

Foundations of Modern Cello Technique

Creating the Basis for a Pedagogical Method

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Declaration

I, Valerie Welbanks, the undersigned, hereby declare that the work submitted in this thesis is my own and where the contributions of others are made they are clearly acknowledged.

Signed.....

Date.....

Valerie Welbanks

This thesis is dedicated to the memory of Alexander Ivashkin.

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Abstract

Throughout their studies, cellists use short technical exercises such as scales and études which, under the supervision of a teacher, provide the skills necessary to play the repertoire. Etudes in particular – this body of formal, pedagogical works that developed in tandem with the rise of the virtuoso – are designed to strengthen specific technical notions in musical context, providing access to more demanding repertoire. Surprisingly, however, the last significant collection of études for the cellist is Popper's *High School of Cello Playing* (1905).

The rich palette of extended techniques for cello, achieved through a century of innovation and experimentation, has no equivalent representation. The cellist who desires, or is required, to meet this new rise in virtuosity must essentially decipher new idioms alone, unless fortunate enough to work with a specialist who will pass on the fruits of personal experience. I suggest that many of the problems which modern music faces today are connected to the performer's dearth of proficiency concerning certain musical and instrumental techniques. As a survey of pedagogical material will show, few steps have been taken to enable cellists to gain the technical fluency needed for providing engaging performances of 20th- and 21st-century repertoire.

Through discussions with contemporary music specialists, the study of existing publications, and my own performing experience, I present the cello's extended techniques as a linear progression of traditional technique. Three future projects guide the content and structure of this thesis: curriculum development, the creation of an online database, and the commissioning of concert études modelled on Paganini's *24 Caprices for Solo Violin*. The 24 sections of this thesis guide the reader through a technique's origin and development, basic acoustical information, and performance advice, creating a pedagogical framework. Only with a clear methodological approach can contemporary music be expected to become more than a specialism.

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¹ All exercises have been collated and provided as a supplement to this thesis.

Introduction: Perspectives & Retrospectives

A professional musician could reasonably be expected to play music from all eras and styles of Western musical culture, from the late Renaissance to the Experimental, from French overtures and Romantic concertos, to Viennese waltzes, jazz standards and pop. Many genres outside the common practice period, for decades belonging uniquely to the realms of the specialist, are now regularly programmed by orchestras, chamber musicians and soloists.

Modern music² is a peculiar example of this phenomenon. While clearly stemming from Western classical tradition or reacting directly to it, much of its performance depends on techniques and mental processes which lie outside standard conservatoire training. It is perhaps for this reason that many musicians still, 70-100 years on, have an open aversion to playing modern music. That such a large percentage of music – the music of our time and, theoretically, that which should speak to us most closely – can lie beyond a performer's reach despite a life-time of refining instrumental or vocal technique, is a frustration that no doubt translates to audiences. Professional musicians do not need a deep passion for every type of music they perform, but do have a responsibility to play everything well, from both a technical and musical standpoint. It would be unacceptable today for a performer to completely ignore the stylistic concepts of period performance, even if playing on a modern instrument – a statement which extends as much to phrasing as to trills and rhythmic idiosyncrasies. The same should also apply to modern music.

While much has been achieved in the systemization and pedagogy of extended techniques for wind players, string players and particularly cellists have a conspicuous lack of materials available to them. Curiously, many of the cellists who have become experts of modern music do not teach; those who do rarely step outside the bounds of

² The terms 'modern', 'contemporary' and 'new' music will be used interchangeably in this text to refer to the art music of the 20th and 21st centuries. Whereas these terms are often used to mean more specific styles or periods, it is unnecessary to make such distinctions in this thesis.

traditional performance practice in their teaching. How can a cellist understand and develop their skills beyond traditional playing?³ Is personal experience the only way?

When looking at filling this gap and creating a complete overview of extended technique⁴ for the cello, one has to inquire why it has not yet been codified in the same way as traditional technique. What efforts have already been made and why have they had limited success? Can extended technique be standardized, or does it by definition defy standardization; is modern music about each individual breaking the boundaries of their own sound, with much of the interest lying in the variety of a chaotic and undefined field of possible colours? Can, and should, the performance of this music be taught as a specialized course in academic institutions, in the same way that period performance, jazz and improvisation recently have? Or should it be more fully integrated into standard performance curricula?

