 2'20 (and the other two instruments follow this lead from 2'40). In this regard, the slower, lower amplitude tail of the first violin's vibrato blends back into the modulation effects heard within the tape materials, as a by–product focussing attention on nearby frequency ranges in the tape part. This type of highlighting could be thought of as the primary role for the instrumental parts, drawing attention to particular microtonal materials/tuning–based sonority effects in the tape. The semitone analogue of the 17th harmonic at 3'40 contributes a similar effect, creating a clear periodic beating (and resulting perceptual segregation) with octave components. In addition, the gradual introduction of a vibrato-articulated interval based on the 121st harmonic in the erhu (figure 138, below, next page) prefigures some of the clear periodicity–based sonorous effects of the drone part from 4'50–5'00 (as the section in the tape part containing vigorous beating around the seventh region, or transpositions of same, is heard).

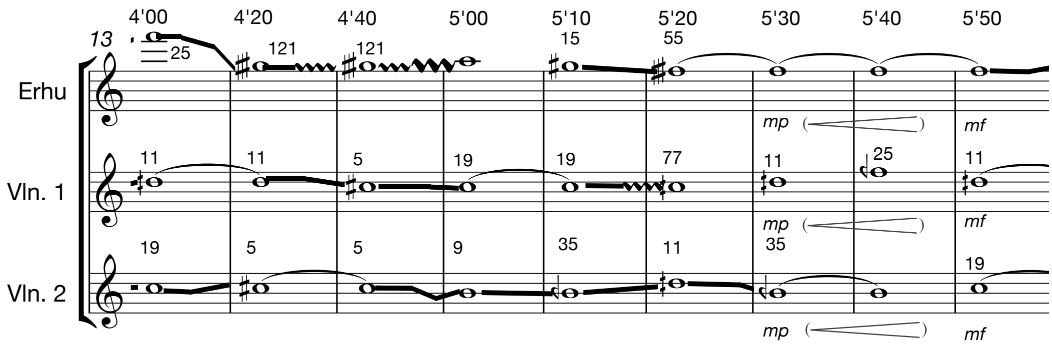


Figure 138: Introduction of higher upper harmonic (121st) in erhu part with significant vibrato articulation

In addition, the entry of the tonic statement of the 17/19/higher drone materials from six minutes (via the bright ‘steel’ timbre) provides a particularly vigorous seventh region for the erhu’s part to interact with through its specification (see figure 139, below, next page) of a rise from a 15 th to 125th harmonic (a little flat at around 840 Hz as opposed to around 860 Hz in specification, so approximately 40 cents too low, but nonetheless clearly articulating a non-chromatic division). Based on the aforementioned tendency of such instrumental articulations to contribute to focussing attention within particular frequency regions, the sonorous effect of the drone’s tuning in engendering complex periodicity effects is still highlighted through the instrumental part’s intervention, even if the tuning is not always fully accurate.

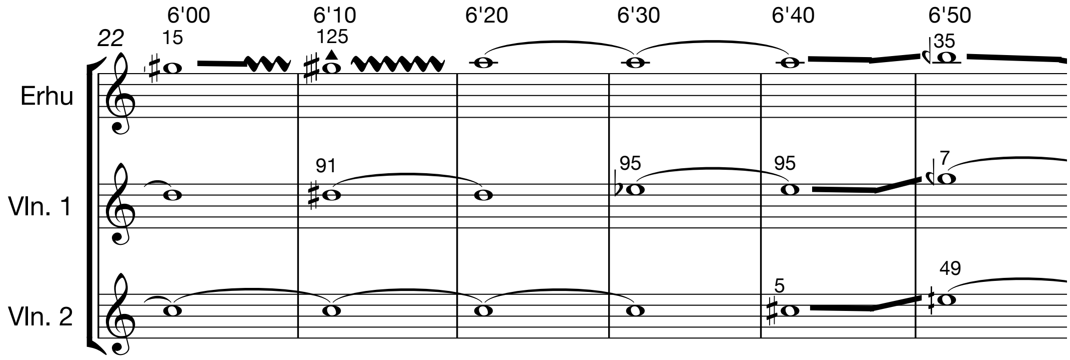


Figure 139: Erhu part engaging with the seventh–to–octave region (mirroring a vigorous seventh region in the tape part)

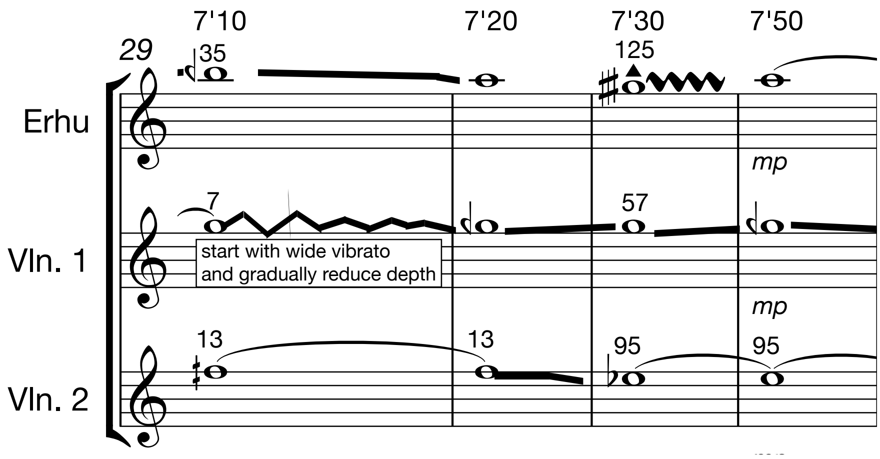


Figure 140: Vibrato articulations within the seventh region (7th and 57th harmonics) in the instrumental part potentially draw attention to the harmonic seventh region in the tape part

This effect is also seen through the vibrato articulations and their interaction with the tape part from 7’10 to 7’20 (see figure 140, above), drawing attention to the harmonic seventh region (which is still prominent in the tape part from the

17/19/ higher drones).[42] In addition, the *sul ponticello* articulations in the violins tend towards producing salient/perceptually segregated partials which stabilise around an octave above the 57th harmonic (essentially, the equal temperament minor 7th) after oscillating between this pitch and a major third (5th harmonic) above. This effect of guiding attention towards perceptually segregated harmonics through playing close to the bridge is a common device in spectral music and serves the purpose of drawing attention to the harmonic partials as potentially separate perceptual entities which can easily emerge from hitherto fused harmonic spectra. In addition, they engender a euphonic purity which provides a point of contrast with the harsher articulations of the rapid violin appogiatura at approximately 8’10 (figure 141, below).

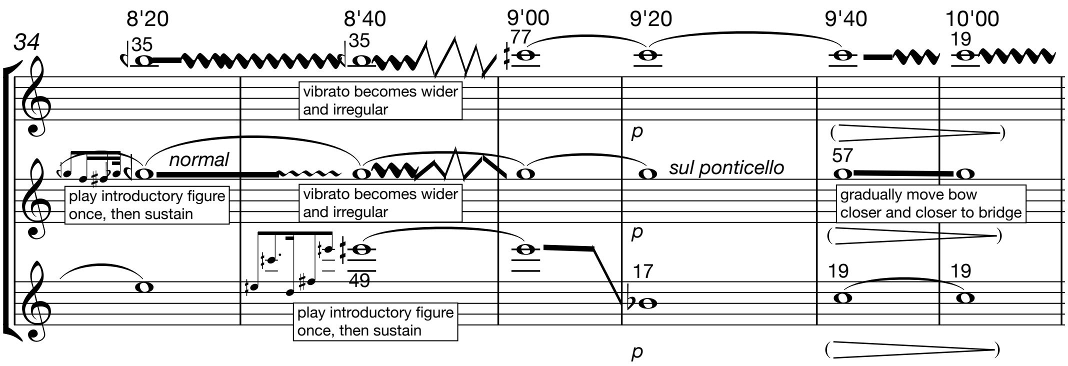


Figure 141: Sul ponticello *articulations contributing to a more euphonic perceptual segregation effect, contributing to a ‘textural’ cadential point of rest*

As previously discussed, the piece is broadly structured around a progression from relative consonance/perceptual stability to relative dissonance, with details of the resulting perceptual configuration subject to details such as the timbre of the component sound sources and the manner of instrumental articulation. The

[42] However, the vibrato articulation of the 125th harmonic at 7’30 is missed in this performance.

piece's tonal centre is broadly constant throughout its length due to the constancy of the drone–based accompaniment and cognitive judgements of relative proximity to tonal centre will therefore tend to be based on this single point of origin. The salience of the individual intervals, coupled with learning/exposure, will determine whether microtonal intervals are assigned to lower or higher functional levels within this model (higher harmonic series intervals will generally be assigned to higher functional levels if perceived as distinct). However, it is likely that in some cases, judgements of which functional level materials are assigned to will depend on competing considerations: the perceptual distinctiveness/salience of different materials and contextual factors such as functionally-based tendencies such as notes in lower proximity to the tonic being perceived as leading notes and, hence, closer to the tonic than might be suggeted by any other distinctiveness factors. As such, intervals such as the 121st and 125th harmonics might be perceived on this basis, even if recognised as distinct, in cases such as those of the 1'10–1'20 and 1'30–1'40 sections of the piece (figure 142, below, next page).

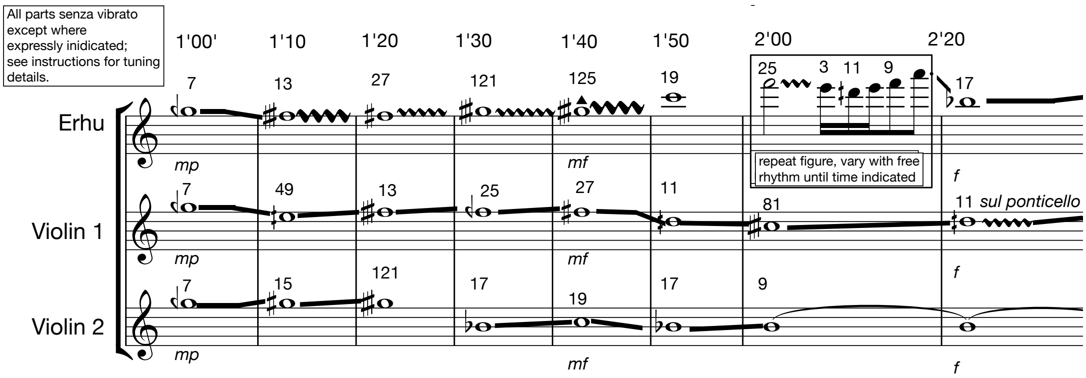


Figure 142 (recap of score excerpt from figure 134): The opening bars of the piece contain extensive activity in the seventh-to-octave region which may be treated in hierarchical terms as closer to the tonic 'level', even in cases of high harmonics such as 121st/125th

However, the sonorous aspect of consonance/dissonance judgements may also influence assessments (in effect, as a competing model) in many cases. The seventh–region materials, whilst being perceived as having a gravitation-inducing proximity to the tonic, are also likely to be perceived on the basis of the simplicity/complexity of their sonorous results, where the overall effect is likely to be primarily based on the composite dissonance of figures materials which do not have any clearly reductive potential to become lower harmonic intervals on non–tonic centres, such as in the 125th/91st/19th–based chord at 6'10 (see figure 143, below). Whilst these potentials are present in the score specification, normative tendencies with regard to tuning may, however, undermine this tendency towards microtonal (and hence, sonorous) distinctiveness. In addition, perceptual individuation of individual lines (for example, through pronounced vibrato articulation) may reduce sensory-based dissonance judgements.

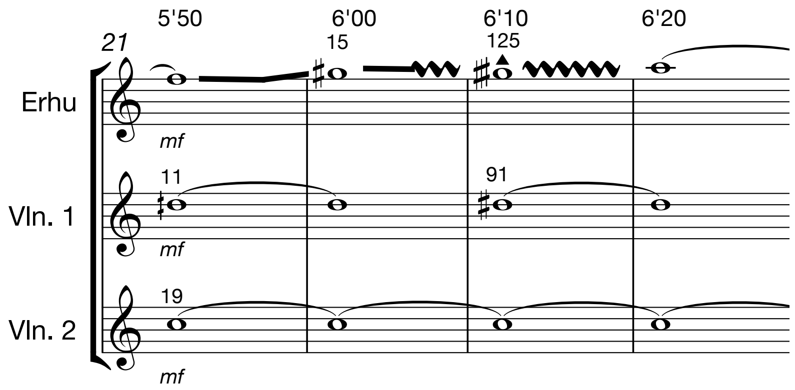


Figure 143: Microtonal harmonic materials which potentially exhibit significant perceptual complexity and, hence, dissonance

Competing judgements may also be in evidence around closely-related microtonal analogues of distinctive intervals such as the major third; for example, at 3’00–3’20 (figure 144, next page). In this case, the 5th and 81st harmonic coexist in a sequential relationship, highlighting the microtonal differences between them, but the 81st harmonic may potentially be perceived as broadly equivalent to the earlier–in–the–series third which it replaces.[43]

[43] However, as noted above, in performance the distinction between the 5th and 81st harmonic tended to be exaggerated such that the 81st tended to gravitate towards the next familiar scale division.

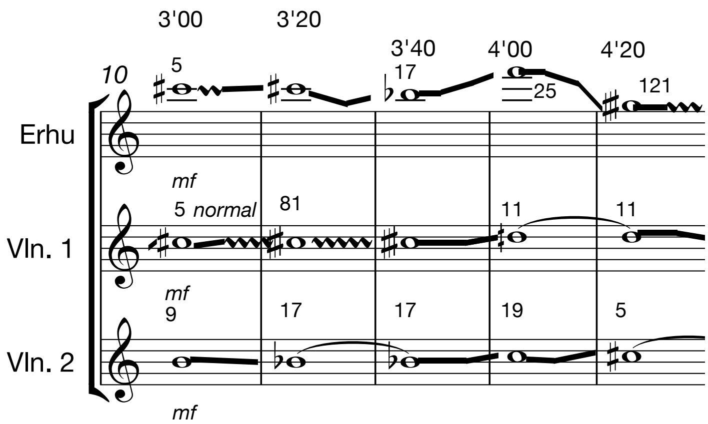


Figure 144: Progression from 5^{th} to 81^{st} harmonics, potentially highlighting their distinctiveness (in terms of sequential melodic distinction and resulting sonority); also, the poccurence of the 121^{st} harmonic potentially registered as an 11^{th} harmonic of an 11^{th} harmonic

In some cases (see figure 144, above), a more sonority-based aspect of reduction may occur, for example, the occurrence of the 121^{st} harmonic (an 11^{th} harmonic above an 11^{th} harmonic), which may therefore be registered as more sonorously simple in relation to a secondary centre (and hence, treated within the context of a lower–order hierarchical relationship). A more extensive example of this type of effect is to be found in the combination of the 55^{th}/77^{th}/11^{th} harmonics (figure 145, next page), which all have clear lower–order relationships with the 11^{th} as a secondary centre of 5:7:1, with the resulting more simple/stable sonority providing a relative point of sonority-based consonance at 5’20. This type of effect is also to be found with the 35^{th}/7^{th}/49^{th} harmonics (5:1:7 on the 7^{th}), see figure 146 (next page).

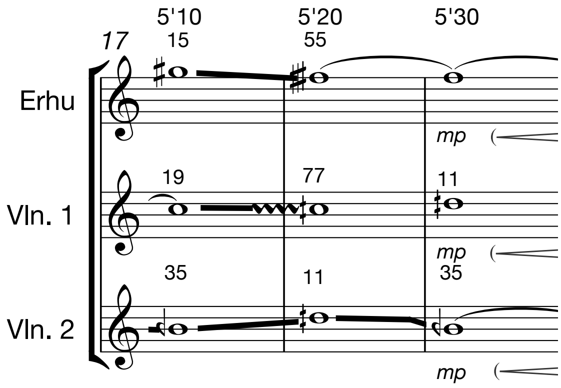


Figure 145: 55th/77th/11th harmonic intervals resolve as 5:7:1 ratios with respect to the 11th harmonic and hence form a point of sonorous stability

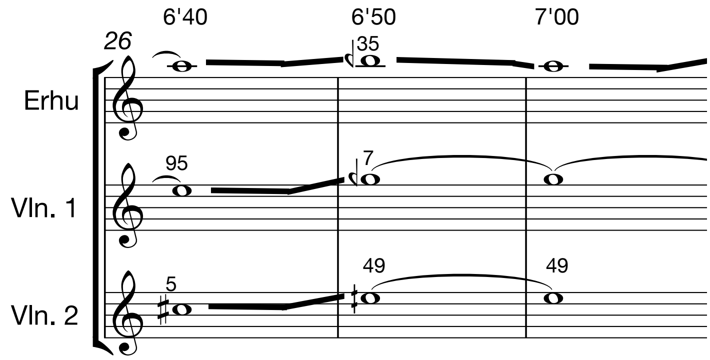


Figure 146: 35th/7th/49th harmonic intervals resolve as 5:1:7 ratios with respect to the 7th harmonic and hence form a point of sonorous stability

This type of reductive potential may also be exhibited (see figure 147, following page) in the final measures of the piece (8'40 to 10'00), with the 77th and 49th harmonics providing a 7–based pairing and the 57th harmonic providing a low–order relationship with the 19th harmonic (a fifth or 3/2 upon this interval), with the upper 77th harmonic (a microtonal analogue of the 19th harmonic) resolving to an octave of the 19th.

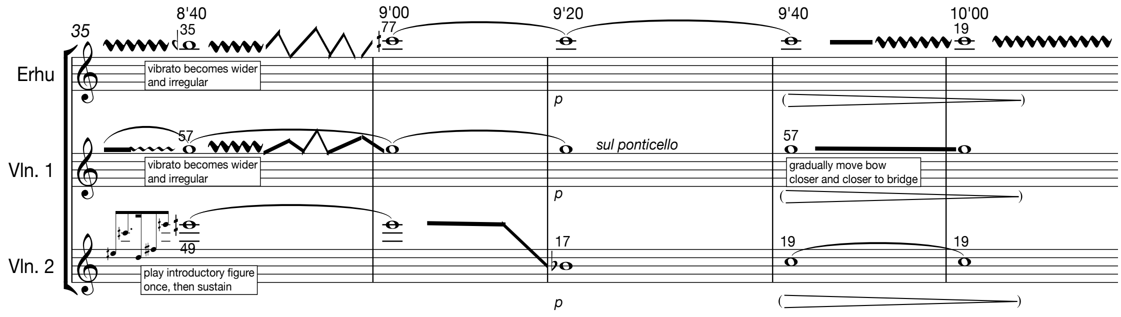


Figure 147: Higher harmonic materials towards the conclusion which may resolve as lower harmonics of secondary centres

The minor–third–region instrumental sonority which dominates as a result might be expected to clash with the activity within the major third region in the tape part (which is particularly active in relation to beating effects within this region from the 81st and 85th harmonics in the drone's specification). However, the processes of perceptual segregation between these sources seems to take account of their sonorous (in terms of composite timbre and periodicity–based distinctiveness) differences and allocates them as two seprate and coexistent segregated sources, thus moderating potential dissonance judgements. As such, judgements relating to consonance/dissonance within the piece may be best described in terms of competing bottom–up and top–down models (or aspects of a single model) which are quite dependant on the circumstances of presentation (instrumental articulations and instrumental timbre which contribute to either (1) simple/stable perceptually–fused percepts or causally–related grouping tendencies (2) individuation/segregation.

7.6.4 *A Space for Tension* (2012): Conclusion

A Space for Tension investigates the potential for interplay between live instrumental and fixed–media drones which are structured on the basis of extended just intonation/harmonic series relationships. Similarly to the previous piece, *A Space for Tension*'s intrumental part is structured on the basis of highlighting pitch materials which are already present in the tape part. However, whilst preserving the textural/spectral sensibilities of the previous piece, the drones within *A Space for Tension* are specified more strictly in procedural terms through a harmonic series tuning logic which progresses from materials which broadly occur at earlier stages in the series (articulated through timbres relatively sparse and qualitatively muted harmonic spectra) to materials based on higher harmonic series intervals stated with much more stridently bright timbres. The result of these broad combinations of materials is a progression from relative consonance to dissonance in both sensory and cognitive–hierarchical terms.

Even though the piece's materials as a whole call for precise microtonal specification, it was anticipated that circumstances might arise in which the instrumentalists might not render the microtonal intervals strictly according to specification. Even in cases such as this, the instrumental lines can contribute in terms of focussing attention on a particular region of the microtonal drone materials, in addition to gesturally animating them through contributing performance articulations including glissandi and a range of different vibrato styles placed in opposition with *senza vibrato* articulations to define an axis from grouping/blending with the drone–based sources to segregation of materials around the vibrato pitch. As such, even if the subtlety of some of the instrumental microtonal figurations may be lost in the context of a brief rehearsal (particularly those intervals which comprise smaller deviations and/or are more unfamiliar), a structural impression of the piece's harmonic series microtonality is still provided through the attention–based foregrounding of nearby microtonal regions within the tape part. In doing so, the piece articulates a multi-part consonance–dissonance concept, based on consonance as being defined in sensory terms (as either perceptual segregation/clarity or as perceptual fusion) or via a functional position/level within a cognitive tonal hierarchy. This multi–part model of consonance/dissonance describes a wide range of structuring possibilities for microtonal musics which may reinforce the salience of individual intervals or the cognition of larger–scale musical structures based on these materials, thus offering a descriptive framework which can apply to a range of musical cases involving these materials.

7.7 Conclusion: Practice–led Insights into Microtonal Composition

The present portfolio outlines a number of distinct approaches to the compositional structuring of microtonal materials with a view to ahieving perceptual/cognitive salience for these novel materials. *Infraction* sees an approach which is based on the use of relatively extended tones combined with tuning guide tracks for the exploration of the distinct sonorous results of small microtonal variations within broader pitch/interval regions (analogues). The monotonic five–second note articulations in the microtonal violin and viola lines are designed to engender a singular focus on the sonorous results of these variations; the melodic progressions within individual parts are also structured on the basis of prioritising movements based on microtonal intervals rather than movements which perform larger leaps. This is intended to contribute to the focus of a listener's attention and perspective on microtonal intervals rather than larger intervals within the piece's scale, which may be obtained through the same scale–construction process, but which may be heard as an analogue of a familiar chromatic interval rather than focussing on any possible microtonal offsets from the learned interval's intonation. Based on this type of articulation, *Infraction* explores the complex sonorous effects and their variations as a variety of microtonal melodic offsets are 'tested' against other intervals (some of which are microtonal in extent, some of which are larger). The resulting sonorities may take the form of strongly fused timbres, as the harmonic relations between intervals and coordinated start times articulated by similar timbres leads the perceptual fusion process to group the sources together as if derived from the one source. However, in some cases, distinct beating effects which result from interactions between harmonics may result in significant perceptual segregation effects, drawing attention to individual frequency components. Although the materials which produce this result may themselves be normally considered dissonant (based on definitions of periodicity or critical band overlap), the perceptual segregation effect may produce a perceptual focus on single frequency components which may therefore be judged as 'texturally consonant'.

The second piece in the portfolio, *Flatlining*, takes a different approach, focussing on a smaller number of microtonal/alt. tuning analogues of standard chromatic divisions. The focus on smaller numbers of intervals was designed to facilitate relatively rapid ear–training during rehearsal processes and was also based on the knowledge that the piece would involve a significant degree of rhythmic complexity, the concentration upon which might undermine the production of a wide range of microtonal interval variants. The piece was intended to explore different types of percceptual grouping and segregation effects (providing the two disitnct axes of consonance/dissonance definitions discussed above) through its microtonal materials; however, without significantly brighter timbres and/or extended durations, this aim was not realised to a significant extent. As a result, functionally–based consonance/dissonance associations of the various microtonal materials could be said to dominate. Furthermore, the rhythmic complexity of the piece worked against the accurate rendering of the specified microtonal intervals, with the musicians tending to prioritise efforts to more accurately render materials in the domain which may be more apparent to the audience, to the significant detriment of the microtonal materials (which, in some cases, were bracketed out almost completely). As such, *Flatlining* sounds a cautionary note in relation to the use of microtonal/alt. tuning materials in cases of relatively significant rhythmic complexity (unless, perhaps, the musicians in question enjoy a high degree of familiarity with microtonal materials).

Angels at the Shotgun Wedding explores microtonal materials in a manner which is quite similar to *Infraction*, focussing on a range of microtonal analogues of familiar interval divisions which are subject to melodic and chordal variation with a view to highlighting their salience through distinct sonorous results based on perceptual grouping or segregation effects. To further highlight the sensory-based distinctiveness of the intervallic materials, different drones based on harmonic series materials are provided for each different movement. These drones contribute to both perceptual segregation effects (through harmonics from the instrumental parts being perceptually segregated as continuations of the drone part) and to the delineation of distinct tuning–based spaces which, through their relative density and the amount and rates of their internal beating effects, which contributes to the affective resonances of the different movements. The preponderance of significantly bright (and mildly distorted), amplified timbres along with the increased density of microtonal materials arrayed through the five guitar parts contributes to the interaction and hence segregation potential of upper partials/harmonics within the resulting sonorities. Furthermore, the guitar's tremolo articulation results in an increased tendency towards stream segregation of the relevant instrumental part. Thus, intervallic combinations which, in other contexts, might be more likely to fuse strongly (due to relatively spaced harmonic intervals) or produce clusters with ambiguous pitch percepts and significant within–cluster beating effects, are in cases such as this successfully perceptually segregated, producing a perceptual clarity—i.e. as 'pure tones' are 'heard out' from within the clusters' materials—which may be associated with consonanceand therefore offers a new consonance/dissonance definition.

Making Ghosts from Empty Landscapes is the only piece in the present portfolio which utilises quartertonal materials. It does so with the aim of specifying a more limited range of relatively large microtonal intervals which may be easily reproduced after a short rehearsal time. The piece also investigates further aspects of instrumental articulation and the construction of drone–based textures in the tape part which contribute to perceptual grouping and segregation effects. Although these quartertone materials were originally intended to simply offer a finer degree of melodic quantisation, based on an aesthetic preference for such subtle gradations obtained through the other microtonal practice over the course of this project, an examination of the structure of these materials in the melodies of the erhu part reveals that this is not its primary function. With the exception of the final gestures of the this part, the rest of these melodic structures appear to be more generally based on providing quartertone offsets for melodies whose internal structures are based on more traditional diatonic/chromatic structures. As such, these melodic offsets may be conceptualised as contributing to the functional distinctiveness of these materials through increased tonal–hierarchical distance; my own listening analysis tends towards such an association.

A Space for Tension is similar to the previous piece in that it investigates the potential for defining grouping and segregation through the use of different instrumental articulations in combination with drones in the tape part based on harmonic series intervals. Being mindful of the limited rehearsal/familiarisation time involved in such an international performance, the piece makes more extensive use of the taped drones for dynamic structural ends than is the case in *Angels at the Shotgun Wedding*. The instrumental parts are designed to provide an approximation of some of the harmonic materials: the working assumption was the even comparatively coarse microtonal approximations in these parts would still be likely to draw attention to relevant intervals (or intervallic regions) within the tape part through perceptual segregation effects and/or through more typical processes of attention–based foregrounding to the relevant pitch–regions. Although previous experience (with *Making Ghosts from Empty Landscapes*) had indicated that the erhu player could effortlessly execute microtonal materials at the quartertone level and the rehearsal process for the present piece was promising in terms of reproduction of intervals close to specification, the pressures of relatively limited rehearsal time coupled with an extensive (over one hour) concert programme of new pieces meant that many of the microtonal intervals were only approximated in performance. Nonetheless, based on the anticipation of this eventuality in the piece's specification, the overall results were of a viable rendering of the piece which highlighted relevant microtonal intervals through the interplay between the live and tape parts. As a progression from the earlier pieces in this portfolio, the piece also outlines a multi–faceted consonance/dissonance definition, based on the following factors, two of which are related, with the other being drawn from a separate process.

1(a) perceptual segregation processes contributing to a perceptual consonance definition through the perceptual 'purity' of single–frequency components

1(b) a consonance definition based on perceptual fusion (based on chordal or stronger timbral grouping processes)

(2) relative consonance/dissonance judgements via the position of the materials within a more congitively–based tonal hierarchy.

This piece therefore offers an example of a comprehensive model of consonance/dissonance potentials within microtonal practice.

The pieces within the enclosed portfolio provide a variety of perspectives on microtonal practice. Whilst there are a number of distinct compositional priorities embodied within the different pieces, they are unified by an engagement with the perceptual and cognitive configurations which may contribute to the salience of microtonal materials. The portfolio discussed has examined various issues in microtonal composition from a practice–led perspective, which has not only informed the perspectives advanced over the previous chapters of this thesis, but has also led to a re–examination of the cognitive model proposed in chapter six. It thus forms a practice–led component of this project which investigates a relatively representative variety of microtonal cases for potential contributors to the perceptual salience and larger–scale structuring of microtonal materials, resulting in the statement of a set of consonance/dissonance concepts which encompass the results of a variety of microtonal practices.

7.8 Chapter Summary

This chapter reflects on the compositional component of this PhD, with a particular focus on the manner in which various configurations of microtonal materials (and presentational conditions) may contribute to their perceptual/cognitive salience. *Infraction* uses monotonic presentations of sustained tones to highlight sonorous effects (and, hence, sensory–based/ecological interval defintionis). *Flatlining*, in its use of alt. tuning chromaticism, engages with just intonation materials in a more functionally–based context, with the functional element coming to dominate the piece’s reception (in part due to the prioritisation of aspects other than intonation by the instrumentalists in the first performance, leading to some intervals being rendered in approximated form). *Angels at the Shotgun Wedding* applies a variety of more extreme musical conditions to just intonation–based microtonality: bright timbres through amplification and extended durations are used to contribute to the creation of unusual sonorous effects on the basis of perceptual grouping and segregation processes. In some contexts, this piece also suggests the influence of more cognitively–based functional concerns, whereby materials which exhibit a relative degree of perceptual clarity may nonetheless possess dissonant assocations related to relative positions within a cognitive tonal hierarchy. In contrast to the other pieces in the portfolio, *Making Ghosts from Empty Landscapes* specifies quartertone–based microtonal materials, thus focussing its investigations on functional aspects of microtonal materials and, in so doing, finding some corroboration of the functional delineations noted by Hába and suggested in experimental findings by Jordan (1987). *A Space for Tension* arranges its drone–based microtonal materials on the basis of spacing/density and slow/fast periodicity with respect to each other. This exploration is coupled with the exploration of the role of instrumental articulation (in particular, different styles of vibrato) in encouraging blending or individuation of these materials with the background drones. In doing so, this piece crystallises a set of consonance/dissonance cases which can encompass cases of perceptual and cognitive distinctiveness which occur through the use of microtonal materials:

(1) consonance judgements based on (1a) perceptual segregation or (1b) perceptual fusion

(2) relative consonance/dissonance judgements based on position of the materials within a cognitive tonal hierarchy

The presence of these diverse bottom–up and top–down factors in consonance/dissonance judgements suggests that a model of relations between microtonal materials which incorporates both factors—such as the present model—is advisable. More broadly, this chapter has suggested and reflected on various strategies for engendering salience for microtonal materials.

Chapter 8: Conclusion

8.1 Summary of Approach and Contributions

This thesis documents a process of research which has led to the creation of theoretical models of how microtonal materials are structured in perceptual experience. Although its primary focus is on microtonality which is based on just intonation, it has also investigated some of the rationales and implications behind tempered subdivision approaches, such as the use of quartertones. The research process has been based on a number of distinct strands: (1) analytical surveys of previous microtonal practice (along with historical and thematic contextualisation); (2) an engagement with psychological theories of perception and cognition from the perspective of their potential contribution to the understanding of microtonality; and (3) the creation of a portfolio of microtonal compositions which has informed the refinement of the microtonal theories contained herein on a practice–led basis.

During the process of research, it became apparent that there was a gap in the literature relating to the broad–based historical and thematic contextualisation of twentieth–century microtonal practice. Although the composers treated in this thesis have been covered by various studies as individuals, more comprehensive narratives are missing regarding the emergence of twentieth–century microtonal practices, perhaps partly due to the wide variety of approaches to microtonal divisions (which sometimes entail fairly distinct analytical perspectives). Therefore, the present work, whilst indebted to previous studies of individual composers, their own theoretical exegeses and/or accounts of particular microtonal methods or individual works, makes a contribution in developing such a narrative in the context of the overall research project. Although coverage of a relatively comprehensive range of practitioners can only be maintained for some of the earliest exponents, the account aims to include some of the primary twentieth–century microtonal specialists who can be taken as having either representative or particularly distinctive approaches.

Beyond this contextualisation, the thesis makes a further contribution in interrogating the assumptions behind the microtonal theories and practices of these practitioners with a view to developing a more unified theoretical framework for microtonality. In many cases, the theories of the composers themselves have provided a fruitful starting place for the elaboration of a psychologically–grounded theory of microtonality, for many of them were quite aware of the profound perceptual (in the broader sense) implications of the compositional deployment of such materials. The exponents of just intonation who are discussed in chapters three and four (Partch, Johnson, Young and Tenney) have all engaged with the field of psychology at various points in their compositional explorations and related theorising. Although some of their explanations are not fully consistent with more recent understanding of psychology (or the composers in question may have had an incomplete understanding of some of the theories which they have engaged with), the investigation of their theoretical perspectives has been informed by two clear currents which can be identified in their approaches. On the one hand, Partch and

Johnston prioritised formal/functional spatial models of relationships between microtonal materials, with Tenney (1983) offering an updated and more extensive psychologically–grounded theory as an elaboration on the previous work. On the other hand, Tenney and Young engaged with ecologically–informed models. These twin perspectives have informed the development of this thesis in its engagement with the field of psychology with a view to the creation of a more unified model. This model encompasses top–down cognitive structures (which may relate microtonal materials to each other) alongside an awareness of the impact of bottom–up sensory factors and ecological contexts which may define and refine relationships within the top–down model.

The theory–focussed chapters (five and six) make a contribution in drawing together a variety of perspectives from psychology within a comprehensive account which treats their relevance to microtonal practice. Although the study of sonic and, more particularly, musical, phenomena from the perspective of psychology has been the subject of many existing publications, that field's priorities have tended to lie with explanations for generalised (i.e. common practice) approaches rather than more particular cases. As a result, microtonality becomes marginalised in these accounts, if it is referred to at all, and these theoretical perspectives may not address the particular features of microtonal approaches which have the potential to contribute to their cognitive–perceptual salience. Taking both a practitioner–led and (personal) practice–led approach to the explanation of the relevance of various features of microtonal music and investigating insights derived from these perspectives using models based on contemporary psychological research, the present thesis seeks to redress this balance.

The portfolio of microtonal compositions has contributed to the refinement of the theoretical perspectives on microtonality which are advanced in chapters five and six. Chapter seven discusses the individual characteristics of the pieces, which comprise a relatively representative range of techniques (just intonation and quartertone approaches) whilst maintaining an overall focus on a sonority–based rationale for microtonal salience which is informed by ecological perspectives. This chapter therefore makes a contribution in relation to the advancement of my own theoretical perspective, in addition to the contribution embodied in the pieces as creative explorations and evocations of various aspects of microtonality in contemporary musical practice, along with reflections on various logistical concerns which may be encountered in performances which utilise these types of materials.

8.2 Summary of Conclusions: Historical Approaches and Theory

The conclusions of this research will now be presented and contextualised. Firstly, a number of discernible trends and currents are present in the work of the microtonal practitioners discussed in chapters two to four.

(1) The earliest twentieth–century microtonalists favoured approaches based on the subdivision of existing tempered intervals, consistent with the overarching philosophy of the ubiquitous 12TET scale.

(2) As these microtonalists sought to explain the role of these new materials, they developed perspectives which could be characterised as incremental developments on existing music theories and practices. As such, their interest was primarily in relation to the applicability of microtonal materials in providing distinct functional roles rather than their sensory distinctiveness (with the notable exception of Ives). One basic organisational impulse related to chromaticism, with Hába proposing a *bichromaticism,* whereby chromatic scales (and resulting melodies) were organised into microtonally–offset and non–offset variants, with resulting functional implications. In addition, both Hába and Wyschnegradsky espoused the use of microtonal offsets within chords, with the expectation of distinct functional roles as a result of such alterations.

(3) The microtonalists who were concerned with just intonation approaches were of a later generation and tended to favour theories and practices

which were less directly indebted to existing functionally–based theories, often prioritising the sonorous distinctiveness of the new divisions.[44]

(4) The just–intonation–based microtonalists could be characterised as having replaced the theoretical context of existing ideas surrounding functional harmony with new contexts influenced by contemporary psychological research (although Partch, Jonston and Tenney were indebted to earlier music theory concepts, such as the *tonnetz* model).

(5) The just intonation practitioners have tended to favour models of two types: either functional/geometrical models relating to numerical descriptions of intervallic materials or models (either implicit or explicit) which relate to sensory–based or ecological structures. Partch and Johnston have both favoured the former type of model, although both have sought psychological contextualisation for their work and Partch also created a sensory–based model of consonance/dissonance with functional annotations (his 'One–Footed Bride'). Tenney (1983) also engaged with multidimensional functional models, although he assumed that cognitive processes would lead to a rationalisation of multidimensional proliferation. However, Tenney also used what might be viewed as an ecologically–based model (Tenney, 1988/2001) in his composition *Critical Band* and a related general philosophy of 'perceptualism' pervades much of his music and that of La Monte Young, whose performance and installation works offer insights into the potential of ecological and embodied modes to ground microtonal experience.

---

[44] Although Partch's presentation of materials was not always structured around the most favourable of conditions to examine sensory distinctiveness, his studies into the consonance and dissonance of his scale steps, embodied within the 'One–Footed Bride' bespeak a high degree of engagement with this issue.

In addition to the utility of the perspectives above in relation to the music by those particular composers, the issues accounted for through their diversity of practice provide useful contributions to the development of a more comprehensive model of microtonal music. Furthermore, the variety of approaches which the just intonation exponents, in particular, espouse, highlights the delineation of key questions for any psychological model of microtonal perception, such as whether bottom–up/sensory considerations/ecological aspects and/or top–down cognitive/formal structures are significant in this regard.

The chapters which advance a psychologically–grounded theory do so on the basis of a broad–based treatment of pitch perception and cognition which includes categorisation processes, memorisation processes (and their potential capacity limits), sensory perception and cognitive models of relationships between pitch materials.

Potential short–term memory capacity limits are investigated in chapter five, based on Miller (1956), which is the origin of many criticisms of microtonal music's proliferation of scale materials, such as McAdams (1989). However, closer examination of Miller (1956) suggests that if pitch is treated in a non–unidimensional fashion, effective capacity limits may be increased through processes of multimodal cross–referencing (which may contribute to enhanced element–capacity through memory chunking processes). In addition, the phenomenon of absolute pitch is investigated as a case which might corroborate microtonal practices for at least a subset of the general population (Burns, 1999, p.223; Levitin, 1994, cited in Levitin, 2002, pp.304–6). Following this, the phenomenon of categorical perception is investigated, with reference to whether the organisation of pitch materials may be considered to be based on sensory factors (Pastore, 1987; Scharf et al., 1987), cognitively–based learned factors which entail an intervallic relativism which is a correspondence of the Whorf/linguistic relativism hypothesis (Kay and Kempton, 1984), or a combination of both. Experimental findings in relation to microtonal materials by Ferrer–Flores (2007) are taken as suggesting that sensory factors play a significant role in interval identification. Based on the processes outlined in Pastore (1987) and Scharf et al. (1987), in addition to the experimental findings of Ferrer–Flores (2007), it is concluded that there is a strong case for the importance of sensory–based factors in microtonal perception, implying that laboratory studies which do not take account of the ecological context of complex tones and their perceptual interactions may tell us little about actual microtonal perceptual capabilities in relevant musical cases. As a result, this part of the account conforms broadly to a Gibsonian perspective, asserting the central importance of ecological context.

