

University of Tasmania

**Harmonic Based Extended Techniques and their Compositional  
Applications:**

**An Investigation in New String Techniques**

An Exegesis Submitted to

Conservatorium of Music

in partial fulfilment of the requirements for the degree of

Bachelor of Music with Honours (or Bachelor of Music (Elite) with Honours)

by

**Rhys Gray**

Hobart, Tasmania

October 29, 2019

## Declaration

I declare that all material in this exegesis is my own work except where there is clear acknowledgement or reference to the work of others and I have read the University statement on Academic misconduct (Plagiarism) on the University website at [www.utas.edu.au/plagiarism](http://www.utas.edu.au/plagiarism) or in the Student Information Handbook. I further declare that no part of this paper has been submitted for assessment in any other unit at this university or any other institution. I consent the authority of access to copying this exegesis. This authority is subject to any agreement entered into by the University concerning access to the exegesis.

Rhys Gray

October 29, 2019

## **Abstract**

I propose to explore a range of extended techniques that utilise the harmonic series and assess how they can be used in my, and other people's, creative practice. These techniques include (but are not necessarily limited to) multiphonics, subharmonics, and half-harmonics. Due to the scope of this project, stringed instruments will be the primary focus. For the purposes of brevity, these harmonic-based extended techniques will simply be referred to as 'techniques' throughout the paper, except for when differentiation between standard techniques is needed.

While some techniques such as harmonics are well established and understood, others, such as subharmonics, are still immature in terms of both repertoire and resources available. The timbral potentials of these techniques are uncharted territories and collectively represent a whole sound world that remains relatively inaccessible to contemporary art music composers.

To identify where further research is required, I will conduct a review of the literature and resources that are readily available to composers to assess what techniques require further investigation and refinement. By researching these techniques and the mechanics behind them, using document analysis, and analysing recordings made, I will gain a better understanding of how these techniques can be implemented in my practice. As part of both the analysis of techniques and my compositional practice, I will assess not only the compositional potential, but also the practicality of techniques. Reviewing the feasibility and notational aspects of the

techniques will render the exegesis a practical document to reference for performance and composition.

I aim for my resulting exegesis to become a useful reference source for artists interested in learning about the mechanics, qualities, and potential implementations of these harmonic based extended techniques. The works that I compose accompanying the exegesis will show idiomatic treatment of the techniques and serve as references as such in the exegesis. The dissemination of the material I research will contribute to the accessibility of new sound possibilities for artists.

Thank you to my supervisor, Matthew Boden, my teachers Dr. Maria Grenfell and Dr. Scott McIntyre, my piano teacher Sally Ward for inspiring my passion in music, my family, and my cats Buttercup and Millie.

## Contents

Illustrations		vii
Chapter 1	Literature Review and Methodology	1
Chapter 2	Assessment of Harmonic Based Techniques and Repertoire	12
Chapter 3	Compositions and Implementation of Techniques	36
Chapter 4	Findings and Research Implications	44
Appendices		58
	<i>what are you doing with the humans</i>	58
	<i>doppelganger</i>	62
	<i>crossing the rubicon</i>	66
	<i>the veldt</i>	70
Bibliography		77

## Illustrations

### Figures

2.1	Excerpt from Crumb’s <i>Black Angels</i> , 4. ‘Devil Music’ . . . . .	18
2.2	Excerpt from Grisey’s playing instructions for <i>Vortex Temporum</i> . . .	19
2.3	Excerpt from Kimura’s <i>Gemini</i> . . . . .	20
2.4	Notation of subharmonics from Long’s website, The Modern Double Bass . . . . .	20
2.5	Excerpt from Rowe’s <i>Submarine</i> . . . . .	21
2.6	Excerpt from Risset’s <i>Variants</i> . . . . .	22
2.7	Excerpt from Botting’s <i>Heights and Depths</i> mm. 94–97 . . . . .	23
2.8	Strange and Strange’s suggested multiphonic notation. . . . .	28
2.9	Excerpt from Buene’s <i>Blacklight</i> . . . . .	28
2.10	Excerpt from Thelin’s thesis. . . . .	29
2.11	Fallowfield’s proposed notation. . . . .	30
2.12	Excerpt from Thurley’s <i>yet another example of the porousness of certain borders</i> . . . . .	30
2.13	Excerpt from Botting’s <i>Study in Harmonics and Multiphonics no. 1</i>	31
2.14	Excerpt from Sciarrino’s 5th capriccio from <i>6 Capricci for Violin</i> . .	33
3.1	Excerpt from <i>what are you doing with the humans</i> . . . . .	38
3.2	Excerpt from <i>what are you doing with the humans</i> . . . . .	39
4.1	Half-harmonic notation examples . . . . .	52
4.2	Half-harmonic displayed with text . . . . .	52
4.3	Half-harmonic circular notation . . . . .	53

4.4	Half-harmonic diamond symbol notation . . . . .	53
4.5	Half-harmonic half-filled notehead . . . . .	53
4.6	Half-harmonic half-empty notehead . . . . .	54

## Tables

2.1	Relation between twists in string and resultant subharmonics . . . .	17
2.2	The different types of multiphonics according to Long . . . . .	26
3.1	Finger Pressure & Resultant Sound . . . . .	38



## Introduction

I propose to explore a range of extended techniques that utilise the harmonic series and assess how they can be used in my, and other people's, creative practice. These techniques are multiphonics, subharmonics, and half harmonics, confined to string based instruments due to the scope of this exegesis.

While some techniques such as harmonics are well established and understood, others, such as subharmonics, are still underdeveloped in terms of both repertoire and resources available. The timbral potentials of these techniques are uncharted territories and collectively represent an entire sound world that remains relatively inaccessible to composers.

To identify where further research is required, I will conduct a review of the literature and resources that are readily available to composers to assess what techniques require further investigation and refinement. By researching these techniques and the mechanics behind them, interviewing professionals, and analysing recordings made, I hope to gain a better understanding of how these techniques can be implemented in my practice. As part of both the analysis of techniques and my compositional practice, I will assess not only the compositional potential, but also the practicality of techniques. Reviewing the feasibility and notational aspects of the techniques will render the exegesis a practical document to reference for performance and composition.

I aim for my resulting exegesis to become a useful reference source for artists interested in learning about the mechanics, qualities, and potential implementations

of these harmonic based extended techniques. The works that I compose accompanying the exegesis will show idiomatic treatment of the techniques and serve as references as such in the exegesis. The dissemination of the material I research will contribute to the accessibility of new sound possibilities for artists.

## Chapter 1

### Literature Review and Methodology

#### Literature Review

This study builds on and contributes to the catalogue of resources available to composers interested in implementing harmonic based extended techniques in their practice. The topic of ‘harmonic based extended techniques and their compositional applications’ is broad, and I will be unable to explore the entire corpus of techniques available to all instruments as this falls outside the scope of this exegesis. This is by design, as certain instruments lack certain facets of research, while others are already well documented, the most obvious example being string harmonics, which are common practice. This broad topic affords a certain level of flexibility to explore what is both novel and feasible given my available resources, all under the unifying theme of harmonic based extended techniques.

Many of the techniques that this study deals with are still in their comparative infancy, especially notationally. As such, engraving the works produced in the course of this study is a more subjective matter, rather than the well-established practice that it normally is. A review of the available literature makes it clear that attempts have been made to standardise contemporary music notation, but have either fallen short, or are now outdated. Kurt Stone organised an international conference on new musical notation in 1974 in Ghent, Belgium, and then produced the treatise *Music Notation in the Twentieth Century* in 1980 as a result of the conference.<sup>1</sup> This, along with Gardner Read’s 1979 *Music Notation*, served as a strong base for the standardisation of music notation, but both are mired

---

1. Kurt Stone, *Music Notation in the Twentieth Century* (New York: W. W. Norton & Company, 1980), xiii.

by their age and computer-based notation not being widespread.<sup>2</sup> It is therefore unsurprising that both omit stringed multiphonics, subharmonics, and the many other techniques covered in my study, which largely postdate publication. Gould's 2016 book *Behind Bars* immediately became the gold standard of engraving manuals, her decades of notational and editorial experience at Faber Music lending weight to her comprehensive treatise.<sup>3</sup> But the same new techniques are omitted from *Behind Bars*, with Gould stating:

‘I have been highly selective in the choice of extended instrumental and vocal techniques included in this book, but it is intended that this should give the reader the facility to create notation for other techniques not in common use.’<sup>4</sup>

Gould's book is less proscriptive than its forerunners, and focuses more on creating a consistent style language, providing the reader with the tools of standardised and codified ‘common practice’ notation to build new extended technique notation. As such, for all notational aspects, I will be drawing upon the Gould for the philosophy of engraving, if not exact notation, which has the benefit of almost forty years of usage and review against its peers.

Gould provides the tools which Ellen Fallowfield uses to construct a notation method for string multiphonics in her PhD ‘Cello Map’, the framework of which this exegesis will follow. A detailed, process-oriented review of technique informs the creation of resources which are then analysed.<sup>5</sup> Fallowfield's analysis produced the

---

2. Gardner Read, *Compendium of Modern Instrumental Techniques*, 1st ed. (Westport, Connecticut: Greenwood Press, 1993).

3. Elaine Gould, *Behind Bars*, 1st (London: Faber Music, 2011).

4. *Ibid.*, iii.

5. Ellen Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers” (Thesis, University of Birmingham, 2009).

website [cellomap.com](http://cellomap.com), a manual of techniques for performers to use. She states that her text maps:

‘[...] “actions that a cellist can make” onto “sounds that a cello can produce”. In other words, we have tried to reduce the cello and cellist to scales of actions and sounds, and show how cellists can influence sound (loudness, overtone content, pitch...) by their actions (bow speed, contact point, stopping position...). This standpoint is a deliberate move away from providing performers and composers with catalogues of special effects and extended techniques. Instead, we would like to provide information about how the cello works that can serve the imagination of performers and composers.’<sup>6</sup>

This approach ‘future proofs’ the thesis by abstracting the elements into their most base form, showing all of the sounds a cello can make using all of the actions a cellist can perform. While the website is comprehensive, Fallowfield seemingly avoids making any judgement calls on the compositional applications of the techniques that she reviews, and the reader is left to draw their own conclusions on the compositional effectiveness of any given technique. Fallowfield does, however, note that a repertoire gap exists for etudes exploring multiphonics for the cello, and indeed, the entirety of the string family. As part of my practice-led research, it seems fitting to compose a piece that addresses this repertoire gap.

Bertram Turetzky’s book, *The Contemporary Contrabass* was written to exemplify the contrabass as a serious solo and melodic instrument, which was underrepresented in the literature.<sup>7</sup> He theorised:

‘[...] concertizing was the key, which in the 1950’s was impossible mainly due to the lack of literature. I attacked this problem in two directions: 1. Locating original contrabass music from the eighteenth and nineteenth centuries, and 2. Commissioning twentieth century music.’<sup>8</sup>

---

6. Ellen Fallowfield, “Cello Map,” accessed May 31, 2019, <http://www.cellomap.com/>.

7. Bertram Turetzky, *The Contemporary Contrabass*, 1st Edition (California: University of California Press, 1974).

8. Ibid., vii.

His practice-led research centered on seeking to understand the techniques that contemporary composers would use in solo contrabass repertoire. Turetzky deliberately omitted including any guidance or judgements on notation, or categorisations of the difficulty of the techniques, stating that

‘[...] the time between this printing and the second edition will suffice to suggest and select the best notational concepts from a more substantial literature than we possess now.’<sup>9</sup>

The second edition saw Turetzky call for more experimentation with multiphonics, stating:

‘I know of no music employing string multiphonics [...] this is entirely new ground, it remains for composers and performers to build the usable technique.’<sup>10</sup>

The specification of both composers and performers being needed to ‘build the usable technique’ is peculiar, until one re-examines the context, in which Turetzky knew of these techniques, and was attempting to rectify it through commissioning new literature. Performers and researchers such as Fallowfield are necessary to establish the technique, but without composers implementing the research carried out by them and contributing to a pool of repertoire to show the correct usage of the technique, it is impossible for a ‘usable technique’ to be built.

Thomas Howell’s 1974 book, *The Avant-Garde Flute* followed Turetzky’s contrabass technique book, as part of Turetzky’s *The New Instrumentation* series, which was published by California Press until Scarecrow Press took over in 2004.<sup>11</sup> It is relatively conservative in its content, and has many omissions. Howell’s

---

9. Turetzky, *The Contemporary Contrabass*, ix.

10. Betram Turetzky, *The Contemporary Contrabass*, 2nd Edition (California: University of California Press, 1992), 138.

11. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers,” 4.

contributions are overshadowed by Robert Dick's *The Other Flute*, which was released the following year, and was notably used as the primary reference for microtonal flute fingerings by John Cage in the preface to his piece *Music For*.<sup>12</sup> *The Other Flute* is a thorough performance technique manual, presenting each fingering and its resultant multiphonics one after the other, using a chart of descriptions to specify the qualities.<sup>13</sup> It specifies the following: 'exact pitch, ease of response, starting time, stability, dynamic range, timbre, and, if present, noise level, residual tone, and degree of modulation.'<sup>14</sup> While this text focuses more on instruction, it is an efficient system, providing much more information in less space than Howell's fingering charts, which were presented without any accompanying context. Dick sorts the multiphonics into four classes graded by difficulty. The multiphonics are presented in order of their method of production; multiphonics derived from natural harmonics, from fingerings of chromatic pitches, and those based on microtonal segments. The scope of my research is limited to the multiphonics based on natural harmonics. From the perspective of a composer, Dick's book provides ample resources on the qualities of each multiphonic, but generic descriptions of their characteristics; enough for a composer to assess whether any given multiphonic is worth investigating with a flautist. While the scope of my research focuses on stringed instruments, Dick's method of cataloguing different fingerings is a logical and comprehensive model to follow. *The Contemporary Violin* is one of the more recent books in Turetzky's

---

12. John Cage, *Music for : Parts for Voice and Instruments without Score (No Fixed Relation)*, Title to Be Completed by Adding to "Music for"— the Number of Players Performing. (Henmar Press, 1984), <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cab02831a&AN=UTas.b2468591&site=eds-live>.

13. Robert Dick, *The Other Flute*, Second Edition (New York: Multiple Breath Music Company, 1989), 86–135.

14. Ibid., 84.

*The New Instrumentation* series.<sup>15</sup> It provides a comprehensive review of various violin techniques, but attempts to shy away from any implication of notational authority, most notable in the section on multiphonics, which seems to contradict rules codified by Gould (though to be fair, the Gould postdates Strange).<sup>16</sup>

Fallowfield identified issues with the presentation format of *The Contemporary Violin* in the literature review of her thesis:

‘The reader will find [information about col legno battuto] under the first chapter heading: ‘Bowing Technique’, the subheading ‘Col legno battuto’. Later, chapter three: ‘Percussion Techniques’ includes the subheading ‘The Bow’, in which col legno battuto is described again.’<sup>17</sup>

Though the scope of my study is significantly smaller in scale, presentation of the findings is paramount to maintain accessibility as a resource. Given that my study focuses on harmonic based extended techniques, overlap of techniques such as multiphonics is possible, and therefore needs to avoid the structural pitfalls of Strange’s layout where information is repeated. Fallowfield’s later concern of a need for a balance between subjectivity and level of detail when describing technique and sound is also relevant to both the Strange book and doubly so to the study. These manuals merely describe the qualities of various techniques, whereas my study will be dealing with the compositional applications of the techniques. Taking the extra-musical content such as blending, appropriateness for use in pitch sets, and other aspects of composition into account poses a threat to the usability of my study due to information overload. Marcus Weiss and Giorgio Netti discuss the reasons for

---

15. Patricia Strange and Allen Strange, *The Contemporary Violin: Extended Performance Techniques*, 1st ed. (Los Angeles, California: University of California Press, 2001).