I believe that a systematic approach, rather than restricting creativity, caters to an intrinsic feature of human creativity, which flourishes under self-imposed restrictions – Picasso's blue period and Shakespeare's use of iambic pentameter are two of countless examples. Leonard Meyer wrote fifty years ago:

...the relation of the creative artist to a tradition which, on the one hand, he wants to preserve (for without it no expression is possible) and within which, on the other hand, he seeks to deviate and create anew, throws into sharp relief the differences between traditional, academic, and decadent art. The traditional artist is one who understands the relationship of norms to deviants and who works within this relationship.⁵

The first in-depth conversation I had with a contemporary music specialist – an interview with Neil Heyde – was key in establishing that these very boundaries which Meyer describes would define the system; Heyde observed that most treatises include quite a small core, and it is accepted that artistry lies outside these boundaries. Though

³ The terms 'traditional playing / technique' and 'common practice period' will be used in relation to music written from around 1600 to 1900.

⁴ The terms 'contemporary technique', 'modern technique' and 'extended technique' will be used interchangeably in this text as they present no practical difference.

⁵ Meyer (1956), p. 71. Partly cited in Ball (2011), p. 338.

he initially remarked that modern music is about ‘learning a kind of “discovery habit” for life, rather than passing on a set of skills’,⁶ as our discussion progressed we came to realise that there are nonetheless basic skills that take players years, if not decades to acquire through experience. Teaching this core set of skills would provide a solid point of departure, from which each player could explore the ‘edges’ of both their own physical capabilities and those of the particular instrument they are using. A publication creating a core body of knowledge for the performance of modern music is indeed necessary and would allow a benchmark to be set, upon which the quality of modern music performance could be measured.

My role as an author would be to decide what aspects should be considered core elements so that a solid foundation could be built for the teaching and learning of extended techniques. It is interesting to note that the contemporary music specialists I spoke to did not receive formal training in this field, nor did they study the new music that their teachers performed. Heyde explains his eventual specialisation as an ‘accident’, his interests triggered by a performance of Xenakis’ *Kottos* by Rohan de Saram. De Saram himself did not perform modern music until his late twenties, well after the completion of his formal studies.

Why should I, at the beginning of my career, feel compelled to organize nearly a century’s worth of technique? I found the answer in the observation that the cellists I know of who specialize in modern music are not only connected by an innate curiosity and openness of mind, but that also, none of them teach contemporary technique (in fact, many of them even have an open aversion to formal teaching). Perhaps these performers have not felt to date that their skills are core, and indeed perhaps they haven’t been core until now. Although these statements may only stem from the luxury afforded by hindsight and can never truly be substantiated, they fuel the sentiment that it is precisely for these reasons that I am qualified to undertake the task of standardizing extended technique. This thesis is being formed as I am forming my own self-styled expertise.

⁶ Interview, 13/03/2013.

My musical pathway can be described as typical: musical awakening classes as a toddler preceded piano lessons from the age of 6 and cello lessons from the age of 11. Specialist high school and conservatoire training was then followed by a Master's course at the Royal Academy of Music in London. Though I developed an interest in modern music from an early age after hearing the Kronos Quartet in concert, modern technique was as lacking from my training as it is for most cellists. I found I had very little understanding of how to produce adequate sounds needed for the music I was interested in playing.

My performance activities and PhD studies went hand-in-hand, each informing the other: I became increasingly comfortable playing modern music as the cellist of the Ligeti Quartet, through our studies at the European Chamber Music Academy,⁷ with the Kronos Quartet⁸ and members of the Arditti Quartet,⁹ collaborations with composers,¹⁰ and many in-depth conversations amongst ourselves on 'how should we do this'. This process, together with my new music encounters with the Marsyas Trio,¹¹ and as a soloist and chamber musician,¹² led to a greater understanding of what steps need to be taken to achieve the technical knowledge and fluency needed to effectively convey the 'difficult' music of the 20th and 21st centuries to an audience – that is to say, music

⁷ Throughout 2013-14, principally with Hatto Beyerle, Patrick Jüdt, and Ferenc Rados.

⁸ Through the Barbican Centre's *Kronos Lab* (London, Jan. 2012), in private sessions, and at Carnegie Hall's '50 for the Future' workshop (New York, Apr. 2016).

⁹ In private sessions the Ligeti Quartet has played to Rohan de Saram and Garth Knox, and has performed with Levine Andrade.