Cognitively–based theories are examined in chapter six for their potential contribution to the cognitive–perceptual validity of microtonal materials. Hierarchical models, such as that proposed by Krumhansl (1979, 1990, 2005; Krumhansl and Shepard, 1979), suggest a potentially non–sensory modality whereby scale structures with more than 7+/-2 elements might be perceived in a structured fashion, although the models do not expressly treat microtonal materials. However, Jordan (1987) followed a similar method to Krumhansl and Shepard (1979) and found some evidence of cognitive–hierarchical distinction for quartertone materials (on the basis of similarity judgements). Although Krumhansl (1990, pp.115–6) briefly discusses Jordan's findings, she does not pursue the question of the place of microtonal materials in such a hierarchy through an appeal to 'the general acceptance of equal–tempered tuning'. In contrast, the present project argues that Jordan's findings are potentially significant in relation to describing microtonal possibilities and constructs a version of Krumhansl's tonal hierarchy cone which adds an extra functional level on the basis of the Jordan (1987) results.

The potential similarity which this thesis notes between Lerdahl's (2001) elaboration of the Krumhansl tonal hierarchy model and the ecological structure of the harmonic series leads to a further investigation of ecological/bottom–up contributions to conceptions of musical harmony. The ecological models proposed by Butler (1989) and Parncutt (1989) are also examined in terms of how these might relate to contemporary microtonal practices. These bottom–up perspectives then contribute to the advancement of a unified model which organises pitch materials within a framework whose structure and internal relationships are variously related to ecological structures (the harmonic series), cognitive structures (the Krumhansl tonal hierarchy models) and ecologically–derived schemas derived from embodied cognition (Brower, 2008; Lakoff and Johnson, 1999). The result is the embodied model outlined in figures 61–63 (volume 1), comprising a functional division which is broadly derived from the harmonic series, but which is also the subject of potential adaptation on the basis of functional/cognitive organisation (i.e. top–down) and sensory (bottom–up) factors. It also treats metaphorical mappings of grounded versus diffuse, enriching the formal and sensory structures with embodied meanings and associations. It is argued that, based on the importance of sensory factors discussed in chapter five, such a framework is the ideal form for unifying a variety of sensory and cognitive factors and processes in the modelling of perceptual engagement with microtonal materials.

8.3 Practice–led Investigations and Extensions of Theory

8.3.1 Sensory–based Contexts and the Extension of Consonance/Dissonance Definitions within the Composition Portfolio

Further conclusions can now be advanced, based on the refinement of the theoretical model through practice–led insights derived from the project's process of compositional exploration. As previously discussed, the composition portfolio has taken as its primary focus materials which contribute to cases of perceptual distinctiveness. Although it has variously investigated both tempered and just intonation microtonal approaches, its primary concern is for just–intonation–based materials articulated through relatively extended duration: a set of conditions which highlight the relative periodicity of intervals, as well as contributing to the delineation of perceptual grouping and segregation effects through processes of auditory scene analysis.

From the theoretical perspectives outlined in the rest of the thesis, it is assumed that the primary case in support of the cognitive–perceptual validity of microtonal materials is derived from careful adherence to the foregrounding of these types of sensory–based distinctiveness and structural configurations related to an ecological context. This has led to the composition portfolio's exploration of a number of distinct consonance/dissonance concepts or definitions; after Tenney (1988). These definitions, which apply to the majority of the pieces, are based on the following cases, expanding on the definitions proposed for *A Space for Tension* in chapter seven:

1(a) The perceptual segregation of elements through auditory stream segregation processes of either coherent single–timbre sources (or sub–groups of partials/harmonics), contributing to consonance by suppressing the tonal interaction effects associated with sensory dissonance, or through the perceptual segregation of single partials/harmonics which are thus heard as 'pure' tones and, hence, timbrally consonant in sensory/perceptual terms.

1(b) The perceptual fusion of elements such that sources which are generated separately on the basis of their adherence to harmonic series tunings and suppression of details which might contribute to perceptual individuation, such as different vibrato or other modulation rates. This perceptually–based coherence, related to the tonal fusion process (which integrates the frequency components of harmonic timbres) is based on more traditional earlier definitions of consonance/dissonance. However, stricter adherence to harmonic tunings can produce a timbral fusion effect even more pronounced than more frequently encountered cases of chordal fusion.

(2) The treatment of salient intervallic materials in a tonal hierarchy context. Individual intervals (or combinations of intervals) which

approximate relatively low–order harmonic interval relationships with a given tonal centre will be perceived as consonant in relation to a proximity to this tonal centre. They will be perceived as dissonant if individual intervals or groups of intervals do not exhibit such straightforward potential generative/procedural connections with the centre.

Cases 1(a) and 1(b) thus provide distinct consonance/dissonance definitions which nonetheless relate to different parts of a single modality derived from bottom–up perceptual processes. Case (2) is related to top–down cognitive processes and frameworks. These cases can separately account for a different consonance/dissonance functions for a broad range of musical materials, including those based on microtonal sonorities.

8.3.2 Extending An Ecological and Embodied Model of Microtonal Relations (Unifying Sensory and Structural Concerns)

However, as discussed in chapter six, top–down cognitive concerns and bottom–up perceptual concerns have the potential to be unified in a single model which is structured on an ecological and embodied basis. The benefit of such a model for musical cases such as many of those within the enclosed portfolio, which may be thought of as containing competing cases (or dimensions) of consonance/dissonance definitions, is that it can provide a single unified descriptive framework for these processes of assessment. The model of microtonal perception and cognition proposed in chapter 6 (figure 63) already provides a framework which encompasses both bottom–up perceptual salience factors (for contributing to interval definitions) and top–down reinforcement of learned category judgements.

This structural model has the potential to be combined with a process which performs a virtual–pitch–style Terhardt/Parncutt resolution of groups of intervals to a single tonal centre at the lowest available functional level, hence providing a bottom–up means of elucidating the position of the composite result for a coherent group of intervals within the tonal hierarchy. The ease (or lack of ambiguity) with which simultaneous intervallic materials are resolved in this fashion could provide a definition of consonance. This aspect of the model also clearly embodies the 'grouping by low–order harmonic relationships' potential of timbre–style grouping as its originating corollary, with the more bottom–up sensory/timbral aspect of this judgement providing a stronger–than–chordal grouping which could resolve such materials to a single interval of origin. However, as explored in the portfolio, certain presentational circumstances in microtonal music may sometimes produce simultaneous groups of pitches which enjoy significant individual salience, being separated into separate auditory objects or streams as a result of auditory scene analysis principles. On this basis, these intervals may be less likely to contribute to a global Terhardt/Parncutt tonal resolution process if they are allocated separately in perception (i.e. if some form of auditory stream segregation occurs). In cases such as this, they might simply be parsed based on the basis that each individual interval possesses a distinct hierarchical/distance–based relationship with a piece's tonal centre. Overall *cognitively–based* consonance judgements for these groups of materials would thus depend on the relative number (or weighting) of distinct pitches (or, if some are chordally or timbrally grouped and rationalised, pitch–groups) at lower levels in the model. In particular, this may explain the conflicting consonance/dissonance judgements (from sensory and cognitive perspectives) for some of the perceptually segregated microtonal groupings in *Angels at the Shotgun Wedding* (such as the material at the start of figure 96), whereby the cognitive–functional perspective on materials which is perceptually–segregated produces an impression of dissonance which is belied by the sensory–based clarity of the materials.

Furthermore, from another perspective, this perceptual salience (of individual materials) may itself become a competing bottom–up definition of consonance, whereby the perceptual clarity of distinct elements is more globally significant. Such clarity may be conceptualised within this model either through increased distance between their positions on the pitch–chroma cycles (within relevant functional levels) or between different functional levels. This point may be articulated through an extended representation of the embodied microtonal model (figure 148, below, next page).

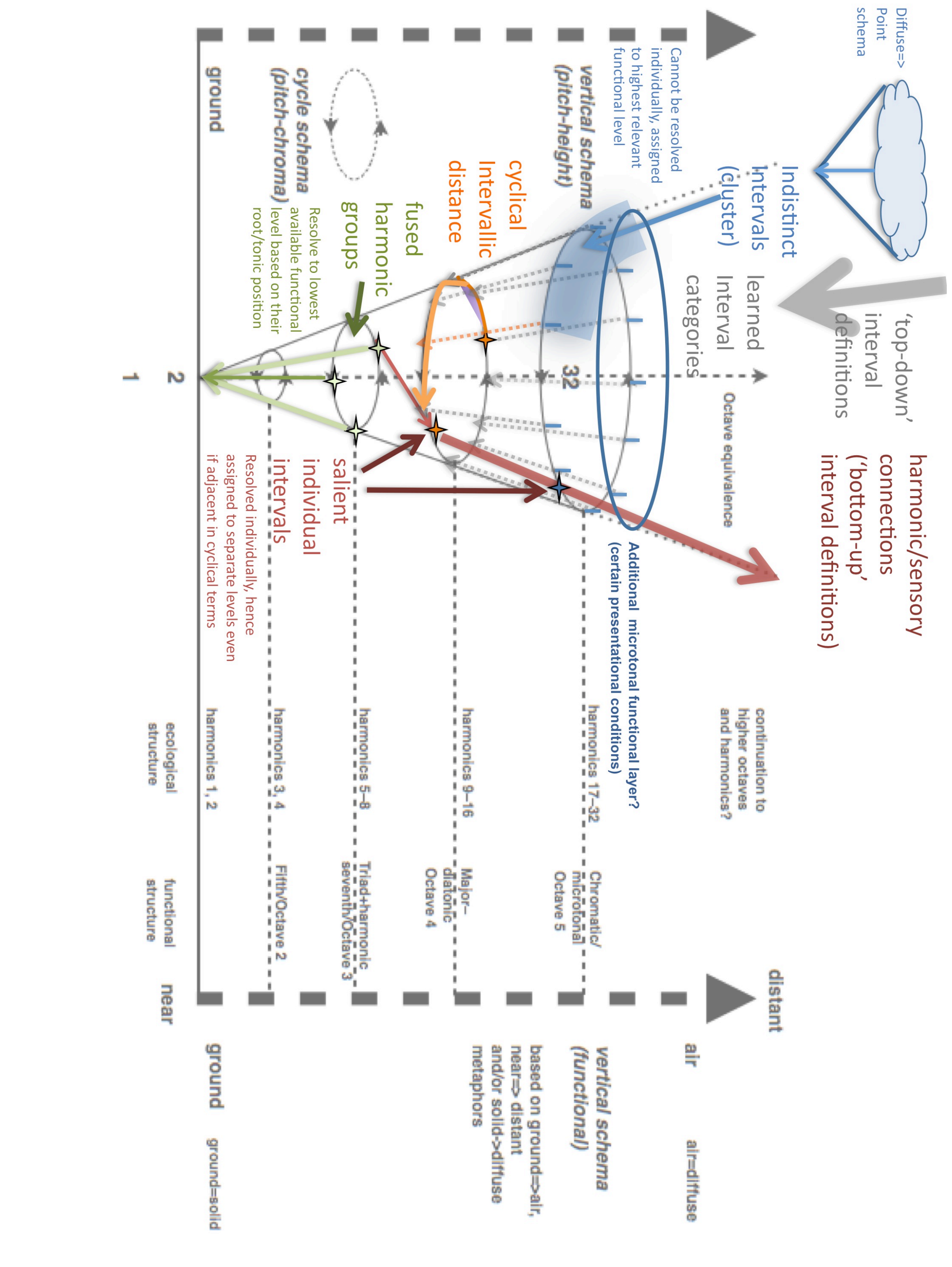


Figure 148: Revised embodied/ecological model of consonance/dissonance, incorporating a diffuse/point source schema as another consonance/dissonance axis

In terms of an embodied/ecological metaphor, such clarity may be seen as part of a *diffuse–to–point* image schema. If a number of intervals coincide within close proximity on a particular cyclical–level, they are likely to produce proximity–based sensory interaction effects which may impede the clarity of their perception (and may make it difficult to resolve them in relation to a tonal point of origin, hence the applicability of the *diffuse* metaphor). In such a case, the ambiguous materials would all be assigned to the highest applicable functional level as a diffuse 'smear' within a given region, e.g. a cluster of *C–C#–D* would be assigned to the chromatic level in spite of the presence of the originating–level *C* and diatonic–level *D*. However, if these materials were spaced by octaves, some of the materials could be offset to lower functional levels based on this octave spacing, taking into account the increased sensory clarity as providing greater potential for clear resolution of elements to lower functional levels (and thus highlighting their greater relative consonance through a diffuse–point schema axis).

Thus, sensory–based perceptual clarity judgements could be conceptualised within this model as being represented by a combination of cyclical distance and relative hierarchical position within the functional levels. In contrast, sensory dissonance cases may be modelled on the basis of diffuse smears within a single higher functional level, with adjacent notes assigned to functional levels relating to their scalar distance from each other. Diatonically–adjacent materials may occupy a region within the diatonic level, chromatically–adjacent materials may occupy one within the chromatic level, whereas chords which contain pitch–chroma–materials offset by octaves may thus resolve their component notes to different hierarchical levels, with the relative spacing in both of these dimensions embodying perceptual clarity. In addition, more complex/unusual cases which contribute to the clear perceptual segregation of individual intervals would be treated in the same manner. Thus, for example, a chord of individually salient microtonal intervals which do not easily resolve to a single tonal centre (in chordal or timbral grouping terms) would nonetheless embody its perceptual clarity in the distribution of its materials across different hierarchical levels.

Such a model has the benefit of providing a unifying basis for the conceptualisation of microtonal materials derived from a number of different structural approaches. The sensory salience of certain microtonal combinations (i.e. sonorous just intonation cases) is incorporated, in addition to the treatment of cognitively–based judgements of relative hierarchical position/proximity. Significantly, however, such a model also treats the manner in which some alternative tuning intervals (i.e. microtonal offsets from familiar interval specifications) may, depending on presentational circumstances conceptualised as occupying higher functional levels or may be 'grounded' to simpler functional roles (through approximation due to learned convention or influence drawn from contextual factors) and hence *gravitate* (to use an ecologically–based cross–domain metaphor) to lower levels following such cognitive–perceptual quantisation processes. For example, a Pythagorean major third is likely to be heard as a version of the major third in many contexts, but the increased sensory dissonance or melodic microtonal offset (and lack of familiarity with such an interval specification) may cause it to be accorded a higher functional level (i.e.

may cause it to be heard as a microtonally–distinct interval, hence occupying a more distant functional level than the harmonically–based major third). Such judgements in relation to microtonal variants near the limits of discrimination are likely to be subject to context to a significant degree. A Pythagorean major third heard without a just major third elsewhere in a piece (or other learned major third such as the 12TET major third) would be defined in this model on the basis of its close (if approximate) relationship to the learned category definition and hence assigned its functional level. In a similar fashion, other microtonal materials which comprise close analogues of familiar/learned categories may perform similar dual–roles, i.e. may be defined as within the familiar category (and hence, that category's functional level) until a point of distinction is drawn attention to through presentational comparison (through microtonal variations within a given interval prototype range, such as those which form the basis of *Infraction*'s materials).

Although this current model lacks specificity with regard to how some of the consonance/dissonance judgements it attempts to encompass may be specifically enumerated, as noted earlier, it has the significant benefit of providing a framework which is plausibly based on ecological and embodied structures. In doing so, it has the potential to explain the relationship between the wide variety of perceptual and cognitive cases relating to microtonality found in exploratory contemporary music such as the work of the composers discussed in chapters three and four, in addition to the relatively diverse cases of the enclosed portfolio of compositions.

8.3.3 Summarising the Final Ecological/Embodied Microtonal Model

To summarise, this final model (see figure 148) is broadly based on the ecological structure of the harmonic series, articulated through a variety of embodied image schemas as structural components and metaphorical mappings. The cognitive processes which occur within this structure further contribute to interval definition and assignment of materials to different points within the functional hierarchy. The model therefore blends the 'traditional' top–down cognitivist approach with structures and processes which are based on bottom–up factors and it is argued that this results in the provision of a suitable cognitive 'space' for the interaction between sensory and cognitive factors in structured perception. These main structural definitions and processes will now be outlined and briefly discussed with regard to their microtonal significance.

(1) The model composes a *vertical schema* (corresponding to the pitch–height dimension) which is further elaborated into a functional hierarchy mapped on the basis of a ground–to–air or point–to–diffuse axis. Materials which are predominantly situated at higher functional levels (such as a preponderance of microtonal configurations) may be situated further away from the grounding level provided by the relevant tonal centre.

(2) The model also comprises *cyclical schema,* providing a representation for relative intervallic spacing or resolution–through–quantisation within different functional levels.

(3) The overall cognitive structure is elaborated from the *ecological structure of the harmonic series*, articulated through a combination of vertical schemas/metaphors and the cycical schema. However, as

discussed in chapter six, certain presentational contexts and/or degrees of exposure may facilitate the elaboration of higher functional levels specifically for microtonal materials, thus deviateing from the strict adherence to the ecological harmonic series template.

Within this structural model, the definition of intervals may occur on the basis of both top–down and bottom–up processes.

(4) *Interval definition: top–down* (learned categories, consolidating cognitive–functional distinction in certain contexts), corresponding broadly to quantised (quartertone–based) functional categories within the cyclical schema at the microtonal functional level; quantised to relevant function–intervals at other levels.

(5) *Interval definition: bottom–up* (distinctive/salient sensory–based cases) corresponding to *nodes* at relevant functional levels, which may be connected in formal/generative terms to nodes at different functional levels and in different cyclical positions.

As noted in earlier chapters, particularly salient conditions of intervallic combination can be seen as providing a Gibsonian/ecological basis for the individuation of microtonal categories. The exploration of distinct perceptual cases in microtonal music is a key focus of the composition portfolio and, in addition to contributing to interval definition, these sensory conditions have been discussed as significant in relation to a number of consonance/dissonance definitions which derive functional definitions from bottom–up/sensory bases:

(6) *Dense clusters* (i.e. which do not engender the salience of individual pitches) would be assigned to higher functional levels, with (metaphorical) mappings of *diffuse* 'smears' across cyclical space at

these higher levels in spite of the presence of materials which would otherwise resolve to lower functional levels.

(7) *Materials which exhibit strong chordal fusion* would be treated as a group and resolved to lower functional levels, based on a Terhardt/Parncutt–style process. (In addition, in terms of auditory scene analysis grouping processes, close adherence to just intonation specifications which engender harmonic series relationships between materials may lead to such materials exhibiting stronger tonal fusion as if they derive from a single coherent harmonic source, resulting in the same functional result for the normal chordal grouing case.) In terms of metaphorical mappings, the identification of strong chordal fusion relates to metaphors of *groundedness* or clearly situated *point sources*, as opposed to *air/diffuse* for stimuli which do not easily resolve in this manner.

(8) *Individually salient pitch materials* (whether due to registral spacing or perceptual decomposition effects) may be assigned as separate instance*s* (rather than grouped/resolved materials, as in the case above) to relevant functional levels.

As such, this practice–informed refinement of the model benefits from the potential to integrate a range of consonance/dissonance cases which include the more unusual perceptual by–products encountered through the use of microtonal materials. Thus, the structural importance of sensory distinctiveness within microtonal music is highlighted on the basis of its contribution to the definition of both interval/scale structure and to more global hierarchical structures and various perspectives on consonance/dissonance distinctions, articulated through an interplay between bottom–up and top–down processes.

8.4 Possibilities for Future Development

This thesis raises a number of possible avenues for future research which are beyond the scope of the present work. Firstly, the compositional component has drawn attention to certain logistical difficulties which may present themselves in microtonal performances by musicians who have not had sufficient time to acclimatise to the new pitch divisions. In this regard, performance systems which could provide relevant pitch cues at key points in a score could be of benefit and would be relatively easy to implement. Indeed, the development of software–based microtonal performance interfaces is a further example of such a possible future development. An interface (or contextual display in response to pitch–data input) which utilises a version of the proposed embodied/ecological model in order to provide insight into the potential structural aspects of microtonal pitch materials chosen by a user could provide significant aid in both performance and compositional/pre–compositional contexts. A touchscreen–based interface based on a cyclical paradigm, utilising this approach, would therefore have the potential to unify interaction modality with the suggested cognitive model, resulting in an elegant (and intuitive) design.

Secondly, in relation to the theoretical model itself, more refinement would be of benefit regarding the functional/hierarchical divisions and the conditions under which they may be subject to adaptive behaviour. Although the initial model (figure 61, volume 1), based on the originating harmonic series structure, conflated chromatic and microtonal levels, the later versions (figures 62, 63 and 148) assume that certain conditions may contribute to the delineation of a microtonal level of functional distinction (informed by the findings of Jordan (1987)). In the pragmatic context of practical implementation, a user of a software interface based on this model could choose such a functional distinction based on their own estimation of its significance. Furthermore, context–dependent information could be provided regarding the selection just intonation or tempered interval types, allowing a user to apply different types of quantisation or to gradually adjust pitches towards a given intervallic target. A tonal centre could be specified in advance, or a key–finding algorithm might be employed (if some form of reductive process was applied to the incoming microtonal materials).

However, beyond the more practical implications for musicians and composers, it is suggested that microtonality warrants a renewed engagement from psychologists in order to settle some of the questions chronicled herein. The tonal hierarchy models have provided researchers with useful theories of music based on standard divisions, but the findings of Jordan (1987) raise the possibility that some microtonal intervals may be structurally significant in a functional sense, in addition to the pressing question of how to pursue studies of music cognition beyond common practice music in ecologically valid contexts.

Finally, it is hoped that the ideas described in this thesis will contribute to the creation of microtonal music which is informed by a greater awareness of its unusual perceptual and cognitive landscape.

Bibliography

Anders, T.E. and Miranda, E., 2011. A Computational Model for Rule–Based Microtonal Music Theories and Composition. *Perspectives of New Music*. 48(2).

Anderson, J., 2000. A Provisional History of Spectral Music. *Contemporary Music Review,* 19(2), pp.7–22.

Antares, 1997. *Autotune*. [Software application]. USA: Antares Audio Technologies.

Apple, 2004. Sculpture. In: *Logic Pro* [Software application]. USA: Apple, Inc.

Appleton, J., 1987. *Eros Ex Machina*. [CD] In: Mathews, M. and Pierce, J.R., ed. 1989, *Current Directions in Computer Music Research*. Cambridge, Mass.: MIT.

Baddeley, A.D., & Hitch, G. 1974. Working memory. In: G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory*, (Vol. 8) New York: Academic Press. pp.47–89.

Baddeley, A.D., 1994. The Magical Number Seven: Still Magic After All These Years? *Psychological Review*, 101(2), pp.353–6.

Baddeley, A.D., 1997. *Human Memory: Theory And Practice.* London: Psychology Press.

Baddeley, A.D., 2003. Working Memory: Looking Backward and Looking Forward. *Nature Reviews Neuroscience*, 4, pp.829–39.

Balzano, G.J., 1980. The Group–Theoretic Description of 12-Fold and Microtonal Pitch *Computer Music Journal*, 4(4), pp. 66-84.

Balzano, G.J., 1982. The Pitch Set as a Level of Description for Studying

Musical Pitch. In: Deutsch, D., ed. *The Psychology of Music*. 1st ed. San Diego and London: Academic Press, pp.321–351.

Barbour, J.M., 1951. *Tuning and Temperament: a Historical Survey.* East Lansing: Michican State College Press. In 2004 facsimile edition. New York: Dover.

Battan, S.M., 1980. *Alois Hába's "Neue Harmonielehre: des diatonischen, chromatischen, Viertel–, Drittel–, Sechstel–, und Zwölfte–Tonsystems".*Thesis, (PhD). The University of Rochester.

Bauer, J., 1969. Mach Bands. *Aspen Magazine* No. 8. [Reproduced online]: Available at: <http://www.ubu.com/aspen/aspen8/machBands.html> [Accessed February 2011].

Beaulieu, M., 1991. Cyclical Structures and Linear Voice-Leading in the Music of Ivan Wyschnegradsky. *Ex Tempore: a Journal of Compositional and Theoretical Research in Music,* 5(2) [Online] Available at: <http://www.ex-tempore.org/beaulieu/BEAULIEU.htm> [Accessed 5 July 2011].

Bellamy, L., 1973. *The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University.

Benson, D., 2006. *Music: a Mathematical Offering*. Cambridge: Cambridge University Press.

Berman, D., 1999. Liner notes for Ives, C. 1924. *Three Quarter–Tone Pieces for Two Pianos*. [CD] USA: New World Records 80618.

Bharucha, J.J., 1999. Neural Nets, Temporal Composites, and Tonality. In Deutcsch, D. ed. *The Psychology of Music*. 2nd ed. San Diego and London: Academic Press, pp.413–440.

Blauert, J., 1997. *Spatial Hearing: the psychophysics of human sound* *localization.* Cambridge, Mass.: MIT.

Boatwright, H., 1960. Some "Quarter–tone Impressions" Introductory Note. In: Boatwright, H. ed., 1969. *Essays before a sonata, and other writings*. London: Calder and Boyers, pp.105–6.

Boulanger, R., 1989. *I Know of no Geometry*. [CD] In: Mathews, M. and Pierce, J.R., ed. 1989*, Current Directions in Computer Music Research.* Cambridge, Mass.: MIT.

Boulanger, R., 1990. *Solemn Song for Evening*. [Online audio recording]: Available at: <http://www.ziaspace.com/elaine/BP/BPmusic/DrB/BP2010_DrB_SolemnSong.mp3> [Accessed 10 July 2011].

Branca, G., 1983. *Symphony No. 3—'Gloria' (Music for the first 127 intervals of the harmonic series).* [CD]. France: Crépuscule, CD TWI 1030.

Branca, G., 1989. *Symphony No. 6 (Devil Choirs At The Gates Of Heaven)*. [CD]. USA: Blast First/Atavistic, 1989.

Branca, G., 2001. *Symphony No. 13—'Hallucination City' (for 100 electric guitars)* [Music composition].

Bregman, A.S., 1990. *Auditory Scene Analysis: The Perceptual Organization of Sound*. Cambridge, Mass.: MIT.

Bregman, A.S., 1993. Auditory scene analysis: Listening in complex environments. In: McAdams, S. and Bigand, E. eds., *Thinking in sound.* London: Oxford University Press, pp.10-36.

Bridges, B., 2003. *Amplified Art-Noise: Amplificaiton, Alternate Tuning and Acoustical Phenomena in the Music of La Monte Young, Rhys Chatham and Glenn Branca.* Thesis (MPhil), Trinity College Dublin.

Bridges, B., 2008. Product of Culture Clash: social scene, patronage and group dynamics in the early New York Downtown scene and the Theatre of Eternal Music. *Maynooth Musicology* 1, pp.215–244.

Brodhead, T., 1994. Ives's *Celestial Railroad* and His Fourth Symphony. *American Music,* 12, pp.389–424.

Brower, C., 2008. Paradoxes of Pitch Space. *Music Analysis*, 27(1), pp.51–106.

Burkhard, M. D. and Sachs, R. M., 1975. Anthropometric Manikin for Acoustic. Research *Journal of the Acoustical Society of America*, 58, pp. 214-220.

Bukofzer, M., 1947. *Music in the Baroque Era—from Monteverdi to Bach*. London: J.M. Dent.

Burns, E.M. and Ward, W.D. 1982. Intervals, Scales and Tuning. In: Deutsch, D. ed. *The Psychology of Music.* 1st ed. San Diego and London: Academic Press, pp. 241–270.

Burns, E.M., 1999. Intervals, Scales and Tuning. In Deutsch, D. ed. *The Psychology of Music.* 2nd ed. San Diego and London: Academic Press, pp.215–264.

Burt, W. 2007. *Algorithms, microtonality, performance: eleven musical compositions.* Thesis (PhD). The University of Wollongong, Australia.

Busoni, F., 1911. Sketch of a New Esthetic of Music. Transated from the German (unattributed). In 1962: *Three Classics in the Aesthetic of Music.* New York: Dover.

Butler, D., Describing the Perception of Tonality in Music: A Critique of the Tonal Hierarchy Theory and a Proposal for a Theory of Intervallic Rivalry. *Music Perception*, 6(3), pp.219–41.

Cage, J., 1968. *A Year from Monday.* London: Marion Boyers.

Cale, J. and Bockris, V., 1999. *What's Welsh for Zen: The Autobiography of John Cale.* London: Bloomsbury.

Carlos, W. 1987. Tuning at the Crossroads. *Computer Music Journal*, 11(1), pp.29-43.

Carrillo, J., 1924. *Preludio a Colón*. In: *American Festival of Microtonal Music––Chamber: Carillo, Partch, Ives, Scelsi, Xenakis, Harrison,* 2005. [CD] USA: Pitch.

Carrillo, J., 1927. *Concertino en cuartos, octavos y dieciseisavos de tono para violín, violonchelo y arpa con acompañamiento orquestal*. [Sound recording/video online] Available at: <http://www.youtube.com/watch?v=3O3H01c2SjE> [Accessed 25 June 2011].

Carrillo, J., 1930. *Pre–Sonido Trece*. Translated from the Spanish by L. Bellamy, 1973. In:*The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University, pp.43–75.

Carrillo, J., 1940. *Génesis de la Revalución Del Sonido 13*. Translated from the Spanish by L. Bellamy, 1973. In: *The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University, pp.218–358.

Carrillo, J., 1948. *Sonido Trece.* Translated from the Spanish by L. Bellamy, 1973. In: *The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University, pp.171–217.

Carrillo, J., 1949. *Leyes de Metamorfosis Musicale.* Translated from the Spanish by L. Bellamy, 1973. In: *The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University, pp.402–471.

Carrillo, J., 1954. *Teoría Lógica de la Música*. Translated from the Spanish by L. Bellamy, 1973. In: *The "Sonido Trece" Theoretical Works of Julián Carillo: A Translation with Commentary*. Thesis (PhD). Indiana State University, pp.76–170.

Celemony, 2001. *Melodyne.* [software application]. Germany: Celemony Software GmbH.

Chowning, J., 1981. *Phoné*. In: *Turenas · Stria · Phoné · Sabelithe.* 1988 [CD] Mainz: WERGO—Digital Music Digital WER 2012–50.

Clark, A., 2008. *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*. New York: OUP USA.

Clarke, E., 1987. Levels of structure in the organization of musical time. *Contemporary Music Reivew,* 2(1), pp.211–238.

Cohn, R., 1997. Neo-Riemannian Operations, Parsimonious Trichords, and Their Tonnetz Representations. *Journal of Music Theory,* 41(1), pp.1-66.

Cohn, R., 1998. An Introduction to Neo–Riemannian Theory: A Survey and Historical Perspective. *Journal of Music Theory*, 42(2), pp.167-180.

Conrad, T., 2007. Interview with Brian Duguid for *ESTweb* [Online] Available at: <http://media.hyperreal.org/zines/est/intervs/conrad.html> [accessed September 2011]

Covey-Crump, R., 1992. Pythagoras at the forge: tuning in early music. In: Knighton, T. and Fallows, D. ed. 1992., *Companion to Medieval and Renaisance Music*. London: J.M. Dent, pp.317–326.

Cowan, N., 2001. The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, 24, pp.87–185.

Cowan, N., 2005. *Working Memory Capacity.* New York: The Psychology Press.

Cowan, N., Morey, C.C., and Chen, Z. 2007. The legend of the magical number seven. In: S. Della Sala ed., *Tall tales about the mind & brain: Separating fact from fiction* Oxford: Oxford University Press, pp.45-59.

Crocker, R.L., 1964. Pythagorean mathematics and music. *The Journal of Aesthetics and Art Criticism*. 22(3), pp.325-335.

Cross, I., 1997. Pitch schemata. In J. Sloboda & I. Deliège (Eds), *Perception and cognition of music.* Hove: The Psychology Press, pp.353-386.

Cycling '74, 2008. Max 5. [Software application]. USA: Cycling '74.

Darreg, I., 1966. *Xenharmonic Bulletin,* 1, [Reproduced online] Available at: <http://sonic-arts.org/darreg/XHB1.HTM> [Accessed 20 June 2011].

Darreg, I., 1974. *Xenharmonic Bulletin*, 2, [Reproduced online] Available at: <http://sonic-arts.org/darreg/XHB2.HTM> [Accessed 20 June 2011].

Darreg, I., 1975. *Xenharmonic Bulletin*, 4. [Reproduced online] Available at: <http://sonic-arts.org/darreg/XHB4.HTM> [Accessed 20 June 2011]

Doty, D.B., 2002. *The Just Intonation Primer.* Santa Fe, New Mexico: self–published, available at <http://www.dbdoty.com> [Accessed 20 June 2011]

Dowling, W.J. and Harwood, D., 1986. *Music Cognition*. London and San Diego: Academic Press.

Duckworth, W., 1995. *Talking Music: Conversations with John Cage, Philip Glass, Laurie Anderson and Five Generations of American Experimental Composers.* New York: Schirmer.

Duffin, R., 2007. *How Equal Temperament Ruined Harmony (and Why You Should Care)*. New York: Norton.

Eiseman, D., 1975., George Ives as Theorist: Some Unpublished Documents. *Perspectives of New Music*, 14(1), pp.139–147.

Elmasian, R. and Birnbaum, M., 1984. A harmonious note on pitch: Scales of pitch derived from subtractive model of comparison agree with the musical scale. *Perception and Psychophysics* 36(6), pp.531–7.

Emmerson, S., 2007. *Living Electronic Music*. Aldershot: Ashgate.

Erlich, P., 1999. *A gentle introduction to Fokker periodicity blocks—part 3*. [online] Available at: <http://www.sonic-arts.org/td/erlich/intropblock3.htm> [Accessed: 11 January 2012].

Erlich, P., 1997. *On Harmonic Entropy*. [online] Available at: <http://sonic-arts.org/td/erlich/entropy-erlich.htm> [Accessed 15 January 2012]

Euler, L., 1739. *Tentamen novae theoriae musicae ex certissismis harmoniae principiis dilucide expositae.* Saint Petersburg Academy.

Féron, F.X., 2011. The Emergence of Spectra in Gérard Grisey's Compositional Process: From Dérives (1973–74) to Les espaces acoustiques (1974–85). *Contemporary Music Review*, 30(5), pp.343-375.

Ferrer–Flores, R., 2007. *The Role of Timbre in the Memorization of Microtonal Intervals.* Thesis, (Master's). University of Jyväskylä, Finland.

Fineberg, J., 2000a. Guide to the basic concepts and techniques of spectral music. *Contemporary Music Review*, 19(2), 81-113.

Fineberg, J.. 2000b. Spectral Music. *Contemporary Music Review*, 19(2), pp. 1-5.

Finger, S., 2001., *Origins of Neuroscience: A History of Explorations into Brain*

Function. New York: Oxford University Press.

Flynt, H., 1962. *My New Concept of General Acognitive Culture*. [Reproduced online]: Available at <http://www.henryflynt.org/aesthetics/acogcult.html> [Accessed 1 October 2011]

Flynt, H., 1963. *Essay: Concept Art.* Reproduced online]: Available at: <http://www.henryflynt.org/aesthetics/conart.html> [Accessed 1 October 2011]

Flynt, H., 1996. La Monte Young in New York 1960–62. In: Duckworth, W. and Fleming, R. *Sound and Light: La Monte Young and Marian Zazeela.* New Jersey: Associated University Press, pp.44–97.

Flynt, H., 2006. *Henry Flynt in New York.* Interview by Piekut, B. [Online video] Available at: <http://www.youtube.com/benjaminpiekut> [Accessed 1 October 2011]

Fokker, A.D., 1955. *Equal Temperament and the Thirty-one-keyed organ.* [Reproduced online] Available at: <http://www.huygens-fokker.org/docs/fokkerorg.html> [Accessed: 11 January 2012].

Fokker, A.D., 1969. Unison Vectors and Periodicity Blocks in the Three–Dimensional (3-5-7-) Harmonic Lattice of Notes. From: *Koninklijke Nederlandse Akademie van Wetenschappen - Amsterdam, Proceedings,* Series B 72, No. 3, 1969. [Reproduced online] Available at: <http://www.huygens-fokker.org/docs/fokkerpb.html> [Accessed: 11 January 2012].

Fonville, J., 1991. Ben Johnston's Extended Just Intonation: a Guide for Interpreters. *Perspectives of New Music* 29(2). pp.106–137.

Gagne, C. and Caras, T., 1982. *Soundpieces: Interviews with American*

Composers. New Jersey: Scarecrow Press.

Gagne, C., 1990. *Sonic Transports: New Frontiers in Our Music*. New York: De Falco Books.

Gagne, C., 1993. *Soundpieces 2: Interviews with American Composers.* New Jersey: Scarecrow Press.

Gann, K., 1992. The peerless Partch. *Village Voice*, 18 February, 1994. p.90.

Gann, K., 1994. The Tingle of p x m(n - 1): installations by La Monte Young and Marian Zazeela *Village Voice,* October 4, 1994. Vol. 39(40). p.84.

Gann, K., 1998. *Anatomy of an Octave,* [Online] Available at: <http://www.kylegann.com/Octave.html> [Accessed: 21 June 2011].

Gann, K., 1996. The Outer Edge of Consonance: The Development of La Monte Young's Tuning Systems. In: Duckworth, W. and Fleming, R., ed. *Sound and Light: La Monte Young and Marian Zazeela.* Lewisburg, PA: Bucknell University Press, 1996, pp. 152-190.

Gann, K., 1997. *American Music in the Twentieth Century*. New York: Schirmer.

Gann, K., 1997b. Just Intonation Explained. [Online]: Available at: <http://www.kylegann.com/tuning.html> [Accessd June 2012].

Gann, K., 2007. Font of Every Blessing. [Online]: Available at: <http://www.artsjournal.com/postclassic/2007/07/font_of_every_blessing.html> [Accessed 01/2012]

Gardner, B. and Martin, W., 1994. HRTF Measurements of a KEMAR Dummy–Head Microphone. *MIT Media Lab–Perceptual Computing. Technical Report #280.*

van de Geer, J.P. Levelt, W.J.M and Plomp, R., 1962. The Connotation of Musical Consonance, *Acta Psychologica*, 20, pp.308–319.

Gibson, J.J., 1966. *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin.

Gibson, J.J., 1979. *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin.

Gilmore, B., 1995. Changing the Metaphor: Ratio Models of Musical Pitch in the work of Harry Partch, Ben Johnston and James Tenney. *Perspectives of New Music.* 33(1/2), pp.458–503.

Gilmore, B., 1998. *Harry Partch: a Biography*. New Haven and London: Yale University Press.

Gilmore, B., 2003. The climate since Harry Partch. *Contemporary Music Review*. 22(1), pp.15–33.

Gjerdingen, R., 1999. An Experimental Music Theory. In: Cook, N., ed. *Rethinking Music.* Oxford: Oxford University Press, pp.161–170.

Goldstone, R.L. and Hendrickson, A.T., 2009. Categorical Perception. In: Wiley Interdisciplinary Reviews: Cognitive Science, 1(1), pp.69–78.

Grimshaw, J., 2012. *Draw a Straight Line and Follow It: The Music and Mysticism of LaMonte Young.* New York: Oxford University Press USA.

Grey, J.M. and Gordon, J.W., 1978. Perceptual effects of spectral modifications on musical timbres. *Journal of the Acoustical Society of America*. 63(5), pp.1493–1500.

Haar, J., 1977. False Relations and Chromaticism in Sixteenth-century Music. *Journal of the American Musicological Society*. 30(3), pp.391–418.

Hába, A., 1927. *Neue Harmonielehre*. In: 1978 [facsimile edition]. Vienna: Universal Edition.

Hába, A., 1947. *Sonata for Quarter-tone Piano*. In: *Centenary: Alois Hába*, 2006

[CD] Prague: Supraphon.

Handel, S., 1989. *Listening: An Introduction to the Perception of Auditory Events*. Cambridge, Mass.: MIT.

Hardy, G., 1999. *Worlds of Bronze and Bamboo: Sima Qian's Conquest of History*. New York: Columbia University Press.

Harnad, S., 1987. Introduction: Psychophysical and Cognitive Aspects of Categorical Perception. In Harnad, S. ed. *Categorical Perception: The Groundwork of Cognition.* Cambridge: Cambridge University Press.

Harrison, J., 1999. Sound, space, sculpture: some thoughts on the 'what', 'how' and 'why' of sound diffusion. In: *Organised Sound* 3(2), pp.117–27.

Heet, G., 2012., *Ebow FAQ*. [online] Available at: <http://www.ebow.com/faq.php> [Accessed September 2012]

Helmholtz, H., 1863. *On the Sensations of Tone as a Physiological Basis for the Theory of Music.* Trans. Ellis, A.J., 1912. London: Longmans, Green.