16. Strange and Strange, *The Contemporary Violin: Extended Performance Techniques*, 134; Gould, *Behind Bars*, 257–258.

17. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers,” 12.



limiting their study to extended techniques in the introduction to their book *The Techniques of Saxophone Playing*, stating:

‘It might indeed be conceivable to compile a multi-dimensional “Encyclopaedia of Saxophone Playing” [, however] the demands on presentation and readability would be so complex as to make such a text impractical’<sup>18</sup>

So far, all of the literature reviewed (with the exception of the Gould and other engraving manuals) has been written either with the performer in mind, or has been written by an instrumentalist. Much of the composer-focused literature is found in the form of orchestration manuals, such as Samuel Adler’s *The Study of Orchestration* and Walter Piston’s *Orchestration*.<sup>19</sup> Attempting to cover the breadth of the art of orchestration, let alone composition, necessitates the omission of extended techniques. This is the inverse of the issue Weiss and Netti encountered, where their study required an omission of ground-level theory regarding the technical aspects of saxophone playing. Read’s *Compendium of Modern Instrumental Techniques* touches upon multiphonics, but delegates to Dick, Howell, and many of the other books from Turetzky’s *The New Instrumentation* series for notation and structure.<sup>20</sup> It becomes apparent that no matter the author, instrument, or technique, the work of packaging extended technique information for composers is left to somebody else. Composers seek to cover the entirety of the craft, while performers seek to cover the entirety of the instrument. Therefore, there is a dearth of resources for composers seeking to incorporate harmonic based extended techniques into their practice. My study addresses this by covering the playability, notation, and implementation of harmonic based extended techniques across relevant instruments.

---

18. Marcus Weiss and Giorgio Netti, *The Techniques of Saxophone Playing* (Kassel: Barenreiter-Verlag Karl Votter, 2010), Introduction.

19. Samuel Adler, *The Study of Orchestration*, Third Edition (New York: W. W. Norton & Company, 2002); Walter Piston, *Orchestration*, First Edition (London: Victor Gollancz Ltd., 1969).

20. Read, *Compendium of Modern Instrumental Techniques*, 160.

Through practice-based research, the exegesis produced by my study will document the process of composing using these techniques, refining the methodology and notation through the creation of several new works. The resulting document will fill a hole in literature aimed at composers by acting as a practical manual for those interested in implementing harmonic based extended techniques in their own practice.

## Methodology

My research topic “Harmonic Based Extended Techniques and their Compositional Applications” is a review of techniques, and how they can be incorporated in my own practice. As such, it is highly subjective, and the research methodology will reflect this, being largely qualitative based. Quantitative based research, such as the analysis of techniques using spectral analysis will be used to support subjective claims. Each technique will be reviewed individually, as they are discrete from one another. Because many of the techniques are uncommon or difficult, consultation with players is paramount to undertake a fair assessment of the techniques. Document analysis of technique manuals will augment oral history research into the qualities and attributes of techniques.

To make an educated opinion on the value of a technique, data must first be collected. Compilation of techniques both in isolated, controlled environments, and in context in musical works will allow a full and accurate use of the analytical method on recordings. Using a Fast Fourier Transformation as in Riera’s thesis on saxophone multiphonics, the prominent harmonics of each technique will be uncovered, for harmonic analysis.<sup>21</sup> Examination of techniques in musical context will allow for value judgements to be made about the musical effectiveness of the technique. The recorded data will be treated, and then interpreted and analysed, with the results being implemented in new works.<sup>22</sup> Through this process, my research will feed into my practice.

---

21. Pablo Ernesto Riera, Martín Proscia, and Manuel Eguía, “A Comparative Study of Saxophone Multiphonics: Musical, Psychophysical and Spectral Analysis,” *Journal of new music research* 43, no. 2 (2014): 202–213, accessed May 9, 2019, <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=A891785&site=eds-live>.

22. Rita Torres and Paulo Ferreira-Lopes, “Multiphonics as a Compositional Element in Writing for Amplified Guitar (2),” *Journal of Science and Technology of the Arts* 4, no. 1 (December 27, 2012): 61–69, accessed May 9, 2019, doi:10.7559/citarj.v4i1.67, <http://artes.ucp.pt/citarj/article/view/67>.

A holistic approach, taking both the sound possibilities and the player implications (“is this technique too difficult for the average player?”, “do I need to write for specific artists if I want to use this technique?”, etc.) is necessary to evaluate its overall potential for incorporation in my practice. To overcome this, oral history methodology will be used to gather first-hand experiences and opinions on techniques. In Barnett’s “Aspects of Vocal Multiphonics”, she conducts several interviews with singers to better understand the way the technique functions from a performer’s perspective.<sup>23</sup>

Interviewing musicians able to play these techniques will deepen my understanding of the mechanics and technical aspects of creating these techniques. While my research is concerned with how I personally can incorporate these techniques into my practice, an effort to interview peer composers will be made, especially those that share common compositional traits with me. Their experiences with composing for these extended techniques will provide more data points to draw comparisons from, and contemporary composer’s compositions and feedback were a valuable component of Dr. Sarah Watts’ thesis to assess the effectiveness of the techniques.

Augmenting the interviews, document analysis will be used on technique manuals that detail the production and quality of techniques. By building off the framework of classification articulated in Robert Dick’s seminal *The Other Flute* and extending it to accommodate a variety of techniques, comparisons across different techniques will be able to be made.<sup>24</sup> Through this, an understanding of the technical and mechanical aspects of the techniques will be gained. Techniques will be assessed

---

23. Bonnie Mara Barnett, “Aspects of Vocal Multiphonics,” *Interface* 6, nos. 3-4 (December 1977): 117–149, accessed May 9, 2019, doi:10.1080/09298217708570239, <http://www.tandfonline.com/doi/abs/10.1080/09298217708570239>.

24. Dick, *The Other Flute*.

on their practicality, ease of use, timbral qualities, and compatibility with my practice. Notation for the techniques varies from composer to composer, and where a common notational standard has not been developed (such as violin subharmonics), a document analysis of current notational standards will be undertaken, making reference to Elaine Gould's seminal text on music notation, *Behind Bars*.<sup>25</sup> Through this, and subsequent consultation with players, development of a consistent and effective notational language can be achieved.

Through the collection of data from a multitude of sources and a range of different methods, it will become evident how harmonic based extended techniques are to be treated idiomatically. By undertaking a holistic review of the techniques including performer and composer points of view, the qualitative research I perform will enable not only me to incorporate these techniques into my own practice, but future composers that are interested in these techniques.

---

25. Gould, *Behind Bars*.

## Chapter 2

### Assessment of Harmonic Based Techniques and Repertoire

Harmonic based techniques invariably make use of the harmonic series in one way or another. The harmonic series is a sequence of tones in which the frequency of each is an integer multiple of the fundamental frequency. The earliest forms of tuning systems were based around these, but modern instruments are tuned using equal temperament. The pitch of sound on stringed instruments is determined via tension, effecting the speed (and consequently pitch) the string vibrates at. Altering the tension is most commonly achieved via fingerings on the instrument's fingerboard, but bow pressure can also play a part in pitch production (see subharmonics).

The objective categorisation of techniques is a Sisyphean task due to the variability of the techniques, but general guidelines can be made; Dick's *The Other Flute* makes good use of quantifying qualitative data about the properties of multiphonics.<sup>1</sup> However, his categorisation is based upon the physical properties of the flute, in which altering fingerings can drastically change the resultant sound. As such, his method of partitioning and evaluating each quality will be used to paint a full picture of the technique in chapter 4, using the descriptive prose found in Adler's *The Study of Orchestration*.<sup>2</sup>

To be able to pass any judgement on the techniques, we must first understand these techniques' capabilities, limitations, qualities, considerations, and values. Without references to other composers' works or professional musicians' opinions, any implication of authority on what constitutes as 'idiomatic' writing is baseless. As such, references to other works, and feedback from sightreading sessions with

---

1. Dick, *The Other Flute*, 84.

2. Adler, *The Study of Orchestration*.

professional musicians will be used to support claims. Where no such references are available, it will be marked as the author's personal opinion. Even without any available references to substantiate compositions as idiomatic, their creation contributes to the literature of the techniques, and thus can be used if not as an example, a warning on what not to do.

All of the techniques covered in this exegesis involve the excitation of a string instrument's string in a non-standard way. A small amount of knowledge of the physics behind these techniques is required in order to understand the methods used to create these techniques. Understanding the conditions under which these techniques are produced will help composers and performers alike realise the techniques' potential accurately and idiomatically.

Strings create sound via the Helmholtz motion, which is a cycle where the string sticks and slips along the bow.<sup>3</sup> Rosin is applied to bows in order to ensure the static friction of the bow is greater than the kinetic friction, allowing the string to stick to the bow better.

Benade describes it as such:

‘When the bow is placed on the string and drawn to one side, the string sticks to the bow, which pulls it aside until the elastic restoring force produced by the string tension becomes large enough to break the string loose from the bow. It now swings back in much the same way it would after slipping off the plectrum of a harpsichord jack; there is, however, a small amount of damping produced by the rapid (and therefore low-friction) sliding of the string against the steadily moving bow hair. At the end of its backward swing the string will come to rest and then recommence its motion in the direction of the bow velocity’<sup>4</sup>

---

3. **wolfeBowsStrings**.

4. Arthur H. Benade, *Fundamentals of Musical Acoustics* (New York: Dover Publications, Inc., 1990), 516.

Typically, the vibration of the string governs the cycle, and therefore the cycle of stick and slip on the bow has the same period as the vibration of the string.<sup>5</sup> Guettler et. al state that two conditions must be met in order to maintain Helmholtz motion;

- (1) during the stick phase the bow force must be high enough to avoid premature slipping of the string, and
- (2) the bow force must be low enough that the circulating Helmholtz corner can trigger the release of the string at the initiation of the slip phase.

When the bow drags the string too far, raucous motion is produced, which is recognisable as the sound produced by an amateur violinist. Under the right conditions, subharmonics are produced.

For the purposes of brevity, these harmonic-based extended techniques will simply be referred to as ‘techniques’ throughout the paper, except for when differentiation between standard techniques is needed. *Normale* will be used throughout this exegesis to denote an arco bow stroke, with no modifying techniques.

---

5. wolfeBowsStrings.



## Subharmonics

First discovered by Mari Kimura, subharmonics are a type of overpressure which produces a sound lower than the fundamental.<sup>6</sup> They are also known as Anomalous Low Frequencies (ALFs), but Kimura argues that the predictable nature of them makes the name a misnomer.<sup>7</sup> As such, they will only be referred to as subharmonics in this exegesis. Subharmonics are produced when the bow is drawn across the string with an excessive amount of pressure. The drag of the bow twists the string, creating torsional oscillation. Under the right conditions, these can interact with the string to produce an identifiable pitch lower than the fundamental.<sup>8</sup>

The physics of how subharmonics are produced are not entirely understood as of time of publication, although many inroads have been made.<sup>910</sup> The exact details fall beyond the scope of this thesis, as composers and performers simply need to know the methods and characteristics of their production, rather than the science behind it. Botting describes the technique as

---

6. Mari Kimura, "How to Produce Subharmonics on the Violin," *Journal of new music research* 28, no. 2 (1999): 178–184, accessed April 11, 2019, doi:<https://doi.org/10.1076/jnmr.28.2.178.3118>, <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=A212434&site=eds-live>.

7. Ibid.

8. "Subharmonics.," *New Scientist* 191, no. 2571 (September 30, 2006): 60–60, <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=22720971&site=eds-live>.

9. Readers interested in learning more about the physics behind them should find the works of Guettler to be an excellent starting point.

10. Knut Guettler, "The Bowed String: On the Development of Helmholtz Motion and On the Creation of Anomalous Low Frequencies" (Doctorate Thesis, Royal Institute of Technology - Speech, Music and Hearing, 2002), <https://pdfs.semanticscholar.org/1d0c/968ee44366cd7d92c63f876be884c9135064.pdf>.

‘[...] using bow placement, overpressure and a steady stroke to access various partials of the subharmonic series which exists in inverse to the harmonic series, ‘beneath’ the fundamental as it were.’<sup>11</sup>

Subharmonics were initially thought to belong to the undertone series, a reflection of the harmonic series in which the fundamental frequency is *divided* by integers, rather than multiplied.<sup>12</sup> The pitches that can be produced do not follow any discernable ratio based pattern.<sup>13</sup> As such, subharmonics strictly speaking are not a harmonic based technique, but remain within the scope of this thesis due to the misinformation surrounding them, and the prevailing similarities with harmonic techniques.

Subharmonics share a common relative with woodwind and brass instrument in pedal tones. They operate in similar ways, though the method of production differs greatly, and the reliability of production of subharmonics is much lower than the equivalent on brass instruments. Because of these commonalities, it is not unreasonable to make comparisons between subharmonics and its equivalents, especially in regards to notation and implementation in works.

Subharmonics represent an incredible opportunity for solo string repertoire. On higher pitched instruments, their use can provide harmonic support (particularly in cadenza passages) and extend the range of the instrument. On lower pitched instruments, subharmonics function better as a timbral mechanic, much like overpressure. One of the newest string techniques, subharmonics are still in their comparative infancy, and their notation has not been formalised.

---

11. Thomas Botting, “Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations” (Thesis, University of Sydney, 2019), 16, [https://ses.library.usyd.edu.au/bitstream/2123/20352/1/botting\\_ta\\_thesis.pdf](https://ses.library.usyd.edu.au/bitstream/2123/20352/1/botting_ta_thesis.pdf).

12. Shaahin mohajeri, “Equaldivisionsoflength(Edl) - 240edo,” October 25, 2019, accessed October 25, 2019, [https://sites.google.com/site/240edo/equaldivisionsoflength\(edl\)](https://sites.google.com/site/240edo/equaldivisionsoflength(edl)).

13. Knut Guettler, “Wave Analysis of a String Bowed to Anomalous Low Frequencies,” *Catgut Acoustic Society*, II, 2, no. 6 (November 1994): 8–14, <http://knutsacoustics.com/files/alf-casj.pdf>.

Subharmonics are explored in my works *the veldt*, and *doppelganger*.

### Subharmonics in the literature

One of the most significant contributions to the literature is Kimura’s article ‘How To Produce Subharmonics’, in which she details specific methods in which one can promote the production of subharmonics, making them easier.<sup>14</sup> Notably, she found that older strings are more sympathetic to the production of subharmonics, theorised to be due to the buildup of fats on the string. Adding twists to the string may also help (or hinder) the production of subharmonics, as shown in Table 2.1.<sup>15</sup>

Table 2.1: Relation between twists in string and resultant subharmonics

	1/2	1	2	3	4	5	6
minor 2nd	x	x					
major 2nd	x	x					
minor 3rd	x	x	x				
major 3rd	x	x	x	x			
perfect 4th				x	x		
diminished 5th					x	x	
perfect 5th	x					x	x
minor 6th							x
octave	x	x	x	x	x		

Possibly the first person to make use of the technique, Crumb described what we know as subharmonics as ‘pedal tones’.<sup>16</sup> Crumb makes use of square noteheads and a separate stave for the resultant pitch in *Black Angels*, which makes the

---

14. Kimura, “How to Produce Subharmonics on the Violin.”

15. Ibid.

16. George Crumb, *Black Angels (Images 1) [Music] : Electric String Quartet*. (Peters, 1971), <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat02831a&AN=UTas.b1139221&site=eds-live>.

technique clear and readily understandable.<sup>17</sup> They are, however, purely timbral, and no recordings seem to treat them as subharmonics.