¹⁰ The following composers have coached the Ligeti Quartet on the performance of their own music: Peter Maxwell Davies, Nicola LeFanu, Garth Knox, Wu Man, John Pickard, Sofia Gubaidulina, Stephen Montague, Robert Keeley, Nirmali Fenn, Gabriel Prokofiev, Ji Sun Yang, Elena Firsova, Martyn Harry, Wadada Leo Smith, William Frampton, Nicola Price, David Lancaster, Simon Bainbridge, Steve Crowther, and many students of various levels in workshops and competitions. Pieces composed specifically for the Ligeti Quartet, by: Christian Mason, George Nicholson, Tom Armstrong, Matthew Butt, Arne Gieshoff, Anna Meredith, Laura Bowler, Tom Green, William Dougherty, Gonçalo Gato, Camilo-Andrés San Juan, and in a 'cross-genre' capacity, Laura Jurd, Elliot Galvin, Neil Cowley, Seb Rochford, and Shabaka Hutchings.

¹¹ Elena Firsova, Laura Bowler, Alan Taylor and Armando Ghidoni have composed for the Marsyas Trio, with whom I have done my first public 'free improvisation', and first look at the music of George Crumb.

¹² Alongside various chamber music projects, I have had the chance to perform the Lutosławski Cello Concerto with the Torbay Symphony Orchestra and Goldsmiths Sinfonia, Gubaidulina's *Sonnengesang* with the Goldsmiths Choir, and have performed and recorded several new works with Peter Sheppard-Skaerved's Longbow Ensemble.

which performers find difficult to play accurately and to which audiences find difficult to listen. A belief that the latter statement was likely caused by the former was the initial thought which led to this project.

The almost total lack of interest for modern music showed by the vast majority of students and teachers throughout my conservatoire years convinced me that a methodology had to be developed as an extension to traditional training. This in turn led to identifying the techniques which should now be considered standard through their prolific use by composers, and establishing a process to learn and teach these. The process was completed by adding all possible means of sound production to present a complete framework of extended technique.

The information presented is the result of six years of absorbing, filtering, condensing and elaborating knowledge gained through various texts, conversations, and personal experience as detailed above. In this way, the development of my thesis, its contents and structure, was very organic. My personal pursuit as a cellist and the collective ambition of my chamber ensembles to find the most effective ways to perform contemporary repertoire, guided my work and led me to a wide variety of musicians, many of them key figures in the development of contemporary music. During my research, various contemporary music specialists discussed their views and approaches to the performance and teaching of 20th-century techniques and I was able to express my own. Sometimes these dialogues were conducted as formal interviews,¹³ other times these were informal conversations, chamber music coaching or correspondence by email.¹⁴ This aspect of my thesis is fundamental to its purpose: while other texts on the

¹³ Neil Heyde and Rohan de Saram.

¹⁴ Of particular importance have been Alexander Ivashkin and Natalia Pavlutsкая, in shaping my conception of Gubaidulina and Lutosławski's music and techniques. The Kronos Quartet's sound designer Brian Mohr has been invaluable in his contributions to Section 23, as has Philip Sheppard with overpressure techniques during my master's degree, and Peter Sheppard-Skaerved in his constant pursuit of colour. Far from negligible have been the many conversations with children and young adults – my students and the many young composers the Ligeti Quartet encounters in competitions and workshops – whose curiosity fueled mine. For example, I was pleased to find during a workshop with secondary school students at St Mary Redcliffe and Temple School in Bristol that I had omitted 'playing under the string' in my survey.

same subject present the authors' viewpoint as core, this text is meant to collect and organize a huge body of knowledge, much of which remains undocumented.

It is my hope that this work will not only guide advanced students and professional cellists in their performances, but that it will encourage greater development in the pedagogy of modern music. Though written specifically for cellists, interest in this text should hopefully extend to composers who wish to further understand the possibilities of writing for the cello, conductors, and contemporary music specialists curious to compare their own solutions to those of others. This thesis could function as a catalogue, but its main purpose is to serve as an educational resource. Where different players have come up with different solutions for a technique, these have been listed with the advantages and disadvantages of each solution for various body-types or musical contexts.