Hennix, C.C., 2010. The Electric Harpsichord. Interview by Simon Duff. *Art and Music: The Saatchi Gallery Magazine*. [online] Available at: <http://www.saatchi-gallery.co.uk/artandmusic/?cid=475&b_log=475> [Accessed September 2011]

Higgins, H., 2002. *Fluxus Experience*. Berkeley and Los Angeles: University of California Press.

Holmes, T., 2008. *Electronic and Experimental Music: Technology, Music and Culture.* 3rd edition. London: Routledge.

Howard, D. and Angus, J., 2009., *Acoustics and Psychoacoustics*. 5th edition. Oxford: Focal.

Hunt, R.H. and Ellis, H.C., 1999. Fundamentals of Cognitive Psychology. New

York: McGraw Hill.

Huxley M.N., 1996. *Area, lattice points, and exponential sums*, Oxford: Oxford University Press.

Ives, C., 1924. *Three Quarter–tone Pieces.* [Score]. London, New York and Frankfurt: Peters.

Ives, C., 1925, Some "Quarter-tone Impressions". In: Boatwright, H. ed., 1969. *Essays before a sonata, and other writings*. London: Calder and Boyers, pp.107–119.

Ives, C., ed. Kirkpatrick, J., 1972. *Memos*. New York: Norton.

Jan, S., 2011. Music, Memory, and Memes in the Light of Calvinian Neuroscience, *Music Theory Online* , 17(2).

Johnson, M., 1987. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason.* Chicago: University of Chicago Press.

Johnson, M., 2008. *The Meaning of the Body: Aesthetics of Human Understanding.* . Chicago: University of Chicago Press.

Johnston, B., 1964. Scalar Order as Compositional Resource. *Perspectives of New Music*, 2(2), pp.56–76.

Johnston, B., 1964b. String Quartet No. 2. [Composition/score]. Vermont: Smith Publications/Sonic Art Editions.

Johnston, B., 1966. Proportionality and Expanded Pitch Relationships. *Perspectives of New Music* 5(1), pp.112–120.

Johnston, B., 1970. String Quartet No. 2. [Liner notes for LP release]. [Reproduced online]: Available at: <http://netnewmusic.net/reblog/archives/2009/05/ben_johnston_st_2.html> [Accessed 15th July 2012].

Johnston, B., 1971. Microtonal Resources. In Gilmore, B. ed. 2006*, Maximum Clarity and other writings on music.* Chicago: University of Illinois Press, pp.41–45.

Johnston, B., 1984. Beyond Harry Partch. *Perspectives of New Music* 22(1/2), pp.223–232.

Johnston, B., 1987. String Quartet No. 9. [Composition/score]. Vermont: Smith Publications/Sonic Art Editions.

Jordan, D., 1987. Influence of the Diatonic Tonal Hierarchy at Microtonal Intervals. Perception and Psychophysics, 41(6), pp.482–8.

Joseph, B., 2008. *Beyond the Dream Syndicate: Tony Conrad and the Arts after Cage*. New York: Zone Books.

Kameoka, A. and Kuriyagawa, M., 1969. Consonance Theory Part II: Consonance of Complex Tones and Its Calculation Method. *Journal of the Acoustical Society of America*. 45(6), pp.1460–1469.

Kárpáti, A., 1987. Translation or Compilation? Contributions to the Analysis of Sources of Boethius' De institutione musica. *Studia Musicologica Academiae Scientiarum Hungaricae,* 29(1), pp.5–33.

Kay, P. and Kempton, W., What is the Sapir–Whorf Hypothesis? *American Anthropologist*, 86(1), pp.65–79.

Keislar, D., 1987. History and Principles of Microtonal Keyboards. *Computer Music Journal,* 11(1), pp.18-28.

Keislar, D., 1991. Six American Composers on Nonstandard Tunnings. *Perspectives of New Music,* 29(1), pp. 176-211.

Kendall, G. and Martens, W., 1984. Simulating the Cues of Spatial Hearing in Natural Environments. *Proceedings of the 1984 International Computer*

Music Conference, Paris, France.

Kirck, G., 1987. Computer Realization of Extended Just Intonation Compositions. *Computer Music Journal*. 11(1), pp.69–75.

Klingbeil, M., 2008. SPEAR—Sinusoidal Partial Editing, Analysis and Resynthesis. [Software Application]. USA: Available at: <http://www.klingbeil.com>

Kopeiz, R., 2003. Intonation of Harmonic Intervals: Adaptability of Expert Musicians to Equal Temperament and Just Intonation. *Music Perception,* 20(4), pp.383–410.

Krueger, T., 2008. This is Not Entertainment: Experiencing the Dream House. *Architectural Design*. 78(3), pp.12–15.

Krumhansl, C. and Shepard, R.N., 1979. Quantification of the Hierarchy of Tonal Functions Within a Diatonic Context. *Journal of Experimental Psychology: Human Perception and Performance*, 5(4), pp.579–594.

Krumhansl, C., 1979. The psychological representation of musical pitch in a tonal context. *Cognitive Psychology*, 11(3), pp. 346–374.

Krumhansl, C. and Kessler, E., 1982. Tracing the dynamic changes in perceived tonal organization in a spatial representation of musical keys. *Psychological Review*, 89, pp.334-368.

Krumhansl, C., 1990. *Cognitive Foundations of Musical Pitch*. Oxford: Oxford University Press.

Krumhansl, C., 2005. The Geometry of Musical Structure: A Brief Introduction and History. *ACM Computers in Entertainment*, Vol. 3, No. 4, pp.1–14.

Labelle, B., 2006. *Background Noise: Perspectives on Sound Art*. London: Continuum.

Lakoff, G. and Johnson, M., 1980. *Metaphors We Live By.* Chicago: University of Chicago Press.

Lakoff, G., 1987. *Women, fire, and dangerous things: What categories reveal about the mind.* Chicago: University of Chicago Press.

Lakoff, G. and Johnson, M., 1999. *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought.* New York: Basic Books.

Lakoff, G. and Núñez, R., 2000. *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics Into Being*. New York: Basic Books.

Langendijk, E.H. and Bronkhorst, A.W., 2002. Contribution of spectral cues to human sound localization. *Journal of the Acoustical Society of America*. 112 (4), pp.1583–1596.

Lerdahl, F., 1988. Tonal Pitch–Space. *Music Perception,* 5(3), pp.315–349.

Lerdahl, F., 1989. Atonal Prolongational Structure. *Contemporary Music Review* 3, no. 2., p. 65-87

Lerdahl, F., 1992. Cognitive constraints on compositional systems. *Contemporary Music Review*, 6(2), pp.97–121.

Lerdahl, F., 2001. *Tonal Pitch–Space*. Oxford: Oxford University Press.

Levitin, D., 2002. *Foundations of Cognitive Psychology: Core Readings*. Cambridge, Mass.: MIT.

Lindley, M., 1984. *Lutes, Viols and Temepraments*. Cambridge: Cambridge University Press.

Lindley, M., 1985. J.S. Bach's Tunings. *The Musical Times,* 128(1714), pp.721–726.

Lehman, B., 2005. Bach's extraordinary temperament: our Rosetta Stone–1. *Early Music*, 23(1), pp.3–23.

Lloyd., Ll.S., 1940. The Myth of Equal Temperament. *Music and Letters*, 21(4), pp.347–361.

Loy, G., 2006. *Musimathics: Volume I.* Cambridge, Mass.: MIT.

Madrid-Gonzalez, A.L., 2003. *Writing Modernist and Avant-garde Music in Mexico: Performativity, Transculturation and Identiy after the Revolution, 1920-30.* Thesis, (PhD). The Ohio State University.

Mandelbaum, M.J.., 1961. *Multiple Divisions of the Octave and the Tonal Resources of 19-Tone Temperament*. Thesis (PhD). Indiana University.

Mathews, M. and Pierce, J.R., 1980. Harmony and nonharmonic partials. *Journal of the Acoustical Society of America*, 68(5), pp. 1252-1257.

Mathews, M., Roberts, L.A. and Pierce, J.R. 1984. Four new scales based on nonsuccessive–integer–ratio chords. *Journal of the Acoustical Society of America*, 75(S1—Program of the 107th Meeting of The Acoustical Society of America), p.S10.

Mathews, M. Pierce, J.R., Reeves, A. and Roberts L.A., 1988. Theoretical and experimental explorations of the Bohlen–Pierce scale. *Journal of the Acoustical Society of America,* 84(4), pp.1214–22.

Mathews, M. and Pierce, J.R., 1989. The Bohlen-Pierce Scale. In: Mathews, M. and Pierce, J.R., ed. 1989, *Current Directions in Computer Music Research*. Cambridge, Mass.: MIT, pp.165-173.

McAdams, S., 1989. Psychological constraints on form–bearing dimensions in music. *Contemporary Music Review* 4(1),pp.181–198.

Miller, G., 1956. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. Reprinted in *Psychological Review*, 101(2), 1994, pp.343–352.

Mokhtari, P., 2009. Acoustic simulation of KEMAR's HRTFs: verification with measurements and the effects of modifying head shape and pinna concavity. *Proceedings of the International Workshop on the Principles and Applications of Spatial Hearing*. Miyagi, Japan.

Monzo, J., 2005. Diesis. In: *Tonalsoft Encyclopedia of Microtonal Music Theory*. [online] Available at: <http://tonalsoft.com/enc/d/diesis.aspx> [Accessed: 21 September 2012].

Moore, B.C.J., 2004. *An Introduction to the Psychology of Hearing*. 5th ed. London: Elesvier.

Moore, B.C.J., 2007. *Cochlear Hearing Loss: Physiological, Psychological and Technical Issues*. Chichester: Wiley.

Negraõ, M., 2010. *Strategies in Diffuse Spatialization*. Thesis (Master's), Institute of Sonology, Den Haag.

Nolan, C., 2002. Music Theory and Mathematics. In: Christiansen, T. ed. 2002. *The Cambridge History of Western Music Theory*. Cambridge: Cambridge University Press, pp.272–305.

Nyman, M., 1999. *Experimental Music: Cage and Beyond*. 2nd edition. Cambridge: Cambridge University Press.

Ó Canáinn, T., 1978, *Traditional Music in Ireland*. London: Routledge.

Op de Coul, M., 1997. *Scala* [Software application]. Netherlands: Huygens–Fokker Foundation, Available at: <http://www.huygens-fokker.org/scala/> [Accessed: 21 September 2012].

Op de Coul, M., and Schiemer, G. 2007. Pocket Gamelan: tuning microtonal applications in Pd using Scala. In: *Trans : Boundaries / Permeability / Reification – Proceedings of the Australasian Computer Music Conference*

2007.

Oppenheim, D., 1969. Notes on Ecologic Projects. *Aspen Magazine* No. 8. reproduced online: <http://www.ubu.com/aspen/aspen8/ecologic.html>

Parncutt, R., 1989. *Harmony: A Psychoacoustical Approach.* Berlin: Springer.

Partch, H., 1940. Patterns of Music. In: McGeary, T., ed. 1991., *Bitter Music: collected journals, essays, introductions and librettos*. Urbana and Chicago: University of Chicago Press, pp.159–161.

Partch, H., 1943/55, *U.S. Highball*. In: *The Harry Partch Collection, Volume 2,* 2004 [CD] New York: New World Records.

Partch, H., 1967, *Daphne of the Dunes* [revision of *Windsong*, 1955]. In: *The World of Harry Partch,* 1969 [LP] New York: Columbia Records.

Partch, H., 1974. *Genesis of a Music.* 2nd ed. New York: Da Capo.

Pastore, R.E., 1987. Categorical Perception: some psychophysical models. In Harnad, S. ed. *Categorical Perception: The Groundwork of Cognition.* Cambridge: Cambridge University Press.

Pierce, J.R., 2001. Consonance and Scales. In: Cook, P. ed. 2001. *Music Cognition and Computerized Sound*. Cambridge, Mass.: MIT, pp.167–185.

Plomp, R. and Levelt, W.J.M., 1965. Tonal Consonance and Critical Bandwidth. *Journal of the Acoustical Society of America,* 38(4), pp.548–60.

Potter, K., 2000. *Four Musical Minimalists.* Cambridge: Cambridge University Press.

Racek, J., Vysloužil, J. and Kocmanová, J., 1965. Problems of Style in 20th-Century Czech Music. *The Music Quarterly*, 51(1), pp.191-204.

Rameau, J.P., 1722. *Treatise on Harmony*. Trans. Gossett, P, 1971. New York: Dover.

Randel, D., 2003. *Harvard Dictionary of Music*. Cambridge, Mass.: Harvard University Press.

Rasch, R., 2000. A Word or Two on the Tuning of Harry Partch. In: Dunn, D., ed. 2000, *Harry Partch: an anthology of critical perspectives.* London: Routledge, pp.25–40.

Rasch, R., 2002. Tuning and temperament. In: Christensen, T., ed. 2002, *The Cambridge History of Western Music Theory.* Cambridge: Cambridge University Press, pp.193–222.

Read., G., 1990. *20th-century Microtonal Notation.* Westport, Connecticut: Greenwood Press.

Regier, T., Kay, P., Gilbert, A.L., and Ivry, R.B., 2010. Language and thought: Which side are you on, anyway? In B. Malt and P. Wolff (Eds.), *Words and the Mind: Perspectives on the Language-Thought Interface.* New York: Oxford University Press USA.

Riley, T., 1996. La Monte Young and Marian, 1967. in Duckworth, W. and Fleming, R. *Sound and Light: La Monte Young and Marian Zazeela.* New Jersey: Associated University Press, pp.21–24.

Roberson D., Davidoff J. and Davies I.R.L,, 2005. Color categories: evidence for the cultural relativity hypothesis. *Cognitive Psychology*, 50, pp.378 – 411.

Roberts, B., and Brunstrom, J. M. 1998. Perceptual segregation and pitch shifts of mistuned components in harmonic complexes and in regular inharmonic complexes. *Journal of the Acoustical. Society of America*, 104,pp.2326–2338.

Roberts, B. and Brunstrom, J. M., 2001. Perceptual fusion and fragmentation of complex tones made inharmonic by applying different degrees of frequency shift and spectral stretch. *Journal of the Acoustical Society of America*. 110, pp.2479–2490.

Roberts, B. and Brunstrom, J. M., 2003. Spectral pattern, harmonic relations, and the perceptual grouping of low-numbered components. *Journal of the Acoustical Society of America*., 114, pp.2118–2134.

Roberts, P.D., 2002. Ivan Vyschnegradsky. In Sitsky, L., ed. *Music of the twentieth-century avant-garde: a biocritical sourcebook.* Westport, CT: Greenwood Press.

Rowlands, M., 2010. *New Science of the Mind: From Extended Mind to Embodied Phenomenology*. Cambridge, Mass.: MIT.

Roederer, J., 2008. *The Physics and Psychophysics of Music*. New York: Springer.

Schaefer, J., 1996. Who is La Monte Young?. in Duckworth, W. and Fleming, R. *Sound and Light: La Monte Young and Marian Zazeela.* New Jersey: Associated University Press, pp.25–43.

Scharf, B., Quigley, S., Aoki, C., Peachey, N. and Reeves, A., 1987. Focused Auditory Attention and Frequency Selectivity. Perception and Psychophysics, 42(3), pp.215–223.

Schoenberg, A., 1922. *Harmonielehre,* 3rd ed. Translated from the German by R.E. Carter, 1978 as *Theory of Harmony*. Berkeley, Los Angeles: University of California Press.

Schwarz. K.R., 1996. *Minimalists*. London: Phaidon.

Sethares, W., 2004. *Tuning, Timbre, Spectrum, Scale,* London: Springer.

Shapiro, L., 2011., *Embodied Cognition*. London: Routledge.

Shepard, R.N., 1964. Circularity of Judgements in Relative Pitch. *Journal of the*

Acoustical Society of America, 36(12), pp.369–380.

Shepard, R., 1981. Psychological Relations and Psychophysical Scales: On the Status of "Direct" Measurement. *Journal of Mathematical Psychology*. 24, pp. 21–57.

Shepard, R.N., 1982. Geometrical approximations to the structure of musical pitch. *Psychological Review*, 89(4), Jul 1982, pp.305–333.

Sitsky, L., 1994. *Music of the repressed Russian Avant-Garde, 1900–1929*. Westport, CT: Greenwood Press.

Skinner, M., 2006. *Toward a Quarter-Tone Syntax: Selected Analyses of Works by Blackwood, Hába, Ives, and Wyschnegradsky*. Thesis (PhD). State University of New York at Buffalo.

Sloboda, J., 1985. *The Musical Mind: The Cognitive Psychology of Music.* Oxford: Oxford University Press.

Solomon, M., 1987. Charles Ives: Some Questions of Veracity. *Journal of the American Musicological Society*, 40(3), pp. 443-470

Snyder, B., 2001. *Music and Memory: an Introduction.* Cambridge, Mass.: MIT.

Snyder, B., 2009. Memory for Music. In: Hallam, S., Cross, I. and Thaut, M., ed. *The Oxford Handbook of Music Psychology*. Oxford: Oxford University Press, pp.107–117.

Stainsby, T. and Cross, I., 2009. The perception of pitch. In: Hallam, S., Cross, I. and Thaut, M., ed. *The Oxford Handbook of Music Psychology*. Oxford: Oxford University Press, pp.47–58.

Stevens, S.S. and Volkmann, J., 1940. The Relation of Pitch to Frequency: a Revised Scale. *The American Journal of Psychology* 53(3), pp.329–353.

Stevens, S.S., 1946. On the theory of scales and measurement. *Science* 103, pp.677–680.

Stevens, S.S., 1957. On the Psychophysical Law. *The Psychological Review* 64(3), pp. 153–181.

Stevens, S.S. and Galantner, E.H., 1957. Ratio Scales and Category Scales for a Dozen Perceptual Continua. *Journal of Experimental Psychology.* 54(6), pp.377–411.

Talmy, L., 2005. The Fundamental System of Spatial Schemas in Language. In. Hampe, B, ed. *From Perception to Meaning: Image Schemas in Cognitive Linguistics.* Berlin: Walter de Gruyter. pp.199–234.

Taruskin, R., 2005. *The Oxford History of Western Music Volume 2*. New York: Oxford University Press.

Tenney, J., 1969. Computer Music Experiences 1961–64. *Electronic Music Reports #1*. Utrecht: Institute of Sonology, 1969. available at: http://www.plainsound.org/pdfs/ComputerMusic.pdf

Tenney, J., 1974. *Spectral CANON for CONLON Nancarrow.* [CD]. USA: Cold Blue.

Tenney, J., 1983. John Cage and the Theory of Harmony. in Kostelanetz, R. ed. 1993. Writings About John Cage. Ann Arbor, Michigan: University of Michigan Press. reproduced online at: www.plainsound.org/pdfs/JC&ToH.pdf (last accessed 01/2012)

Tenney, J., 1985. *Sixty-four Studies for Six Harps.* [Composition/Score]. Lebanon, New Hampshire: Frog Peak.

Tenney, J., 1986. *Meta/Hodos: a phenomenology of 20th-century musical materials and an approach to the study of form ; and, META Meta+Hodos*. Oakland, California: Frog Peak.

Tenney, J. and Belet, B., 1987. An Interview with James Tenney. interview by Belet, B. *Perspectives of New Music* 25 (1/2), pp.459–466.

Tenney, J., 1988. *A History of 'Consonance' and 'Dissonance'.* New York: Excelsior.

Tenney, J., 1988b/2001. *Critical Band*. [Composition/score]. New Hampshire: Frog Peak Music.

Tenney, J., 2008. (interviewed by Dennehy, D.). Interview With James Tenney. *Contemporary Music Review* Vol. 27, No. 1, pp. 79 – 89.

Terhardt, E., 1978. Psychoacoustic Evaluation of Musical Sounds. *Attention, Perception, & Psychophysics,* Volume 23, Number 6 (1978), 483-492,

Tong, K., 1983. Shang Musical Instruments: Part Two. *Asian Music*, 15(1), pp.102-184.

Toole, T., 2008. *Sound Reproduction: the Acoustics and Psychoacoustics of Loudspeakers and Rooms.* Oxford: Focal Press.

Varela, F.J., Thompson, E.T., and Rosch, E., 1991. *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, Mass.: MIT.

Wannamaker, R., 2008. The spectral music of James Tenney. *Contemporary Music Review* 27(1), pp.91–130.

Ward, W.D., 1954, Subjective Musical Pitch. *Journal of the Acoustical Society of America*, 26(3), pp.369–380.

Ward, W.D., 1999. Absoute Pitch. In Deutsch, D., ed., The Psychology of Music. 2nd ed. San Diego and London: Academic Press, pp.265–298.

Wernzt, J., 2001. Some New Thoughts, Ten Years after Perspectives of New Music's "Forum: Microtonality Today. *Perspectives of New Music*, 39(2), pp.159-210.

Whorf, B.L., 1956. In: Carroll, J.B., ed., *Language, Thought and Reality: Selected Writings of B.L. Whorf.* Cambridge, Mass.: MIT.

Wiecki, R., 1991. Relieving "12–tone Paralysis": Harry Partch in Madison, Wisconsin, 1944–7, *American Music* 9(1), pp.43–66.

Williams, P., 1983. J. S. Bach's Well-tempered Clavieer: A new approach –1. *Early Music*, 11(3), pp.48–52.

Wishart, T., 1996. *On Sonic Art*. 2nd ed. London: Routledge.

Wolf, D.J., 2003. Alternative Tunings, Alternative Tonalities. *Contemporary Music Review*, 22(1),pp.3–14.

Wyschnegradsky, I., 1934. Op.22, *24 Préludes dans l'échelle chromatique diatonisée à 13 sons.* In: *Étude sur les Mouvements rotatoires, 24 Préludes,* 2006 [CD] Vienna: Col Legno.

Wyschnegradsky, I., 1961. Op.45, *Étude sur les Mouvements rotatoires.* In: *Étude sur les Mouvements rotatoires, 24 Préludes,* 2006 [CD] Vienna: Col Legno.

Wyschnegradsky, I., 1976. Interviewed by Charles Amirkhanian, original radio broadcast KPFA-FM Berkeley, [Online] Available at: <http://www.archive.org/details/AM_1976_06_04> [Accessed 2 July 2011].

Yasser, J., 1975. *A Theory of Evolving Tonality*. Facsimile edition of 1932 edition. New York: Da Capo Press.

Young, L,. 1964. *The Pre–tortoise Dream Music*. [Composition].

Young, L., 1969. Notes on Continuous Periodic Composite Sound Waveform Environment Realizations. in *Aspen* Magazine No. 8. [Reproduced online], Available at: <http://www.ubu.com/aspen/aspen8/waveform.html> [Accessed: 21st November 2011].

Young, L., 1989. *The Romantic Symmetry (over a 60 cycle base) in Prime Time from 144 to 112 with 119*, [Composition/sound installation]. Tuning chart in: Gann, K. 1996. The Outer Edge of Consonance: The Development of La Monte Young's Tuning Systems. In: Duckworth, W. and Fleming, R., ed., *Sound and Light: La Monte Young and Marian Zazeela*. Lewisburg, PA: Bucknell University Press, 1996, pp. 152-190.

Young, L,. 1989b/1990. interview with David B. Doty. *1/1, The Journal of the Just Intonation Network* 5(4). 6(1). [Reproduced online]. Available at: <http://www.dbdoty.com/Words/LMYInterview_01.html> [Accessed January 2012].

Young, L., 1990. *The Prime Time Twins in the Ranges 576 to 448; 188 to 224; 144 to 112; 72 to 56; 36 to 28; with the range limits 576, 448, 288, 224, 144, 56 and 28.* [Composition/sound installation]. Tuning chart in: Gann, K. 1996. The Outer Edge of Consonance: The Development of La Monte Young's Tuning Systems. In: Duckworth, W. and Fleming, R., ed., *Sound and Light: La Monte Young and Marian Zazeela*. Lewisburg, PA: Bucknell University Press, 1996, pp. 152-190.

Young, L., 1991. *The Base 9:7:4 Symmetry in Prime Time...* [Composition/sound installation]. Tuning chart in: Gann, K. 1996. The Outer Edge of Consonance: The Development of La Monte Young’s Tuning Systems. In: Duckworth, W. and Fleming, R., ed., *Sound and Light: La Monte Young and Marian Zazeela*. Lewisburg, PA: Bucknell University Press, 1996, pp. 152-190.

Young, L., 2000. Notes on The Theatre of Eternal Music and The Tortoise, His Dreams and Journeys. [Online], Available at:

<http://melafoundation.org/lmy> [Accessed January 15th 2012]

Young, R., 2002. *Undercurrents: the Hidden Wiring of Modern Music*. London: Continuum.

Zbikowski, L., 2010. *Conceptualizing Music*: *Cognitive Structure, Theory, and Analysis.* Oxford: Oxford University Press.

Zuckin, S., 1982. Art in the Arms of Power. *Theory and Society* 11(4), pp.423–51.

Zwicker, E., Flottorp, G., and Stevens, S.S., 1957. Critical band width in Loudness Summation. *Journal of the Acoustical Society of America*, 29, p. p.548–57.

Appendix 1: Glossary of Key Terms

Alphabetised definitions of key terminology from this thesis, accompanied by relevant citation if the term is frequently associated with a particular publication or usage.

Absolute pitch (abbreviated AP): a phenomenon whereby individuals can accurately encode and reproduce the tuning of learned pitch intervals and melodic structures without recourse to external references in a manner which significantly exceeds the abilities of the majority of the population. Possessors may thus exhibit the ability to recognise small deviations in tuning for these learned intervals. See also **relative pitch (abbreviated RP).**

Acognitive culture: a cultural form which is intended to replace a wide range of cognitively–based activities such as mathematics, structural approaches to artistic expression, etc., which focusses instead on more 'immediate' sensory experience as opposed to the engendering of cognitively–based complexity (Flynt, 1962). The present thesis relates this concept to those of **ecological perception** and **embodied cognition**.

Accretion principle: the principle whereby the preference for preservation of enharmonic tuning distinctions is reflected in the physical design of keyboard instruments. This is accomplished through the use of split keys in a modified version of more established scalar layouts. Such designs may therefore producing tuning distinctions which exhibit potential utility for microtonal music, even if they were originally intended simply to preserve more accurate intonation and enharmonic distinctions (Keislar, 1987).

Additive dissonance metric: a mathematical evaluation of the periodicity–based dissonance, obtained through summing the numerator and denominator of a given frequency ratio; see (Loy, 2006, p.59).

Alternate/alternative tuning (abbreviated alt. tuning): an approach to tuning which deviates significantly from established tuning practice, which, in Western common practice music, is primarily based around equal temperament. See also **xenharmonic**.

Attention bands (perceptual): improved perceptual discrimination abilities for sequential pitch cases when successive stimuli occur within a set division of the **critical bandwidth**, suggesting that some form of perceptual priming allows for such improved performance (Scharf et al., 1987).

Auditory scene analysis: a set of processes and organisational principles defined by Bregman (1990) whereby structured auditory perception is accomplished by **heuristics** which are predicated upon *environmental regularities* (Bregman, 1993).

Basilar membrane: a physiological component of the hearing system which is part of the cochlea of the mammalian inner ear and which resonates at different points along its length with respect to different input frequencies. This configuration allows for the physical 'encoding' of pitch information based on location along the membrane, which is then the subject of transduction and further processing through the nervous system and lower–order cognitive processes.

Bichromaticism: the division of quarter-tone materials into two distinct and offset **12TET** chromatic scales, resulting in the potential to integrate these materials in a manner which extends rather than contradicts existing practice in common practice functional harmony (Hába, 1927). See also **ultrachromaticism**.

Bohlen-Pierce scale: a **non–octave scale** which is based around thirteen equal (or approximately equal) divisions of an octave plus a fifth (compound perfect fifth). The scale is named after Heinz Bohlen, who proposed it in 1978, along with John R. Pierce, who independently discovered and championed it (Mathews et al. 1988, 1989).

Bottom–up perception: a model of the general act of perception which focusses primarily on primitive perceptual transduction processes which are not the subject of complex cognitive processes. In this model, perceptual experience is primarily dictated by the structures created by such transduction processes. See also **perceptual.** For the opposing model, see **top–down perception**.

Categorical Perception (abbreviated CP): a perceptual or cognitive quantisation of a continuous variation of a particular sensory modality**.**

Chunking: a process of encoding data in **short–term memory** whereby elements are cross–referenced and grouped to overcome capacity limitations in this process (Miller, 1956; Cowan, 2005).

Cognitive (or cognitive–perceptual): for the purposes of this thesis, *cognitive/cognition/cognitive–perceptual* are used to denote processes in the act of perception which are related to more sophisticated processing/structuring, as opposed to simple perceptual transduction (see also **top–down perception**).

Comma (tuning): a ratio describing the discrepancy between different means of generating the tuning of a musical interval. See also **Pythagorean comma**, **syntonic comma**.

Consonance/dissonance–concept (abbreviated CDC): a number of models proposed by Tenney (1988) to explain differences in definition and usage of 'consonant' and 'dissonant' materials in Western art music.

Corporeal music: that which is connected with a broad conception of expression rather than abstraction, influenced by pre–Western traditions which unified poetry, dance and drama with music (Partch, 1974).

Critical bandwidth: the physiological frequency resolution of the **basilar membrane** for clear tonal percepts of frequency components which are adjacent;

if frequency components exceed the critical bandwidth, the physical vibrations of the basilar membrane do not overlap significantly, resulting in **sensory consonance**.

Cross-domain mapping: in **embodied cognition,** the function of mapping from sensorimotor structures to cognitive processes; see also **image schemas**.

Decomposition: a perceptual process whereby a set of stimuli are assigned/grouped as apparently separate auditory ‘objects’ or streams in spite of deriving from a single source. See also **false positive** and **segregation**.

Direct perception: see **ecological perception**

Discriminability (psychophysics): the ability to distinguish between different magnitudes for parameters/attributes of a given stimulus.

Discretisation: the perceptual or cognitive process of encoding a continuously–varying stimulus as a set of discrete intervals; see **categorical perception**.

Dissonance curve: a plot of comparative sensory consonance/dissonance with respect to interval size based on the critical band response for idealised harmonic spectra, first computed by Plomp and Levelt (1965); see also Sethares (2004).

Ecological perception: a theory of perception, also known as **direct perception**, which places environmental structures at the centre of the processes of perception. This theory assumes that the environment's typical structures affords the possibility of accurately structured perception, rather than a perceiver being reliant on more complex cognitive processes of representation to structure their perception (Gibson, 1966; 1979).

Echoic memory: in the modal memory model, this is the memory system for storing transduced auditory data (which has been the subject of some prior feature extraction) in a very short–term 'buffer' before it is subject to more advanced processes of cognitive organisation.

Embodied cognition (or situated cognition): a theoretical perspective in cognitive science which seeks to contextualise the general problem of environmental perception as being linked to the structures of the environment in which it takes place, including its interaction possibilities. In some forms of this theory, the environmental structures act as a **replacement** for more abstracted cognitive models (see also **ecological perception**). In other theories, structures based on patterns of sensorimotor engagement with the environment (termed **image schemas**) are considered to be the building–blocks of cognitive models.

Equal temperament: an approach to scale construction and temperament in which the scale is built on equal divisions of a given interval (generally the octave) with resulting standardisation of step size, although at the expense of intonational accuracy for many intervals in comparison with just intonation or other integer–based approaches. This form of scale is sometimes abbreviated as *N*–TET (*N*-tone equal temperament), e.g. 12TET (twelve-tone equal temperament), which assumes the interval so divided is the octave. Some sources favour a notation which specifically mentions the octave as the subject of such a division, e.g. *N*–EDO (*N*–tone equal division of the octave), e.g. 12EDO.

Extended just intonation: a tuning and scale–construction system which is based on using lower-order multiples of integer ratios of primes which are higher than 5, the prime–limit for earlier and more widely–distributed just intonation systems in Western music. (Johnston, 1987). See also ***N*-limit, just intonation** and **Ptolemaic tuning**.

False positive: an error introduced by a perceptual process whereby there is an incorrect attribution of a new state, configuration or object in the environment surrounding a perceiver. In the present thesis, this term is used to describe perceptual **decomposition** which is due to processes of auditory scene analysis incorrectly grouping stimulus tones due to their configuration structure subverting the expectations of perceptual **heuristics**.

Functional relationships/functional consonance and dissonance (harmony): the formal and non–simultaneous relationships between pitches as defining consonant/dissonant configurations. This model of harmony is thus syntactical and contextual, rather than being solely focussed on localised sensory attributes. Tenney (1988) terms the most developed version of this approach (that found in Classical/Romantic/common practice music) **consonance/dissonance–concept** IV (**CDC**–IV).

Fusion (or tonal fusion): a perceptual process whereby different frequency components are integrated into a single percept, due to aspects of the structural relationships between them (e.g. the integration of harmonic partials from a single source due to their integer relationships with a common fundamental).

Gibsonian: see **ecological perception**

Gestalt psychology (perceptual theory): a theory of descriptive principles for the grouping of objects in visual perception related to ecologically–based aspects such as similarity of attributes, proximity, commonality of movement in dynamic stimuli, integration of elements which could reasonably be assumed to be continuation of partially–obscured structures (closure), etc. Bregman's (1990) **auditory scene analysis** theory contains heuristics which are based on similar processes to many of those which Gestalt psychology proposes.

Grouping (perceptual): the integration of stimuli into a single perceptual 'object' or related groups of objects (streams, in dynamic configurations found in auditory perception); see also **auditory scene analysis**, **fusion**, and **decomposition** and **segregation**.

Harmonic series: the archetypal structural relationship of frequency components based on whole–number multiples of a common fundamental frequency (or lowest component) within complex periodic tones.

Heuristic (perception): a strategy whereby prior experience of a given environment or configuration leads to an evaluative process based on that prior experience, e.g. the *environmental regularities* in Bregman's (1990, 1993) **auditory scene analysis** theory can be viewed as contributing to related heuristics which contribute to effective parsing of source stimuli in a wide variety of cases.

Head-related transfer function (abbreviated HRTF): a description of the frequency–dependent filtering effects which are due to the shape of outer ears, head and upper–body; the cues which result from the resulting changes with respect to a moving stimulus are significant contributors to human abilities in sound localisation.

Hybrid (microtonal) approaches: in this thesis, the term *hybrid approaches* is used to denote microtonal systems which seek a compromise between scale construction principles based on tuning using integer ratios and equal division of the octave. Examples of such systems are 19TET (nineteen-tone equal temperament), for more on which see Yasser (1932/1975) and Mandelbaum (1961), and 31TET (thirty-one tone equal temperament), for more on which see Fokker (1955).

Intonation: the degree of accuracy with which the tuning of a pitch interval conforms to the specified scale construction system being used; the term is also used as part of terminology denoting a tuning system (e.g. **just intonation**) based on precise specification using integer ratios.

Image schemas (embodied cognition): a term for the abstracted versions of sensorimotor structures applied as **cross-domain mappings** in the embodied cognition theories of Lakoff and Johnson; see (Lakoff 1987; Johnson, 1987; Lakoff and Johnson 1999, p.77).

Just intonation: a scale construction and tuning system which uses integer ratios based on multiples of 5 or less; also termed **Ptolemaic tuning**.

Just noticeable difference (abbreviated JND, or DL for difference linen): a minimum value for reliable discrimination between stimuli; specifically in relation to pitch, the minimum value for sequential discrimination of pitch. See also **discriminability**.

Lattice (pitch relationships): a diagrammatic form which illustrates pitch relationships using two or more dimensions to highlight functional/generative relationships (using an extra dimension for each functional/generative relationship, with the general exception of representing octaves due to **octave equivalence**). See also ***Tonnetz.***

Linguistic relativity: see **Sapir–Whorf theory**

Long-term memory (abbreviated LTM): in the modal model of memory, long–term memory is the memory storage which allows humans to retain a large quantity of experiential and conceptual information which is only available to conscious thought when activated to provide context for current conscious awareness, which is mediated by the **short–term memory** process.

Miller limit: in this thesis, this term is a shorthand for the element–capacity limit for **short–term memory** proposed by Miller (1956) of 7+/-2 items, although further elements may be stored through performance enhancements obtained by **chunking** processes which group and rationalise stored elements.

Mean–tone tuning/temperament: a form of unequal temperament in which the **intonation** of the perfect fifth is sacrificed to the benefit of that of the major third. The name of this temperament is based on the general approach of dividing the major third into two equal–sized tones (mean–tones) which combine to create a close approximation of a 5/4 just intonation major third.
A variety of such temperaments exist, but the most common is 1/4 comma mean–tone temperament, which flattens each perfect fifth by 1/4 of the syntonic comma, resulting in the just intonation major third ratio being present in exact or approximate form for those intervals within keys closer to the original tuning reference. In contrast, sizes of fifths will vary more considerably.

Metathetic continua: psychophysical functions whose perceived scale structure are linearly related to the **discriminability** of changes along the continuum (Stevens, 1957). See also **prothetic continua**.

Multidimensional (psychophysics): a spatial representation of related parameters which are typically associated with a single perceptual attribute, e.g.

timbre, organised as multiple separate unidimensional continua (relating to a parameter or function) assigned to different spatial dimensions.

Multimodal (perception and cognition): the integration of information from different sensory modalities to contribute to the perceptual coherence of perceived forms. In the present thesis, this term is also used for integration of information from different processes within single sensory modalities (i.e. different aspects of auditory processing for the same perceptual circumstances).

Music cognition: the psychology of music with respect to the cognition of musical percepts, rather than focussing on transduction–based psychophysical relationships (as in the field of **psychoacoustic**s).

***N*–limit scales:** scales constructed using ratios based on *N*–limit prime factors (or **prime limits**); e.g. 3-limit scales, which are also known as **Pythagorean scales;** 5-limit (**Ptolemaic/just intonation** scales), etc.

Non–octave scales: scales whose interval identities do not repeat in the same way within every octave; the octave is therefore not a constant structural delimiter in the manner in which it is in typical scale construction practice. One prominent example is the **Bohlen–Pierce** (BP) scale, which is based on a **tritave** (octave-plus-fifth).

Neutral third: an interval which is halfway between a tempered major and minor third (thus, a quarter–tone between them) in the musical systems of Hába

(1927) and Wyschnegradsky (1932, cited in Mandelbaum, 1961), providing regions of relative stability between these oppositional functional definitions. Wyschnegradsky's usage of these intervals facilitates cyclical modulation to new keys derived from quarter–tone divisions as a microtonal extension of chromatic harmony.

Natural intervals/pure tuning impulse (scale construction): the preference for constructing scale systems based on the use of integer ratios to create intervals which exhibit relatively simple periodicity. See also **subdivision impulse**.

Octave equivalence: the phenomenon whereby intervals which are related by octaves are considered to be identical in **pitch–chroma**. See Shepard (1964).

Old–plus–new–heuristic: an auditory parsing process affecting the grouping of partials proposed by Bregman, (1990), which implies that materials which can be considered to be continuation of a previous spectral state are allocated separately from materials which could be considered to be new materials, even if such materials might otherwise be in configurations which would contribute to grouping/tonal fusion. Such a process can cause **false positives** resulting in perceptual decomposition.

Otonality: relationships in Patch's (1974) **tonality diamond** which are based on harmonic series/overtone relationships, e.g. major tonalities. See also **Utonality.**

Perceptual: for the purposes of this thesis, *perceptual* is used to denote processes in the act of perception which are related to more basic processes of perceptual transduction rather than more sophisticated cognitive processing; see also **bottom–up perception**.
see bottom-up

Perceptual–conceptual/perceptualism: is applied in this thesis to the work of La Monte Young and James Tenney; this rubric refers to their exploration of perceptual phenomena as the key structural and/or conceptual grounding of many compositions.

Periodicity: the time interval which it would take a pair of tones with frequencies related by a given interval to come back into synchronisation; in some theories of consonance, dissonance is considered to be partly or largely related to higher periodicity values with resulting higher rates of beating for interacting tonal materials. The present thesis regards a **consonance/dissonance–concept** based on periodicity to be of greater potential significance for musics which largely use simultaneous sonorities of sustained harmonic tones of relatively long duration.

Periodicity block: a form of notation representing a closed region of harmonic space and its intervallic connections for a given scale design (Fokker, 1969). The region is considered to be self–contained since transposition in certain directions (termed **unison vectors**) produce (microtonal) intervals which are considered to be negligible in terms of production and/or perception.