Figure 2.1: Excerpt from Crumb's *Black Angels*, 4. 'Devil Music'

Sekulic describes subharmonics as:

‘[...] a sound that sounds an octave lower than g string. To produce this sound it is of great importance the use of bow [sic]- the place, speed, and pressure. It is however extremely unsustainable and unpredictable, thus it is difficult to use it much in the compositions.’<sup>18</sup>

Sekulic erroneously claims that subharmonics are solely producible on the G string, and can only produce an octave. Kimura's work, and my own experiments on a contrabass show that subharmonics are possible on any string, and octaves, major sevenths, and minor seconds are all readily achievable without specialist practice.<sup>19</sup>

17. *Black Angels*, in collab. with George Crumb and Cikada Quartet (London: Cala Records, 1995).

18. Dejana Sekulić, “Do You Hear Me?” (Essay, Royal Conservatory Brussels, 2012), 15, [http://dejanasekulic.com/essay-do\\_you\\_hear\\_me.pdf](http://dejanasekulic.com/essay-do_you_hear_me.pdf).

19. Kimura, “How to Produce Subharmonics on the Violin.”

Gerard Grisey's *Vortex Temporum* features overpressure, with a subharmonic of specifically a seventh.<sup>20</sup> He notates the subharmonic technique using a triangular filled notehead showing the intended pitch, along with a double down-bow, with an arrow above it, shown in Figure 2.2. Somewhat abstracted out, this hides the intended effect behind symbols, and is slower to sight read.

### 3) Bow pressures

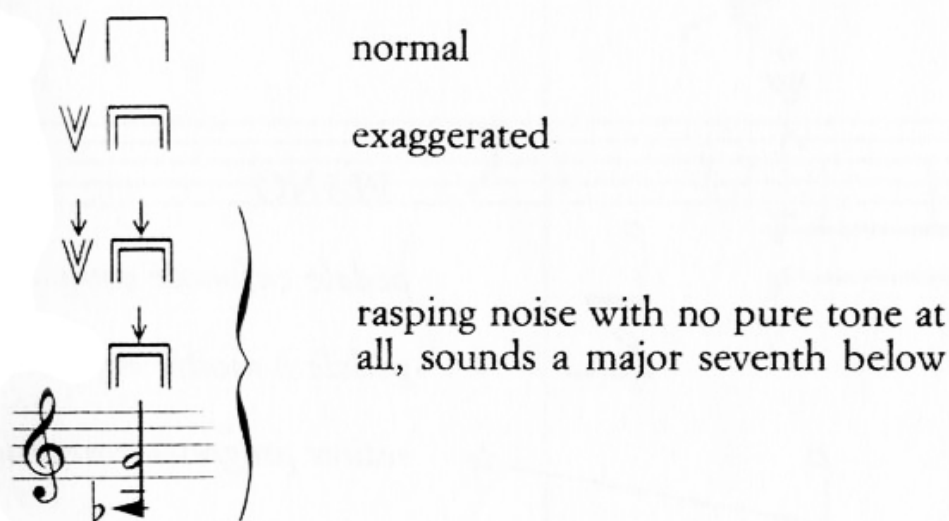


Figure 2.2: Excerpt from Grisey's playing instructions for *Vortex Temporum*.

Mari Kimura's *Gemini* (Figure 2.3) is an example of idiomatic usage of subharmonics on the violin.<sup>21</sup> Kimura's notation practice of using a harmonic denoting the intended pitch below the fundamental is similar to the standard notation of harmonics, which Gould states is to 'write harmonics as the player will

20. Gerard Grisey, *Vortex Temporum*.

21. Mari Kimura, *Gemini*, 1992.

finger them.’<sup>22</sup> Unfortunately, this method proved somewhat counterintuitive in practice, as the notation was too similar, and caused sight reading issues.<sup>23</sup>

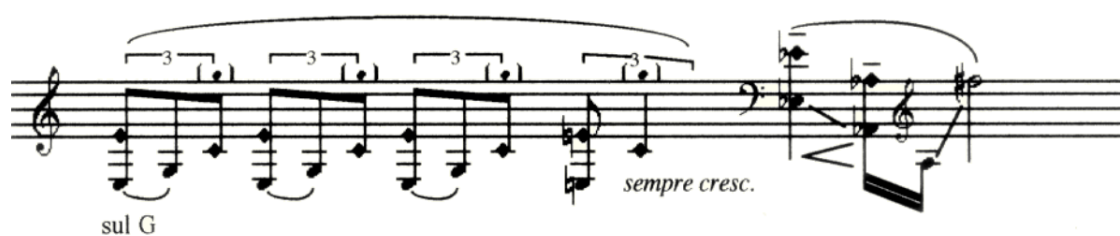


Figure 2.3: Excerpt from Kimura's *Gemini*

The example used on Long's website, *The Modern Double Bass* (Figure 2.4) features a square notehead with the intended sound at pitch in a bracketed notehead, with harmonics and a technique line of 'S.H'.<sup>24</sup>

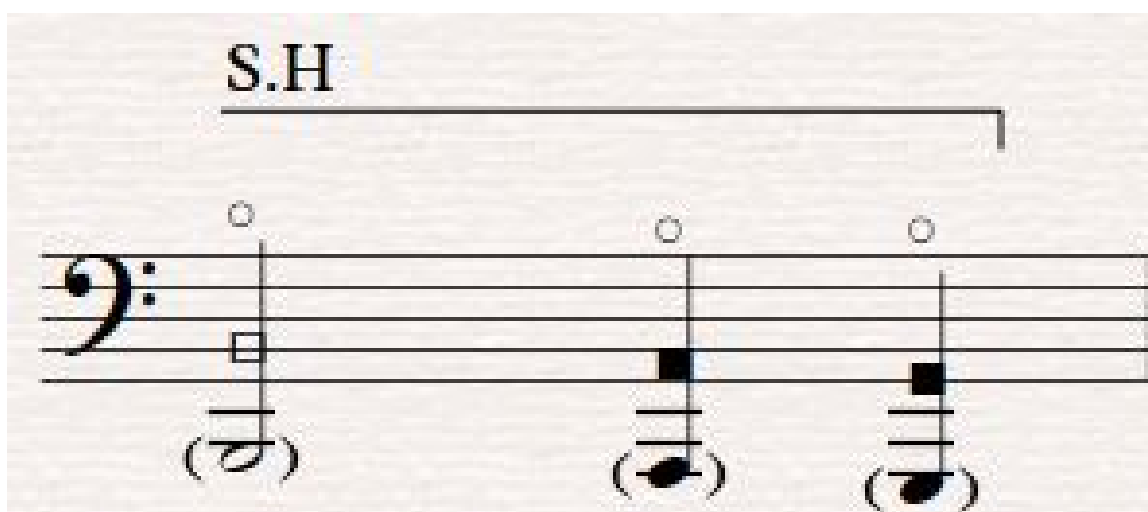


Figure 2.4: Notation of subharmonics from Long's website, *The Modern Double Bass*

It is the author's opinion that this is somewhat redundant, as just square noteheads with the intended produced pitch would be enough to delineate the

22. Gould, *Behind Bars*, 413.

23. *Feedback from Exploratory Session*, in collab. with Angus Appleseed, October 17, 2019.

24. Ashley John Long, "Subharmonics," 2019, accessed September 21, 2019, <https://www.themoderndoublebass.org.uk/subharmonics.html>.

technique. The technique line is supernumerary, and it would only be advisable to use it in extended passages of uninterrupted subharmonics.

Rowe wrote a work for Kimura, and uses a regular notehead for fingering, with a square bracketed cue sized notehead, as seen in Figure 2.5.<sup>25</sup> *Submarine* uses subharmonics early in the work as a contrast to the higher pitched material. They are referred back to several times, either as a mechanism to further muddy the soundworld created by the digital processing, or to ‘clear the palette’, the electronic audio cutting out leaving just the authoritative tone of the subharmonic. Rowe makes use of the audio processing, recording the subharmonics and playing them back later; an economical way to use the technique, which can be unreliable. Near the end of the work, Rowe immediately plays back the just-recorded subharmonic, overcoming the limitation of the subharmonic’s inability to handle sustained durations through technology. It should be noted that Rowe uses notation that has fallen out of style to notate *normale* harmonics, notating the fingering position with the diamond notehead, and the resultant pitch with a harmonic circle above it. Harmonic circles always denote resultant pitch, and are usually reserved for octave harmonics; the inclusion of the fingering obfuscates the intent.<sup>26</sup>



Figure 2.5: Excerpt from Rowe's *Submarine*

25. Robert Rowe, *Submarine*, 1996 (revised 2004).

26. Gould, *Behind Bars*, 420.

Jean-Claude Risset's *Variants*, also written for Kimura, is a work that makes use of both subharmonics and digital processing of live sound.<sup>27</sup> It uses a separate staff for the subharmonics and digital processing, as seen in Figure 2.6.

The image displays three systems of musical notation for Jean-Claude Risset's *Variants*. The first system, titled "Energetico", shows a violin part in treble clef with a tempo of 60 beats per minute. It includes a dynamic marking of *f* and a "REV normal" instruction. The second system, labeled "Digital Processing and Violin low part", shows a treble staff with notes and a bass staff with a single note, with a "pitchshift -2/-6" instruction. The third system shows a treble staff with notes and a bass staff with a single note, with a "pitchshift -2/-4" instruction and dynamic markings of *p* and *f*.

Figure 2.6: Excerpt from Risset's *Variants*

In *Variants*, Risset uses digital processing software to create chords out of singular melodic lines on the violin. This gives the impression of a full string section when the violin is playing fast *normale* passages, and emphasises the raucous, harsh timbre when playing subharmonics. They are used as a timbral device, rather than anything pitch based, with the longest subharmonic going for little more than two seconds, with three subharmonics appearing in the piece in total.

Botting uses a fingering stave, and two staves for the resultant pitch which also contains the technique information, denoted by 'SH' and a diamond notehead

27. Jean-Claude Risset, *Variants*, 1995,  
<http://composers21.com/compdocs/rissetjc.htm>.



(confusingly, the staff is called the ‘written pitch’).<sup>28</sup> Apart from the technique text belonging attached to the staff that is performed, this is an acceptable method of showing resultant pitches when subharmonics are used in conjunction with harmonics. Botting’s score was included in the appendices of his thesis, but it is unclear if frontmatter was omitted; given that Botting performs the piece personally, it is not unreasonable to assume that the work was written solely for his own practice (and therefore required no explanation of the techniques). This is, however, not acceptable for composers looking to use the technique in pieces performed by other people, and Gould is quite explicit in stating that all extended techniques must be covered in the frontmatter.<sup>29</sup>



Figure 2.7: Excerpt from Botting’s *Heights and Depths* mm. 94–97

This section of movement between subharmonics, *normale*, and harmonics lasts for no more than seventeen bars, but is enough to recognise the compositional potential. The textural movement from rough, gravely subharmonics through to pure harmonics, combined with the ascending pitch material gives a natural wedge shape to the phrase. The effect is more pronounced on the harmonics that result in a major

---

28. Botting, “Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations,” 109.

29. Gould, *Behind Bars*, 494.

third interval and minor seventh at bars 102 and 103 respectively. It then shifts into multiphonics, showing that these techniques can work in quick succession.<sup>30</sup>

Through an examination of the literature, there appears to be a range of different notation methods and levels of understanding of the mechanics of subharmonics.

---

30. Botting, “Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations,” 154–155.

## Multiphonics

Multiphonics, also known as split tones, are ‘the simultaneous sounding of two or more harmonics on a single string’.<sup>31</sup> For the purposes of this exegesis, they will only be referred to as multiphonics. An acoustical explanation for the production of multiphonics is still lacking, although it can be surmised that much like how octave harmonics can withstand a large margin of pitching error in order to activate, several partials’ ‘tolerance zones’ for activation overlap.<sup>32</sup> Multiphonics are most commonly the domain of wind, and occasionally brass instruments, but they are an emerging technique in string writing, Turetzky writing about them in 1974.<sup>33</sup> Multiphonics on stringed instruments are difficult, but with appropriate preparation and notation, are feasible. Production of multiphonics, as with wind instruments, is not guaranteed, and can be dependant on a variety of external factors, including the humidity, make of the instrument, bow used, and other variables that are outside of the control of a composer.

Multiphonics are explored in my piece for violoncello, *crossing the rubicon*, and contrabass work *the veldt*.

### Multiphonics in the literature

Fallowfield explores multiphonic production on the cello in her thesis CelloMap comprehensively, with video recordings of all possible multiphonics and

---

31. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers,” 108; Fallowfield, “Cello Map,” <http://www.cellomap.com/index/the-string/the-left-hand.html>.

32. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers,” 146; *Feedback from Contrabass Session*, in collab. with Joe Bloggs, October 20, 2019.

33. Turetzky, *The Contemporary Contrabass*, 138.

permutations, including pizzicati.<sup>34</sup> These are isolated, though, and give little indication to the difficulty of the multiphonics.

In Strange and Strange’s *The Contemporary Violin*, Tracy Silverman compares the sound to electronic feedback.<sup>35</sup> Welbanks compares and contrasts between Fallowfield and Silverman’s assessment of the technique, and concludes that Silverman believes that multiphonics are a predominantly left-hand technique, while Fallowfield argues for a more holistic view, with the bow.<sup>36</sup>

Ashley John Long’s ‘The Modern Double Bass’ website serves a similar purpose as Fallowfield’s CelloMap for the double bass.<sup>37</sup> He divides them into different categories as detailed in Table 2.2, some of which have more information and detail than others.

Type	Description
‘Natural’ multiphonics	Chart of different fingerings, similar to Fallowfield.
Pizzicato multiphonics	Description of technique, production, and result.
Textural multiphonics	Description of technique, production, result, and considerations.
Multiphonics behind the bridge	Description of technique.
Artificial multiphonics	Chart of different fingerings, similar to Fallowfield.
Percussive multiphonics	Description of technique, production, result, and considerations.
Timbral multiphonics	Description of technique.
Transformative multiphonics	Description and production of technique
Multiphonics through Variations in Finger Pressure	Description of technique, production, result, considerations, and example.

Table 2.2: The different types of multiphonics according to Long

Despite the varying degrees of detail, his work on cataloguing multiphonics is more in depth than many other resources.

---

34. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers.”

35. Strange and Strange, *The Contemporary Violin: Extended Performance Techniques*, 132.

36. Valerie Welbanks, “Foundations of Modern Cello Technique”:161–164.

37. Ashley John Long, “The Modern Double Bass,” accessed September 2, 2019, <https://www.themoderndoublebass.org.uk/>.

## Notation of Multiphonics in the literature

It should be noted that multiphonics are markedly different to the multiphonics of wind instruments due to the fingering systems. While wind instruments achieve multiple tones by exploiting the construction of their instrument, string multiphonics are produced agnostic of specific fingerings. As such, the challenges that string multiphonic notation face are different to wind instruments. With no fingering chart necessary, string instrument multiphonics also have no frame of reference for what sounds can be expected to be produced. String instruments also are not solely monophonic instruments, so notating the resultant multiphonic on the staff produces confusing results. Compounding this issue, string instrument multiphonics are a subset of harmonics, which use a different notehead to denote the fingering pressure difference. This means that any resultant pitches would need to be notated with regular noteheads, to discern the fingering pitch from the resultant. Therefore, another system of denoting multiphonics must be used, as the existing wind literature is not suited for the purpose.

Strange and Strange discuss multiphonics at length, but lacked the literature necessary to form an opinion regarding their notation, stating that ‘to our knowledge these string multiphonics have never been notated.’<sup>38</sup> They present a potential notation system as seen in Figure 2.8, and justify it thus;

‘The effect is a variant of an open harmonic, so it is logical to begin with that symbol- a small circle over the sounding pitch. The timbral characteristics of the multiphonic is a distortion, or breaking up of the various other partials, much like a true *sul ponticello*.’

---

38. Strange and Strange, *The Contemporary Violin: Extended Performance Techniques*, 132–134.

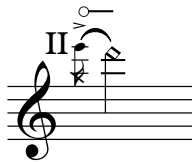


Figure 2.8: Strange and Strange's suggested multiphonic notation.

Buene uses a chart of diamond noteheads with their corresponding intended multiphonic in the score for his work for two double basses, *Blacklight*.<sup>39</sup> It mimics Fallowfield's charts of corresponding nearby quartertones, though the diamond notehead is already used in common repertoire for harmonics, not an extended technique. This has the potential to cause confusion, and could be easily avoided with a symbol or 'M' denoting the special quality of the multiphonic, and Gould warns against such repurposing of existing symbols.<sup>40</sup>

DIAMOND HEADED NOTES ARE MULTIPHONICS ON THE E-STRING. TOUCH STRING WITH NORMAL FLAGEOLETTE FINGER PRESSURE EXCEPT WHERE INDICATED. 8-NUMBERS REFER TO HARMONIC NODE FOR PLACEMENT OF BOW. THE RESULTANT PITCHES ARE SHOWN APPROXIMATED ON UPPER STAFF BELOW (SUONI REALE), SOME WITH ALTERNATIVE RESULTS IN PARANTHESIS. ALL MULTIPHONICS HAVE A MORE OR LESS PRONOUNCED E SOUNDING FROM THE FUNDAMENTAL OF THE STRING. WHEN PLAYED AS A SEPARATE PIECE (NOT IN THE CONTEXT OF 'INTO THE VOID'), THE PIECE ENDS IN BAR 61 (WITH REPETITIONS)

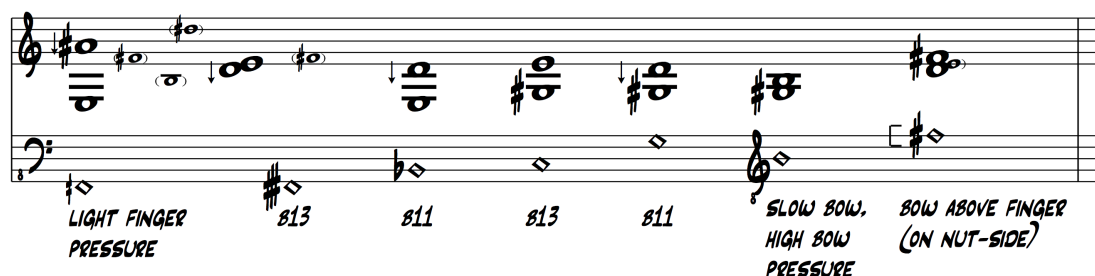


Figure 2.9: Excerpt from Buene's *Blacklight*.

Thelin's thesis on double bass multiphonics states:

39. Håkon Thelin, "Multiphonics on the Double Bass" (Norwegian Academy of Music, 2011), 39–42, <http://haakonthelein.com/multiphonics/uploads/files/4%20Multiphonics/Multiphonics%20on%20the%20Double%20Bass.pdf>.

40. Gould, *Behind Bars*, 494.

‘Multiphonics is [sic] always notated with the harmonic diamond sign, in tablature notation indicating finger positions rather than musical pitches. I suggest using the symbol M. above or below the note to indicate that it is a multiphonic sound, together with the indication on which string to play the note (in Roman numerals).’<sup>41</sup>

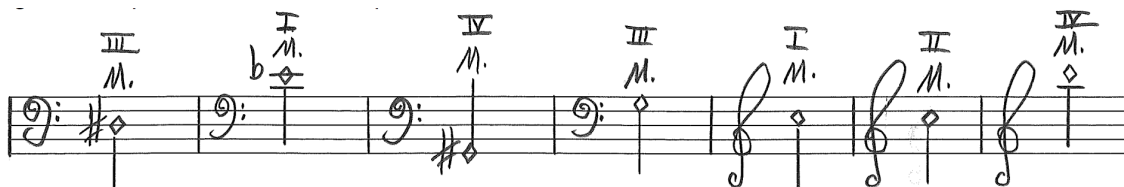


Figure 2.10: Excerpt from Thelin's thesis.

His notation, seen in Figure 2.10, is a somewhat less sophisticated version of Fallowfield's, lacking the tuning information necessary to produce the multiphonic. It should also be noted that Gould warns against technique text being placed below the staff.<sup>42</sup>

Fallowfield proposes the form of notation seen in Figure 2.11, stating:

‘[...] it is necessary to indicate both the left-hand finger position and the pitch content. The left-hand finger touches the string above the node of the highest harmonic that contributes to the multiphonic, so the finger position is always that of the highest harmonic in the group. I suggest notating finger position with the rhombus that is usually used for harmonic finger pressure. The pitch of the contributing harmonics could be notated in brackets or on a separate staff. It is necessary to indicate which string the multiphonic should be played on and helpful to use the indication ‘M’ for multiphonic.’<sup>43</sup>

This notation is effective, although omits the indication of which string the multiphonic should be played on as she specified.

41. Thelin, “Multiphonics on the Double Bass,” 6.

42. Gould, *Behind Bars*, 492.

43. Fallowfield, “Cello Map,”  
<http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>.

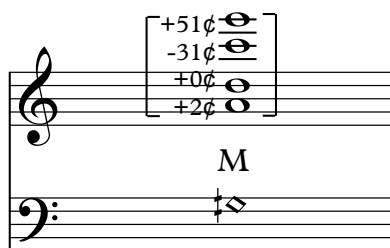


Figure 2.11: Fallowfield's proposed notation.

We can see this in practice in Oliver Thurley's work for solo contrabass, *yet another example of the porousness of certain borders*, where he adds another staff showing the intended pitches to be produced.<sup>44</sup>

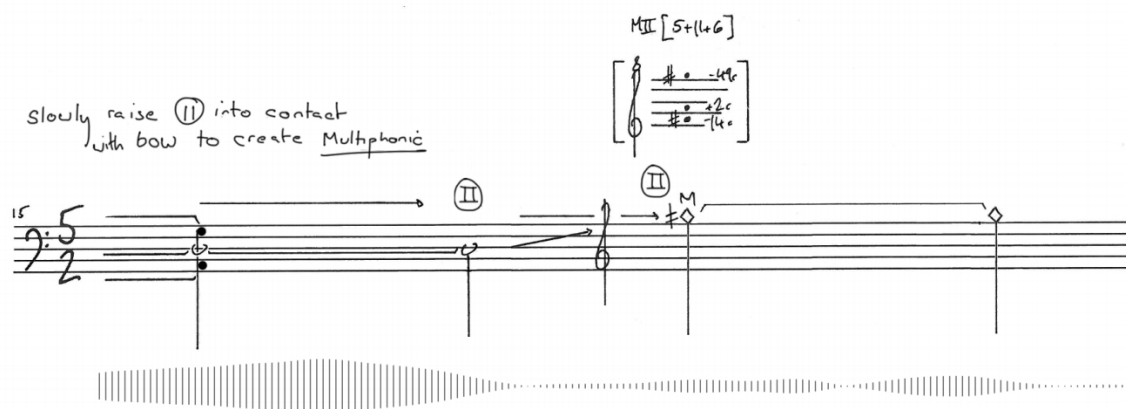


Figure 2.12: Excerpt from Thurley's *yet another example of the porousness of certain borders*

Thurley embraces the fragility of these multiphonics, and uses their variability as a feature, rather than a hindrance. Slow, quiet transitions between multiphonics, double-stopped harmonics, and other extended techniques make the occasional unintentional destabilisation of a multiphonic a point of textural interest, rather than a flaw.

44. Oliver Thurley, *Yet Another Example of the Porousness of Certain Borders*, 2014, <http://oliverthurley.co.uk/scores/yaeotpocb-score.pdf>.



Botting uses a diamond notehead for fingering, and a staff above containing the resultant pitches as diamond noteheads with an ‘M’ above them, as shown in Figure 2.13.<sup>45</sup>

The image displays a musical excerpt from Botting's *Study in Harmonics and Multiphonics no. 1*. It consists of two staves. The upper staff, labeled 'Written Pitch', is in 4/4 time and features diamond-shaped noteheads with an 'M' above them, signifying multiphonics. The lower staff, labeled 'Finger Position', shows the fingering for the notes. Below the lower staff, the fingerings are written as Roman numerals: II I, III, II I, III, II I, III II I, III II I.

Figure 2.13: Excerpt from Botting's *Study in Harmonics and Multiphonics no. 1*

The *Study in Harmonics and Multiphonics no. 1* repeats the melodic material, and we see that the multiphonic not only slots in as something that can be played at an *andante rubato*, but we see the bow move across the strings, shifting from D to G to a multiphonic on the A string. It should be noted that Botting produced this notation system without reference to the preexisting works of Fallowfield. This suggests that the use of an ‘M’ to specify a multiphonic is a relatively intuitive way of conveying the information (preceded, of course, by front matter explaining the technique).

It becomes apparent through the examination of the literature surrounding multiphonics that they are still an emerging technique, but are not shrouded in mystery or disinformation as subharmonics are.

---

45. Botting, “Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations,” 35.

## Half-Harmonics

Half-harmonics is a term assigned to the fingering pressure found somewhere in between a regular note and harmonic. The technique is not difficult to produce, and the resultant sound is not dissimilar to the fragility of a multiphonic, producing both the fundamental pitch, and the harmonic. It should be noted that the half-harmonic is a modifying left-hand technique; it can be applied to multiphonics (although the resultant sound would likely be more noise than discernably either of the two techniques), but is not compatible with subharmonics due to the bow pressure needed to produce subharmonics eliminating the possibility of half-harmonics being produced. The terminology has not been formalised, but is most widely known as half-harmonics, although some works describe the technique without ascribing a name.

Half-harmonics are explored in my work for violin, *what are you doing with the humans*.

### Half-harmonics in the literature

Half-harmonics, like the other techniques covered in this exegesis, have relatives in the wind and brass literature. Half-fingered and half-valved techniques appear in the respective nomenclature, and share common attributes of speaking poorly with bleedover into partials with the half-harmonic technique. Unlike multiphonics, the mechanical production of the technique is not dissimilar to the wind and brass facsimiles; all three families' respective techniques revolve around pressing almost to the point of a *normale* sound, but not quite, resulting in a pinched sound. Because of this, it is not unreasonable to draw parallels between the half-valved and fingered literature, and half-harmonic literature.

Half-harmonics do not feature heavily in the literature, with the most notable work being Sciarrino's 6 Caprices for solo violin.<sup>46</sup> It should be noted that Sciarrino wrote these in response to Paganini's caprices. They appear to take the same approach to composing in the same philosophy as New Complexicists, in the sense that the written score is the Platonic ideal, and that approximations are all that are expected. This is supported by the fact that many performers play them as harmonics.<sup>47</sup>

Lachenmann also makes use of them, and states it is

[...] 'important not to produce any harmonics here; the result should be a veiled, almost immaterial and hardly perceptible coloring of the dominating string sound produced by the stopped note'<sup>48</sup>

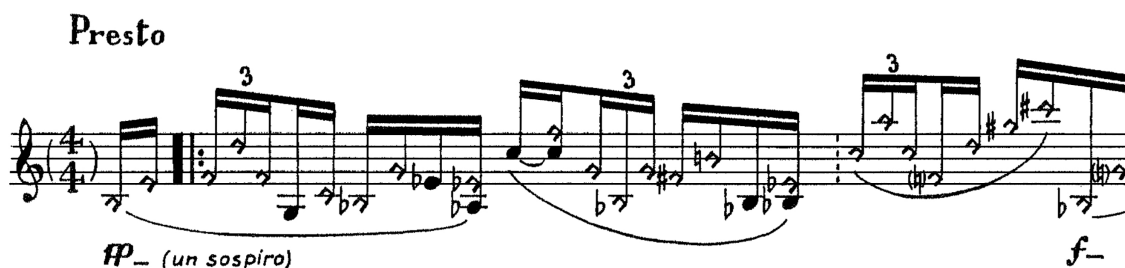


Figure 2.14: Excerpt from Sciarrino's 5th capriccio from *6 Capricci for Violin*

Sekulic adds to this quote, stating in *Do you hear me?* that the stopped note:

'[...] which, as indicated, is only lightly touched, in conjunction with the flautato bowing.'<sup>49</sup>

46. Salvatore Sciarrino, *6 Capricci Per Violino*, 1976.

47. *Feedback from Exploratory Session*.

48. Helmut Lachenmann, *Musik Für Streichquartett*, 1972, foreword.

49. Sekulić, "Do You Hear Me?," 28.

In his work *Es Vee Pea*, Bunk notates half-harmonics with a triangle notehead, and instructs the player to:

‘Bow very slow and lightly. The pitch should be fingered with a bit more pressure than a harmonic, but the string should not touch the fingerboard. The result will be a quiet scratchy sound blended with a faint and unstable pitch’

50

In her thesis on extended viola techniques, Kwok describes half harmonics as producing ‘a “flutey” sound, similar to that of *sul tasto* and a natural harmonic’.<sup>51</sup>

In his piece *The Plate of Transition Nourishes the Chameleon Appetite*, Applebaum uses the half-harmonic technique with a half-filled diamond notehead, describing it as being ‘fingered lightly to produce noisy, semi-uncontrolled pitch’.<sup>52</sup>

Dimpker takes half-filled diamond noteheads found in Pröve’s *Firebird*, and compares it with Kagel’s notation in his *Streichquartett I/II*.<sup>53</sup> Dimpker notes the metrical disadvantages that half-filled diamond have, but fails to note that regular harmonics overcome the same issue with little fanfare. The subject of transitions between half harmonic and harmonic, and half harmonic and *normale* is discussed, with the conclusion that

The transition from half harmonic pressure to harmonic pressure, and vice versa, could be requested by using two notes of the same pitch (one for

---

50. Lou Bunk, *Es Vee Pea*, 2002, <http://www.loubunk.com/scores/Es%20vee%20Pea%20Bunk.pdf>.

51. Sarah Wei-Yan Kwok, “Breaking the Sound Barriers : Extended Techniques and New Timbres for the Developing Violist” (University of British Columbia, 2018), accessed May 30, 2019, doi:10.14288/1.0365754, <https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0365754>.

52. Mark Applebaum, *The Plate of Transition Nourishes the Chameleon Appetite*, 1992.

53. Christian Dimpker, “Extended Notation: The Depiction of the Unusual” (University of Plymouth, 2012), 120–121, <https://pearl.plymouth.ac.uk/bitstream/handle/10026.1/3184/2013Dimpker10320048PhD.pdf?sequence=3&isAllowed=y>.

the half harmonic and one for the harmonic stops) and connecting them by means of a legato slur.<sup>54</sup>

He also specifies that half harmonics ‘are not limited to the nodes and hence the natural harmonics, but may be executed on all fingerboard positions’.<sup>55</sup>

We begin to see that half-harmonics are relatively consistent throughout the literature, and although the terminology and descriptions of the resultant sound varies, there is a general consensus on what the sound should be. There is not, however, as much consensus with regards to the notation of half-harmonics, and the binary nature of the technique seems to work against its favour, resulting in new forms of notation being constructed rather than composers using existing literature’s notation to form a standardised notation system for half harmonics.