Pitch–chroma: the **cognitive–perceptual** dimension of pitch relating to interval identities for pitches within an octave, based on the phenomenon of **octave equivalence** (Shepard, 1964). See also **pitch–height**.

Pitch–height: the absolute physical difference of frequency stimuli (Shepard, 1964). See also **pitch–height** and **octave equivalence**.

Pitch–space: a spatially–based representation of pitch materials, which may be based upon arbitrary formal/procedural connections in some approaches, or may be based upon theories of cognitive relationships between tonal materials. See also (Lerdahl, 2001).

Place theory: a theory in which pitch perception is related to the registering of frequency information based on the location of vibration upon the basilar membrane, transduced by the firing of nerve cells at this location. See also **temporal theory**.

Probe–tone technique: a technique employed in psychological investigations of tonality (i.e. cognitive structuring of musical pitch) whereby an incomplete priming pattern (e.g. a musical scale) is presented with a range of possible completion states (i.e. different intervals), termed probe–tones.

Prothetic continua: psychophysical continua whose psychophysical scales related directly to magnitude estimation (with equal ratios between successive intervals) rather than being based on (less accurate) judgements of rank order based on multiples of discriminability, see Stevens (1957); such psychophysical scales are also termed **ratio scales**.

Pseudo–octave: an interval within a scale system which occupies a role which is analogous to the octave in standard musical scales due to formal or sensory–based attributes; one such example is the **tritave** of the **Bohlen–Pierce scale.**

Psychoacoustics: the scientific study of the relationship between the structure of simple auditory stimuli and their ordering along psychological scales of magnitude; it is a subset of **psychophysics**.

Psychophysics: the scientific study of the relationship between the physical structures of a range of stimuli and their ordering along psychological scales of magnitude.

Ptolemaic scale/tuning: scale constructed after the manner documented by Claudius Ptolemy (2nd century C.E.), see **just intonation** for further details

Pythagorean scale/tuning: scale constructed after the principles traditionally associated with Pythagoras of Samos (6th century B.C.E.) in which the scale is generated through tuning by perfect fifths 'folded back' within a single octave, resulting in a 3–limit scale (one which utilises ratios based on multiples of three or less).

Pythagorean comma: the **comma** obtained through the tuning discrepancy between the enharmonic equivalents (or **unison vectors**) of a very sharp major seventh, obtained through twelve modulations by a perfect fifth, and the adjacent octave of the root note of the scale. This interval is roughly a quarter–tone (23.5 cents) and its exact frequency ratio is 531441/524288.

Prime-limit : see ***N*-limit scales**

Pure tuning impulse: see **natural intervals impulse**

Quantisation: see **discretisation**

Ratio scale: see **prothetic continua**

Relative pitch: a category of performance abilities for pitch/tuning recognition and production which is typical of more general capabilities. Subjects may attain accurate performance in the presence of pitch references, but do not possess the more extensive abilities of **absolute pitch** possessors with respect to accurate performance for a wide range of pitch categories without pitch references being present.

Recoding: in **categorical perception** (CP), recoding signifies a case where the CP process leads to within–category distinctions being eliminated, as is the case in the recognition of speech phonemes. Although this was considered to be the canonical case of CP, later models (Studdert-Kennedy et al., 1970, cited in

Pastore, 1987) propose that CP for certain modalities nonetheless results in the retention of information about within–category distinctions, which may better account for such a model as applied to musical pitch, though the extent of this may depend on presentational circumstances.

Representation (cognition): structural aspects of cognition which entail the creation of complex/abstracted cognitive models based on sensory data and experience/learning, in contrast to the perspectives of **ecological perception** and **embodied cognition**, which seek to explain aspects of cognition through the **replacement** of representational models with direct reference to environmental structures.

Replacement (cognition): in the context of **ecological perception** and **embodied cognition**, this perspective entails the replacement of complex/abstracted cognitive structural models with direct reference to environmental structures.

Room mode: the resonant responses of a room based on its dimensions.

Salience (perception and cognition): the perceptual or cognitive distinctiveness of a particular stimulus.

Sapir-Whorf theory/hypothesis (also termed the Whorf hypothesis or linguistic relativity): a theory relating to a language–dependent effect on the perception and cognition of categories.

Secondary ratios: Partch's term for intervals produced by the subdivisions of his initial 11–limit scale of 29 steps into a 43–tone scale based on **extended just intonation** (Partch, 1974) for the purposes of circumventing the presence of gaps within the initial scale's structure.

Segregation (perceptual): the separation of stimuli into a different perceptual 'objects' or, more commonly, related separate groups of objects (streams, in dynamic configurations found in auditory perception); see also **auditory scene analysis**, **fusion**, **decomposition**, **grouping** and **streaming**.

Sensory consonance and dissonance (also termed tonal consonance/dissonance): sensory/perceptually–based judgements of consonance and dissonance related to overlap of frequency components within **critical bandwidths** on the **basilar membrane** and/or the **periodicity** of beating effects, depending on presentational circumstances. See also **functional relationships/functional consonance and dissonance.**

Septimal: pitch materials in **extended just intonation** which are based on 7–limit ratios. See also ***N*-limit scales**.

Situated cognition: see **embodied cognition**

Sonido Trece **(or 'Thirteenth Sound'):** the name for microtonal divisions and systems proposed by Julián Carrillo on the basis that the introduction of any microtonal division creates a new interval identity outside 12TET, and can therefore be termed the 'thirteenth sound'. In Carrillo's usage, the term is used to signify his entire microtonal project and not any single type of interval **subdivision**.

Subdivision impulse (scale construction): the principle of scale construction based on a preference for the equal subdivision of a given interval rather than generating scale materials directly from integer ratios (the **natural intervals/pure tuning impulse**). The subdivision approach to microtonal scale construction was dominant in much early microtonal practice, most likely due to the influence of the dominant **equal temperament** paradigm.

Streaming: the allocation of auditory percepts into different dynamic groups, termed *streams*, based on **heuristic** principles of **auditory scene analysis**. See also **grouping** and **segregation**.

Syntonic comma: the **comma** of ratio 81/80 which is obtained from the tuning discrepancy between the **Pythagorean** major third (81/64) and the **Ptolemaic/just intonation** major third (5/4), or, more generally, between many 3–limit (Pythagorean) and 5–limit (just intonation) intervals, such as the two major seconds found in just intonation diatonic scales (9/8 and 10/9).

Temperament/tempering: the modification of intervals within a scale to either prioritise the configuration of certain intervals over others (unequal temperaments, e.g. **meantone temperament**) or to completely standardise step size (**equal temperament**).

Temporal theory: a theory in which pitch perception is related to the firing rates of nerve cells in the cochlea. See also **place theory**.

Thirteenth sound: see ***Sonido Trece***

Tone–salience: in Parncutt's (1989) theory, a value denoting the probability of noticing individual pitches in a chord/complex, based on the modelling of generalised harmonic timbres along with the computation of masking factors.

Top-down perception: a model of the general act of perception which focusses primarily on more complex **cognitive** modelling processes. In this model, perceptual experience is primarily dictated by the structures created by such transduction processes. See also **perceptual.** For the opposing model, see **bottom–up perception**.

Tolerance (tuning/intonation): in a model of tonal relations and interval identities, the degree of tolerance which is applied in judging the salience and categorical distinctiveness of individual intervals; if a variety of pitch intervals are within a tolerance limit, such pitches are considered to be equivalent. Tenney (1983) used this concept to defend a preference for spatial representations of pitch relationships based on lower–order prime factors. In Fokker's (1969)

periodicity blocks, transpositions in the direction of intervals within such a tolerance limit would be termed **unison vectors**.

Tonality Diamond: Partch's (1974) two–dimensional spatial model or **lattice–based** model (based on the ***Tonnetz***) of relationships between **just intonation** (and **extended just intonation**) pitch materials which was later embodied in the physical construction of his Diamond Marimba.

Tonnetz: a spatial model (**lattice** structure) of relationships between pitch intervals, initially based on formal relationships between **just intonation** materials, pioneered by Euler (in 1739), reprised and developed by Oettingen (from 1866) and Riemann (from 1880), eventually forming providing a basis for Partch's **Tonality Diamond** (Partch, 1974) and the later multidimensional lattice structures of Johnston—see (Gilmore, 1995)—and Tenney (1983).

Transduction (perception): the process of encoding sensory data into neural impulses through the activities of the physiological (including neurological) components of sense organs. See also **recoding**.

Tritave: in the Bohlen–Pierce scale, the tritave is the octave–analogue (or **pseudo–octave**) which marks the boundary of the scale before it repeats its intervallic structure. Its similarity to the octave can be enhanced through careful specification of harmonic spectra such that only odd–numbered harmonic partials are used; this will result in the tritave components aligning with each other without adding additional interposed harmonic materials in a manner which is similar to that encountered in the combination of complex periodic tones at octave offsets.

Universalist (perceptual categorisation) hypothesis: theory which relates perceptual category definition primarily to psychophysical factors. See also **Sapir–Whorf theory** and **categorical perception**.

Utonality: relationships in Patch's (1974) **tonality diamond** which are based on undertone relationships, e.g. minor tonalities. See also **Otonality.**

Ultrachromatic/ultrachromaticism: Wyschnegradsky's preferred term for his subdivision–based microtonality, conceptualised as an extension of functionally–based chromaticism based on their deployment as intermediate scale steps, in addition to formally–based cyclical structures (Wyschnegradsky, 1972, cited in Beaulieu, 1991, section 1). This approach is in partial contrast to the **bichromatic** approach of Hába, assigns quarter-tone materials into two distinct and microtonally offset 12TET chromatic scales.

Unidimensional (psychophysics): a perceptual continuum whose organisation corresponds to the varying of a key single parameter of the stimulus from low to high.

Unison vector: in the **periodicity block** notation of Fokker (1969), a unison vector marks the boundary of a closed region of harmonic space (such as a musical scale) when transpositions in a particular direction yield intervals which are considered to be equivalent (i.e. whose differences are considered to be negligible in terms of production and/or perception).

Well–temperament/well–tempered: an unequal **temperament** which attempts to produce relatively (but not completely) consistent results for interval sizes such that an instrument may perform in the majority of major and minor keys without noticeably different intonational results.

Working memory: see **short–term memory**

Xenharmonic: music based on alternative scale structures which deviate significantly from Western common practice, resulting in alternative harmonic and melodic practices (Darreg, 1966). The term was initially intended to describe microtonal practice, but was later expanded (Darreg, 1974) as a supra–category incorporating both microtonal music and music for **alternate/alternative tuning** scales which contain a small number of steps.

Appendix 2: Links to online audio examples of compositions discussed in this thesis (alphabetical by composer)

Note:

Please see bibliography for full citations. Links provided are live at the time of submission (and are intended to provide the reader with the possibility of preliminary consultation in addition to the more durable references in the main bibliography) but may be subject to removal or change of hosting location.

Some compositions from the bibliography which are not available or publicly accessible outside subscription-based services have not been listed. Please note that this list only provides links to pieces which are discussed in the context of this thesis and its arguments and is not intended to constitute a representative survey of microtonal music (indeed, a small number of the compositions listed here are not expressly microtonal but are used to illustrate points of discussion related to microtonal music).

Boulanger, R., 1989. *I Know of no Geometry*. [Online audio recording: Available at: http://www.ziaspace.com/elaine/BP/BPmusic/DrB/IKnowOfNoGeometry_RB.mp3 [Last accessed: October 2012]

Boulanger, R., 1990. *Solemn Song for Evening*. [Online audio recording]: Available at: http://www.ziaspace.com/elaine/BP/BPmusic/DrB/BP2010_DrB_SolemnSong.mp3 [Last accessed: July 2011].

Branca, G., 1983. *Symphony No. 3––'Gloria' (Music for the first 127 intervals of the harmonic series).* [Online audio recording: streaming version at Youtube.com channel: minimalism in music] Available at: http://www.youtube.com/watch?v=OpdnVS3FrGE [Last accessed: June 2012]

Carrillo, J., 1924. *Preludio a Colón*. [Online audio recording: streaming version at Youtube.com channel: Rodrigo Navarro] Available at: http://www.youtube.com/watch?v=lOihGnn6HoE [Last accessed: June 2011]

Carrillo, J., 1927. *Concertino en cuartos, octavos y dieciseisavos de tono para violín, violonchelo y arpa con acompañamiento orquestal*. [Online audio recording: streaming version at Youtube.com channel: sciprio] Available at: http://www.youtube.com/watch?v=3O3H01c2SjE   [Last accessed: June 2011].

Chowning, J., 1981. *Phoné*. [Online audio recording: streaming excerpt at www.classicsonline.com] Available at : http://www.classicsonline.com/catalogue/product.aspx?pid=1419661 [Last accessed: July 2012]

Hába, A., 1929. *Matka/La Madre* (opera). [Online audio recording: streaming version at Youtube.com channel: TheWelleszTheatre] Available at: https://www.youtube.com/watch?v=127K6DGpbhc [Last accessed: May 2012]

Hába, A., 1947. *Sonata for Quarter-tone Piano*. [Online audio recording: streaming version at Youtube.com channel: Rodrigo Navarro] Available at:

http://www.youtube.com/watch?v=s7vZURdhucM [Last accessed: May 2012]

Ives, C., 1924. *Three Quarter–tone Pieces.* [Online audiovisual recording: streaming version at Youtube.com channel: Richard Winfeld]

1. *Largo*, Available at: http://www.youtube.com/watch?v=EXJPnUZhETg [Last accessed: October 2012]
2. *Allegro*, Available at: http://www.youtube.com/watch?v=EU85bUyDPWs [Last accessed: October 2012]
3. *Chorale, Adagio*, Available at http://www.youtube.com/watch?v=0JESZY4VK68 [Last accessed: October 2012]

Johnston, B., 1964. String Quartet No. 2. [Online audio recording: streaming version at Youtube.com channel: TheWelleszCompany] Available at: http://www.youtube.com/watch?v=YOozBrB2XT0 [Last accessed: July 2012]

Johnston, B., 1980. String Quaret No. 6. [Online audio recording: streaming version at Youtube.com channel: TheWelleszCompany] Available at: http://www.youtube.com/watch?v=9ujeXlFP7p0 [Last accessed: July 2012]

Johnston, B., 1987. String Quartet No. 9. [Online audio recording: streaming version at Youtube.com channel: NewDissonance] Available at: http://www.youtube.com/watch?v=MPHLS5mJrJk [Last accessed: July 2012]

Partch, H., 1943/55, *U.S. Highball*. [Online audio recording: streaming version at Youtube.com channel: EyeforAyler] Available at: http://www.youtube.com/watch?v=BMqXP56bMhY [Last acessed: July 2012]

Partch, H., 1967, *Daphne of the Dunes* [revision of *Windsong*, 1955]. [Online audio recording: streaming version at Youtube.com channel: TheWelleszCompany] Available at: http://www.youtube.com/watch?v=v9W3ZOs6C2A [Last accessed July 2012]

Tenney, J., 1974. *Spectral CANON for CONLON Nancarrow.* [Online audiovisual recording: streaming version at Youtube.com channel: playerpianoJH] Available at: http://www.youtube.com/watch?v=hUrfKBnQ9a4 [Last accessed: August 2012]

Tenney, J., 1988. *Critical Band.* [Online audio recording: streaming version at Youtube.com channel: ferney43] Available at: http://www.youtube.com/watch?v=jEMCpUoQ_OQ [Last accessed: October 2012].

Wyschnegradsky, I., 1934. Op.22, *24 Préludes dans l'échelle chromatique diatonisée à 13 sons.* [Online audio recording: streaming version at Youtube.com channel: musicaignotus] Available at: http://www.youtube.com/watch?v=vI3QXON4THQ&list=PL891E4B340C6DD9F2 [Last accessed: June 2012]

Wyschnegradsky, I., 1961. Op.45, *Étude sur les Mouvements rotatoires.* [Online audio recording: streaming version at Youtube.com channel: OMaclac] Available at:

http://www.youtube.com/watch?v=6E5mrmIwAOY [Last accessed: May 2012]

Young, L,. 1964. *The Pre-tortoise Dream Music*. [Online audio recording: streaming version at Youtube.com channel: MesothermicTertiary] Available at: http://www.youtube.com/watch?v=aLitnrAd9jg [Last accessed: July 2012]

Young, L., 1991. *The Base 9:7:4 Symmetry in Prime Time...* [Composition/sound installation]. . [Online audio recording: streaming versions at Youtube.com channels: legendtofski, Edo Pietrogrande, nanju73; note that some parts of these examples exhibit clipping] Available at [last accessed July 2012]:

1. http://www.youtube.com/watch?v=ojewHhNVTEs
2. http://www.youtube.com/watch?v=D3JYuGNtdv8
3. http://www.youtube.com/watch?v=7U3wOjc0Bjk

Young, L. 1964/1973/1981–present. *The Well–tuned Piano*. [Online audio recording: streaming version at Youtube.com channel: TheWelleszCompany]. Available at: http://www.youtube.com/watch?v=KB1_YUXgivE [Last accessed: July 2012]

Appendix 3: Composition Portfolio Materials

(Scores and Charts)

Appendix 3.1 *Angels at the Shotgun Wedding* (2007/08) specification charts and scores

Angels at the Shotgun Wedding

[2008] for 23 electric guitars and tape (drone)

Specification charts and scores

1. Tuning charts—drones
2. Tuning charts—guitars
3. Specification/analysis scores—by movement
4. Performance scores (guitar tablature)—by movement

Introductory note

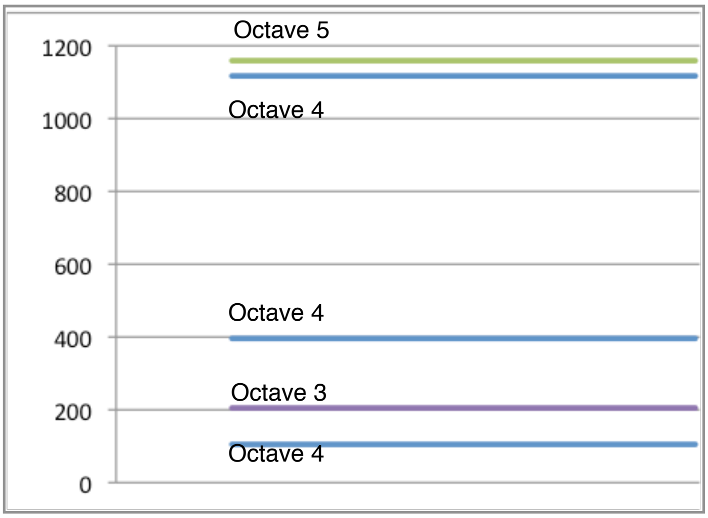
This piece is scored for a ‘tape-based’/fixed media drone part and multiple electric guitarists divided into five different tuning-based groups, articulating a rapid plectrum-based tremolo effect for each five-second note duration (or compounds of same). The optimum number of performers is four or five guitarists per group (circa 23 guitars), although the piece can be performed with as few as two per part if enough apparent uniformity/continuity of sound can be obtained through sustained rapid tremolo articulation and reverberant diffusion. Guitarists follow a tablature-based score, reinforced by a conductor and timecode display to highlight timing cues.

Tuning charts—drones

All ratios relative to sub-octave of E330 Hz (82.5 Hz)

Movement 1: ratios (cents)

Oct 5	125/64 (1158)
Oct 4	61/32 (1117), 5/4 (386), 17/16 (105)
Oct 3	9/8 (204)
Oct 1	1/1 (0)

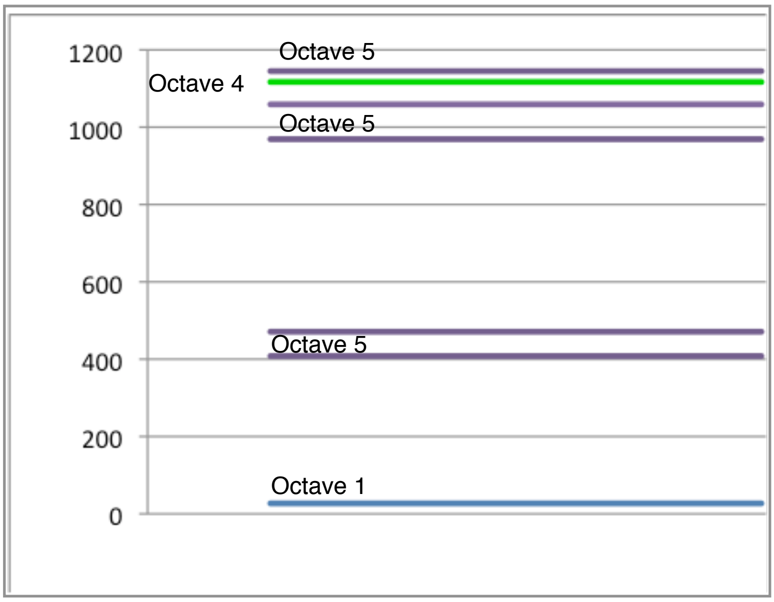


Movement 2: ratios (cents)

Oct 5 31/16 (1145), 59/32 (1059), 7/4 (969), 21/16 (470), 81/64 (408)

Oct 4 61/32 (1117)

Oct 1 65/64 (27)

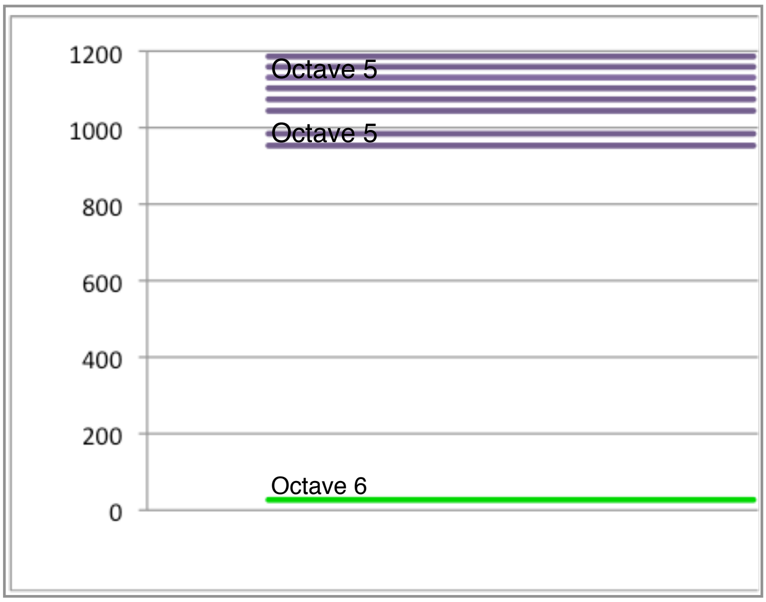


Movement 3: ratios (cents)

Oct 6 65/64 (27)

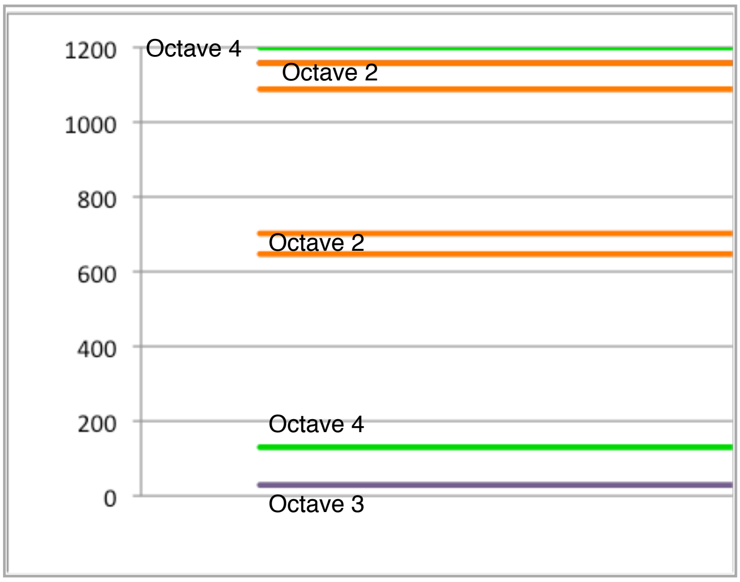
Oct 5 127/64 (1186), 125/64 (1159), 123/64 (1131), 121/64 (1103)
119/64 (1074),117/64 (1044), 113/64 (984) ,111/64 (953)

Oct 1 no components



Movement 4: ratios (cents)

Oct 4	69/64 (130), 65/64 (27), 1/1 (0)
Oct 3	125/64 (1159), 65/64 (27), 1/1 (0)
Oct 2	125/64 (1159), 15/8 (1088), 3/2 (702) ,93/64 (647)
Oct 1	no components



NB: some octave-duplicated components not shown

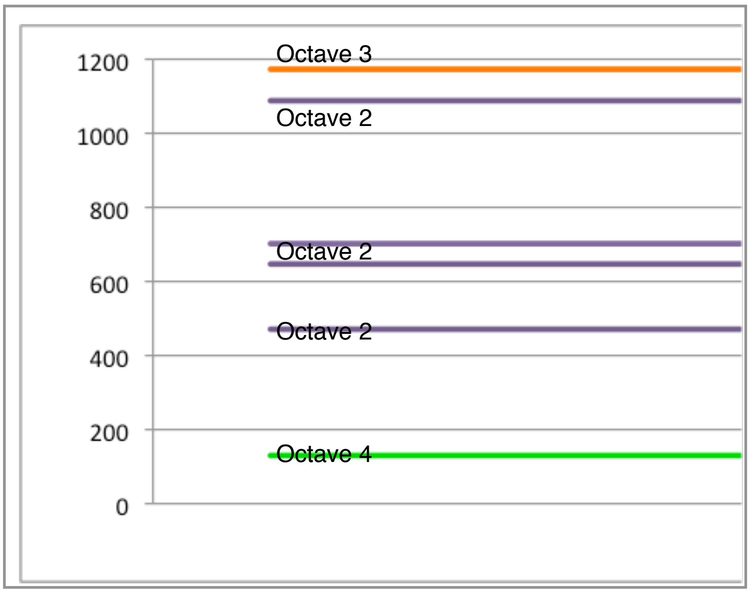
Movement 5: ratios (cents)

Oct 4 69/64 (130)

Oct 3 63/32 (1173), 69/64 (130)

Oct 2 15/8 (1088), 3/2 (702),93/64 (647),21/16 (471)

Oct 1 no components



NB: some octave-duplicated components not shown

Tuning charts—guitars

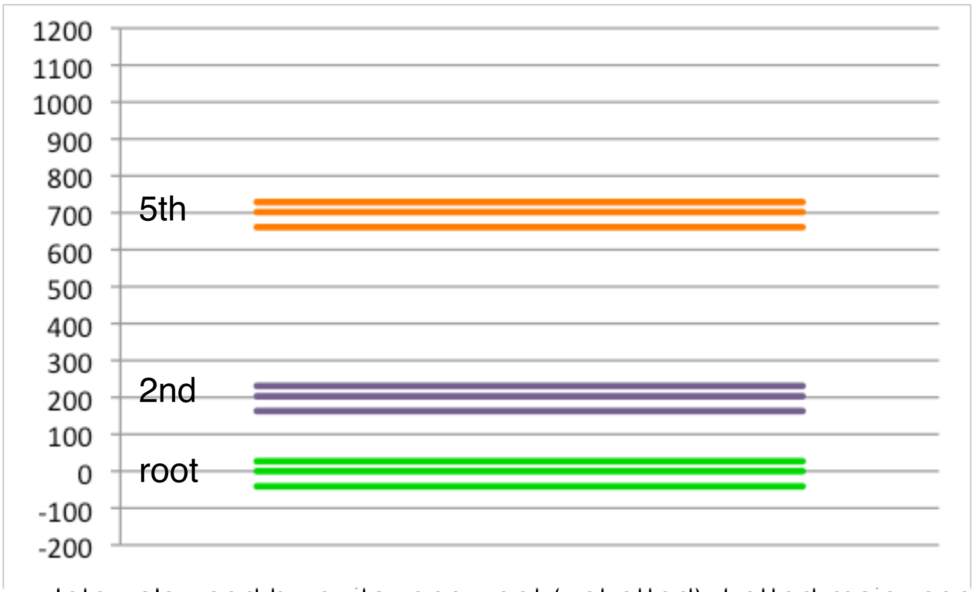
Each guitar is tuned in two octave-offset groups of the three intervals below (from higher to lower notes); i.e. the three intervals are grouped together

Guitar 1: ratios

'roots'	**x 9/8 (analogues of '2nds')**	**x 3/2 (analogues of '5ths')**
65/64	73/64 [585/512]	97/64 [195/128]
1/1	9/8	3/2
125/64	35/64 [1125/1024]	47/64 [375/256]

Guitar 1: cents

'roots'	**x 9/8 (analogues of '2nds')**	**x 3/2 (analogues of '5ths')**
27	231	729
0	203	702
-41	163	661



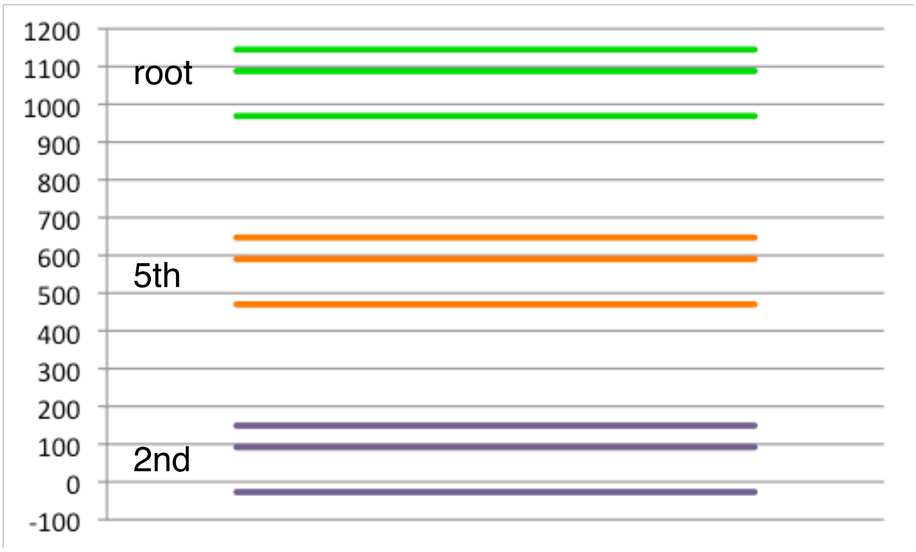
Intervals used by guitar one: root (unfretted), fretted major second, fretted perfect fifth

Guitar 2: ratios

'7ths'	x 9/8 (analogues of 'roots/8ves')	x 3/2 (analogues of '4ths')
31/16	35/32 [279/256]	93/64
15/8	not used [135/128]	45/32
7/4	63/32	21/16

Guitar 2: cents

'7ths'	x 9/8 (analogues of 'semitone/roots')	3/2 (analogues of '4ths')
1145	149	647
1088	92	590
969	-27	470



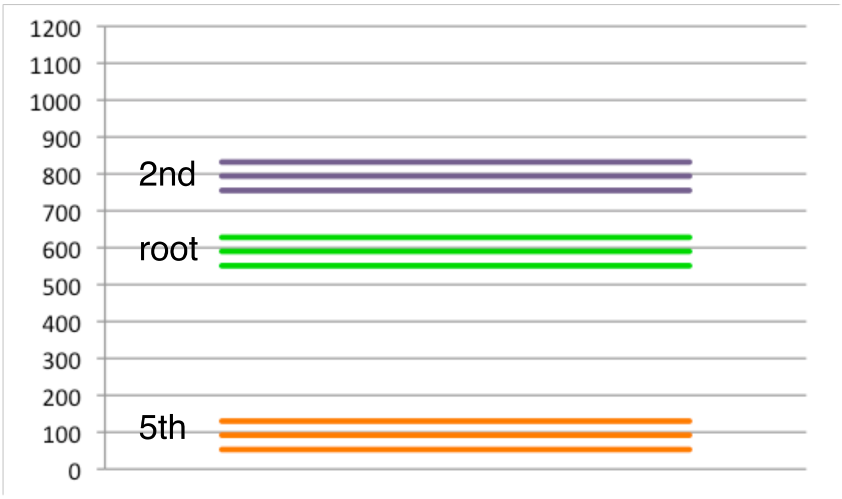
Intervals used by guitar two: root (unfretted), fretted major second, fretted perfect fifth

Guitar 3: ratios

'4ths'	x 9/8 (analogues of '6ths')	x 3/2 ('roots'/'semitones')
23/16	13/8 [207/128]	69/64
45/32	101/64 [405/256]	[not used] 135/128
11/8	99/64	33/32

Guitar 3: cents

'4ths'	x 9/8 (analogues of '6ths')	x 3/2 ('roots'/'semitones')
628	832	130
590	794	92
551	755	53



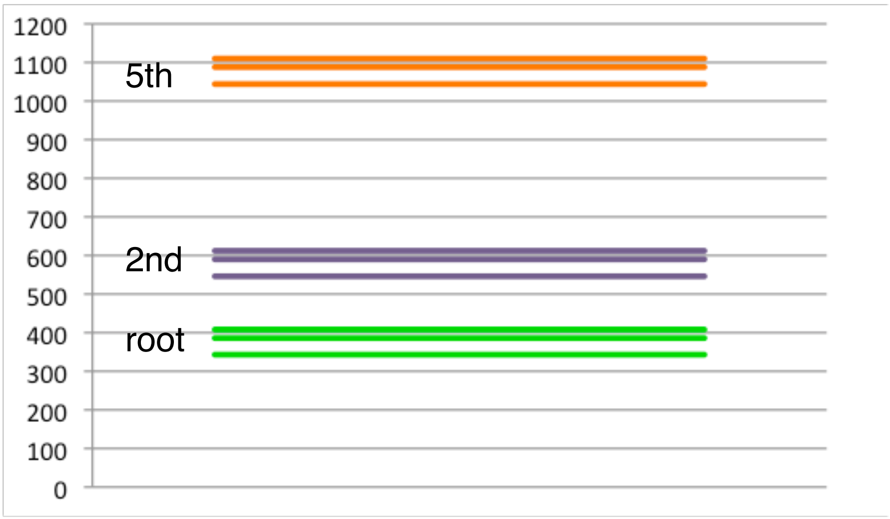
Intervals used by guitar three: root (unfretted), fretted major second, fretted perfect fifth

Guitar 4

'3rds'	x 9/8 (analogues of 'tritones')	x 3/2 (analogues of '7ths')
81/64	69/64 [729/512]	not used [243/128]
5/4	45/32	15/8
39/32	11/8 [351/256]	117/64

Guitar 4

'3rds'	x 9/8 (analogues of 'tritones')	x 3/2 (analogues of '7ths')
408	612	1110
386	590	1088
343	546	1044

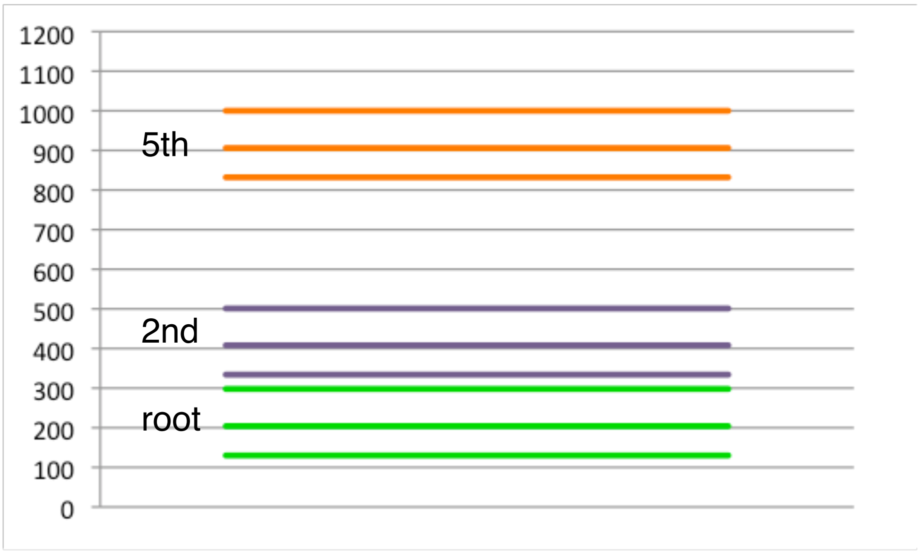


Guitar 5

'2nds[1]'	x 9/8 (analogues of '3rds')	x 3/2 (analogues of '6ths')
19/16	not used [171/128]	57/32
9/8	81/64	27/16
69/64	39/32 [621/512]	13/8 [207/128]

Guitar 5

'2nds'	x 9/8 (analogues of '3rds')	x 3/2 (analogues of '6ths[2]')
298	501	1000
204	408	906
130	334	832



---

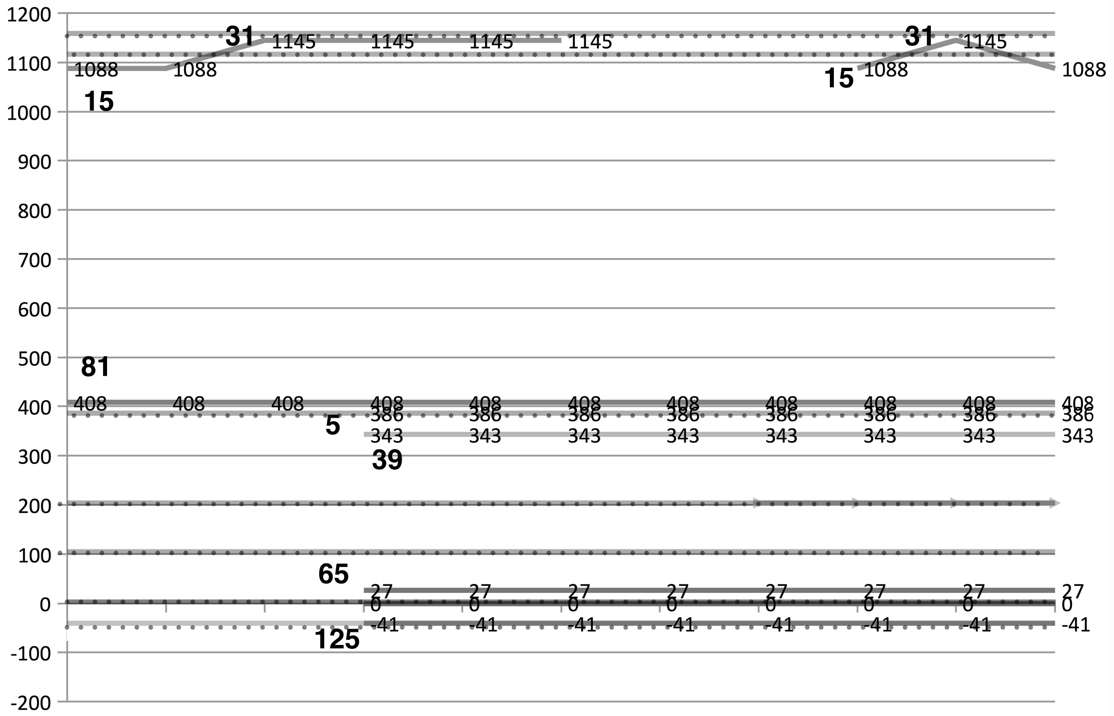
[1] Also includes minor third (19th harmonic) analogue.

[2] Also includes 1000 cent equal temperament minor seventh.