#### Notation of half-harmonics in the literature

Perhaps the most straight-forward technique covered in this exegesis, notation for half-harmonics have just a single variable of finger pressure to convey in notation. The use of standard notation, modified to reflect the idea that the technique fits in ‘half way between’ two well established techniques (normale and harmonics) would be ideal, conforming to Gould’s ideology of maintaining uniformity.

---

54. Dimpker, “Extended Notation: The Depiction of the Unusual,” 121.

55. Ibid.

## Chapter 3

### Compositions and Implementation of Techniques

My folio of works comprises of four pieces: *doppelganger*, for solo viola, *the veldt*, for solo contrabass, *crossing the rubicon*, for solo cello, and *what are you doing with the humans*, for violin. These works all deal with different facets of the techniques that I have researched in this exegesis. Through the process of practice based research and reflection on the implementation of these pieces, it is hoped that a clear identity of idiomatic treatment of these techniques will be elucidated. Shortcomings are still valuable data points due to the lack of information readily available about the treatment and usage of these techniques. It is envisaged that these works are to be used as etudes, both for musicians as testing grounds for the capabilities of the techniques, and for composers seeking to study scores to better understand how to implement these techniques in their own works. Through the process of journalling my compositional intent, it will become clear what the function of each piece is. Comparisons and contrasts to pre-existing literature and works will support the techniques' idiomacy.

I worked with several instrumentalists proficient in their instruments at a professional level, but were not familiar with the techniques. They sight-read the works, and provided feedback on the writing, the technique, and how to better produce the techniques. Participants intimately familiar with the techniques were not approached both due to their unavailability, and because players unfamiliar with the techniques better fit the purpose of this exegesis; to inform composers and performers unfamiliar with the techniques to the point where they are able to accurately replicate the techniques.

Because these were sight-reading sessions, and due to the scope of the research, the names of the participants have been altered to preserve their anonymity.<sup>1</sup> Their pseudonyms and instruments are as follows:

- Angus Appleseed — viola
- Jane Smith — cello
- Joe Bloggs — contrabass

Due to the scope of this exegesis and time constraints, it was not possible to obtain recordings of each piece in full. Excerpts have been recorded where possible, and are supported by examples of other works from the literature, and instructional videos that support the idiomacy of the treatment of the techniques. As the goal of the exegesis is to produce a practical document that future composers can refer to, the entirety of the scores are included in the appendices of this exegesis. To aid the reader in referencing the relevant document quickly, hyperlinks are provided initially to the corresponding scores. Excerpts are provided for further references to the scores.

### *what are you doing with the humans*

*what are you doing with the humans* is a solo work for violin that explores half-harmonics. It is a non-programmatic work, and the title was inspired by a question that my supervisor posed to me while I sought ethics approval for the exegesis. Half-harmonics are perhaps one of the simplest techniques to achieve, produced by applying finger pressure halfway between that required to create a harmonic, and a *normale* sound. This means that the scale of finger pressure is thus;

The one-dimensional nature of this facet of the techniques leaves little variability in the implementation of the technique. Thus, *what are you doing with the*

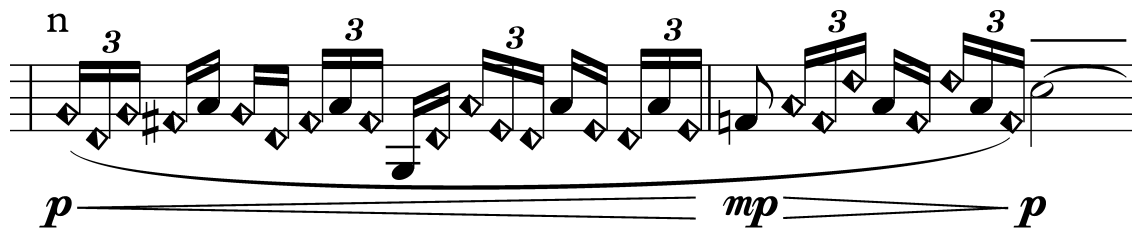
---

1. This is because the participants had limited rehearsal time, and the techniques are not representative of their normal playing. As such, pseudonyms are necessary to avoid any professional reputational damage/

Table 3.1: Finger Pressure &amp; Resultant Sound

Finger pressure	Result
Open	Fundamental
Touching	Harmonic
More pressure	Half-harmonic
Fingerboard	Normale

*humans* explores the relationship between half-harmonics and other finger pressures. Rapid change between half-harmonics, regular harmonics, and *normale* makes the work an exercise in finger control, as well as an introductory work to half-harmonics. Below, I demonstrate the rapid changes of the half-harmonics in mm. 5 of *what are you doing with the humans*.

Figure 3.1: Excerpt from *what are you doing with the humans*

In mm. 27–32, I use the D string to provide additional available harmonics; the fifth D string harmonic, octave D string harmonic, and a fourth artificial harmonic using a stopped A are all readily available underneath the violinist’s fingers. Thus, the difficulty is not in the fingering on the fingerboard, but the quick changes between harmonic, half-harmonic, *normale*, and artificial harmonic. Through this facet of eliminating needless complexity, the work serves as an etude targeting specifically the production of half-harmonics.

*what are you doing with the humans* takes inspiration from Sciarrino’s fifth Caprice, and serves as a stepping stone to the more difficult work.<sup>2</sup> In practice, the

2. Sciarrino, *6 Capricci Per Violino*.



pitch content of my work was obscured by the glassy texture of half-harmonics, rendering large portions of it as noise. With the knowledge that properly performed, the harmonic content would be obscured, I leant into this, writing in a more tonal style than I do usually.

Another facet of half-harmonics that I wanted to explore was the timbral aspect of them, bar 27 shown in Figure 3.2. Similar to a multiphonic in their rich harmonic content, half-harmonics do not have the purity of tone that regular harmonics have, and are more often a type of multiphonic, as evidenced by Fallowfield’s example. I explore the interplay of half-harmonics, regular harmonics, and *normale*, double stopped minims and semibreves slowly changing from one mode of pressure to another. In this way, violinists that play *what are you doing with the humans* will become familiar with different modes of pressure played concurrently.

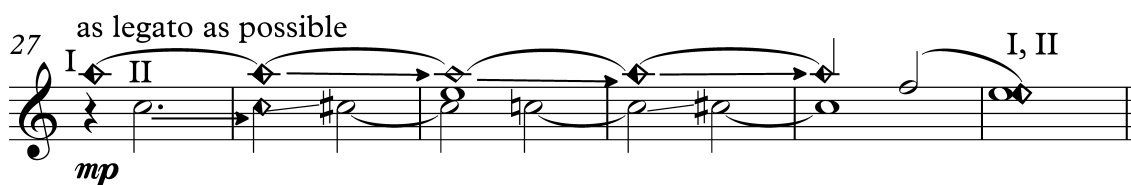


Figure 3.2: Excerpt from *what are you doing with the humans*

Notationally, the rapid changes between half-harmonics and other techniques were an ideal testing ground for different notation types. Notably, the issue of half-filled diamond noteheads not having any distinction between crotchets and minims is not an issue due to the bulk of the work dealing in small divisions of the beat. The considerations of how to best notate half-harmonics are discussed further in section 4.

Ultimately, I opted to implement the half-filled diamond noteheads, finding them to most accurately present the information in a way that was inobtrusive, and built upon pre-existing notation. It should be noted that this is contrary to the

opinion set out in Dimpker’s seminal thesis on notation, *Extended notation. The depiction of the unconventional*, but conforms to Gould’s opinion on the matter.<sup>3</sup>

### *doppelganger*

*doppelganger* is a piece for solo viola, written to explore the lower register of the viola using subharmonics juxtaposed with upper harmonics. The pitch distance between subharmonics and harmonics sidestep the viola’s usual role occupying the middle register.

### Findings of *doppelganger*

Workshopping an early draft of *doppelganger* with Angus, I found that subharmonics came fleetingly, and were prone to ‘jump back’ to the fundamental.<sup>4</sup> This resulted in a rewrite, redirecting the focus of the technique as a more textural element. As such, I amended the score to treat subharmonics largely as a ‘special effect’, and not ascribe importance to their pitched content.

A second workshop with Angus was more productive, and we found that the subharmonic technique spoke much more readily with a slower bow speed, combined with a consistent amount of pressure.<sup>5</sup> We found that the A string of the viola did not respond nearly as readily to the technique, to the point of being unusable. The D and G strings both spoke acceptably, but due to the pressure required, often resulted in unwanted double-stopping. The C string spoke very freely, with the technique coming readily. Contrary to Fallowfield stating ‘It is very difficult to sustain the tone, which

---

3. Dimpker, “Extended Notation: The Depiction of the Unusual,” 120–121; Gould, *Behind Bars*, 61.

4. *Feedback from Exploratory Session.*

5. *Feedback in Sightreading Session*, in collab. with Angus Appleseed, October 23, 2019.

often has a high noise component’, we found that with practice, the subharmonic was able to stabilise to the point of it being usable for longer sustained notes.<sup>6</sup>

To ‘ease the player into’ the technique, *doppelganger* begins with a *sul ponticello* open C string, which drones for a few seconds before crescendoing while moving the bow towards the fingerboard and slowing the bowing speed down. The pressure used to play *sul ponticello* is the same as the pressure needed to play subharmonics, priming the player to only need to concentrate on the bow speed and location on the string. This technique of applying the thought process of playing *sul ponticello*, but actually playing near the fingerboard appears to be an ideal way to guide players unfamiliar with the technique into achieving it without lengthy in-person demonstrations.<sup>7</sup>

### *crossing the rubicon*

*crossing the rubicon* is an exploration in multiphonics. I wanted to explore multiphonics as I explored half-harmonics in the piece section 3. Unfortunately, while workshopping with Sarah, I found the non-binary nature of multiphonics precluded this from being a possibility.<sup>8</sup> I discovered several facets of the technique that were not previously discussed in the literature found in Fallowfield’s work.<sup>9</sup>

For each pair of nodes that produce multiphonics, the lower of the two is easier to pitch due to the logarithmic correlation between string length and pitch;

---

6. Fallowfield, “Cello Map: A Handbook of Cello Technique for Performers and Composers,” <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>; *Cello Map - Example 24* (Basel: Academy of Music, January 11, 2013), <https://vimeo.com/57219720>; *Feedback in Sightreading Session*.

7. *Feedback in Sightreading Session*.

8. *Feedback from Cello Sightreading Session*, in collab. with Jane Smith, October 18, 2019.

9. Fallowfield, “Cello Map.”

that is to say, because the gaps between semitones are correlationally larger as the pitch lowers, the pitching can be more precise.

Double-stopped multiphonics are feasible, but because the angle of attack can impact the partials the multiphonic produces, the shift between single strings and double stopping can stop the multiphonic from speaking clearly. Aurally, double stopped multiphonics seem to be more effective with the *normale* note on a lower string than the multiphonic.

### *the veldt*

Inspired by the eponymous short story by Ray Bradbury, *the veldt* is a composition for solo contrabass that explores both multiphonics and subharmonics in the context of a soundworld; the musical language is derived from the harmonic series, exploiting the resonance of the bass to maintain a drone. Similarly like the plot of Bradbury's work, this world is filled with danger but also beauty. This is reflected in my work in the use of subharmonics and multiphonics; difficult and fragile techniques that can break at a moments notice. My intent with Veldt was to create a soundworld and space that the performer was able to 'roam around' in, and features several sections of improvisation or stochastic aleatory based around the harmonic series, representing the possibilities of the veldt.

### Findings of *the veldt*

Writing for contrabass, I found subharmonics came most easily on the G string. This was confirmed in a workshop with Joe, although they Subharmonics on the lower strings did not speak as well, and it was difficult to discern the lower frequency's shifts. Because of this, *the veldt* uses the technique as a textural tool, rather than a melodic or defined pitch.

Working with Joe, he identified the need for subharmonics to be. Because of the techniques used, a second stave displaying the music notated at actual pitch was necessary. In contradiction of Gould's recommendations, I opted to notate it in treble clef, rather than treble transposed down an octave.<sup>10</sup> This is because the multiphonics activate partials well above those usually expected, resulting in the advice not being relevant.

---

10. Gould, *Behind Bars*, 423.

## Chapter 4

### Findings and Research Implications

In this chapter, I will be presenting my findings as an instructive manual for composers and performers interested in using the techniques. Because my folio of works has some degree of overlap in usage of techniques, this chapter will deal with each technique, rather than be a review of findings from each piece singularly. Where relevant, I will include my findings from working with performers.

Due to the limited number of permutations of these techniques, the Dick model of categorization is unnecessary, as space is not at a premium.<sup>1</sup> It will also take into account how common the technique is, as well as notational challenges.

#### Notation

If the composer wishes to use a technique once off, or in sparing amounts, the technique can be shown with plain English text explaining what is desired of the player. For all other cases where a technique is used multiple times, composers must include the technique in the frontmatter of the work that it is used in.<sup>2</sup> If a technique uses a new symbol or notehead, this should be reflected in the frontmatter. Where possible, composers should retain the same clef for both fingered and sounding pitches.<sup>3</sup> Composers would do well to include a description of the desired sound, and method of production; example frontmatter is provided for each of the techniques, subharmonics, multiphonics, and half harmonics.

---

1. Dick, *The Other Flute*.

2. Gould, *Behind Bars*, 494.

3. Ibid., 422.

## Subharmonics

Subharmonics are a difficult technique that lend themselves to solo works, or works where they can be brought to the forefront. They produce a sound lower than the fundamental through precise control of torsional oscillation, which usually produces the sound of an amateur string player's heavy handed, slow bowing. The timbre of overpressure can vary, but is identifiably pitched, and typically is somewhat nasal. They are notably different to overpressure, but bleed over into non-pitched overpressure is common. This, plus the difficulty in their execution, makes them unsuitable for melodic content.

Several different intervals are available as subharmonics, and a myriad of factors feed into which are easily replicable, but as a rule, octaves come most easily, with minor seconds, major sevenths, and perfect fifths coming after that. Composers should be aware that producing the specific pitch is not *necessarily* guaranteed. Subharmonics are unable to be performed *laissez vibrer*, as the pitch returns to the fundamental as soon as the bow is no longer in contact with the string.<sup>4</sup> Due to the pressure needed, subharmonics are most comfortable at at least *mezzo-forte*, although quieter subharmonics are possible. Sympathetic resonances from the other strings are common at higher volumes. Playing on the two inner strings is slightly harder due to the angle of attack being restricted to not inadvertently play double-stopped notes.<sup>5</sup>

Composers looking to use this technique should be aware that it is not a standard technique, and instrumentalists will need copious amounts of practice and guidance in order to fully and reliably realise this technique.