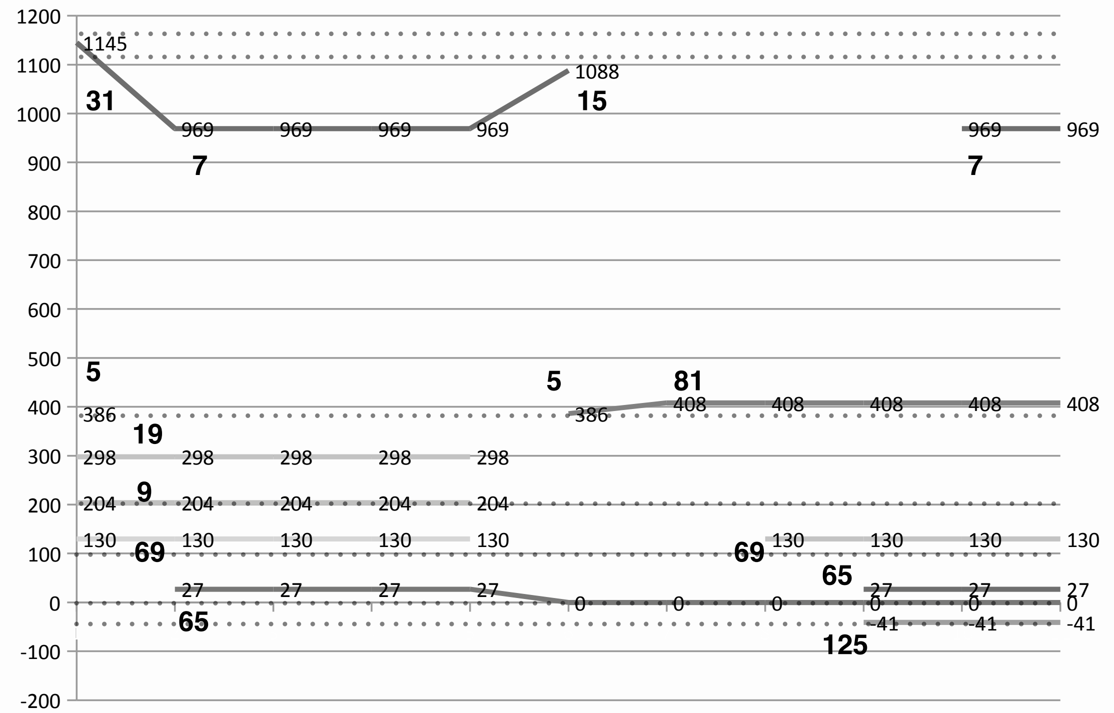
Specification/analysis scores

Movement 1: ‘Departure’

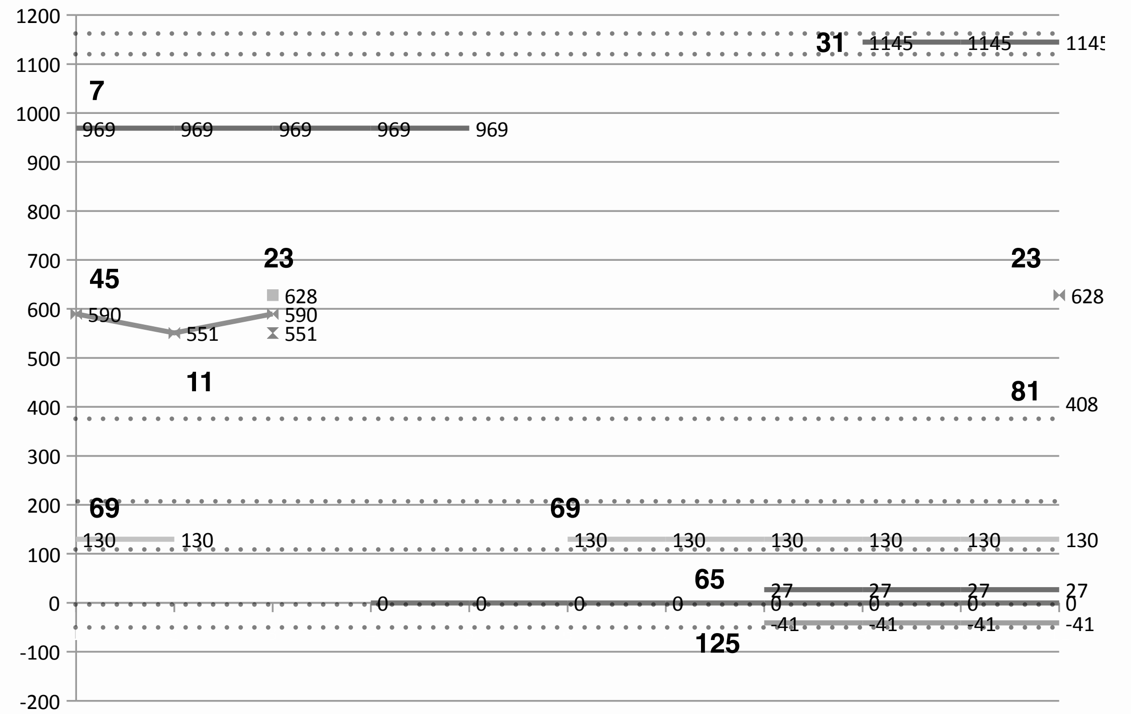
0 secs to 55 secs



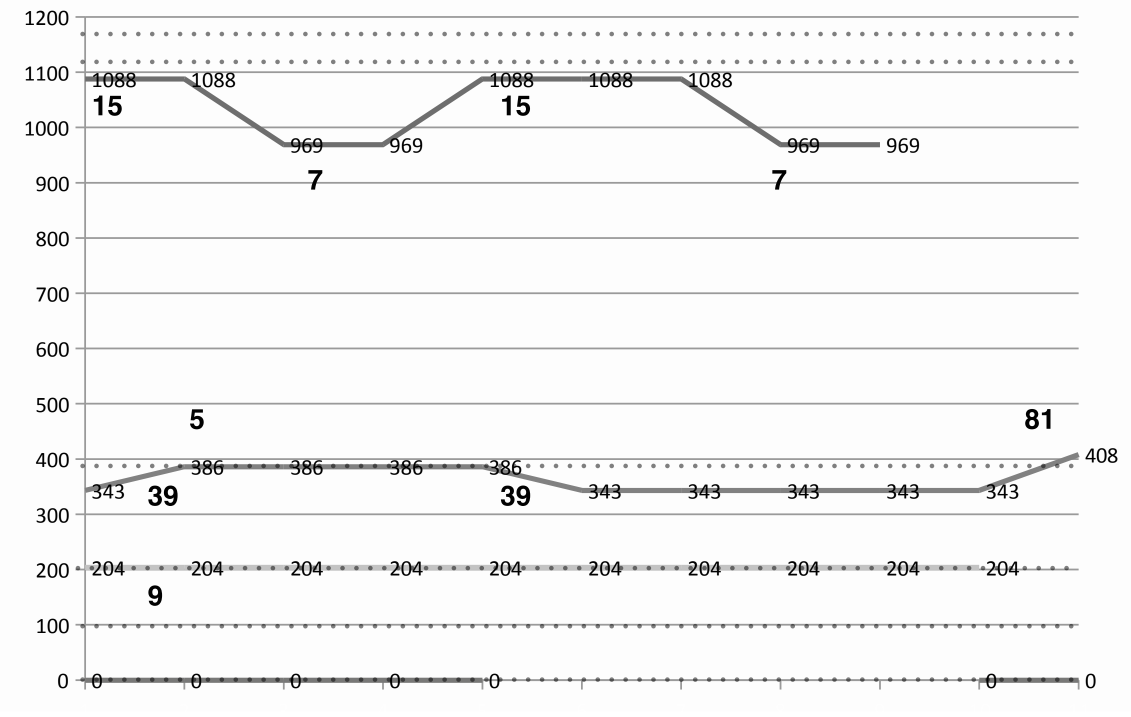
1 min to 1 min 55 secs

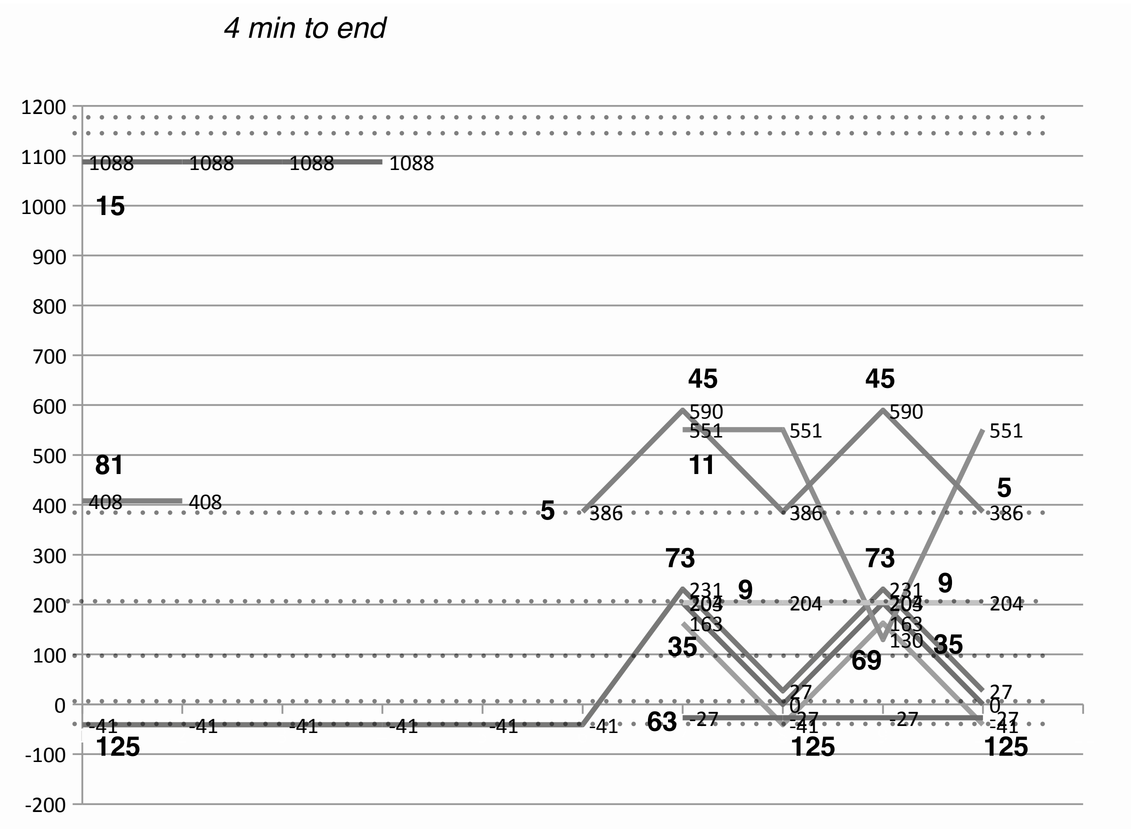


2 min to 2 min 55 secs

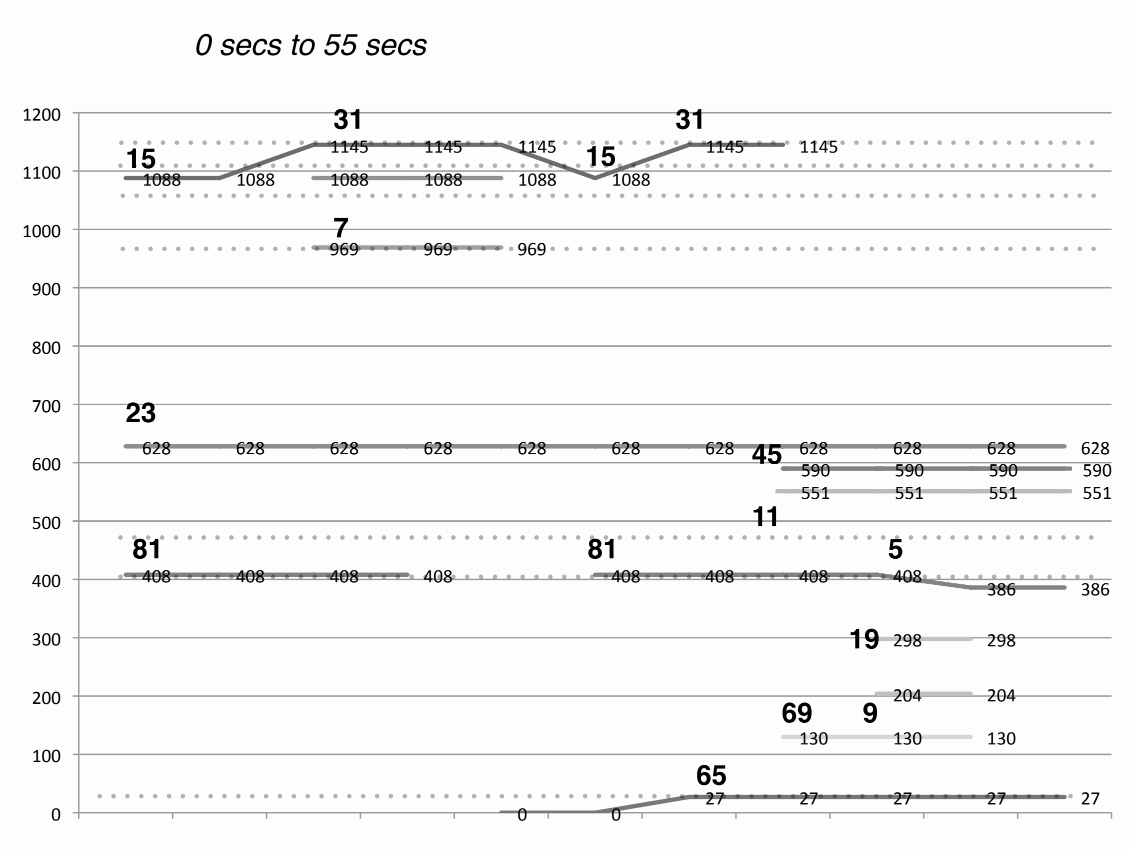


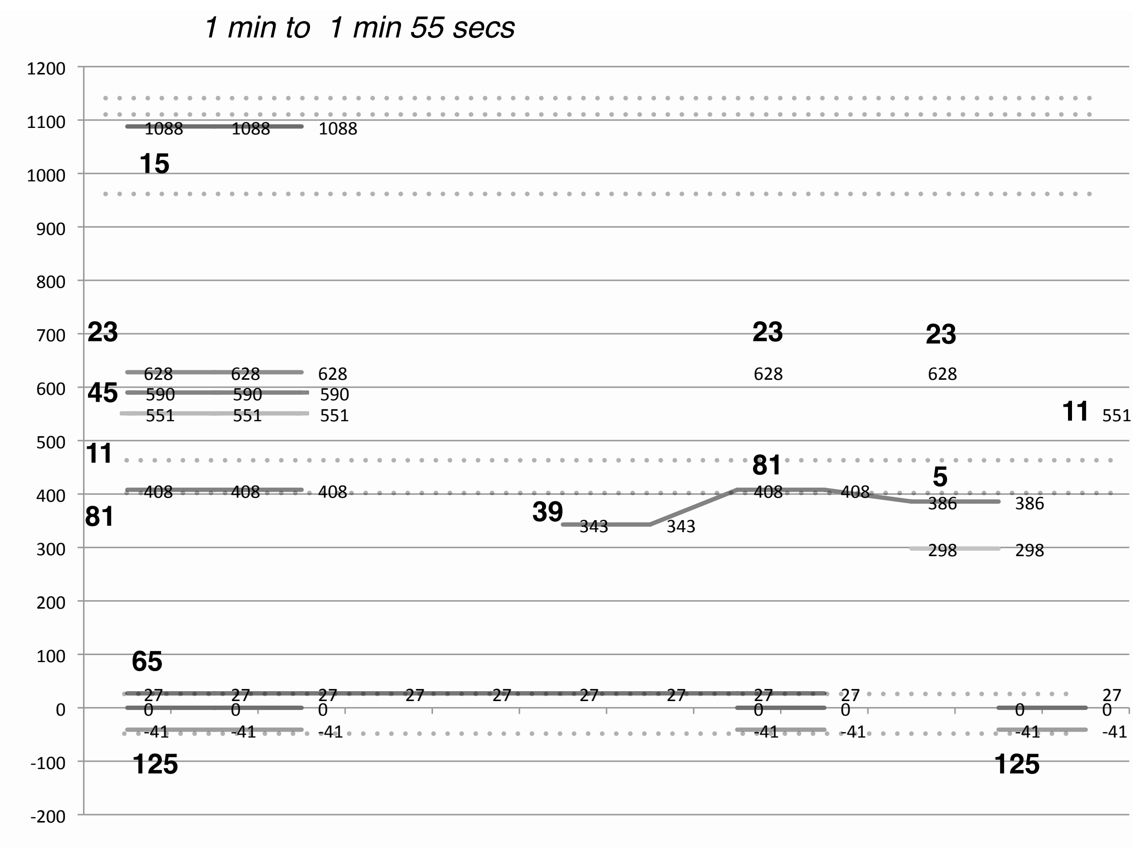
3 min to 3 min 55 secs



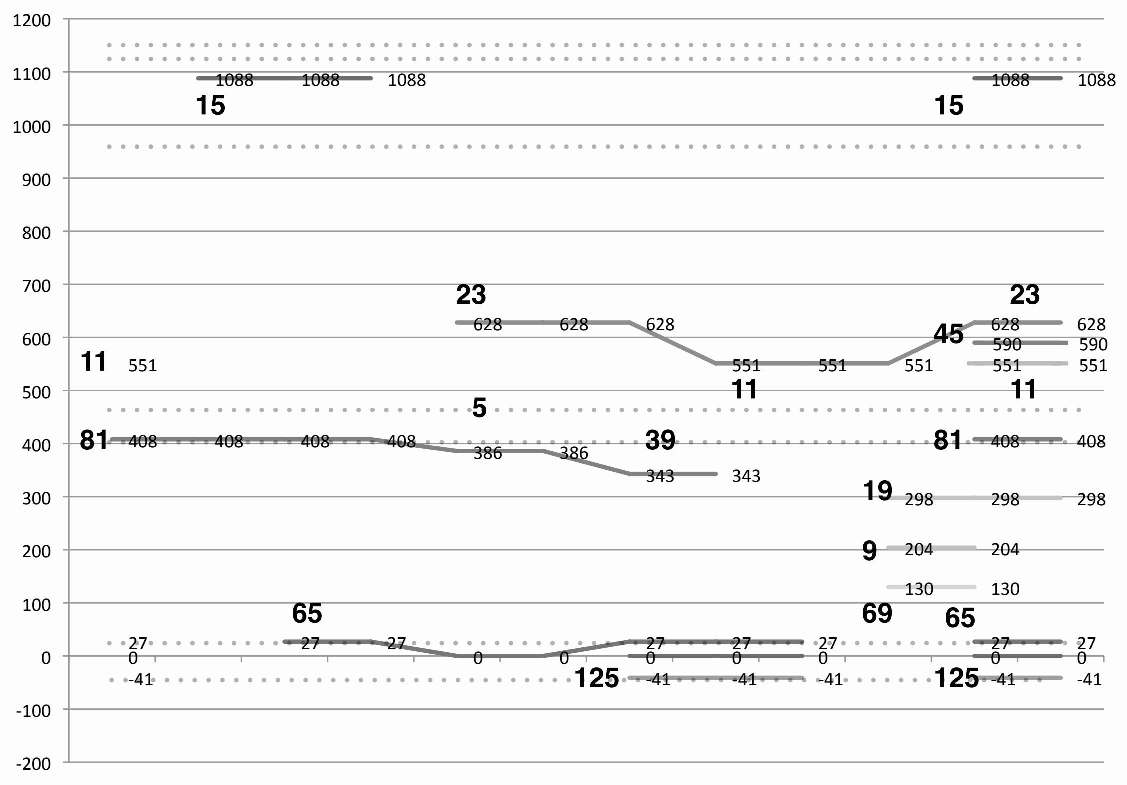

4 min to end
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
1088
15
81
408
5
386
45
590
551
11
73
231
204
163
9
35
63
-27
-41
125
27
0
130
69

Movement 2: ‘Inhalation/ Choke’


0 secs to 55 secs
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
31
15
1088
1145
7
969
23
628
45
590
551
11
81
408
5
386
19
298
204
69
9
130
65
27

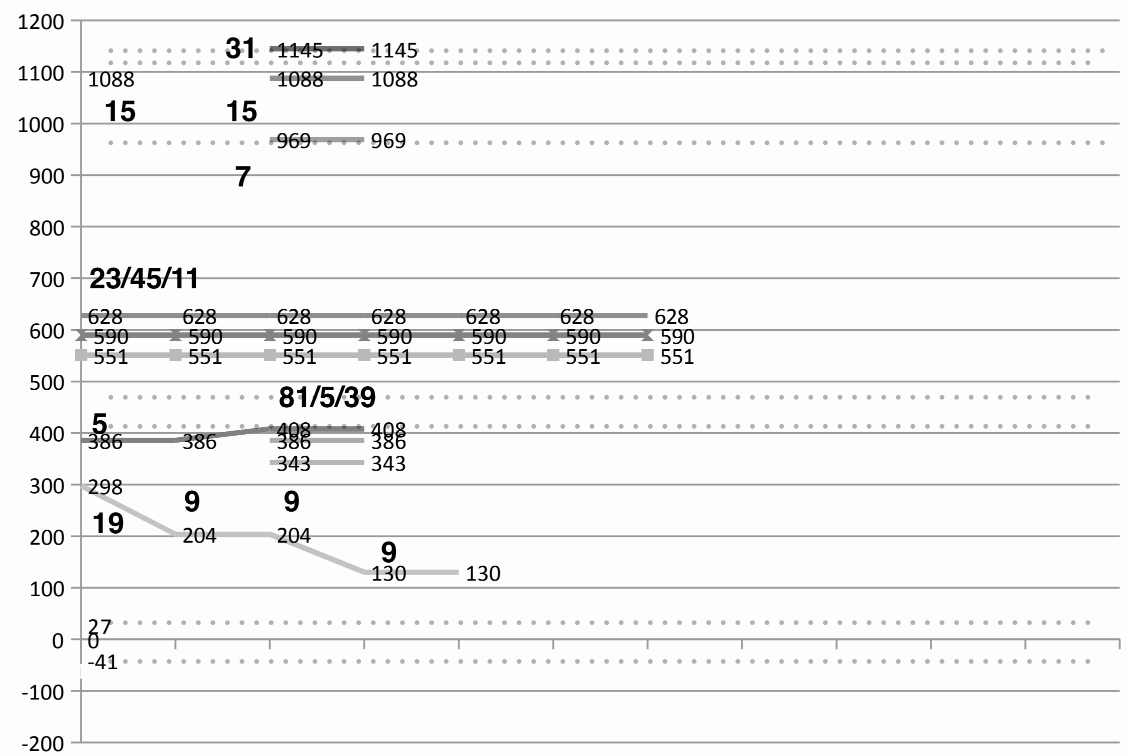

1 min to 1 min 55 secs
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
1088
15
23
628
45
590
551
11
81
408
39
343
5
386
298
65
27
0
-41
125

2 min to 2 min 55 secs



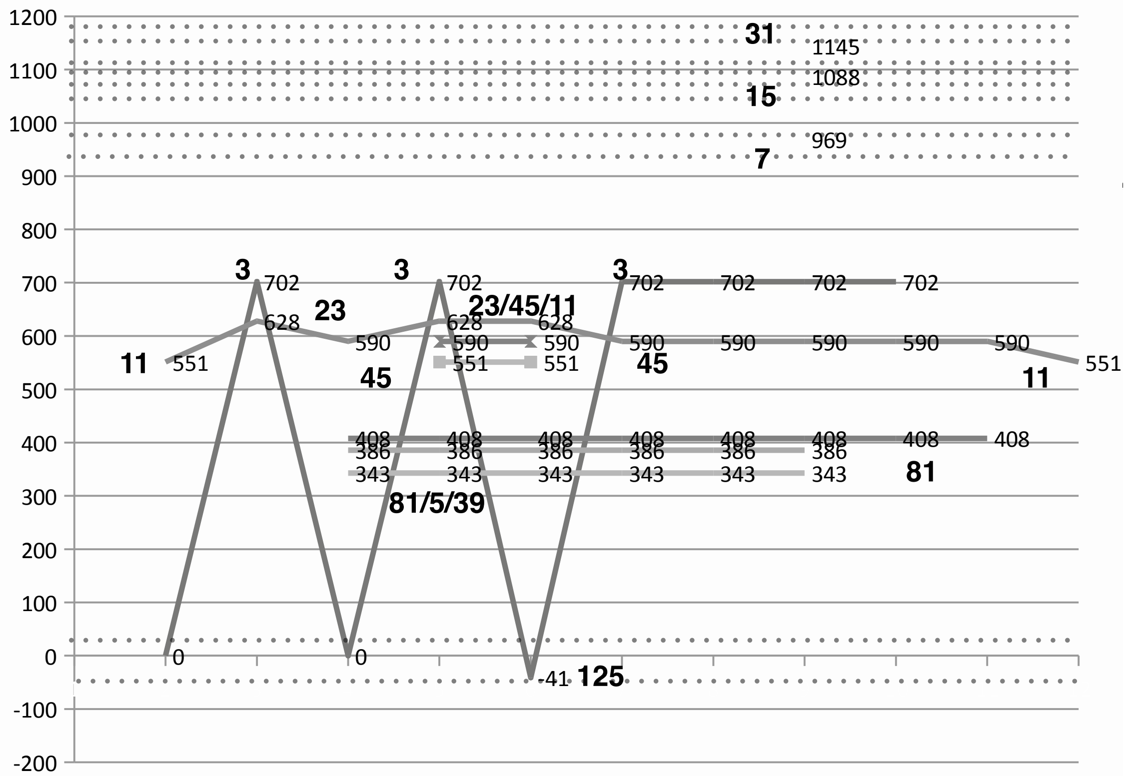
cents

3 min to end

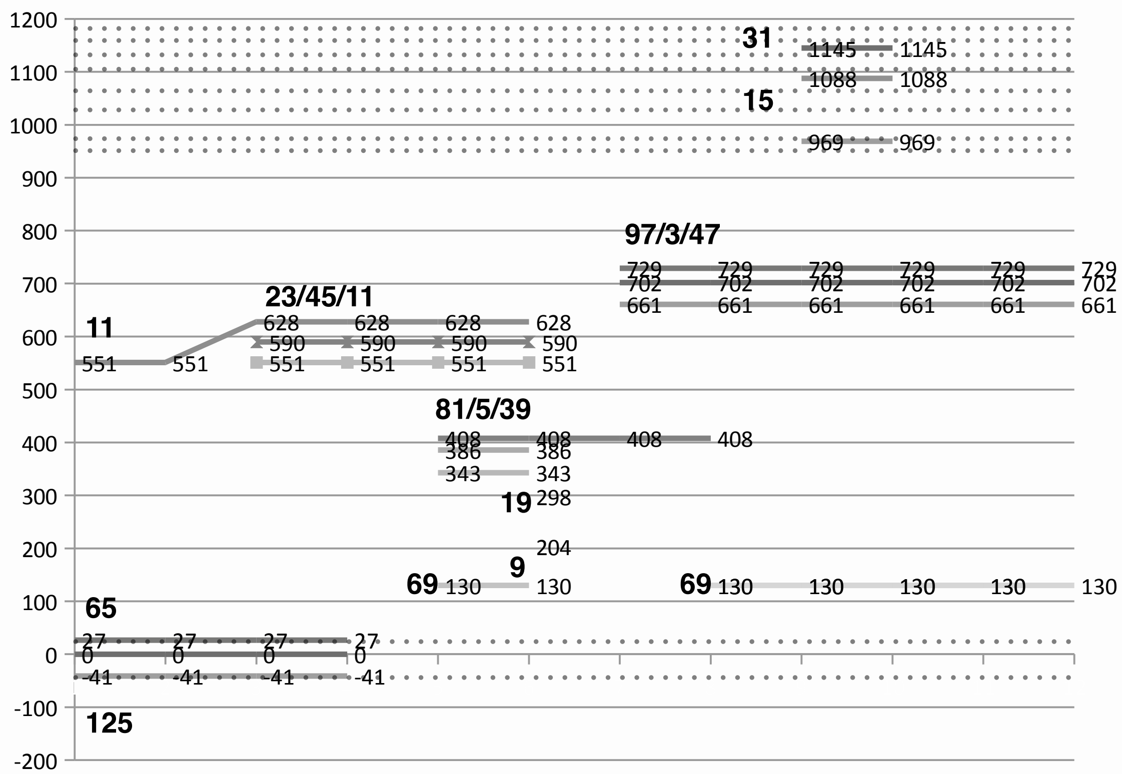


Movement 3: ‘Take God out and Show Her a Good Time’

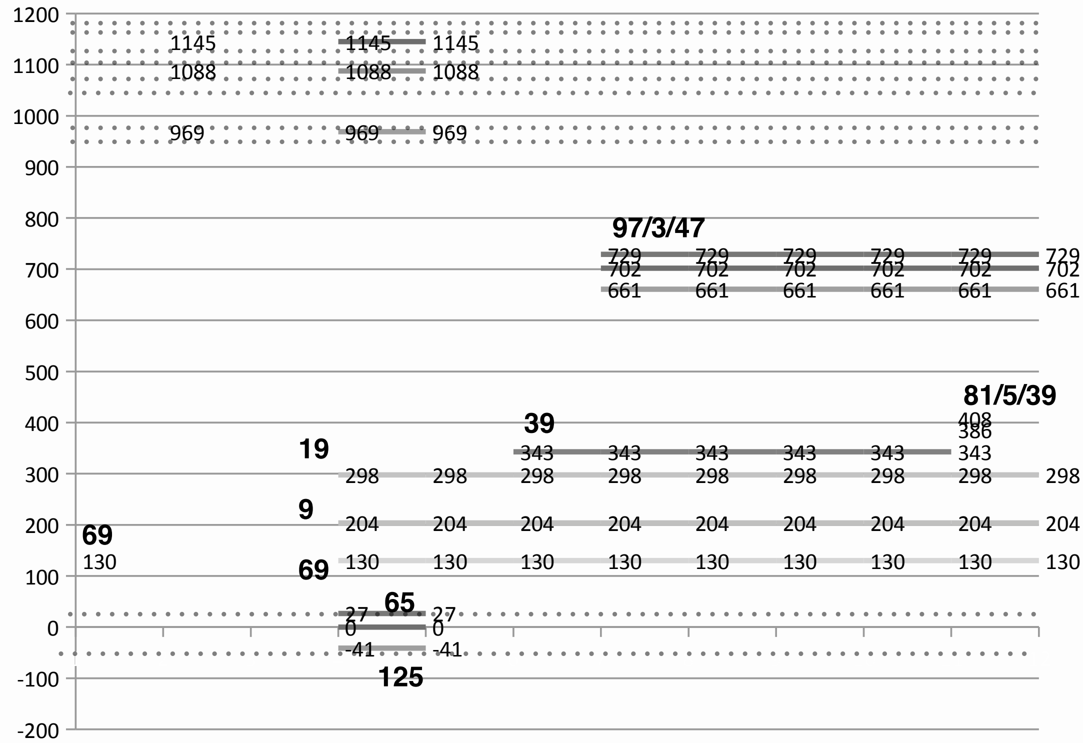
0 secs to 55 secs



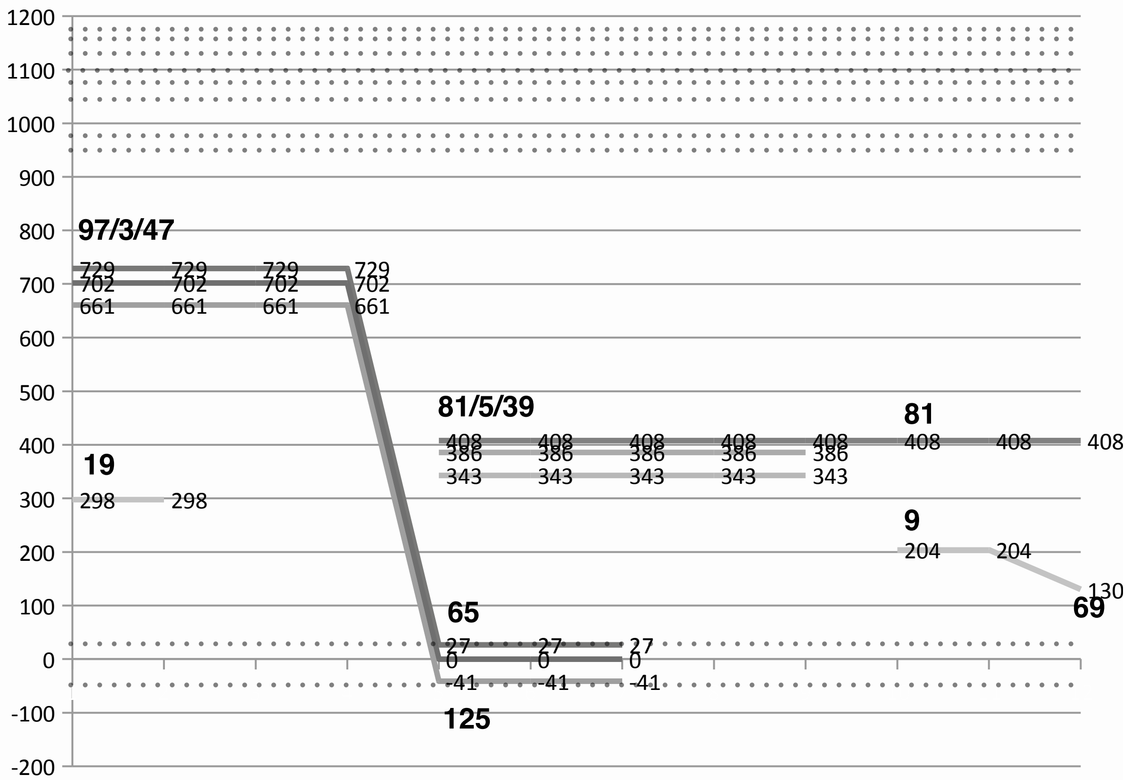
1 min to 1 min 55 secs

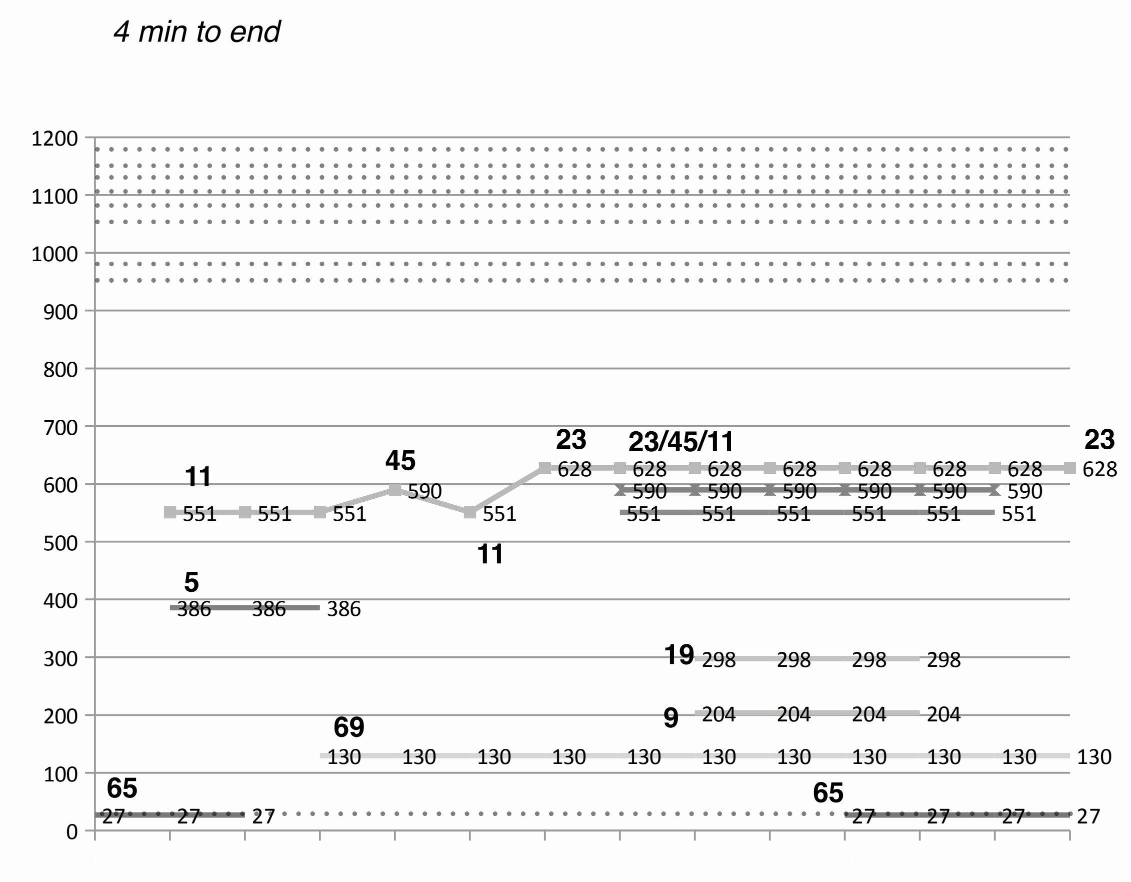


2 min to 2 min 55 secs



3 min to 3 min 55 secs

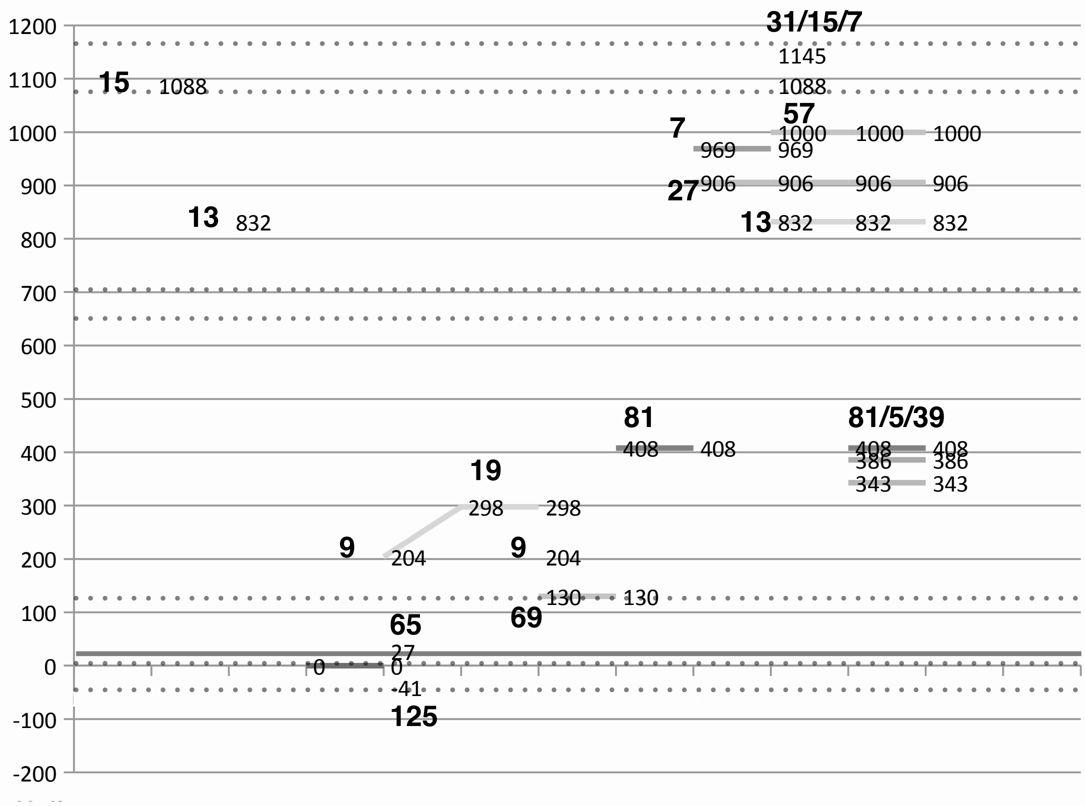




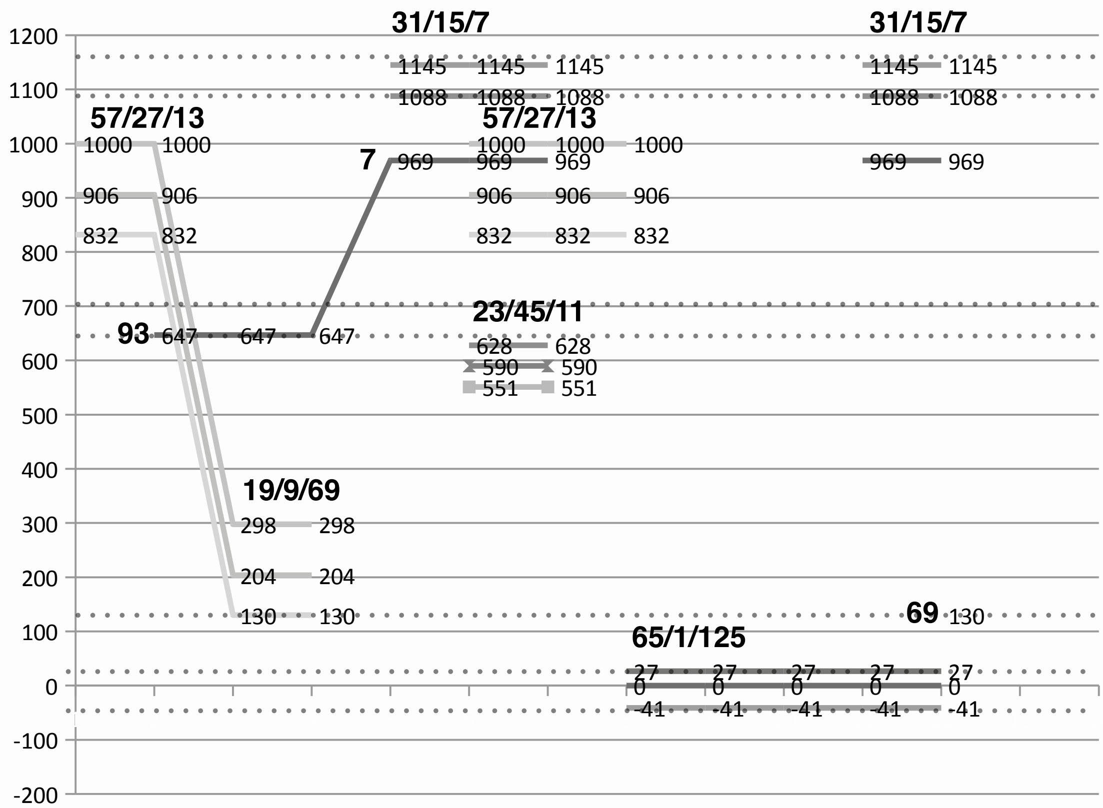
4 min to end
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
11
551 551 551
45
590
551
11
23
628
23/45/11
628 628 628 628 628 628
590 590 590 590 590 590
551 551 551 551 551 551
23
628
5
386 386 386
19
298 298 298 298
9
204 204 204 204
69
130 130 130 130 130 130 130 130 130 130 130
65
27 27 27
65
27 27 27 27

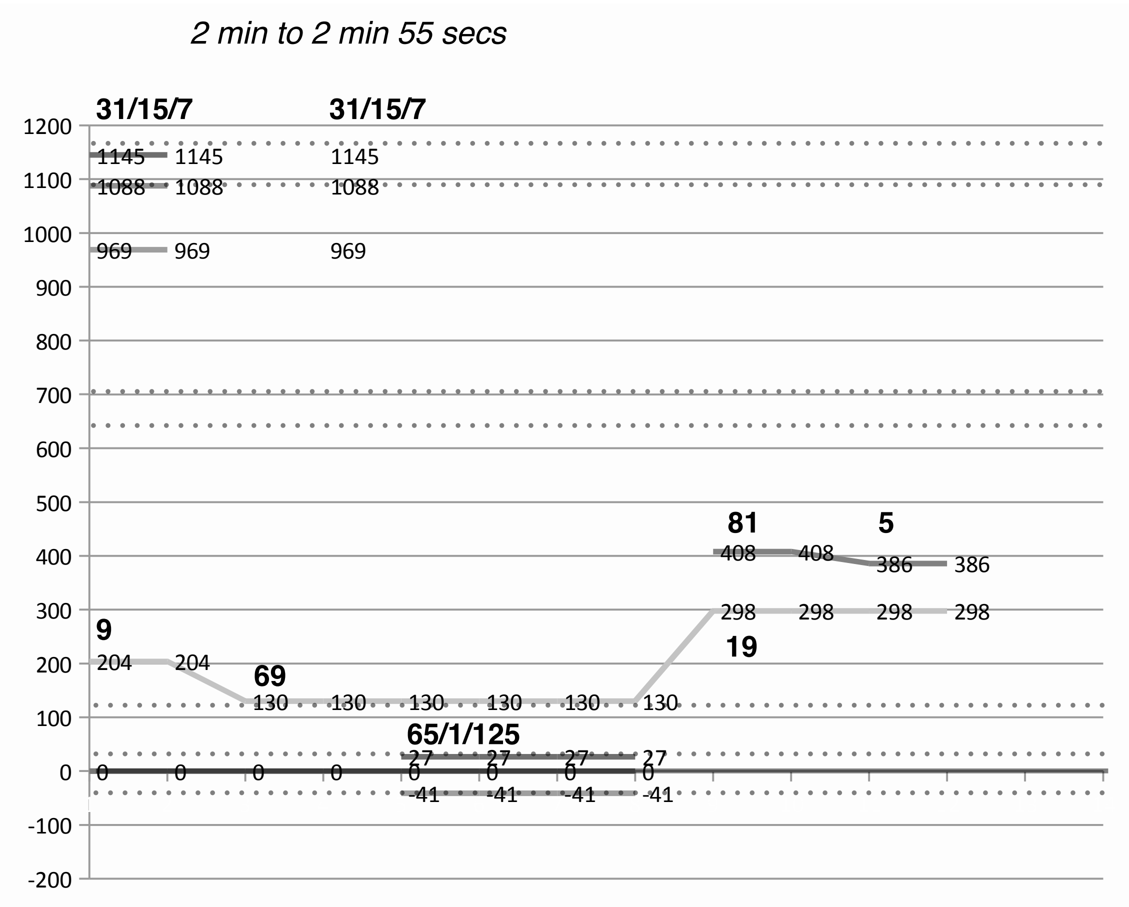
Movement 4: ‘Pathfinding’

0 secs to 55 secs

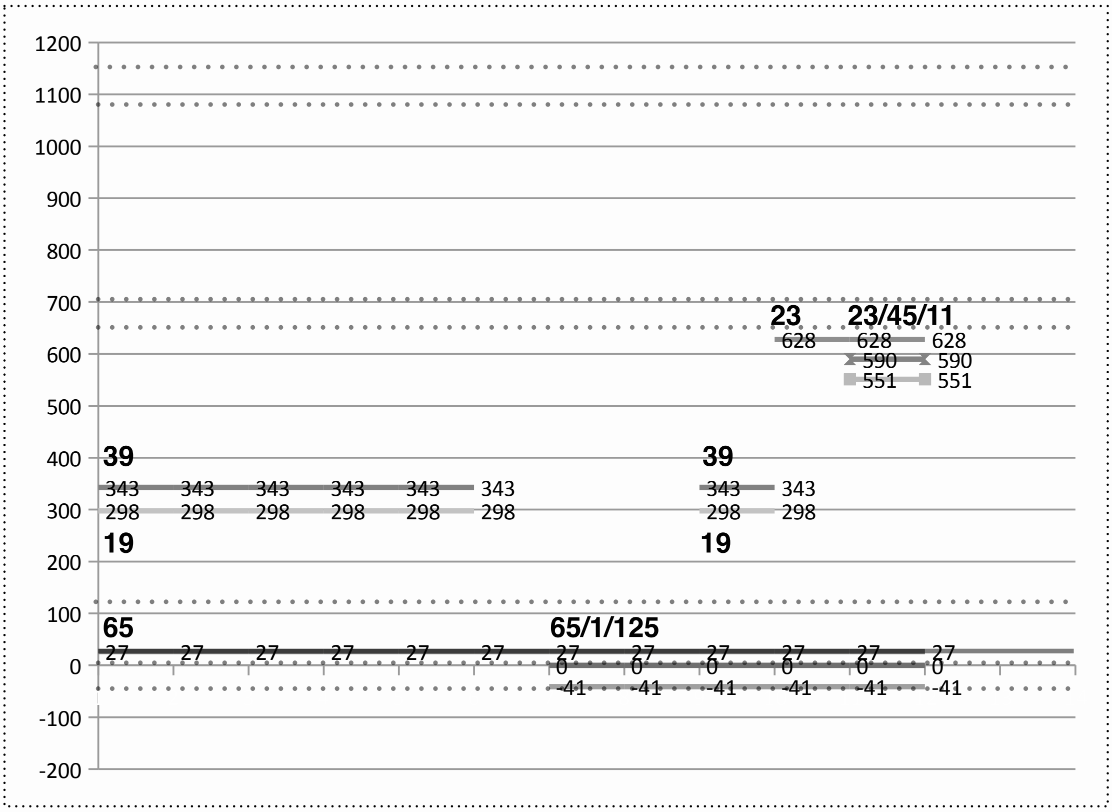


1 min to 1 min 55 secs

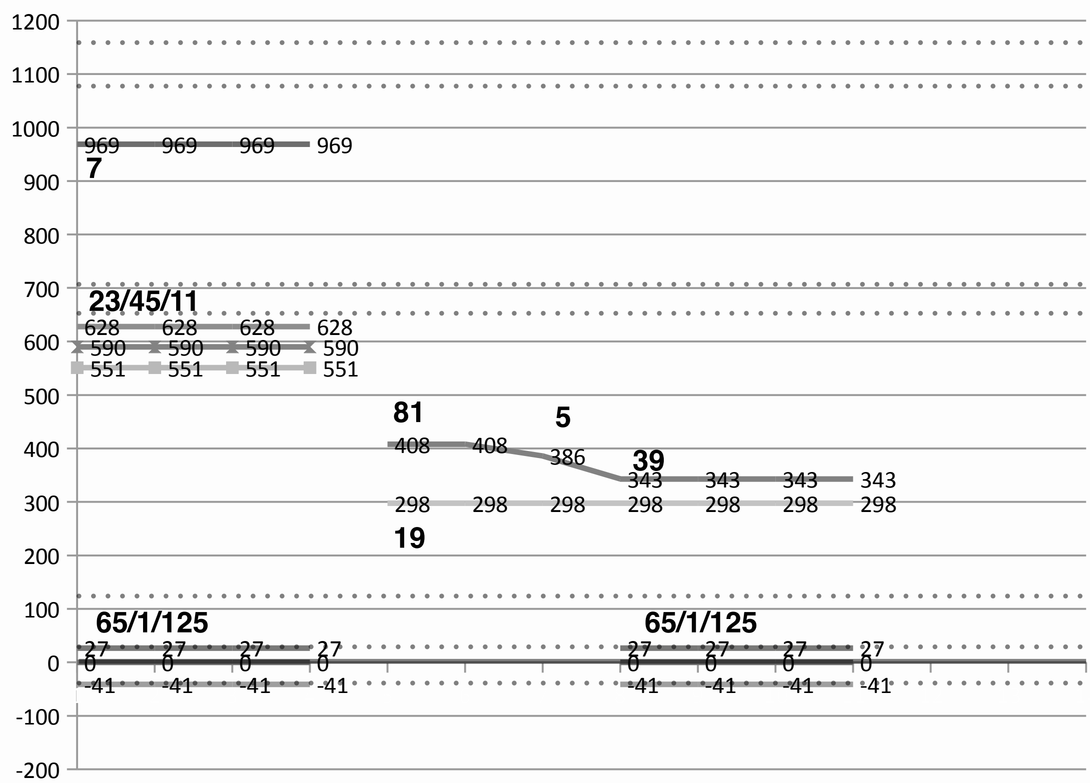



2 min to 2 min 55 secs
31/15/7
31/15/7
9
69
65/1/125
81
5
19
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200

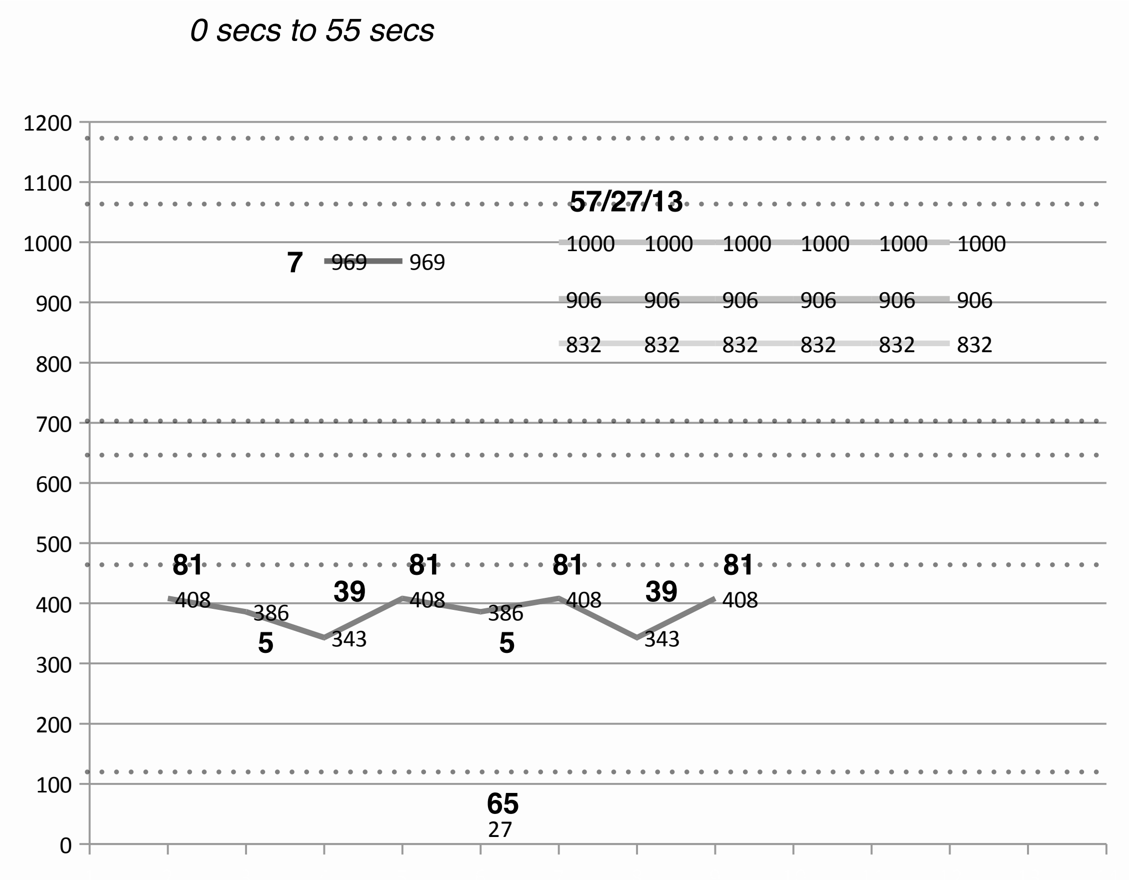
3 min to 3 min 55 secs

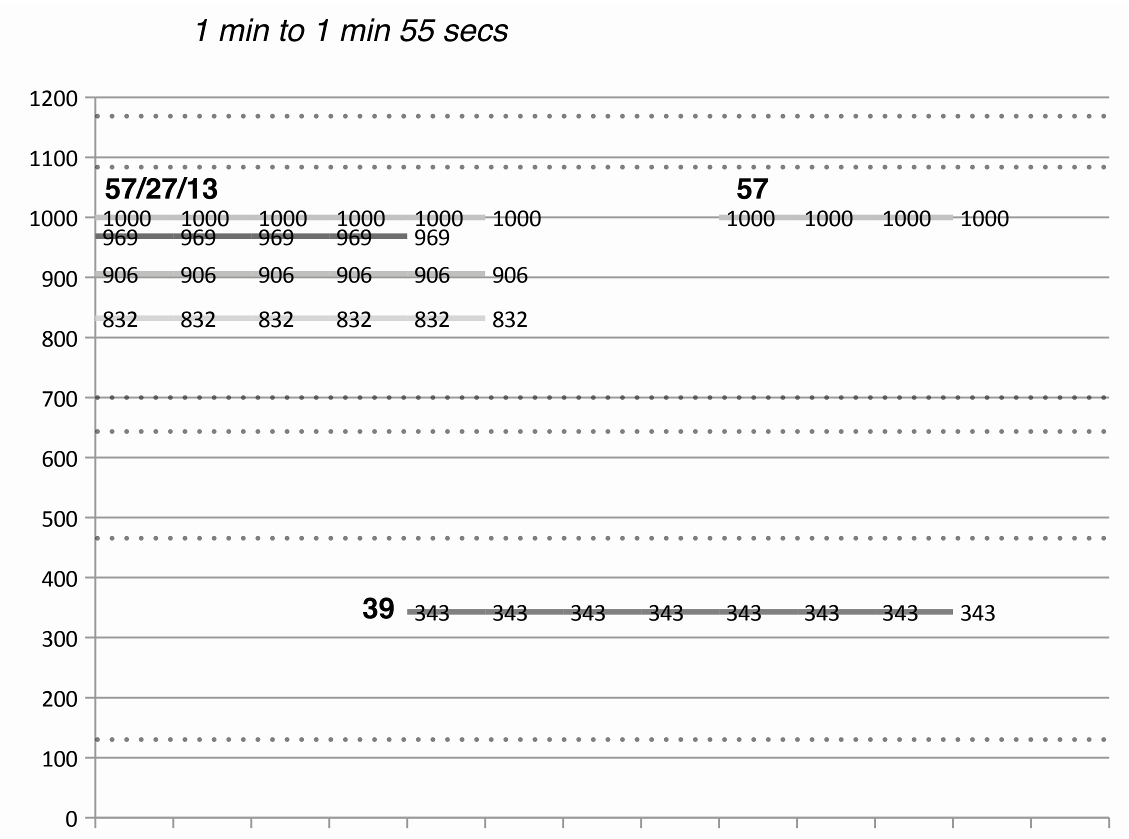


4 min to end

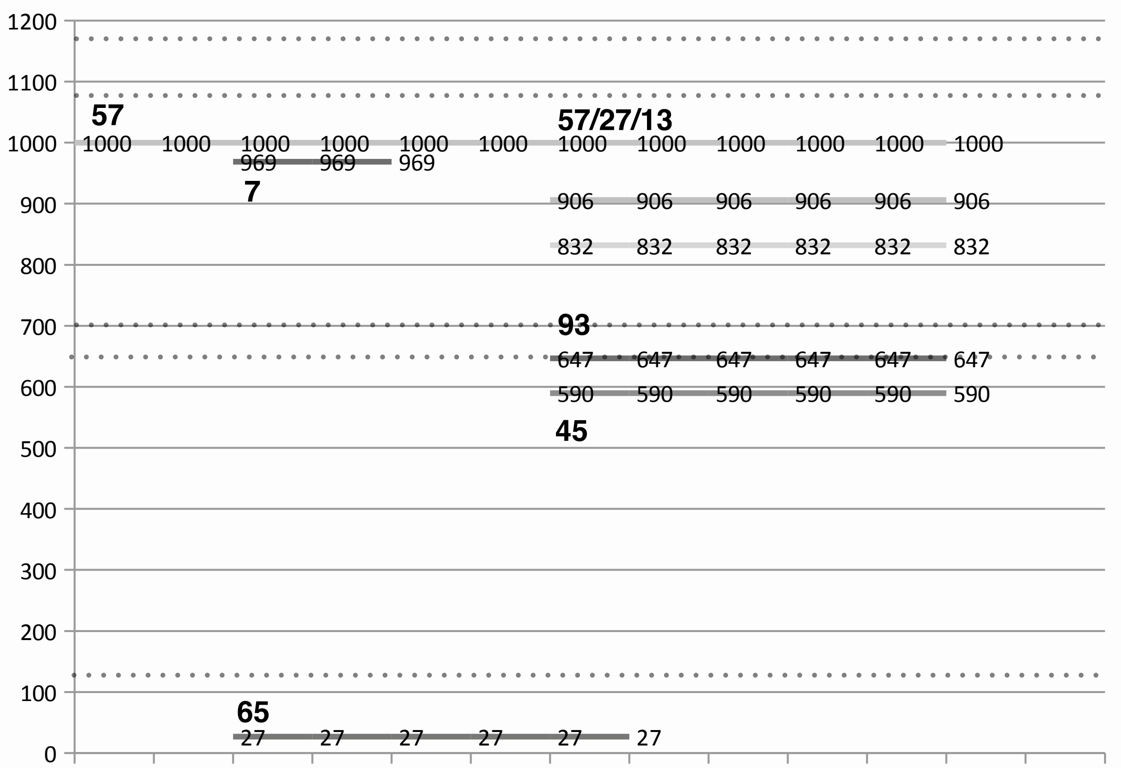


Movement 5:
'Return'

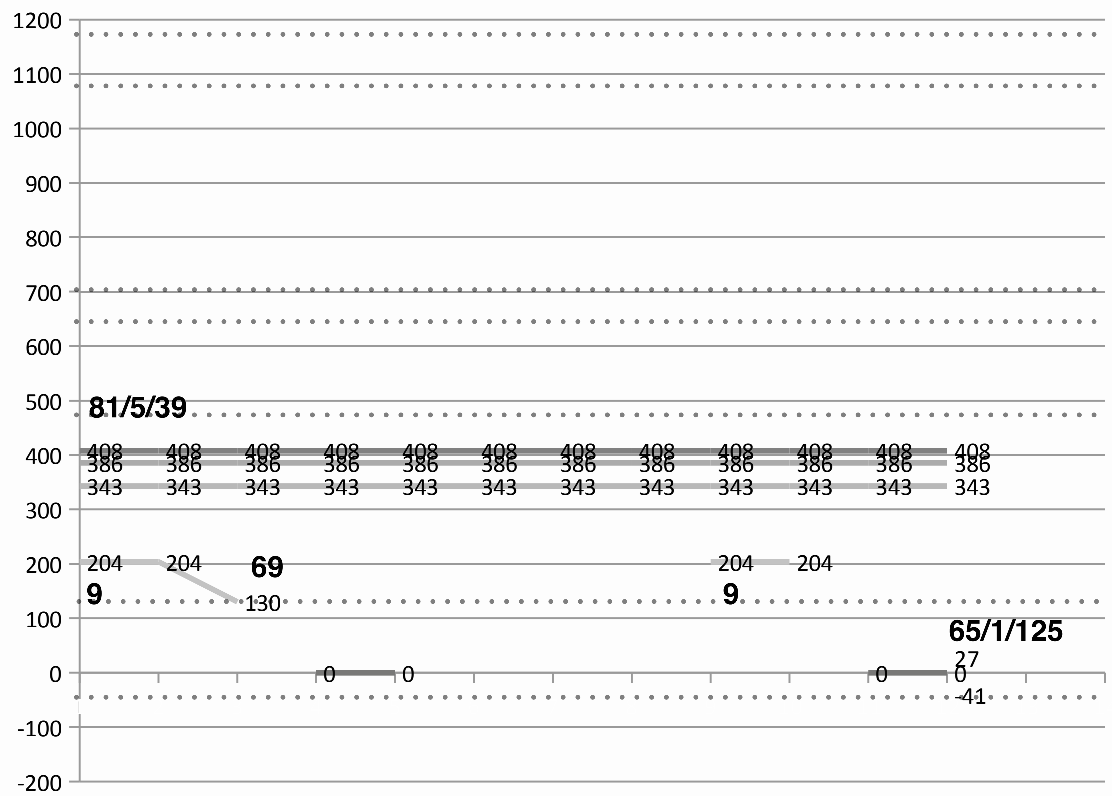

0 secs to 55 secs
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
57/27/13
1000 1000 1000 1000 1000 1000
906 906 906 906 906 906
832 832 832 832 832 832
7 969 969
81 408
386 5
39 343
81 408
386 5
81 408
39 343
81 408
65 27

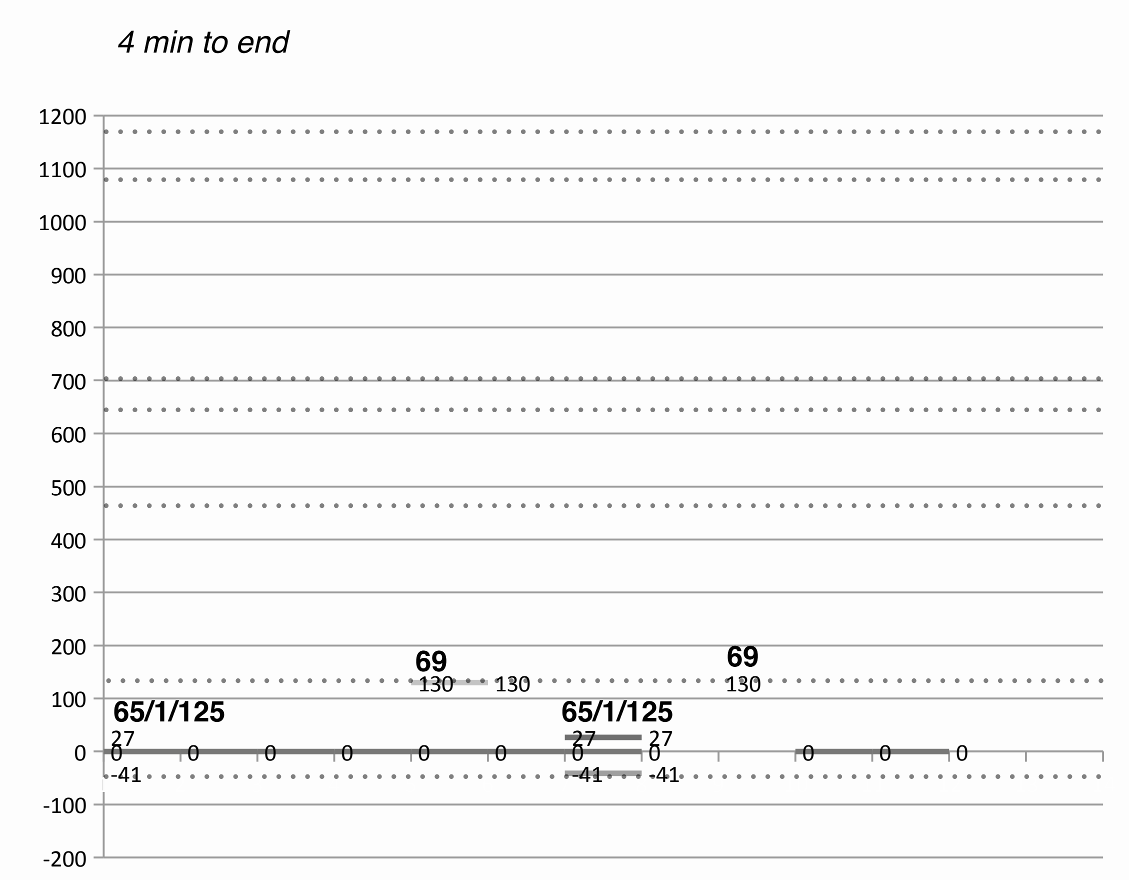

1 min to 1 min 55 secs
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
57/27/13
1000 1000 1000 1000 1000 1000
969 969 969 969 969
906 906 906 906 906 906
832 832 832 832 832 832
57
1000 1000 1000 1000
39 343 343 343 343 343 343 343 343

2 min to 2 min 55 secs



3 min to 3 min 55 secs





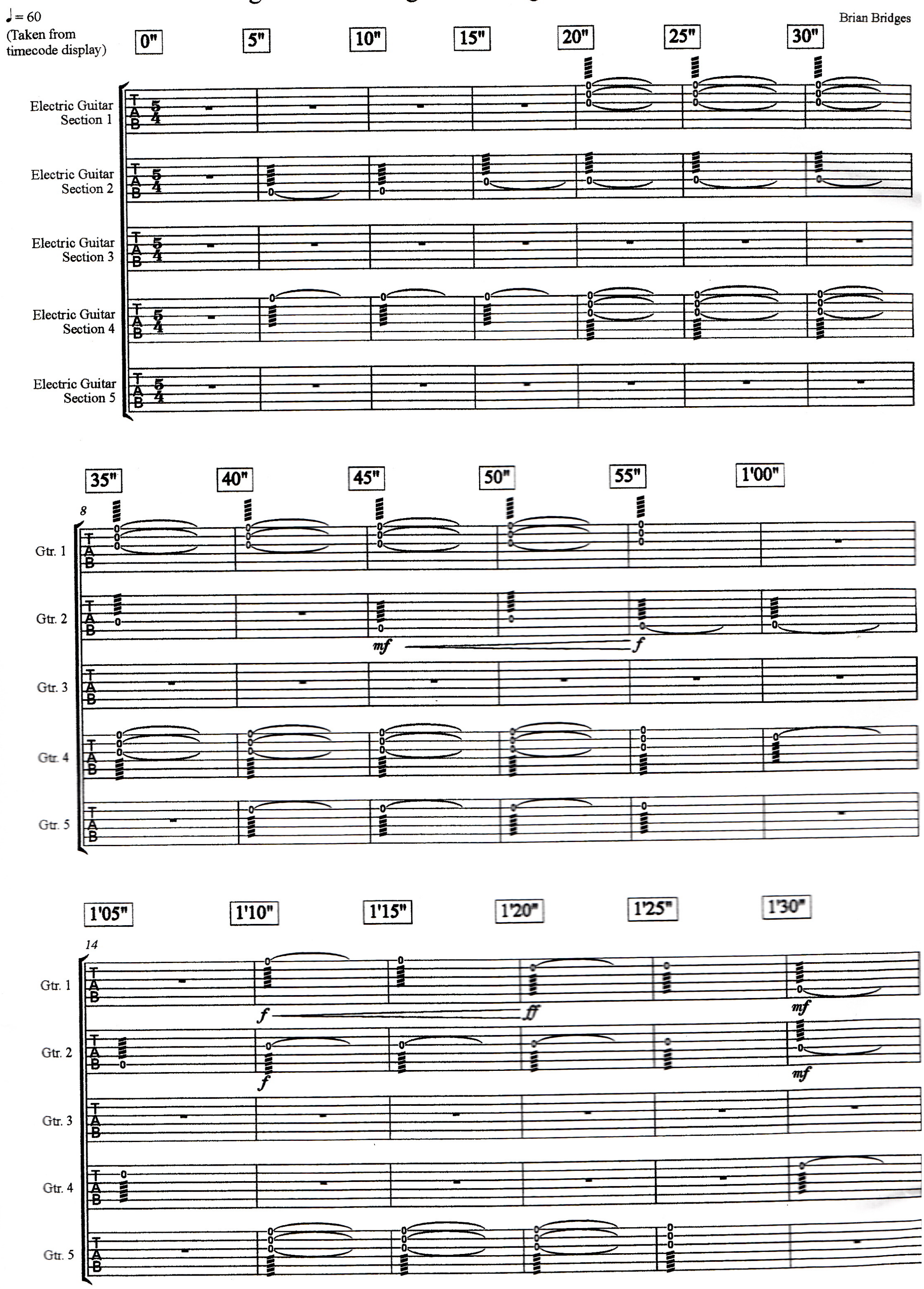
4 min to end
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
69
130
130
69
130
65/1/125
65/1/125
27
27
27
0
0
0
0
0
0
0
0
0
0
0
-41
-41
-41

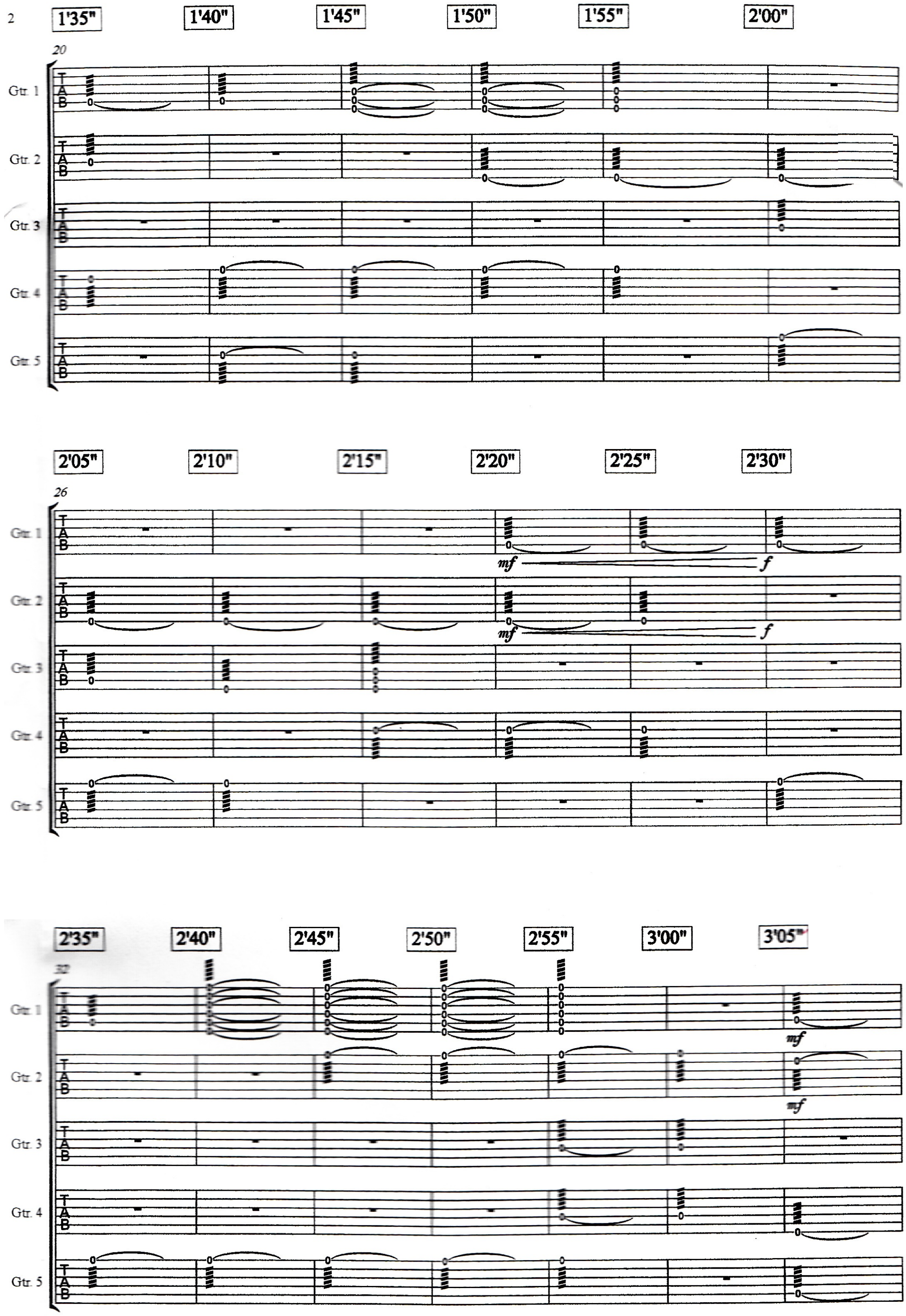
Performance scores (tablature)

Movement 1: ‘Departure’

Angels at the Shotgun Wedding, Movement No.1

Brian Bridges




1'35"
1'40"
1'45"
1'50"
1'55"
2'00"
20
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'05"
2'10"
2'15"
2'20"
2'25"
2'30"
26
mf
f
2'35"
2'40"
2'45"
2'50"
2'55"
3'00"
3'05"
mf


3'10"
3'15"
3'20"
3'25"
3'30"
3'35"
39
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
3'40"
3'45"
3'50"
3'55"
4'00"
4'05"
4'10"
45
4'15"
4'20"
4'25"
4'30"
4'35"
4'40"
4'45"
52
mf
ff

Movement 2: ‘Inhalation/ Choke’

Angels at the Shotgun Wedding, Movement No.2

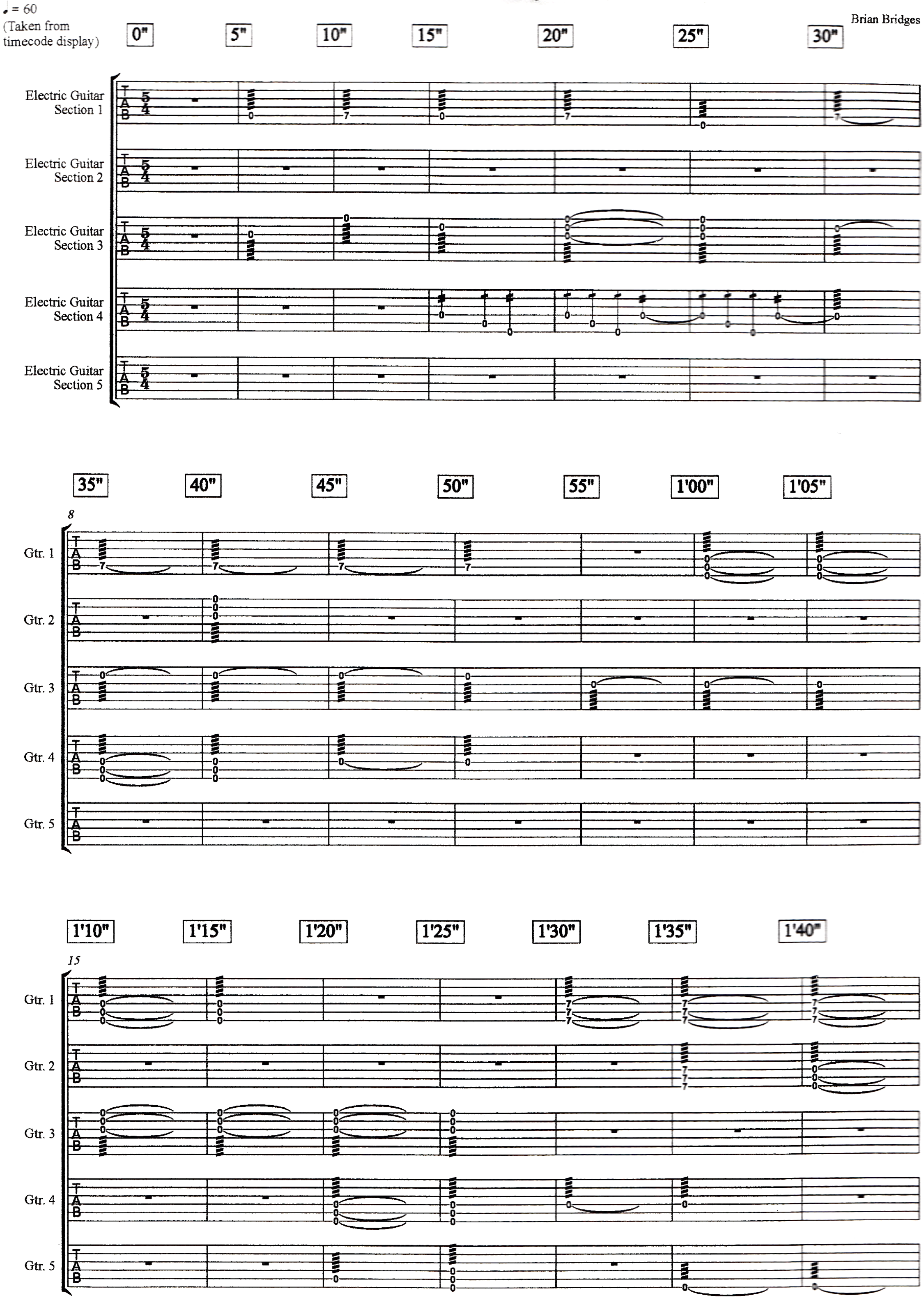
Brian Bridges

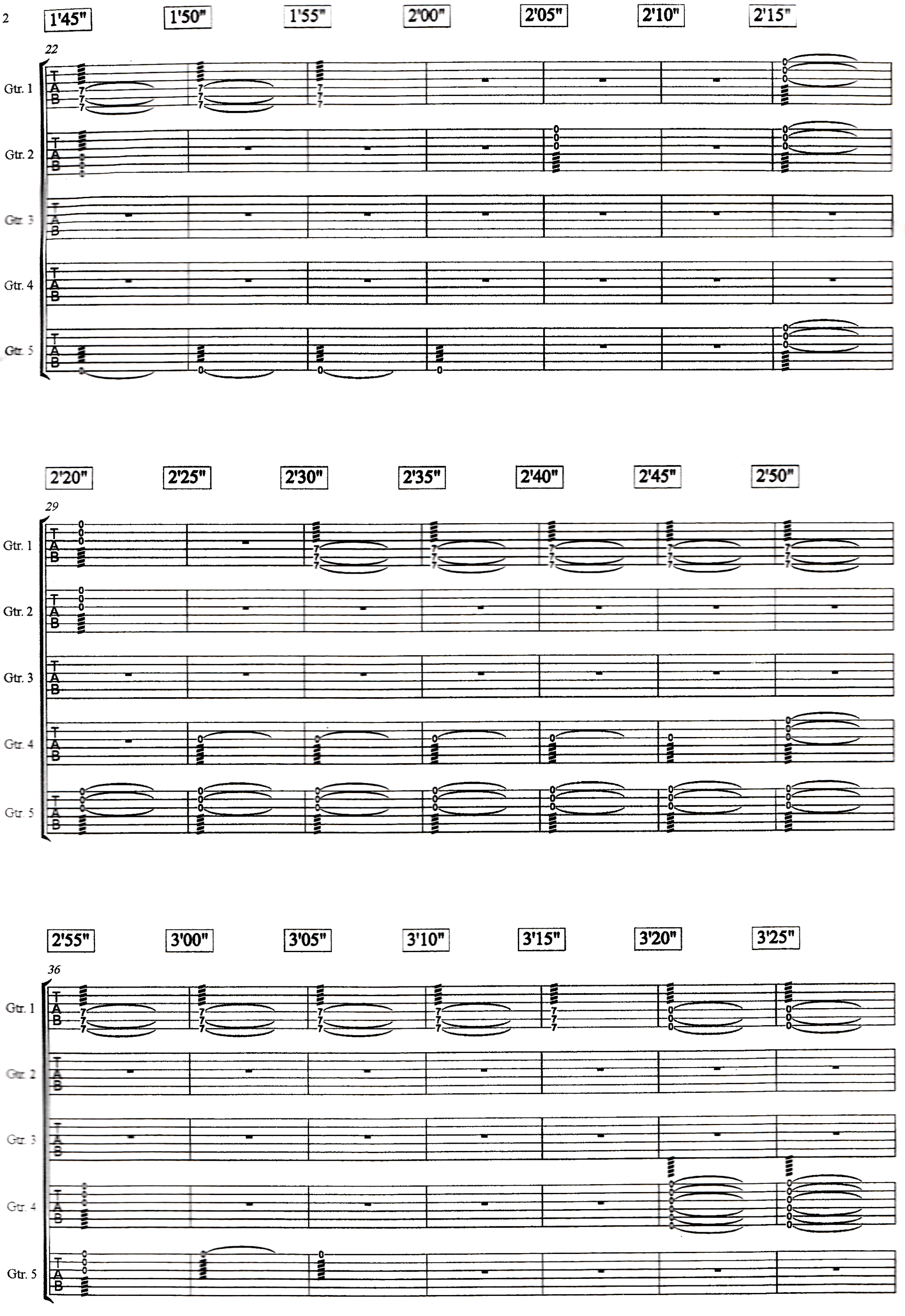

1'45"
1'50"
1'55"
2'00"
2'05"
2'10"
2'15"
22
mf
2'20"
2'25"
2'30"
2'35"
2'40"
2'45"
2'50"
29
2'55"
3'00"
3'05"
3'10"
3'15"
3'20"
3'25"
36