---

4. *Feedback from Exploratory Session.*

5. Welbanks, "Foundations of Modern Cello Technique," 99.

### Considerations for players

Rope core strings produce more harmonics, but are more difficult to produce subharmonics with. Strings with a single or nylon core make the technique easier, due to their low tension.<sup>6</sup> Players may find that subharmonics are easier on older strings, and they may also find that adding twists to the string may also help, or hinder the production of subharmonics, as shown in Table 2.1.<sup>7</sup>

Botting notes that experimentations with octavic subharmonics yielded a pitch slightly flatter than an octave. He states

‘I developed a left hand finger technique whereby I rotate my hand slightly clockwise, pivoting on the finger stopping the string, which has the effect of sharpening the subharmonic enough to be more in tune with the fundamental.’<sup>8</sup>

To ‘find’ the subharmonic, an excellent method to practice is to play *sul ponticello* at a *forte* dynamic on an open string, and then move towards the fingerboard, keeping the pressure but slowing the bowing speed down. Subharmonics are easier to find at nodal points, particularly the 6th node (closest to the bridge).<sup>9</sup>

Bow pressure should be totally consistent throughout the bowing stroke; rather than the tapered start and finish of *normale*, players should imagine a more binary stop and start, beginning and ending on the string. The bow hair should remain flat throughout the stroke, in order to exert the maximum amount of

---

6. Welbanks, “Foundations of Modern Cello Technique,” 99.

7. Kimura, “How to Produce Subharmonics on the Violin.”

8. Botting, “Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations,” 111.

9. *Feedback in Sightreading Session*.



pressure.<sup>10</sup> Different bow positions on the string can make different subharmonics speak more easily.<sup>11</sup>

### **Instrument specific considerations for subharmonics**

Subharmonics are easier to produce on the contrabass with a lighter bow, preferably a cello bow, or alternatively a French style bow.<sup>12</sup> Conversely, violin and violas may benefit from the use of a heavier bow.<sup>13</sup> The tension of the string appears to impact the feasibility enormously; 13 inch violas may have more success producing subharmonics on the A string than 18 inch violas.<sup>14</sup>

### Notation of Subharmonics

Subharmonics should be notated with a square notehead, and a small notehead (optionally in parenthesis) at the desired pitch. The technique description and notation should be included in the performance notes. If the resultant pitch falls well outside the stave, a second stave can be used in the appropriate clef to ensure that the performer knows what pitch is intended, as seen in Figure 2.6.<sup>15</sup> It should be noted that Risset's notation omits a fingered pitch, which is not recommended.

---

10. Kimura, "How to Produce Subharmonics on the Violin."

11. Ibid.

12. Long, "Subharmonics."

13. *Feedback in Sightreading Session*.

14. Ibid.

15. Risset, *Variants*.

## Subharmonic Frontmatter

### Works featuring subharmonics

- Mari Kimura — ALT in three movements for solo violin (1992)
- — Gemini for solo violin (1993)
- — 6 Caprices for subharmonics for solo violin (1997)
- — JanMaricana (for subharmonics) for solo violin (2016)
- Joshua Burel — Sonata No. 2 for violin and piano ‘Subharmonics’ (2011)
- Jean-Claude Risset — Variants (1995)
- Robert Rowe — Submarine (1996)

## Multiphonics

Multiphonics are fragile, and require much practice to execute reliably.

Despite this, they can be used to achieve harmonies that are not otherwise achievable through double-stopping, and lend themselves well to drawn out or slow passages of music. Multiphonics’ exact pitching makes them ideal for music that uses ratios, microtones, or tone rows. Multiphonics are easier to achieve on larger instruments, due to the need for precise ratio-based fingering to achieve the resonance of multiple partials.

The open string (or first partial) can be activated as part of a multiphonic.<sup>16</sup> The second partial (octave harmonic) is *never* produced in a multiphonic. The technique description and notation should be included in the performance notes.

---

16. Welbanks, “Foundations of Modern Cello Technique,” 161.

## Considerations for players

Multiphonics should be played closer to the bridge than one would normally play them. Overly high and low bow pressure can limit the lower partial content of resultant multiphonics. Faster bow speed favours higher partials over lower partials, and similarly, slower bow speed favours lower partials over higher. Moving the contact point closer to the bridge yields more noise content and favours lower partials, until the contact point is very close to the bridge, where it produces a clearer sound and favours higher partials over lower partials.<sup>17</sup> Multiphonics containing higher partials require a lighter and faster bow stroke, closer to the bridge than multiphonics that have lower ranges of partials.<sup>18</sup>

To first find a multiphonic, Welbanks and Fallowfield both recommend playing the harmonics individually.<sup>19</sup> Then play the harmonic with the highest resultant pitch. Use a slower bow stroke with higher pressure and closer to the bridge, and slightly lighter finger pressure.

## Instrument specific considerations for multiphonics

Multiphonics are easier on large instruments, as more precise pitching is possible with the longer strings. Composers should be aware that of the pair, the multiphonic node closer to the bridge can be harder to produce because of this fact. ‘Artificial’ multiphonics are possible, although much more difficult.<sup>20</sup>

---

17. Fallowfield, “Cello Map,”  
<http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>.

18. Welbanks, “Foundations of Modern Cello Technique,” 165.

19. Ibid., 167.

20. Knut Guettler and Håkon Thelin, “Bowed-String Multiphonics Analyzed by Use of Impulse Response and the Poisson Summation Formula,” *The Journal of the Acoustical Society of America* 131, no. 1 (January 2012): 772, accessed May 28, 2019, doi:10.1121/1.3651251, <http://asa.scitation.org/doi/10.1121/1.3651251>.

## Notation of Multiphonics

Much has been written about multiphonics, and they are a well established technique in woodwind writing. The notation between them differs, though; precise fingering charts above resultant pitches do not translate precisely into string writing. Fallowfield’s method of denoting the multiphonic with a diamond notehead is, in the author’s opinion, preferable to the alternatives.

## Multiphonic Frontmatter

‘Multiphonics are notated as a harmonic position, with an ‘M’ and the string number (I-IV). The theoretical sounding pitches are given in a bracketed staff above the main stave. String multiphonics are achieved through clusters of close harmonic nodes, and by playing a harmonic close to the highest partial. Note that not all of these pitches will actually sound in practice. The bow should exert slightly more pressure than usual and should be drawn with a consistent speed which should be slower than for harmonics.’

## Works featuring multiphonics

- Mari Kimura — 6 Caprices for subharmonics for solo violin (1997)
- Andrew Greenwald — On Structure (2a) — for clarinet, violin, and cello (2010)
- Stefano Scodanibbio — composed e/statico (1980)
- Håkon Thelin — oibbinadocS (2004)
- — Glasperlenspiel (2010)
- Michael Liebman — Sonata for double bass, movement 2: Legato sonore (2001)
- Kaija Saariaho — Lichtbogen (1986)
- Kimmo Hakola — Thrust, Rubato (1989, rev. 1991)
- Eivind Buene — ‘Blacklight’ (2019)
- Fernando Grillo — ‘Fluvine’ (1974)

## Half-harmonics

Half-harmonics are produced via left-hand finger pressure that is halfway between that of a harmonic and a *normale* sound produced when the string is pressed to the fingerboard. The pitch content is sharpened slightly, and the overtone content is relatively weak.<sup>21</sup> Half harmonic stops are not limited to the nodes and hence the natural harmonics, but may be executed on all fingerboard positions, as well as executed as ‘artificial’ harmonics.<sup>22</sup> Half-harmonics are what many would interpret as notes that ‘fail to speak’.

### Considerations for players

Half harmonics are pitched slightly sharp, and so should be fingered accordingly flat to compensate for this.<sup>23</sup>

### Notation of Half-harmonics

Half-harmonics can be notated in one of several ways (see Figure 4.1 for examples of both the crotchet and semibreve notation of each), but regardless of the chosen symbol, should be included and described in the performance notes.

The simplest method, using text rather than a graphic may produce good results, as seen in Figure 4.2. No scores appear to use this method, despite it being the only example able to convey more precise ratios of finger pressure as Fallowfield states is possible.<sup>24</sup>

---

21. Welbanks, “Foundations of Modern Cello Technique,” 113.

22. Dimpker, “Extended Notation: The Depiction of the Unusual,” 127.

23. Welbanks, “Foundations of Modern Cello Technique,” 113.

24. Fallowfield, “Cello Map,” <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds/other-multiple-sounds.html>.

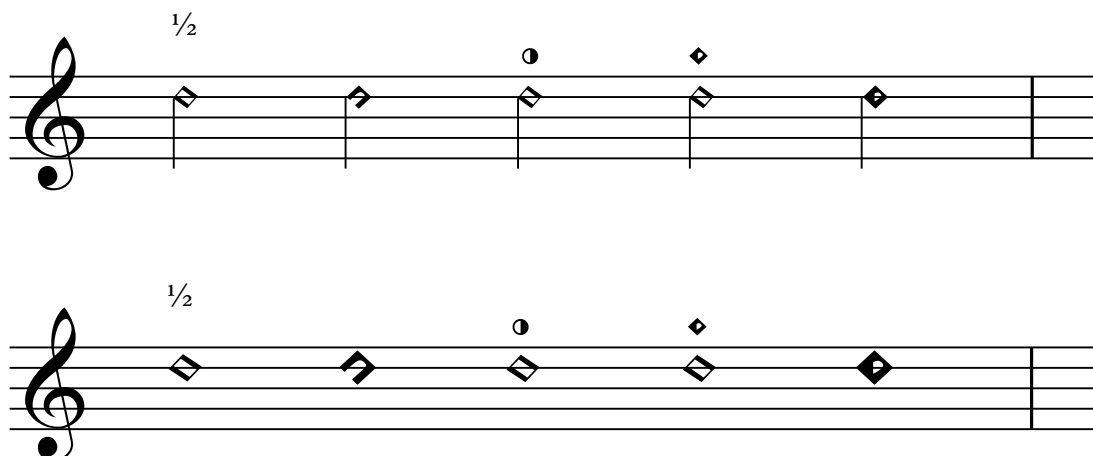


Figure 4.1: Half-harmonic notation examples



Figure 4.2: Half-harmonic displayed with text

The second and last of the examples in Figure 4.1 do not have discrete noteheads for crotchets and minims like regular diamond noteheads. As such, if there is rhythmic ambiguity, rhythms should be clarified above the staff as normal. The second example, as seen in Sciarrino's *Six Capricci for Violin* (Figure 2.14) shows the ambiguity of this. The 'slant' of the regular harmonic notehead is opposite to the unfinished diamond, going from up to down, helping distinguish it.

The third example unfortunately is not without issues, either; (*normale*) harmonics denoted with a circle are exclusively for the resultant pitch.<sup>25</sup> While half harmonics *do* produce the notated pitch, rapid transitions between half harmonics and *normale* harmonics using half-filled circles may cause confusion due to the translation between a symbol that denotes pressure needed and a resultant harmonic

---

25. Gould, *Behind Bars*, 419.

respectively, as illustrated in Figure 4.3. This is compounded by the circle notation's inability to handle harmonics that fall well outside the range of the staff (i.e. major 3rd and minor 3rd harmonics), resulting in a need for at least two types of notation; circular half-harmonics, and diamond noteheads for problematic *normale* harmonics.

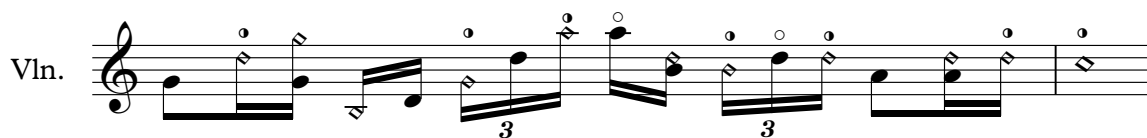


Figure 4.3: Half-harmonic circular notation

The fourth example of notation displayed in Figure 4.4 is a non-standard symbol, and also suffers the same issues that plague the previous example.

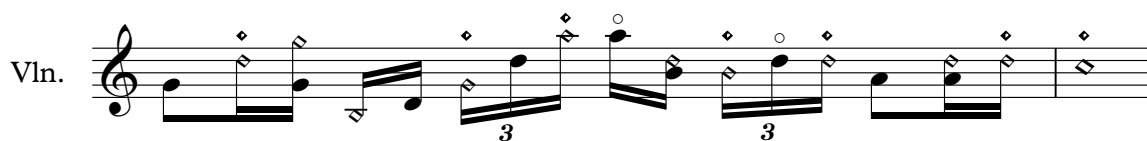


Figure 4.4: Half-harmonic diamond symbol notation

Compare this with Figure 4.5 and Figure 4.6, which is an example of Sciarrino's half-empty notation as seen in Figure 2.14.

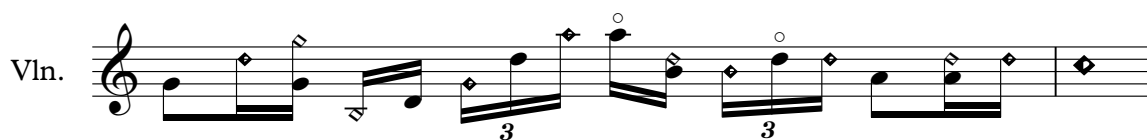


Figure 4.5: Half-harmonic half-filled notehead

It should be noted that the half-filled notehead as depicted in Gould and Figure 4.5, nor the Sciarrino style half-empty notehead as seen Figure 4.6 are not



Figure 4.6: Half-harmonic half-empty notehead

available in modern versions of Sibelius or Dorico as of the time of writing.<sup>26</sup> The flagship Standard Music Layout Font (SMuFL), Bravura, includes the half-harmonic circle as depicted in Figure 4.3, but is only available on Dorico and the Sibelius port of Bravura, Norfolk.<sup>27</sup>

## Half harmonic Frontmatter

### Works featuring half-harmonics

- Robert Rowe — Flood Gate (1989)
- Salvatore Sciarriono — 6 Capricci for violin (no. 5) (1976)
- Helmut Lachenmann, Gran Torso
- Trevor Bača — Al-Kitab Al-Khamr (2015)
- Claudio Pompili — Scherzo Alla Franciscana (1990, revised 1994)
- Mary Bellamy — Transference (?)
- Sam Park — The Colour of Light (2010)
- Jack Symmonds — Hell Is Murky (2018)
- Mark Applebaum — The Plate of Transition Nourishes the Chameleon Appetite (1992, revised 1994)
- Henrik Deneren — seals II (2014–15)

---

26. Gould, *Behind Bars*, 424.

27. W3C Committee, “Standard Music Font Layout (SMuFL),” March 5, 2019, <https://w3c.github.io/smufl/gitbook/>.



- Ramteen Sazegari — Slate Representative (2015)

### **Reflection**

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

These techniques are underrepresented because of a variety of reasons, one of them being that there is a lack of resources dedicated to writing for them.

### **Impact and Further Research**

This exegesis will help inform other composers interested in writing for these techniques. Compositionally, the scope of this exegesis has been limited to the techniques in a soloistic context.

# Appendices

FOR SOLO VIOLIN

---

*what are you doing with the humans*

---

October, 2019

Rhys Gray

## Program Notes

*what are you doing with the humans* is a solo work for violin that explores half-harmonics. It is a non-programmatic work, and the title was inspired by a question that my supervisor posed to me while I sought ethics approval for my exegesis; a simple phrase laden with possible contexts, spurring the imagination to try and complete the meaning.

It is, in a way, an etude, treating the half-harmonics in a way similar to those found in Sciarrino's *6 Caprricio for violin*. Half-harmonics are produced by applying left hand finger pressure halfway between that required to create a harmonic, and a *normale* sound. The sound that is produced should be a mixture of the stopped string pitch, the harmonic pitch, and a resistant, slightly noisy quality.

## Notation

- Half-harmonics are notated in the score as a half-filled diamond notehead.
- sp denotes *sul ponticello*.
- msp denotes *molto sul ponticello*.
- similarly, st denotes *sul tasto*, and mst denotes *molto sul tasto*

what are you doing with the humans?

Rhys Gray

Violin

$\text{♩} = 82$   
II, III

*fp* *< f* *p* *3* *3* *3* *3* *3* *3*

4 *sp* normale *mf* *p* *mp* *p* *3* *3* *3* *3* *3* *3*

8 *sp* *pp* *mf* *p* *3* *3* *3* *3* *3* *3*

11 *sp* *f* *mf* *mp* *p* *3* *3*

14 *pp* *3* *3* *3* *3* *3* *3* *3* *3*

16 *p* *3* *3* *3* *3* *3* *3* *3* *3*

18 *mf* *pp* *p* *3* *3* *3* *3*

21 *mp* *p* *mp* *pp* *3* *3* *3* *3*

24

*p* *f*

27

III

*mf* *p* *pp*

31

*mf* *p*

34

as legato as possible

I II

*mf* *mp*

*gliss.*

38

*gliss.*

*p*

I, II

*mf*

II III

*gliss.*

*mp*

42

to normale

*p* *mp*

47

*mf* *mp*

52

*mf*

FOR SOLO VIOLA

---

*doppelganger*

---

October, 2019

Rhys Gray



## Program Notes

*Doppelganger* is a piece for solo viola, written to explore the lower register of the viola using subharmonics juxtaposed with upper harmonics.

To play subharmonics, one should place the bow at the 6th partial of the harmonic series of the fingered pitch, and bow with excessive pressure and an absolutely consistent speed. The increased pressure will distort the vibration of the string, producing a phase loop which, in turn, produces the subharmonic.

Subharmonics are achieved through precise control of torsional oscillation, which usually produces the sound of an amateur string player's heavy handed, slow bowing.

The production of subharmonics can be aided by using older strings (which work better due to fats building up on the strings). Making a counter-clockwise half-twist in the string can also make it easier to produce octave and major second subharmonics (additional twists can help achieve lower subharmonics, at the expense of higher ones).

## Notation

- Subharmonics are notated in the score using a square notehead for the fingering, with a small notehead at the desired resultant pitch.
- sp denotes *sul ponticello*.
- msp denotes *molto sul ponticello*.
- similarly, st denotes *sul tasto*, and mst denotes *molto sul tasto*

# Doppelganger

for solo viola

Rhys Gray

**♩=52 Rubato**

sp → msp → n

*f* *p* *ff* *pp* *mf* *p*

5 *tr* *msp* *pizz. arco* *3* *rit.* *II* *II III*

*f* *mp* *f*

**A tempo**

9 *II* *pizz. port.* *arco* *3*

*mp* *f*

13 *3* *gliss.* *3* *port.*

18 *let harmonics sneak in* *ff* *mf* *ff*

22 *n* *III* *sp* *gliss.* *3* *msp* *n* *op* *n* *I* *sffp*

*p* *mp* *sffp*

27 *tr* *incorporate fundamental into trill* *trill between* *mf*

30 pizz. arco *p* *fp* *f* III 65

33 pizz. arco II III

36 *p* *f* *p*

38 *mp* *pp* *f* *sp* n , 3 II I

42 *ff* *ff* *sp*

45 3

FOR SOLO VIOLONCELLO

---

*crossing the rubicon*

---

October, 2019

Rhys Gray

## Program Notes

*crossing the rubicon* is a piece for solo violoncello, written to explore multiphonics.

Multiphonics are notated as a harmonic position, with an ‘M’ and the string number (I-IV). The theoretical sounding pitches are given in a bracketed staff above the main stave. String multiphonics are achieved through clusters of close harmonic nodes, and by playing a harmonic close to the highest partial. To aid the performer during their practice, the sounding partials are given (i.e. M IV [4th + 13th + 9th + 15th + 5th]). Note that not all of these pitches will actually sound in practice. The bow should exert slightly more pressure than usual and should be drawn with a consistent speed which should be slower than for harmonics.

## Notation

- Multiphonics are denoted with a diamond notehead, marked with an M. Precise tuning in cents (i.e. +41c) is provided to help the performer pitch the multiphonic.
- Sounding pitch for multiphonics and harmonics is provided in the lower stave.
- n denotes *normale*.
- sp denotes *sul ponticello*.
- msp denotes *molto sul ponticello*.
- similarly, st denotes *sul tasto*, and mst denotes *molto sul tasto*

Rhys Gray

Violoncello

$\text{♩} = 72$

*mp legato*

II M

+51¢

arco pizz arco pizz

Resultant Pitch

4+11+7+3

+51¢

-31¢

+0¢

+2¢

8<sup>vb</sup>

4 arco

*f*

*mp*

III M

-18¢

5+11+8

+51¢

+0¢

+2¢

III IV III III

7 II

+39¢

I M

5+9+13+4

-41¢

+4¢

-14¢

+0¢

11

sp n

3

3

5

Vc.

13

Vc.

I  
+37¢ II M

II M  
+33¢

5

$7+10+13+3$

$+41¢$   
 $-14¢$   
 $-31¢$   
 $+2¢$

$15+12+7$

$+2¢$   
 $-31¢$   
 $-14¢$

*p* *f*

17 **A tempo**

Vc.

5

*gliss.*

19

Vc.

+33¢

pizz arco III M

+51¢

pizz arco II M

+51¢

M

+37¢

$5+12+7$

$4+11+7+3$

$8+11+7+3$

$7+10+13+3$

$+2¢$   
 $-31¢$   
 $-14¢$

$+51¢$   
 $-31¢$   
 $-2¢$   
 $+0¢$

$+51¢$   
 $-31¢$   
 $+0¢$   
 $+2¢$

$+41¢$   
 $-14¢$   
 $-31¢$   
 $+2¢$

FOR SOLO CONTRABASS

---

*the veldt*

---

October, 2019

Rhys Gray



## Program Notes

Inspired by the eponymous short story by Ray Bradbury, *the veldt* is a composition for solo contrabass, and uses subharmonics and multiphonics. Similarly like the namesake, this world is filled with danger but also beauty. It is non-programmatic, and my intent with Veldt was to create a soundworld and space that the performer was able to ‘roam around’ in, and features several sections of improvisation on pitch-sets.

### Subharmonics

To play subharmonics, one should place the bow at the 6th partial of the harmonic series of the fingered pitch, and bow with excessive pressure and an absolutely consistent speed. The increased pressure will distort the vibration of the string, producing a phase loop which, in turn, produces the subharmonic. Subharmonics are achieved through precise control of torsional oscillation, which usually produces the sound of an amateur string player’s heavy handed, slow bowing. The production of subharmonics can be aided by using older strings (which work better due to fats building up on the strings). Making a counter-clockwise half-twist in the string can also make it easier to produce octave and major second subharmonics (additional twists can help achieve lower subharmonics, at the expense of higher ones).

### Multiphonics

Multiphonics are notated as a harmonic position, with an ‘M’ and the string number (I-IV). The theoretical sounding pitches are given in a bracketed staff above the main stave. String multiphonics are achieved through clusters of close harmonic nodes, and by playing a harmonic close to the highest partial. To aid the performer during their practice, the sounding partials are given (i.e. M IV [4th + 13th + 9th +

15th + 5th]). Note that not all of these pitches will actually sound in practice. The bow should exert slightly more pressure than usual and should be drawn with a consistent speed which should be slower than for harmonics.

### Notation

- Subharmonics are notated in the score using a square notehead for the fingering, with a small notehead at the desired resultant pitch.
- Multiphonics are denoted with a diamond notehead, marked with an M. Precise tuning in cents (i.e. +41c) is provided to help the performer pitch the multiphonic.
- Sounding pitch is provided in the stave below.
- Bridge position is provided in the stave above. The bottom line is *sul tasto*, the fourth line is *sul ponticello*, and the top line is overpressure.
- *battuto* is letting the bow hit the string, with no horizontal movement.
- *gettato* is like battuto, but with a slight amount of horizontal movement.
- *jeté* is bouncing the bow on the string, letting gravity do the work in conjunction with horizontal movement.
- sp denotes *sul ponticello*.
- msp denotes *molto sul ponticello*.
- similarly, st denotes *sul tasto*, and mst denotes *molto sul tasto*

## the veldt

**Lent**

Bridge

Contrabass

Sounding Pitch

jéte

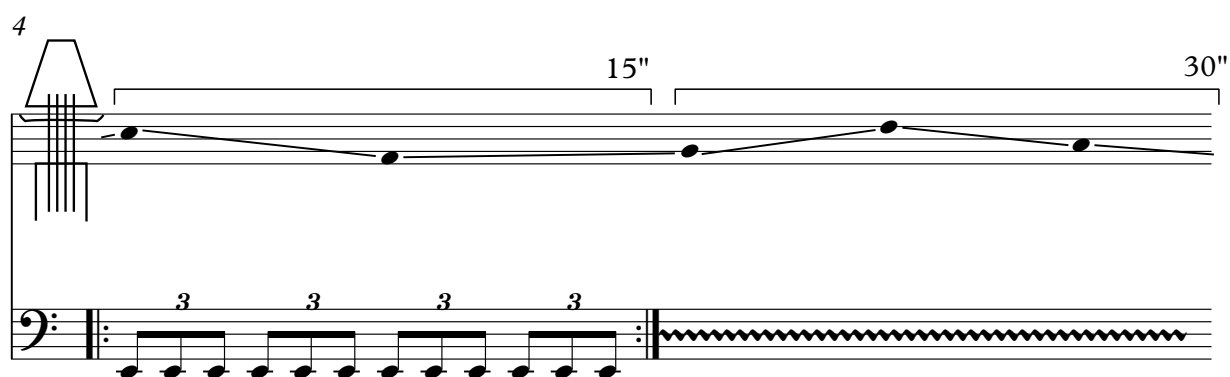
*pp*



4

15"

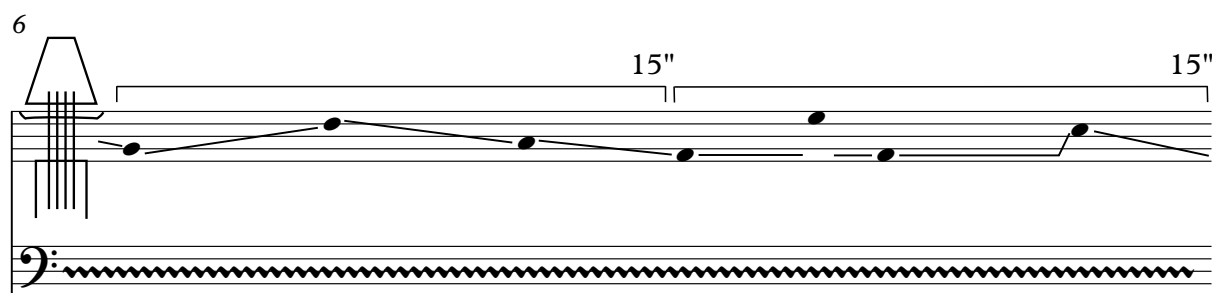
30"



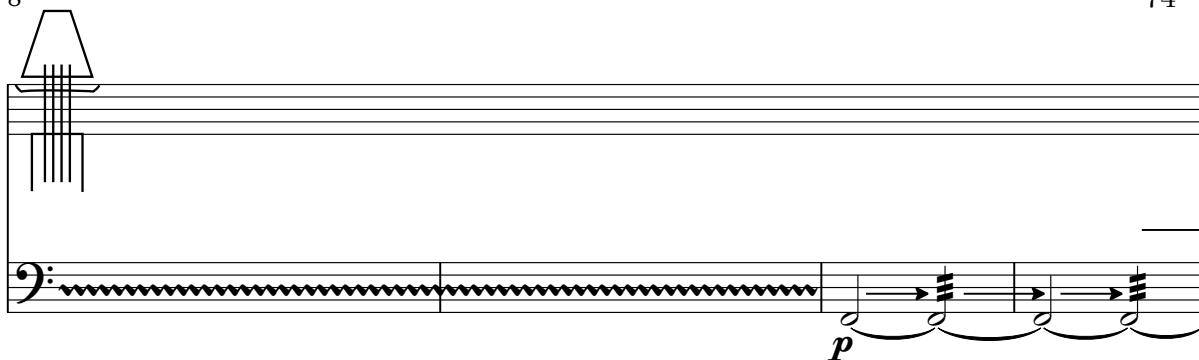
6

15"

15"




8



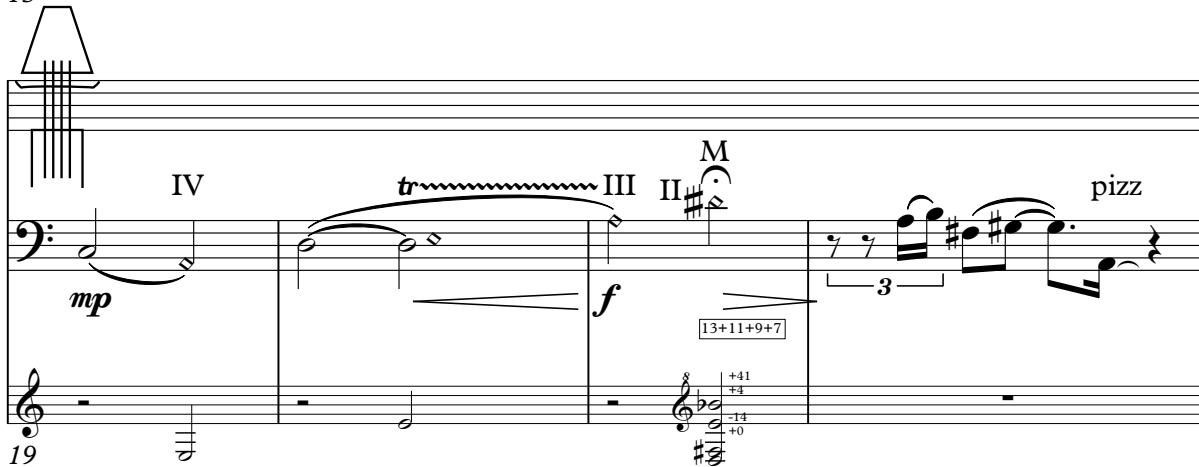
Measures 8-11. Measure 8 features a trapezoidal diagram above the staff. The bass staff contains a wavy line from measure 8 to 10, followed by a melodic line in measure 11 starting with a piano (*p*) dynamic.

12



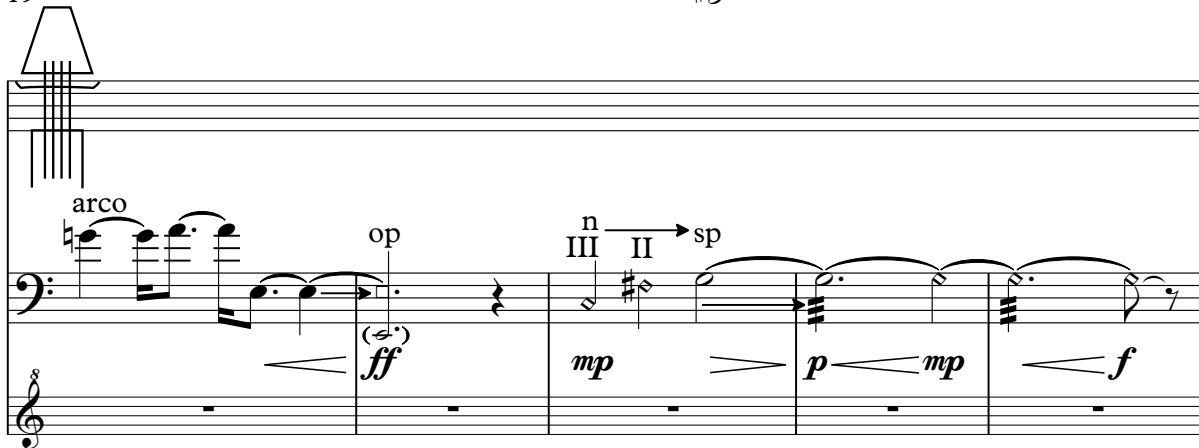
Measures 12-14. Measure 12 features a trapezoidal diagram and the instruction *sp* → *n*. The bass staff has a melodic line with a triplet in measure 13. A treble staff with a triplet is shown below the bass staff in measure 13.