Movement 3:
‘Take God out and Show Her a Good Time’

Angels at the Shotgun Wedding, Movement No.3

Brian Bridges

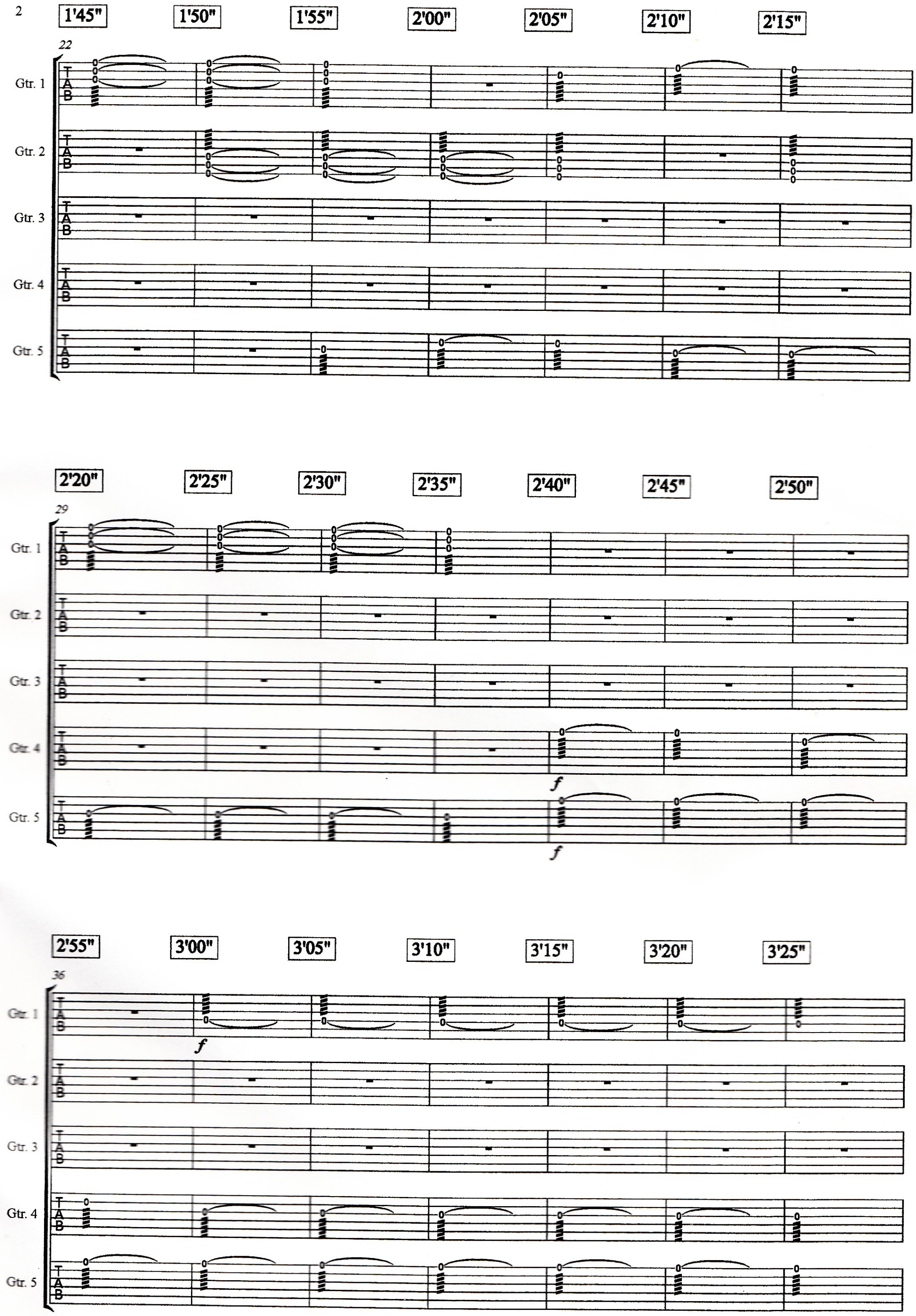



1'45"
1'50"
1'55"
2'00"
2'05"
2'10"
2'15"
22
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'20"
2'25"
2'30"
2'35"
2'40"
2'45"
2'50"
29
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'55"
3'00"
3'05"
3'10"
3'15"
3'20"
3'25"
36
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5


3'30"
3'35"
3'40"
3'45"
3'50"
3'55"
4'00"
43
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
4'05"
4'10"
4'15"
4'20"
4'25"
4'30"
4'35"
50
mf
4'40"
4'45"
4'50"
4'55"
5'00"
5'05"
57
f

Movement 4: ‘Pathfinding’

Angels at the Shotgun Wedding, Movement No.4

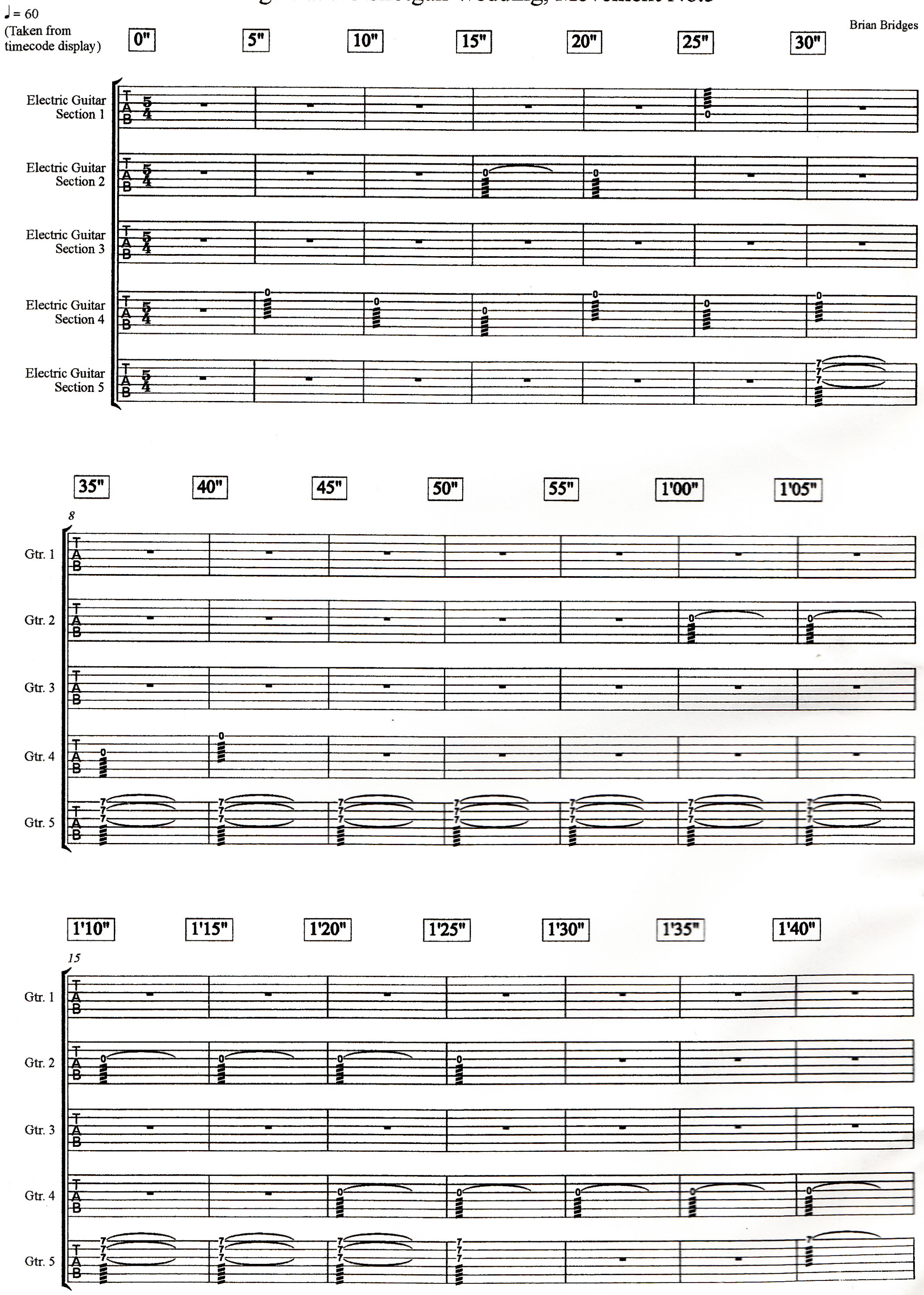

1'45"
1'50"
1'55"
2'00"
2'05"
2'10"
2'15"
22
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'20"
2'25"
2'30"
2'35"
2'40"
2'45"
2'50"
29
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
f
f
2'55"
3'00"
3'05"
3'10"
3'15"
3'20"
3'25"
36
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
f


3'30"
3'35"
3'40"
3'45"
3'50"
3'55"
43
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
f
4'00"
4'05"
4'10"
4'15"
4'20"
4'25"
49
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
f
mf
mf
4'30"
4'35"
4'40"
4'45"
4'50"
55
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
mf

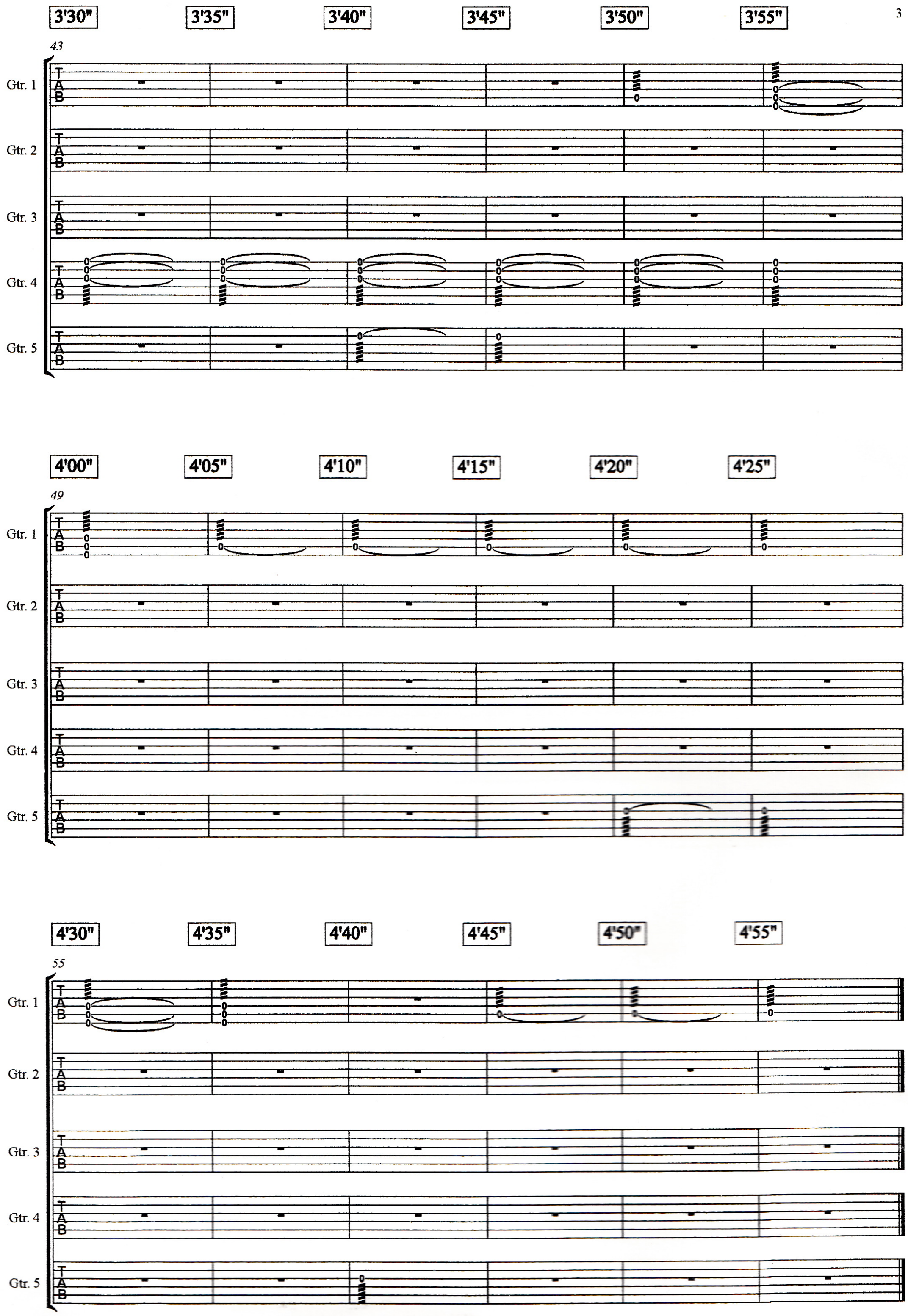
Movement 5:
‘Return’

Angels at the Shotgun Wedding, Movement No.5

Brian Bridges




1'45"
1'50"
1'55"
2'00"
2'05"
2'10"
2'15"
22
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'20"
2'25"
2'30"
2'35"
2'40"
2'45"
2'50"
29
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
2'55"
3'00"
3'05"
3'10"
3'15"
3'20"
3'25"
36
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5


3'30"
3'35"
3'40"
3'45"
3'50"
3'55"
43
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
4'00"
4'05"
4'10"
4'15"
4'20"
4'25"
49
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5
4'30"
4'35"
4'40"
4'45"
4'50"
4'55"
55
Gtr. 1
Gtr. 2
Gtr. 3
Gtr. 4
Gtr. 5

Appendix 3.2 *A Space for Tension* (2012) specification charts and scores

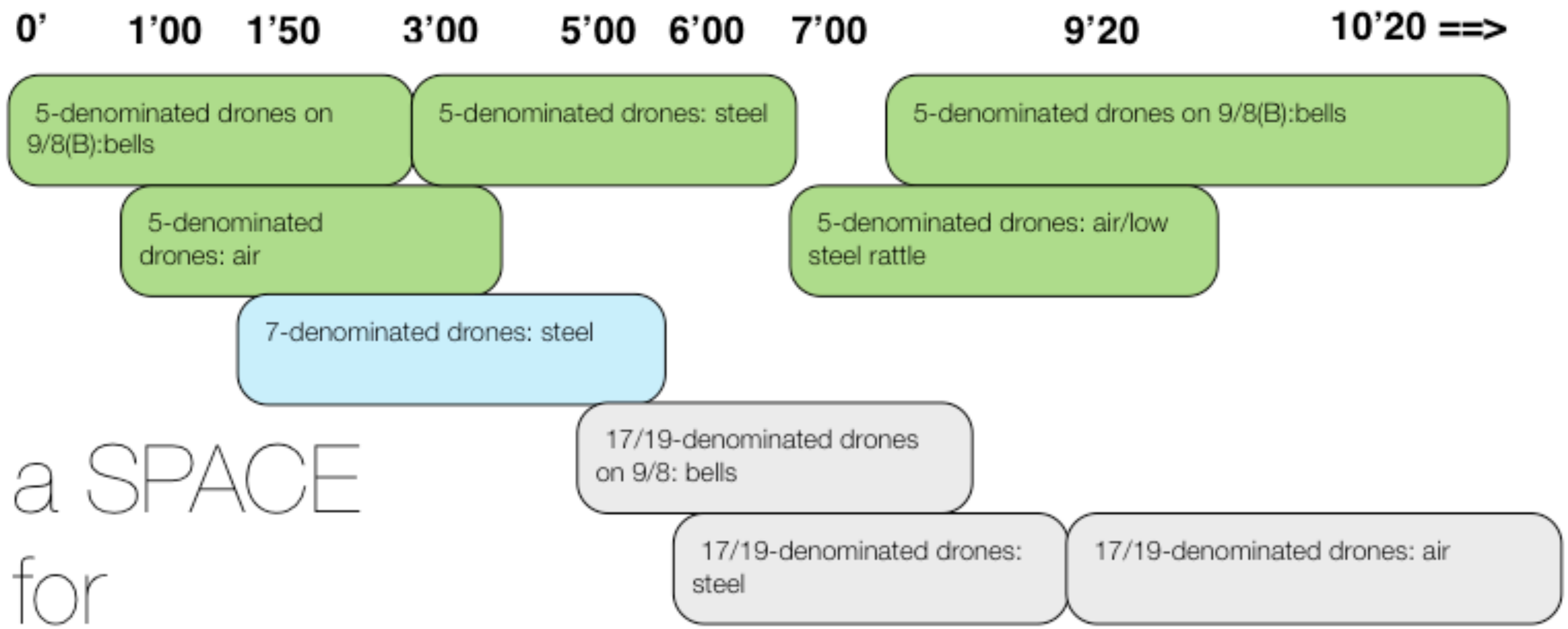
(Note: separate numbering beyond title page of score)

A Space for Tension

[2012] for erhu, 2 violins and tape

Specification charts and scores

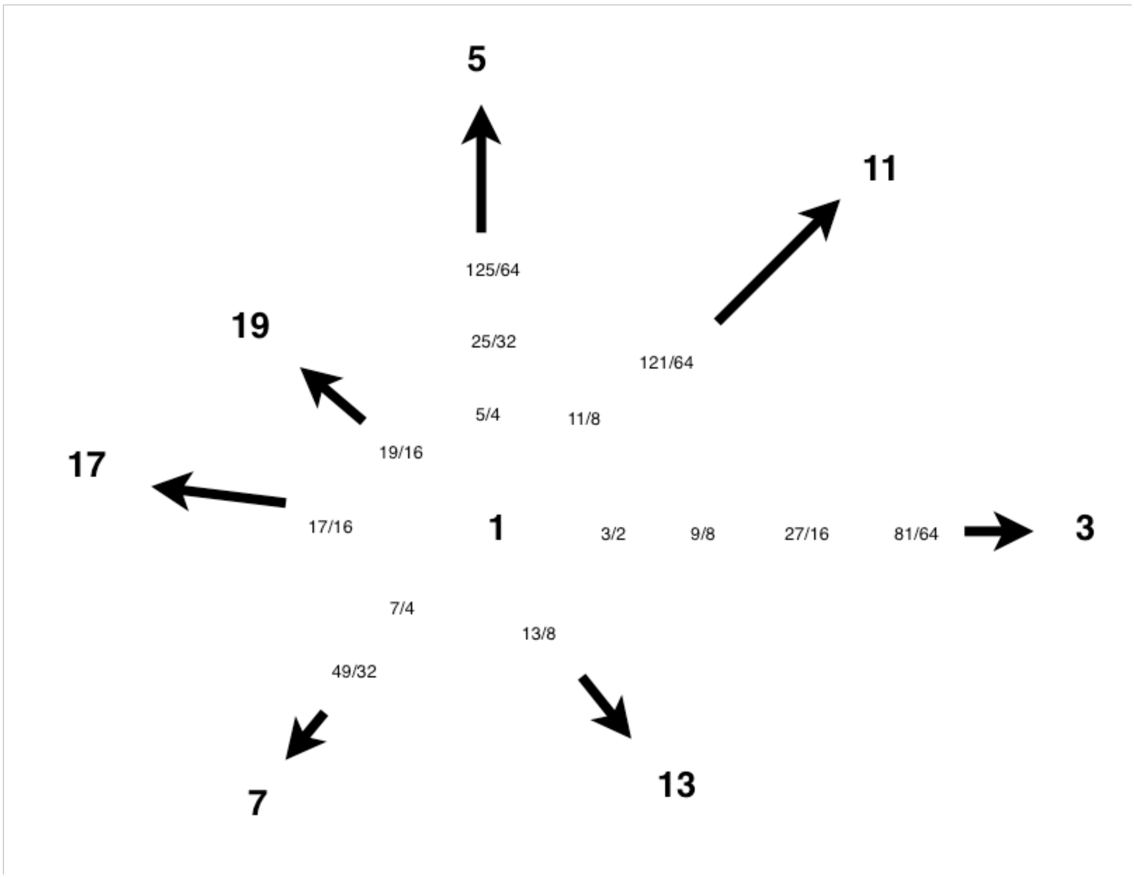
1. Reduction of tape part
2. Generative tuning charts
3. Performance score



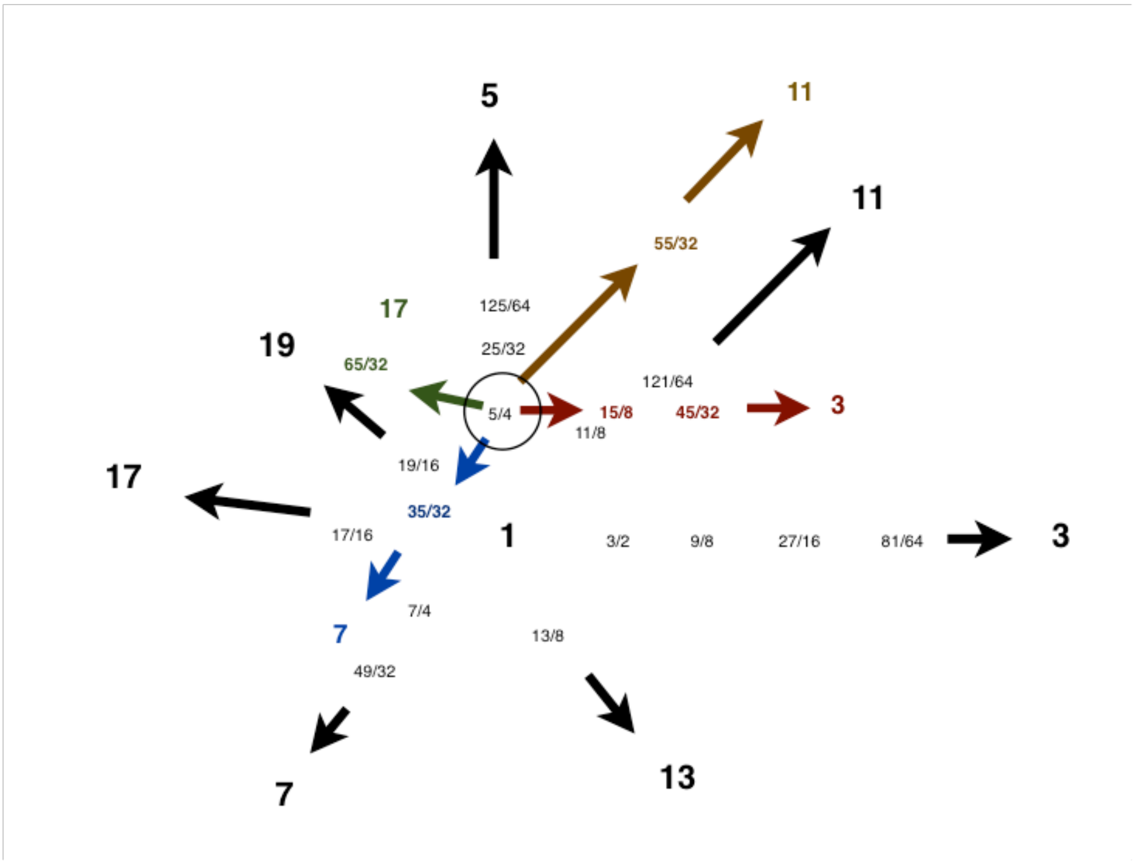
a SPACE for TENSION

reduction of tape/drone part

Generative Tuning Charts



Basic harmonic 'clock' representation for the simplest harmonic-generative relationships in its tuning structure (with the first interval in each functional 'direction' providing a rough indication of relative interval size in cents)



Harmonic clock indicating generative relationships for 5-denominated drones (5 as highest common factor or centre)

5-space

	x	=
5/4	7/4	35/32
5/4	3/2	15/8
5/4	9/8	45/32
5/4	11/8	55/32
5/4	17/16	65/32

5-denominated harmonic space

5 as highest common factor to all intervals so generated

note: not the same as 5-limit tuning: other prime-limit intervals expand on 5/4 to produce new divisions.

generative

↓

usage

1/1

65/64=26.84 cents

35/32=155.14 cents

5/4=386.31 cents

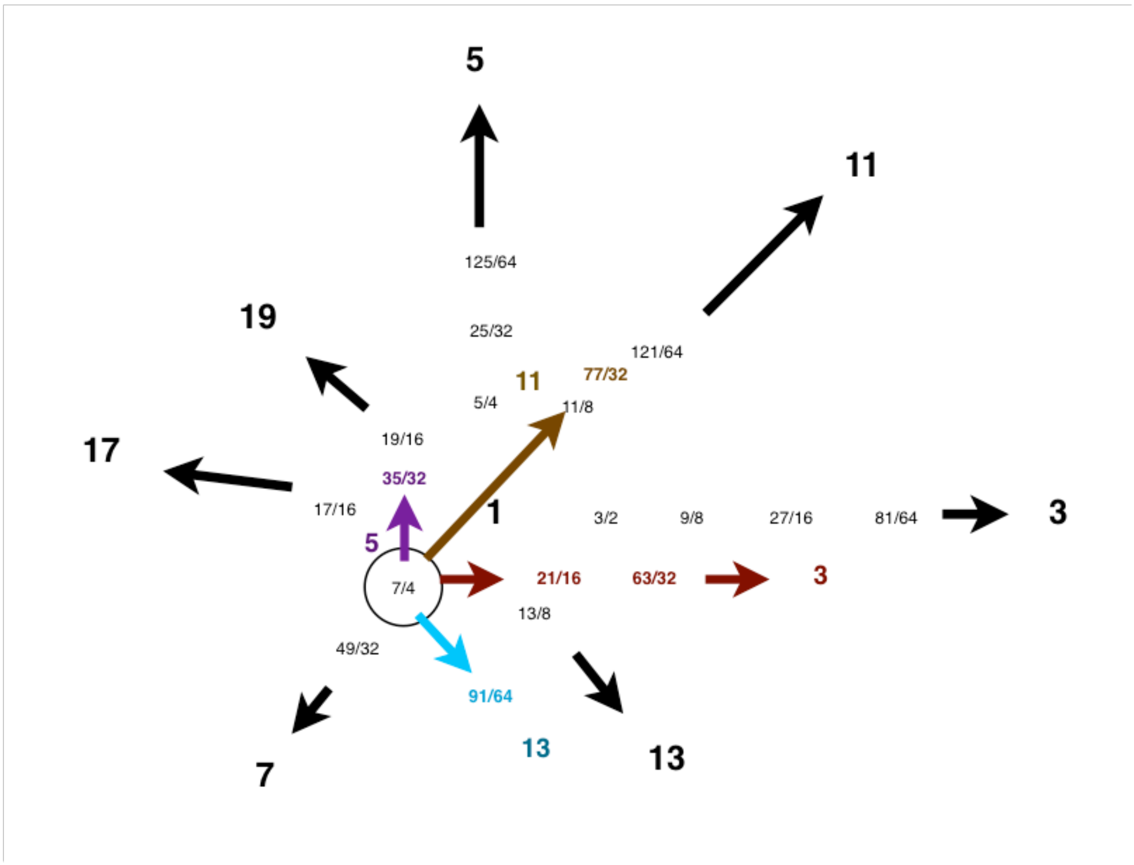
45/32=590.22 cents

55/32=937.63 cents

15/8=1088.27 cents

2/1

5-denominated interval identities used in drone parts



Harmonic clock indicating generative relationships for 7-demoninated drones (5 as highest common factor or centre)

	x		=	
7/4		9/8		63/32
7/4		5/4		35/32
7/4		3/2		21/16
7/4		11/8		77/64
7/4		13/8		91/64
7/4		7/4		49/32

7-space

generative

usage

7-denominated harmonic space

7 as highest common factor to all intervals so generated

note: not the same as 5-limit tuning: other prime-limit intervals expand on 5/4 to produce new divisions.

note: normalised to within single octave

1/1

35/32=155.14 cents

77/64=320.14 cents

21/16=470.78 cents

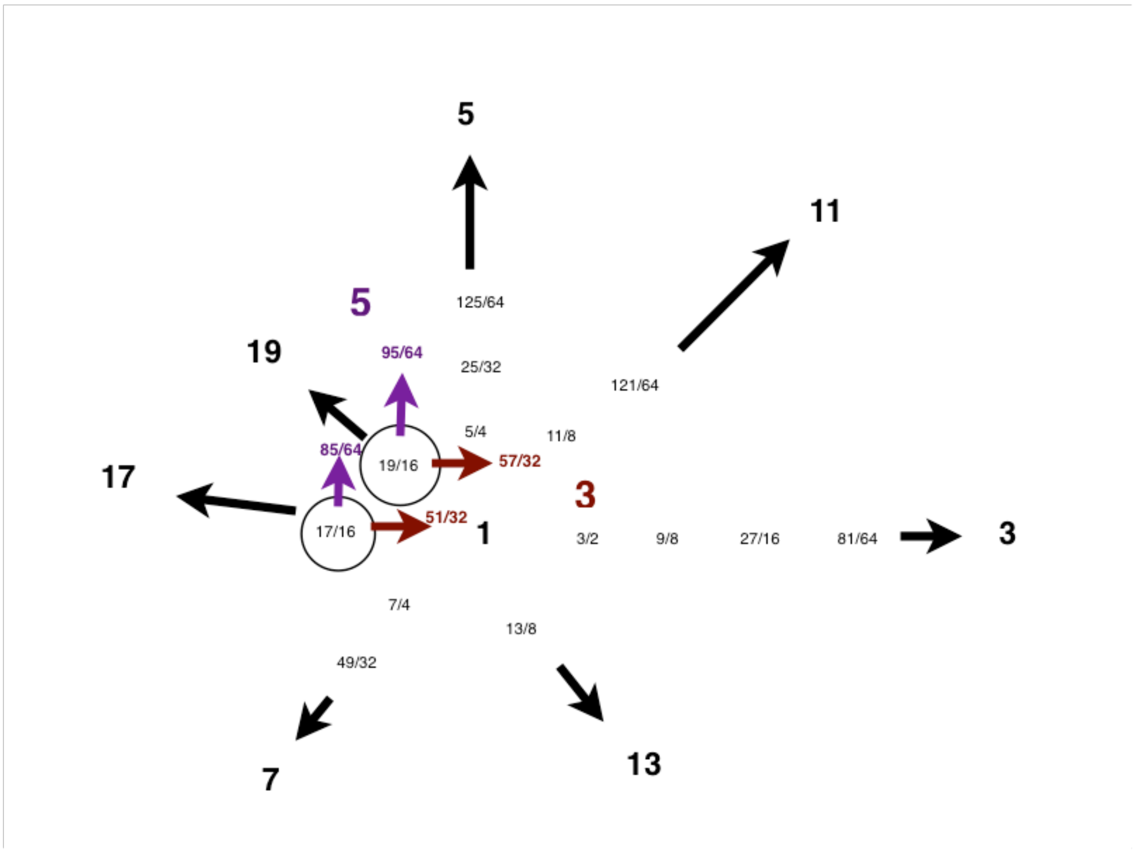
91/64=609.35 cents

49/32=737.65 cents

63/32=1172.74 cents

2/1

7-denominated interval identities used in drone parts



Harmonic clock indicating generative relationships for higher harmonic intervals

x	=	
19/16	5/4	95/64
19/16	3/2	57/32
17/16	5/4	85/64
17/16	3/2	51/32
25/16	5/4	125/64
9/8	9/8	81/64

higher harmonic space (to 17/19)

17–19 space

plus other higher harmonics

generative

usage

1/1

81/64=407.82

85/64=491.27 cents

95/64=683.83 cents

25/16=777.63 cents

51/32=806.91 cents

57/32=999.49 cents

125/64=1158.94 cents

interval identities in higher harmonic space (to 17/19)

A Space for Tension

[2012] for erhu, 2 violins and tape

SCORE

A Space for Tension - performance instructions

A Space for Tension is for erhu and two violins, along with a tape part which plays slowly-moving electronic drones in a microtonal tuning system. The instrumental parts use some of these microtonal intervals. They are approximated in the score using quarter-tone notation. However, the harmonies are more accurately rendered when played with the tunings noted below, which are referenced in the score by numbers above each note.

The piece is based on harmonic tunings over *A*. The numbers above notes in the score act as a key to tuning (see chart below), alongside the approximation in quarter-tone notation (indicated below with +/- for up/down quarter-tone). Audio files with tuning references will also be provided.

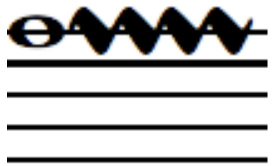
Pitches and tunings in ascending order of interval size:

Pitch	Harmonic No.	Interval size (from A) in cents
A	1	0
B*b*	17 (harmonic semitone)	105
B*b*+	35	155
B	9	204
C	19	298
C+	77	320
C#	5 (Just major third)	386
C#+	81 (Pythagorean major third)	408
D	11	551
D#	91	609
E-	95	684
E	3 (perfect fifth)	702
E+	49	738
F-	25	773
F+	13	840
F#	27	906
F#+	55	938
G-	7	969
G	57	999
G#	15	1088
G#+	121	1103
G#+(variant)	125	1159

Performance indications: instrumental articulations

Erhu:

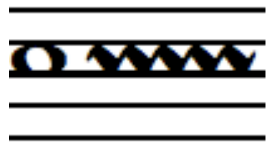
Pressing vibrato



Rolling vibrato

Violin:

Normal vibrato

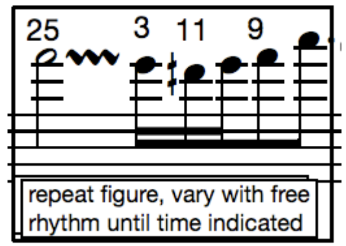


All:

Trajectory of glissando

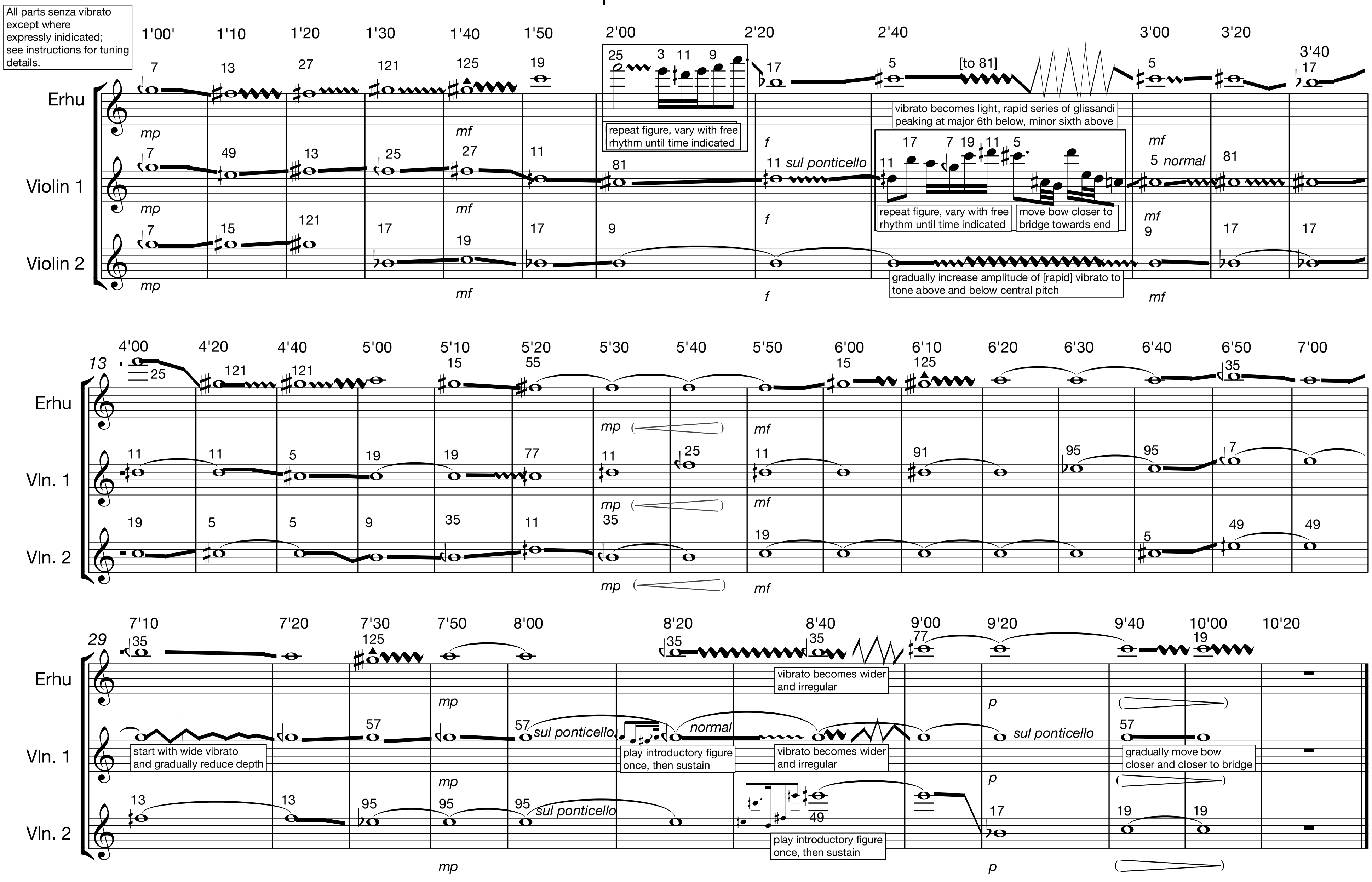
All:

Modular figure



Play approximation of notated rhythm as if tempo approx. 120, then repeat with variations for durations indicated.

A Space for Tension



Appendix 3.3 *Infraction* (2009): score and tuning chart/performance instructions

(separate numbering beyond title page)

Brian Bridges

Infraction

I N F R A C T I O N

for E-bowed electric guitar, amplified viola, amplified violin

Tuning and Pitch Materials

This piece utilises microtonal notation whereby an approximate indicator of the interval class is given by the use of accidentals indicating semitone or quarter-tone offset. The definitive rendering of the interval is given by means of a frequency ration (e.g. 81/64), which denotes the exact pitch.