15



Measures 15-18. Measure 15 features a trapezoidal diagram. The bass staff includes fingerings IV, *tr*, III, II, and M. Dynamics include *mp*, *f*, and *pizz*. A triplet is marked in measure 18. A box contains the sequence 13+11+9+7. A treble staff with a triplet and a box containing +41, +3, -14, +0 is shown below the bass staff in measure 18.

19



Measures 19-22. Measure 19 features a trapezoidal diagram and the instruction *arco*. The bass staff includes fingerings *op*, *n*, III, II, and *sp*. Dynamics include *ff*, *mp*, *p*, *mp*, and *f*. A treble staff is shown below the bass staff in measure 19.

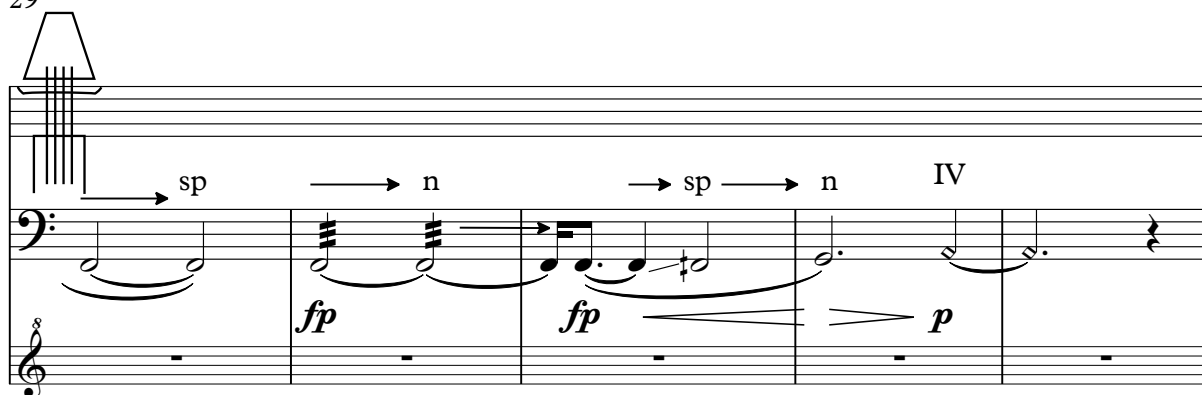
24

75 3



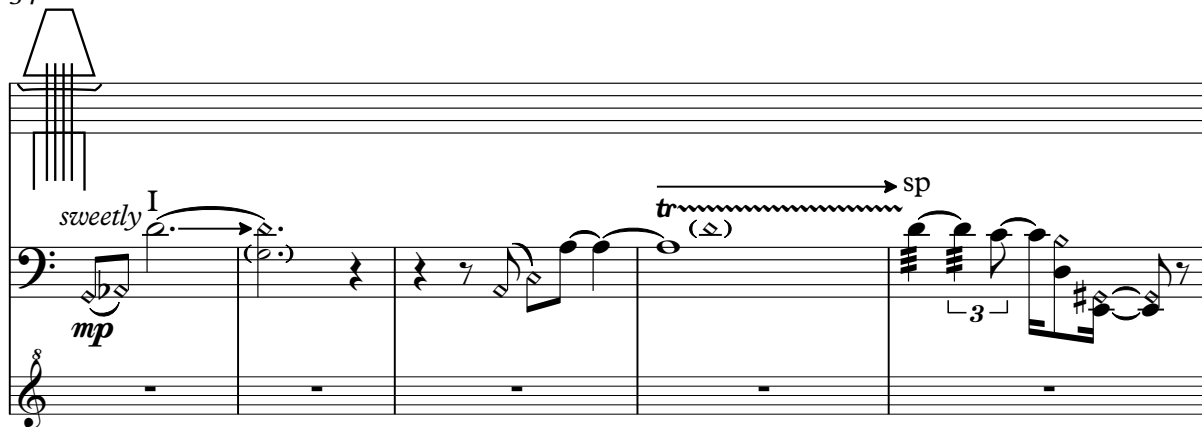
Measures 24-28. The score is written for a single melodic line on a bass clef staff. Measure 24 begins with a trapezoid symbol above the staff. The music features a series of eighth and sixteenth notes, with some measures containing triplets. Fingerings are indicated by Roman numerals: III, III, and II. A dynamic marking of *fp* (fortissimo piano) appears at the end of measure 28.

29



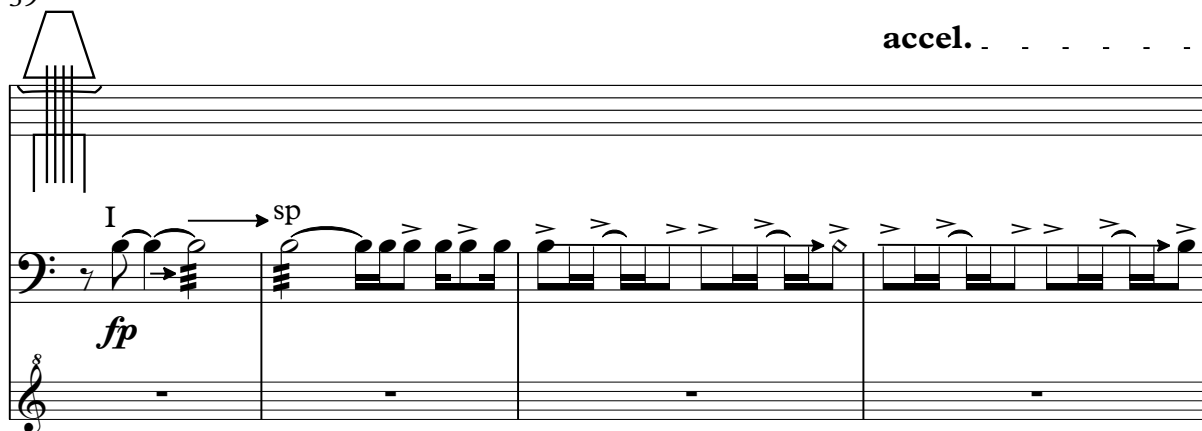
Measures 29-33. The score continues on the bass clef staff. Above the staff, there are articulation markings: *sp* (sforzando), *n* (accendo), *sp*, *n*, and *IV*. The music includes a series of eighth notes and a triplet. Dynamic markings include *fp* (fortissimo piano) and *p* (piano). A trapezoid symbol is present at the beginning of measure 29.

34



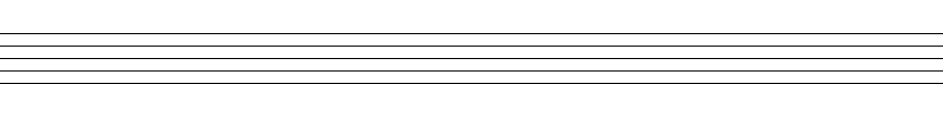
Measures 34-38. The score continues on the bass clef staff. Above the staff, there are markings: *sweetly*, *I*, *tr* (trill), and *sp*. The music includes a series of eighth notes and a triplet. Dynamic markings include *mp* (mezzo-piano). A trapezoid symbol is present at the beginning of measure 34.

39



Measures 39-43. The score continues on the bass clef staff. Above the staff, there are markings: *I*, *sp*, and *accel.* (accelerando). The music includes a series of eighth notes and a triplet. Dynamic markings include *fp* (fortissimo piano). A trapezoid symbol is present at the beginning of measure 39.

76



*cresc.*

[illegible]

49

III  
IV

II

gliss.

## Bibliography

- Adler, Samuel. *The Study of Orchestration*. Third Edition. New York: W. W. Norton & Company, 2002.
- Applebaum, Mark. *The Plate of Transition Nourishes the Chameleon Appetite*, 1992.
- Barnett, Bonnie Mara. "Aspects of Vocal Multiphonics." *Interface* 6, nos. 3-4 (December 1977): 117–149. Accessed May 9, 2019.  
doi:10.1080/09298217708570239.  
<http://www.tandfonline.com/doi/abs/10.1080/09298217708570239>.
- Benade, Arthur H. *Fundamentals of Musical Acoustics*. New York: Dover Publications, Inc., 1990.
- Black Angels*. In collaboration with George Crumb and Cikada Quartet. London: Cala Records, 1995.
- Botting, Thomas. "Developing a Personal Vocabulary for Solo Double Bass Through Assimilation of Extended Techniques and Preparations." Thesis, University of Sydney, 2019. [https://ses.library.usyd.edu.au/bitstream/2123/20352/1/botting\\_ta\\_thesis.pdf](https://ses.library.usyd.edu.au/bitstream/2123/20352/1/botting_ta_thesis.pdf).
- Bunk, Lou. *Es Vee Pea*, 2002.  
<http://www.loubunk.com/scores/Es%20vee%20Pea%20Bunk.pdf>.
- Cage, John. *Music for : Parts for Voice and Instruments without Score (No Fixed Relation), Title to Be Completed by Adding to "Music for" – the Number of Players Performing*. Henmar Press, 1984.  
<https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat02831a&AN=UTas.b2468591&site=eds-live>.
- Cello Map - Example 24*. Basel: Academy of Music, January 11, 2013.  
<https://vimeo.com/57219720>.
- Crumb, George. *Black Angels (Images 1) [Music] : Electric String Quartet*. Peters, 1971. <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat02831a&AN=UTas.b1139221&site=eds-live>.
- Dick, Robert. *The Other Flute*. Second Edition. New York: Multiple Breath Music Company, 1989.

Dimpker, Christian. "Extended Notation: The Depiction of the Unusual," University of Plymouth, 2012. <https://pearl.plymouth.ac.uk/bitstream/handle/10026.1/3184/2013Dimpker10320048PhD.pdf?sequence=3&isAllowed=y>.

Fallowfield, Ellen. "Cello Map." Accessed May 31, 2019.  
<http://www.cellomap.com/>.

———. "Cello Map: A Handbook of Cello Technique for Performers and Composers." Thesis, University of Birmingham, 2009.

*Feedback from Cello Sightreading Session.* In collaboration with Jane Smith, October 18, 2019.

*Feedback from Contrabass Session.* In collaboration with Joe Bloggs, October 20, 2019.

*Feedback from Exploratory Session.* In collaboration with Angus Appleseed, October 17, 2019.

*Feedback in Sightreading Session.* In collaboration with Angus Appleseed, October 23, 2019.

Gould, Elaine. *Behind Bars*. 1st. London: Faber Music, 2011.

Grisey, Gerard. *Vortex Temporum*.

Guettler, Knut. "The Bowed String: On the Development of Helmholtz Motion and On the Creation of Anomalous Low Frequencies." Doctorate Thesis, Royal Institute of Technology - Speech, Music and Hearing, 2002.  
<https://pdfs.semanticscholar.org/1d0c/968ee44366cd7d92c63f876be884c9135064.pdf>.

———. "Wave Analysis of a String Bowed to Anomalous Low Frequencies." *Catgut Acoustic Society*, II, 2, no. 6 (November 1994): 8–14.  
<http://knutsacoustics.com/files/alf-casj.pdf>.

Guettler, Knut, and Håkon Thelin. "Bowed-String Multiphonics Analyzed by Use of Impulse Response and the Poisson Summation Formula." *The Journal of the Acoustical Society of America* 131, no. 1 (January 2012): 766–772. Accessed May 28, 2019. doi:10.1121/1.3651251.  
<http://asa.scitation.org/doi/10.1121/1.3651251>.

Kimura, Mari. *Gemini*, 1992.



- Kimura, Mari. "How to Produce Subharmonics on the Violin." *Journal of new music research* 28, no. 2 (1999): 178–184. Accessed April 11, 2019. doi:<https://doi.org/10.1076/jnmr.28.2.178.3118>. <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=A212434&site=eds-live>.
- Kwok, Sarah Wei-Yan. "Breaking the Sound Barriers : Extended Techniques and New Timbres for the Developing Violist," University of British Columbia, 2018. Accessed May 30, 2019. doi:10.14288/1.0365754. <https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0365754>.
- Lachenmann, Helmut. *Musik Für Streichquartett*, 1972.
- Long, Ashley John. "Subharmonics." 2019. Accessed September 21, 2019. <https://www.themoderndoublebass.org.uk/subharmonics.html>.
- . "The Modern Double Bass." Accessed September 2, 2019. <https://www.themoderndoublebass.org.uk/>.
- "Subharmonics." *New Scientist* 191, no. 2571 (September 30, 2006): 60–60. <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=22720971&site=eds-live>.
- Piston, Walter. *Orchestration*. First Edition. London: Victor Gollancz Ltd., 1969.
- Read, Gardner. *Compendium of Modern Instrumental Techniques*. 1st ed. Westport, Connecticut: Greenwood Press, 1993.
- Riera, Pablo Ernesto, Martín Proscia, and Manuel Eguía. "A Comparative Study of Saxophone Multiphonics: Musical, Psychophysical and Spectral Analysis." *Journal of new music research* 43, no. 2 (2014): 202–213. Accessed May 9, 2019. <https://login.ezproxy.utas.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=A891785&site=eds-live>.
- Risset, Jean-Claude. *Variants*, 1995. <http://composers21.com/compdocs/rissetjc.htm>.
- Rowe, Robert. *Submarine*, 1996 (revised 2004).
- Sciarrino, Salvatore. *6 Capricci Per Violino*, 1976.
- Sekulić, Dejana. "Do You Hear Me?" Essay, Royal Conservatory Brussels, 2012. [http://dejanasekulic.com/essay-do\\_you\\_hear\\_me.pdf](http://dejanasekulic.com/essay-do_you_hear_me.pdf).

- Shaahin mohajeri. "Equaldivisionsoflength(Edl) - 240edo." October 25, 2019. Accessed October 25, 2019. [https://sites.google.com/site/240edo/equaldivisionsoflength\(edl\)](https://sites.google.com/site/240edo/equaldivisionsoflength(edl)).
- Stone, Kurt. *Music Notation in the Twentieth Century*. New York: W. W. Norton & Company, 1980.
- Strange, Patricia, and Allen Strange. *The Contemporary Violin: Extended Performance Techniques*. 1st ed. Los Angeles, California: University of California Press, 2001.
- Thelin, Håkon. "Multiphonics on the Double Bass," Norwegian Academy of Music, 2011. <http://haakonthelein.com/multiphonics/uploads/files/4%20Multiphonics/Multiphonics%20on%20the%20Double%20Bass.pdf>.
- Thurley, Oliver. *Yet Another Example of the Porousness of Certain Borders*, 2014. <http://oliverthurley.co.uk/scores/yaotpocb-score.pdf>.
- Torres, Rita, and Paulo Ferreira-Lopes. "Multiphonics as a Compositional Element in Writing for Amplified Guitar (2)." *Journal of Science and Technology of the Arts* 4, no. 1 (December 27, 2012): 61–69. Accessed May 9, 2019. doi:10.7559/citarj.v4i1.67. <http://artes.ucp.pt/citarj/article/view/67>.
- Turetzky, Bertram. *The Contemporary Contrabass*. 1st Edition. California: University of California Press, 1974.
- Turetzky, Betram. *The Contemporary Contrabass*. 2nd Edition. California: University of California Press, 1992.
- W3C Committee. "Standard Music Font Layout (SMuFL)." March 5, 2019. <https://w3c.github.io/smufl/gitbook/>.
- Weiss, Marcus, and Giorgio Netti. *The Techniques of Saxophone Playing*. Kassel: Barenreiter-Verlag Karl Votter, 2010.
- Welbanks, Valerie. "Foundations of Modern Cello Technique":320.