To facilitate the tuning of these intervals, a guide track is provided on tape. The left channel should feed headphones for the viola player. The right channel should feed headphones for the violin. (Separate dual-mono versions of the audio files in question are also available.) The player then glides up to or down to the note in question. A certain degree of lassitude is permitted within the smaller of these intervals, so it is acceptable to slowly approach the exact tuning of the note over the course its duration.

The electric guitarist uses an e-bow to excite the strings at all times . A compressor should be used where available to moderate***s*** the dynamic range of the e-bow articulation.

Timing

Rhythmically, the piece uses a simplified rendering of time values whereby a semibreve equals 5 seconds. A timecode display on computer (or timing information on a CD player) should be used to maintain accurate timing, but, given the long-duration nature of the piece, transitions do not need to be absolutely on the five-second-mark.

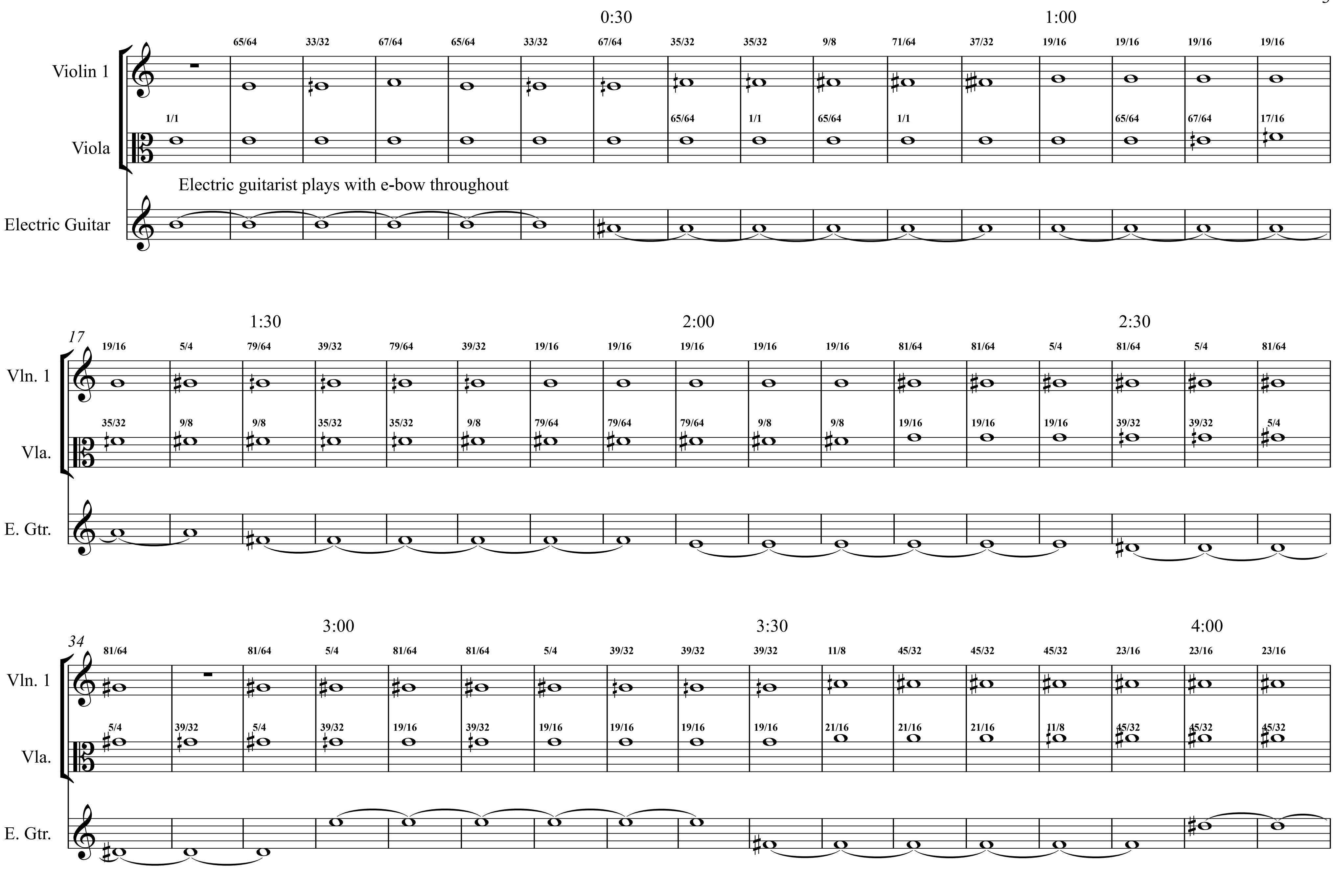
Balance and Dynamics

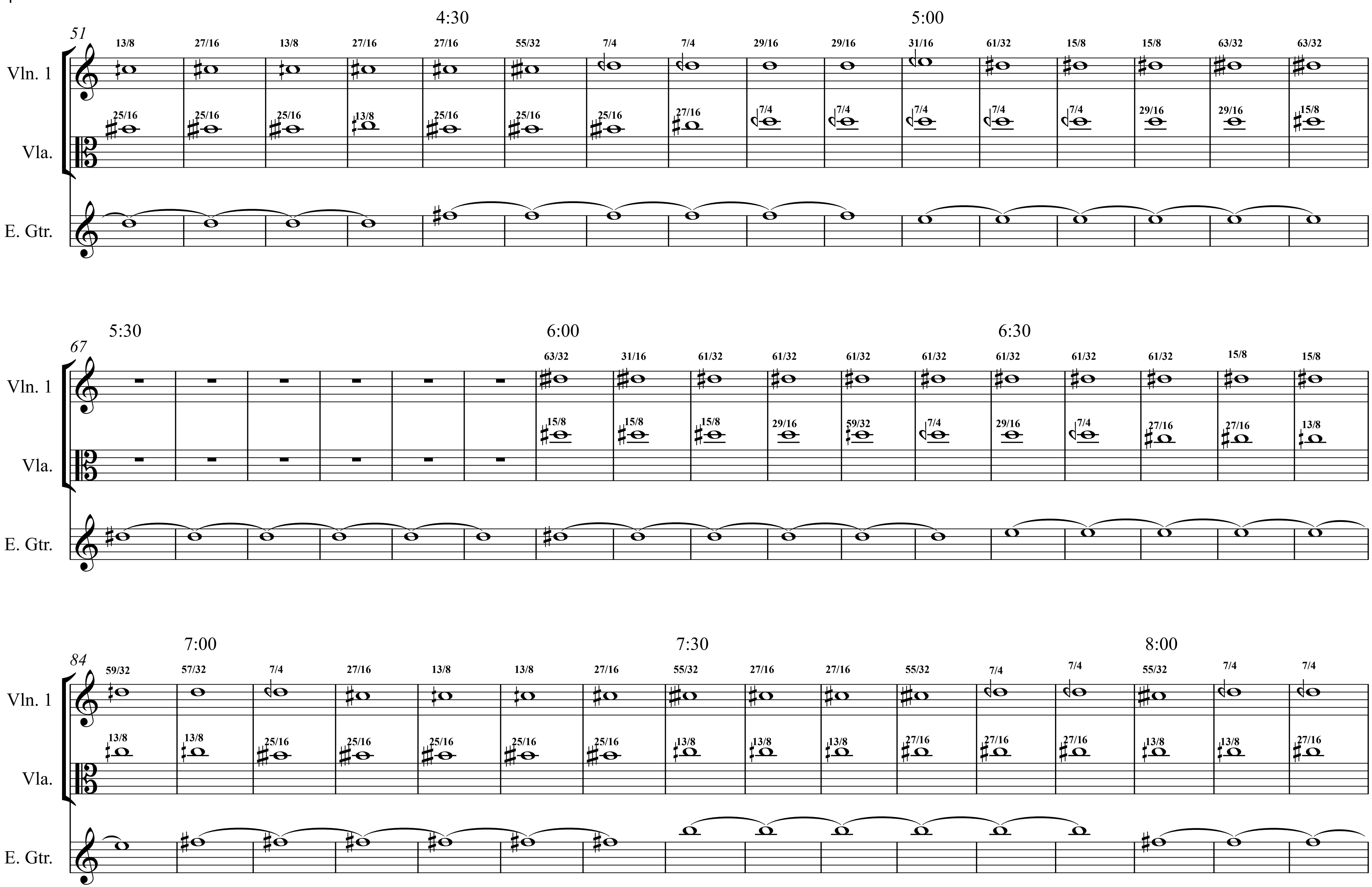
A careful balance in amplification of instruments should be maintained. The violin and viola should be just loud enough to 'cut through' the guitar part.

Regarding dynamics, the piece does not seek to exploit dynamics for the perception of structural details. Each 5-***s***second note for the violin/viola can be played with a modest swell.

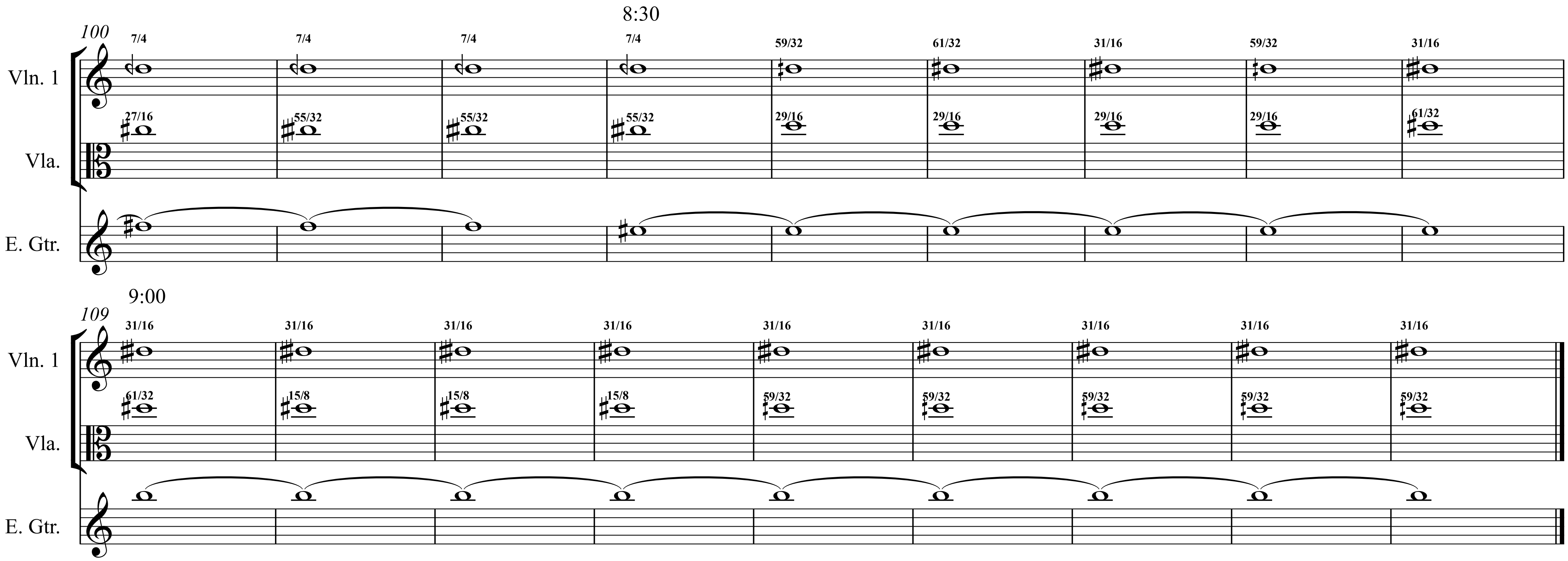
Infraction

Brian Bridges





4:30
5:00
51
13/8
27/16
13/8
27/16
27/16
55/32
7/4
7/4
29/16
29/16
31/16
61/32
15/8
15/8
63/32
63/32
Vln. 1
25/16
25/16
25/16
13/8
25/16
25/16
25/16
27/16
7/4
7/4
7/4
7/4
7/4
29/16
29/16
15/8
Vla.
E. Gtr.
5:30
6:00
6:30
67
63/32
31/16
61/32
61/32
61/32
61/32
61/32
61/32
61/32
15/8
15/8
Vln. 1
15/8
15/8
15/8
29/16
59/32
7/4
29/16
7/4
27/16
27/16
13/8
Vla.
E. Gtr.
7:00
7:30
8:00
84
59/32
57/32
7/4
27/16
13/8
13/8
27/16
55/32
27/16
27/16
55/32
7/4
7/4
55/32
7/4
7/4
Vln. 1
13/8
13/8
25/16
25/16
25/16
25/16
25/16
13/8
13/8
13/8
27/16
27/16
27/16
13/8
13/8
27/16
Vla.
E. Gtr.


8:30
100
7/4
7/4
7/4
7/4
59/32
61/32
31/16
59/32
31/16
Vln. 1
27/16
55/32
55/32
55/32
29/16
29/16
29/16
29/16
61/32
Vla.
E. Gtr.
9:00
109
31/16
31/16
31/16
31/16
31/16
31/16
31/16
31/16
31/16
Vln. 1
61/32
15/8
15/8
15/8
59/32
59/32
59/32
59/32
59/32
Vla.
E. Gtr.

Appendix 3.4 *Flatlining* (2008): score and tuning chart/performance instructions

(separate numbering beyond title page)

Brian Bridges

Flatlining

Flatlining

Brian Bridges

This piece uses some microtonal notation to denote certain pitches. Where a pitch deviates significantly from standard tuning, standard quarter tone symbols are used to approximate the pitch change required.

However, these are merely inexact indications of direction, not exact intervals. Therefore, in addition to these, interval ratios are also used: e.g. 7/4 (a type of minor seventh) 15/8 (major seventh), 31/16 (sharp major seventh). Tuning tracks will be provided on CD so you can get these intervals 'on your ear'. There are only a relatively small number of intervals which change from standard, which are outlined below.

E - no change

F - no change

F# - no change

G - 19/16 - 19th harmonic / minor 3rd - the change is not very significant

G# - no change - I'm presuming that string players play fairly 'just' thirds

A - no change - using standard fourth

A# - not used

B - no change - the fifth is fine in standard tuning

C - 13/8 - 13th harmonic / minor sixth - a little flat

C# - 27/16 - Pythagorean major sixth

D - 7/4 - 7th harmonic / minor seventh - this interval has quite a strong identity and will become quite familiar once you've heard it, La Monte Young has called it 'bluesy'

D# - 15/8 - Just major seventh

D#+ - 31/16 - 31st harmonic / large major seventh

The most significant intervals are the different types of sixth and seventh.

The piece does not involve a tape part. However, it may be amplified slightly in performance to bring out some of the harmonic detail.

Layout (stage right to left):
Violin II, Cello, Viola, Violin I.

Brian_D_Bridges@yahoo.com
Tel. 087-9915066

Flatlining

Brian Bridges


33
Vln. I
Vln. II
Vla.
Vc.
gliss.
f
pizzicato
f
pizzicato
f
f
39
Vln. I
Vln. II
Vla.
Vc.
gliss.
gliss.
arco
42
Vln. I
Vln. II
Vla.
Vc.
gliss.
45
Vln. I
Vln. II
Vla.
Vc.
arco
pizzicato
pizzicato
arco
arco
mf
mf
mf
mf


Vln. I
Vln. II
Vla.
Vc.
gliss.
sul ponticello
sul ponticello
normal
normal


69
Vln. I
Vln. II
Vla.
Vc.
gliss.
gliss.
gliss.
72
gliss.
sul ponticello
76
ff
ff
ff
ff
80
normal

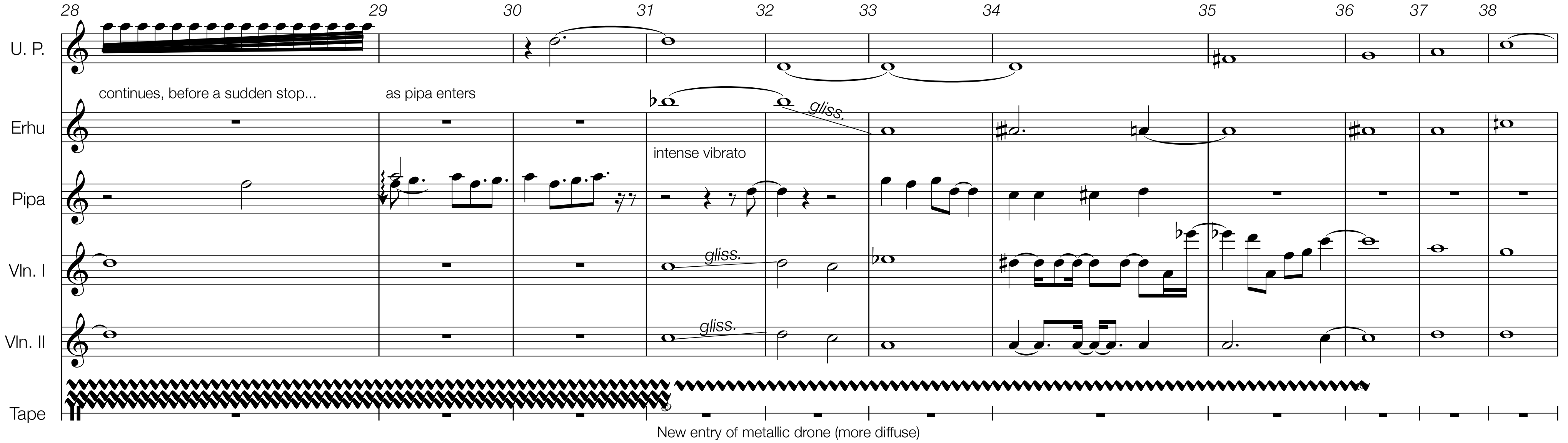

84
Vln. I
Vln. II
Vla.
Vc.
f
mf
92
mp
gliss.
99
104
p

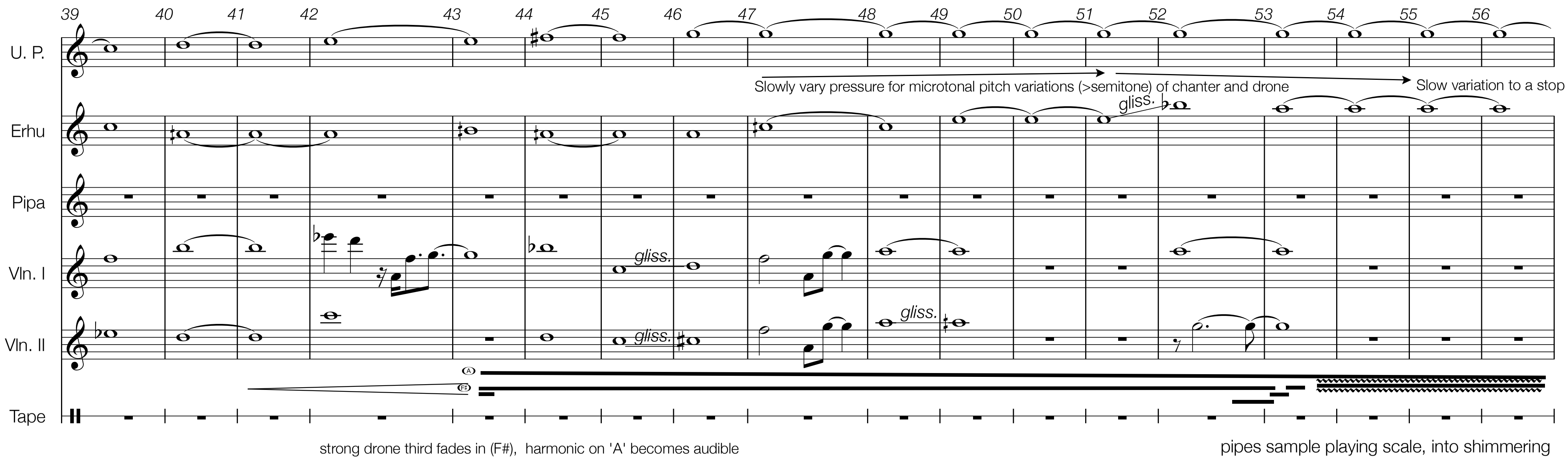
Appendix 3.5 *Making Ghosts from Empty Landscapes* (2010): score

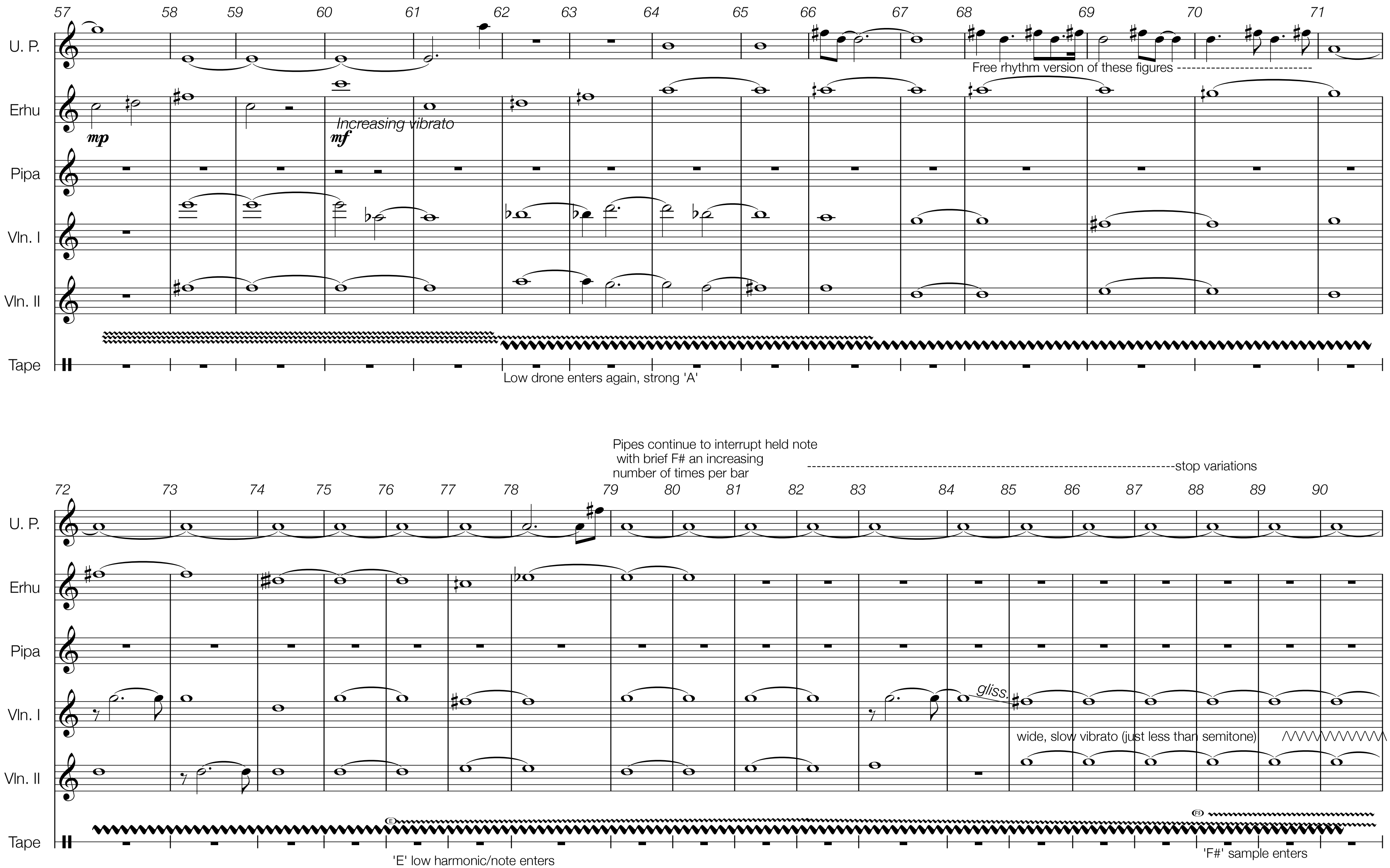
(separate numbering beyond title page)

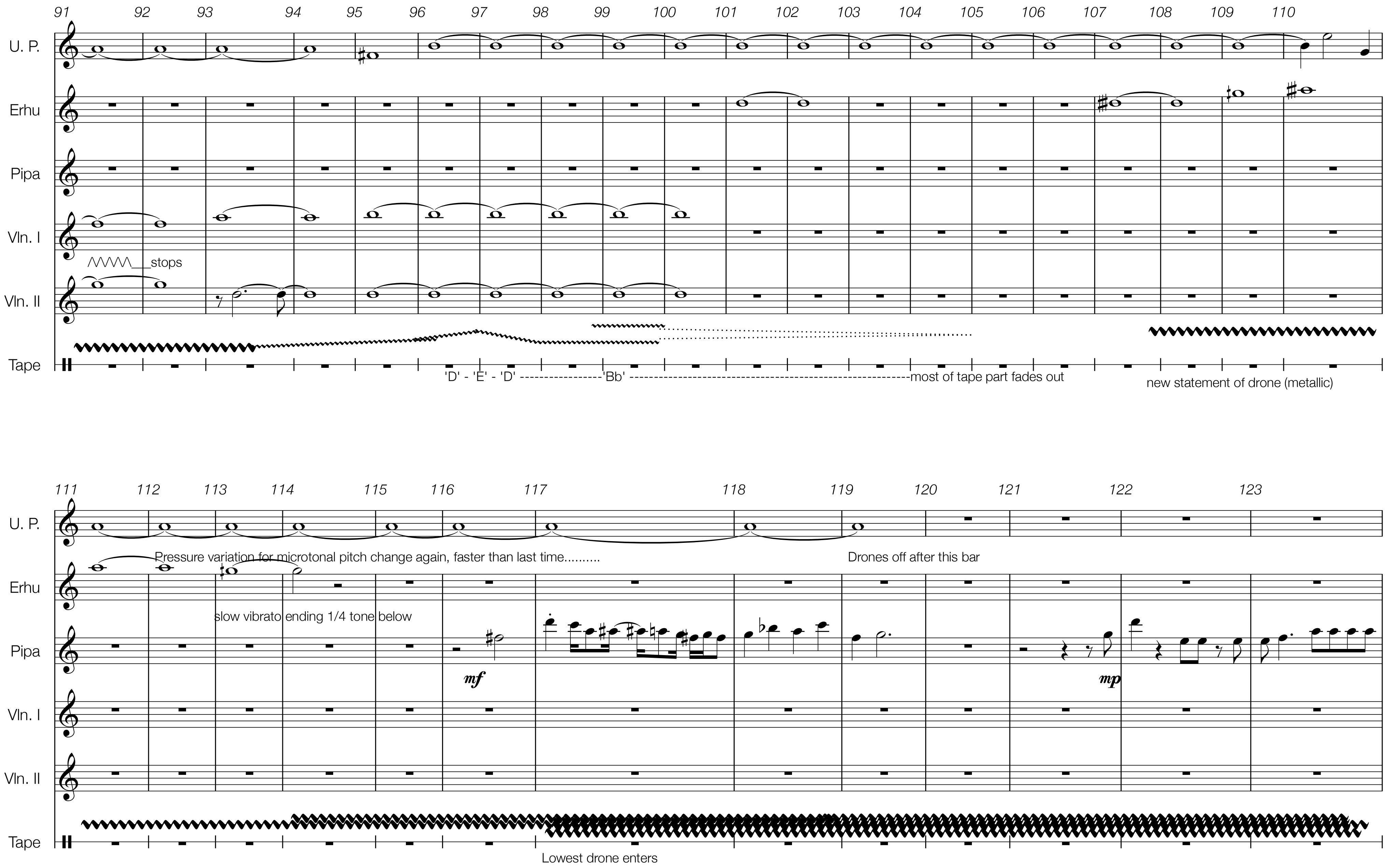
Making Ghosts from Empty Landscapes

Brian Bridges, March 2010


28
29
30
31
32
33
34
35
36
37
38
U. P.
continues, before a sudden stop...
as pipa enters
Erhu
gliss.
intense vibrato
Pipa
Vln. I
gliss.
Vln. II
gliss.
Tape
New entry of metallic drone (more diffuse)


39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
U. P.
Slowly vary pressure for microtonal pitch variations (>semitone) of chanter and drone
Slow variation to a stop
Erhu
gliss.
Pipa
Vln. I
gliss.
Vln. II
gliss.
gliss.
Tape
strong drone third fades in (F#), harmonic on 'A' becomes audible
pipes sample playing scale, into shimmering

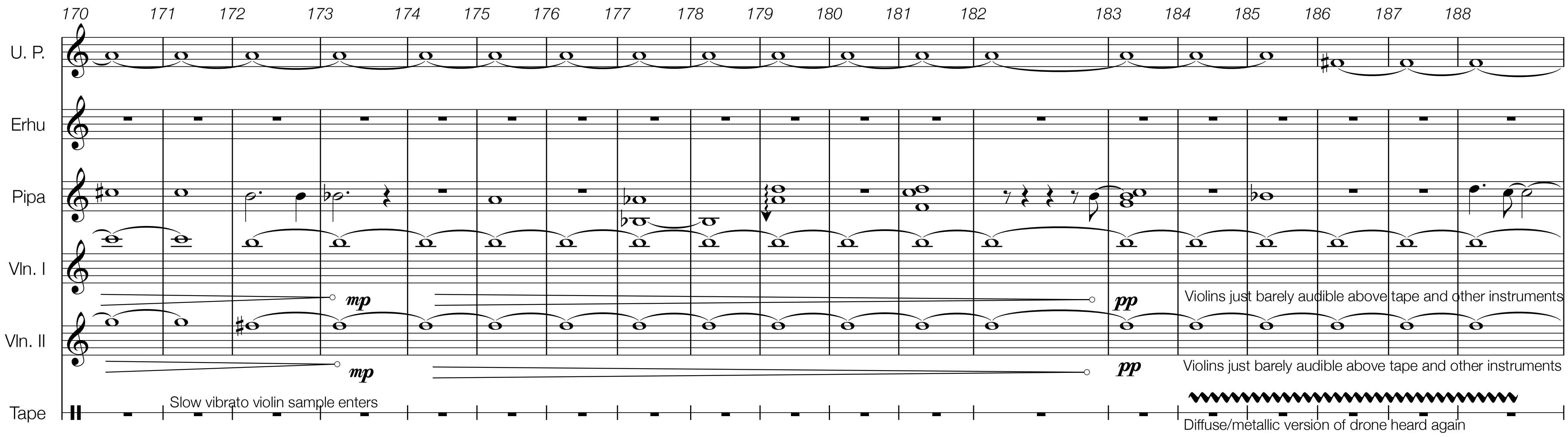

57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
mp
Increasing vibrato
mf
Free rhythm version of these figures ---------------------------
Low drone enters again, strong 'A'
Pipes continue to interrupt held note
with brief F# an increasing
number of times per bar
--stop variations
72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
gliss.
wide, slow vibrato (just less than semitone)
'E' low harmonic/note enters
'F#' sample enters


91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
stops
'D' - 'E' - 'D' ----------------'Bb' --most of tape part fades out
new statement of drone (metallic)
111
112
113
114
115
116
117
118
119
120
121
122
123
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
Pressure variation for microtonal pitch change again, faster than last time..........
Drones off after this bar
slow vibrato ending 1/4 tone below
mf
mp
Lowest drone enters

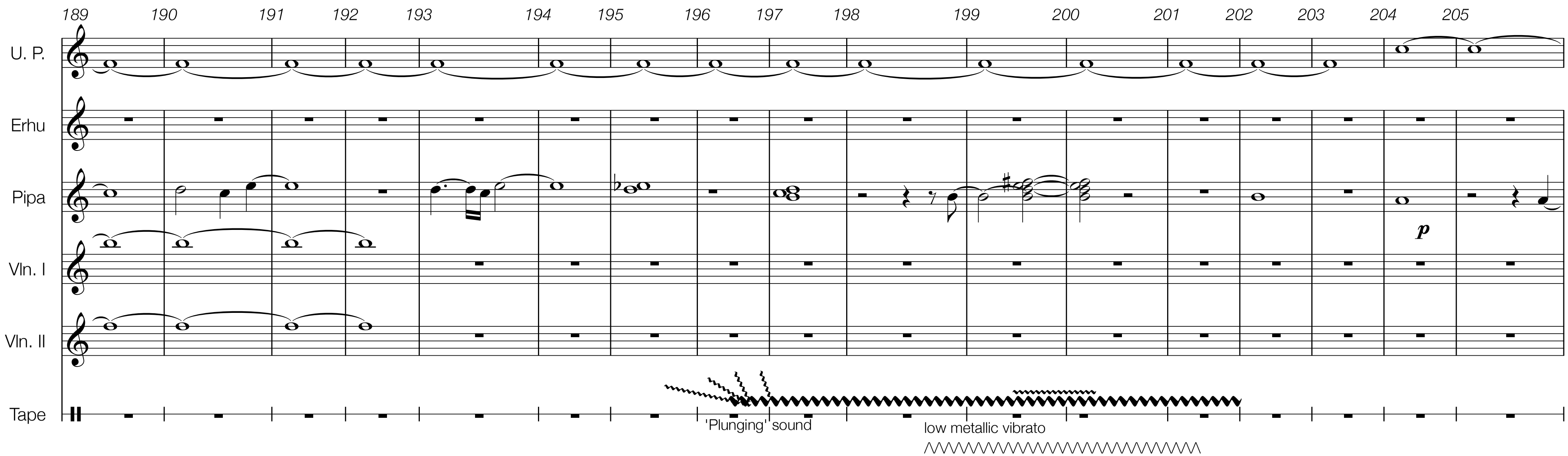

124
125
126
127
128
129
130
131
132
133
134
U. P.
[w/o drone]
slowly increase pressure to make regular pitch (next 4 bars)
Erhu
Pipa
Vln. I
Vln. II
Tape continues with drones, dense cloud of harmonics slowly gliding
Tape
135
136
137
138
139
140
141
142
143
144
145
146
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape continues with drones, dense cloud of harmonics slowly gliding
Tape


147
148
149
150
151
152
153
154
155
156
157
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
Stretched violin sample enters

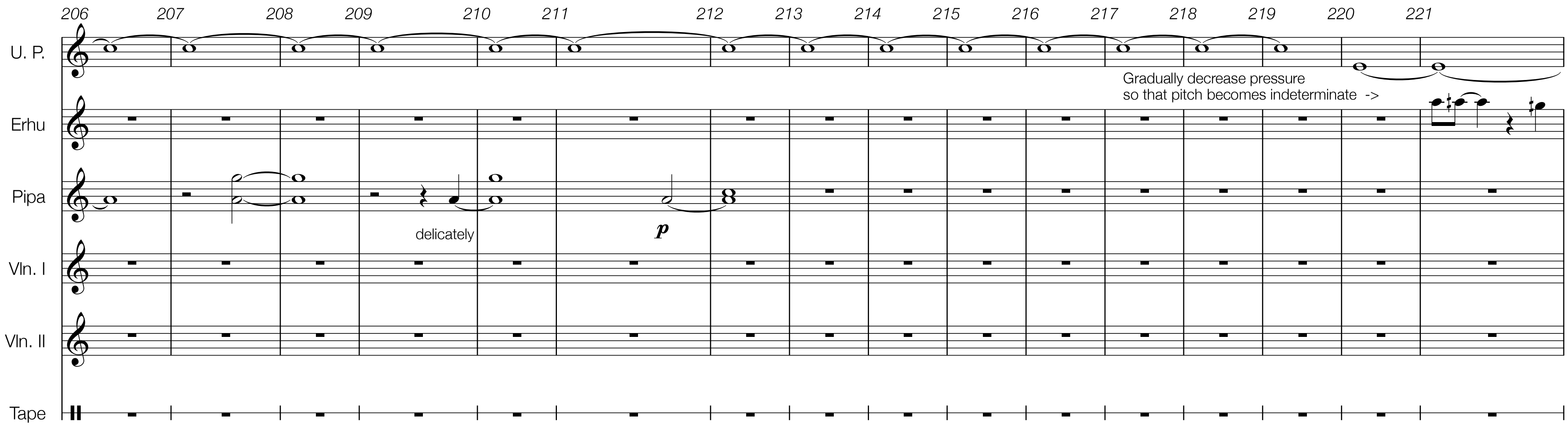

158
159
160
161
162
163
164
165
166
167
168
169
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
Violins decrescendo and slowly 'sink into tape part'
Violins decrescendo and slowly 'sink into tape part'
Violin sample with minor third enters

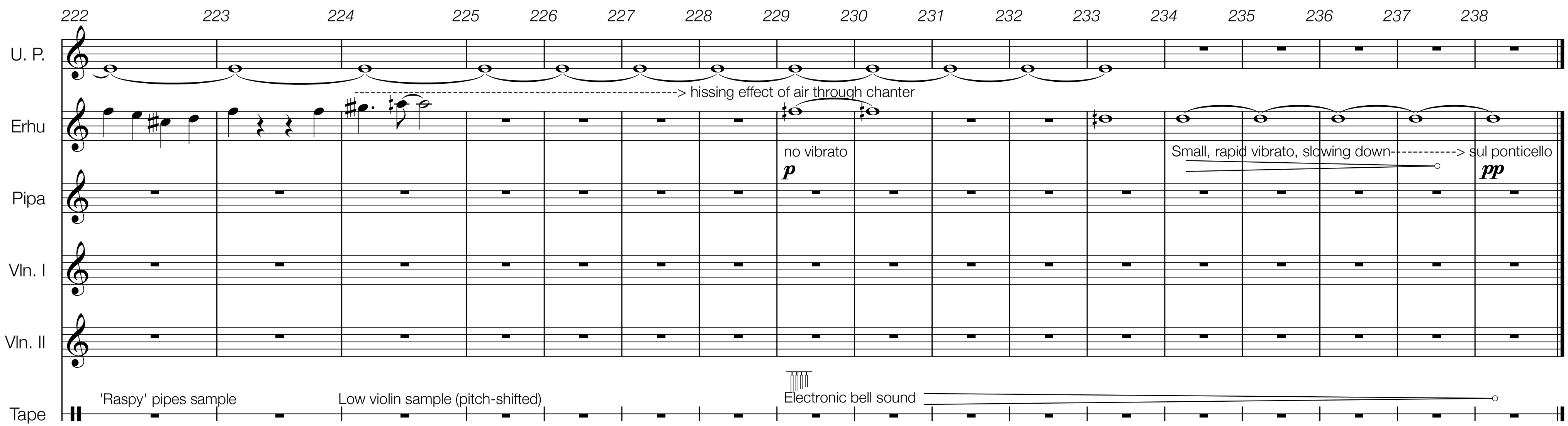


170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
mp
pp
Violins just barely audible above tape and other instruments
Slow vibrato violin sample enters
Diffuse/metallic version of drone heard again



189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
p
'Plunging' sound
low metallic vibrato


206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
delicately
p
Gradually decrease pressure
so that pitch becomes indeterminate ->


222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
U. P.
Erhu
Pipa
Vln. I
Vln. II
Tape
-> hissing effect of air through chanter
no vibrato
p
Small, rapid vibrato, slowing down-> sul ponticello
pp
'Raspy' pipes sample
Low violin sample (pitch-shifted)
Electronic bell sound

Appendix 4: List of Audio Examples (accompanying DVD–R)

Scale examples:

Audio examples:

(1) Pythagorean diatonic scale

(2) Just diatonic scale

(3) Quartertone scale

(4) Just chromatic scale

(5) 19TET scale

(6) 31TET scale

(7) Bohlen–Pierce (equal temperament) scale

(8) Bohlen–Pierence (just intonation) scale

(9) Partch 43–tone extended just intonation scale

(10) Johnston 53–tone extended just intonation scale

(11) Young *Pre–Tortoise Dream Music* harmonic series scale

Max patches:

(1) Microtonal equal temperament scale demo

(2) Just intonation scale demo with Scala scale file input

Composition portfolio recordings:

(1) *Infraction* (2009): concert recording, synthesised tuning guide track and synthesised mockup

(2) *Flatlining* (2008): concert recording and synthesised scale/tuning tones

(3) *Angels at the Shotgun Wedding* (2007/08): concert recording, drone tracks, tuning tones and synthesised mockup

(4) *Making Ghosts from Empty Landscapes* (2010): concert recording, tape part

(5) *A Space for Tension* (2012): concert recording, video recording (Quicktime .mov/H264 codec), Max patch for tuning and performance