This thesis is divided into four parts. The first is a literature review of the pedagogical initiatives that share expertise in 20th- and 21st-century music. The second and third parts, and main body of this thesis, find inspiration in the Method,¹⁵ the traditional instruction booklet to playing an instrument. I present a taxonomy of contemporary techniques, an ordered system which emphasises relationships of techniques based on sound production. The fourth and final part presents my suggestions for building a pedagogical infrastructure from the foundations established here.

The content and structure of a Method is of course dictated by what its author (a teacher and performer) deems most interesting and useful, which is in turn defined by this individual's experience and musical environment at the time of writing. Any inherent flaws to such a subjective system are evident. The alternative – a study covering every single aspect of playing the cello – would be impracticable within the terms set here, which are to build and develop a functional understanding of the ergonomics and musicianship skills of playing modern music. Hence a certain level of skill and knowledge is assumed.

¹⁵ When discussing the Method as a performance treatise, the word will be capitalized.

The materials in this thesis are presented as a digest. Far more detailed information is available on many of these subjects; where some of the sections below are only meant to be an introduction to a given topic, further reading is suggested in ‘Appendix IV: Further Study’. It must be emphasised that this thesis does not aim to introduce anything new; even the presentation of material is based on the tradition of the Method. What is new, perhaps, is the historical context given for each section, which is vital in supporting the premise on which this thesis is built: modern technique is an extension of traditional playing.

To adequately define the process of standardization as such and to connect our present to the past, a certain amount of historical research was needed. Technical and musical aptitude, like any other art or science, is continually evolving based on what was achieved before – Schoenberg wrote that ‘new music was merely a logical development of [existing] musical resources’.¹⁶ How then is to be defined the point when a certain musical development becomes the norm and in turn a resource on which to be built?

Examining the reasons for codifying technique in the Classical and Romantic eras gives us some clues as to whether this is presently a viable undertaking. Historically, standardization is imposed by the authors with the most widespread reputation, and hence most widely disseminated publications, but also whose presentation and arguments are clearest.

History shows us several examples of success. Valerie Walden explains that thumb position as we still know it today was uniformly adopted from the middle of the 18th century, while several fingering schemes existed throughout the entire 18th century for the lower positions.¹⁷ This suggests that thumb position was an element of technique which was rapidly codified, while fingering wasn’t for nearly two centuries. It may seem obvious now that thumb position is the most efficient way to overcome the physical limitations of placing the fingers in the higher positions, but there are other

¹⁶ Schoenberg (1985), p. 180; discussed by Whittall (1977), p. 4.

¹⁷ Walden (1998), p. 134. Many examples of codification are discussed by Walden.

ways of playing the notes in the higher register, just as there were multiple fingering schemes in use which were less effective than what we now use.

One might assume that thumb position was quickly codified because of the wide reach of Luigi Boccherini's music throughout Europe, thumb position being central to the performance of his music. Similarly, it was Jean Louis Duport's widely distributed *Essai*¹⁸ (published the year after Boccherini's death) which succeeded in rectifying the fact that no unified method of fingering existed for the cello to date. Duport expressed in his preface the wish for his publication to bring all cellists in agreement of the principles involved, despite differences of opinion on certain points. *Batteries* – patterns of alternating notes on neighbouring strings – is yet another example of a technique which existed long before it was codified by Tillière in 1764.¹⁹

Many of these early rules now seem self-evident, but it was essential that they were formalized in order for technique to continue its development. The 19th century saw numerous bow strokes evolve, as well as left-hand pizzicato, a greater variety of vibrato, and longer sequences of double-stops. New techniques are initially restricted to a very few especially imaginative musicians; this is as true now as it was in the earliest days of the cello. Ever faster, higher, ever more precise and more complex still continues to be a driving tension between composer and performer, which can be traced back to the earliest compositions for the cello as a soloist's instrument. Walden cites Boccherini, J. L. Duport and Bernhard Romberg as the three cellists who were 'viewed by contemporaries as especially progressive technicians',²⁰ each with very specific contributions. Indeed, each of these cellists had a wide-reaching reputation and large distribution network for their music and writings throughout Europe.

After examining techniques that have successfully been standardized, we look at examples of those which haven't yet been. A prophecy made by Berlioz in 1844 on the use of pizzicato (cited on page 60) is yet to be fulfilled. Notation is another example:

¹⁸ Duport (1806).

¹⁹ Tillière (1764).

²⁰ Walden (1998), p. 134.

Nyman's comment that notation such as Cardew's would 'scare off any musician who has been brought up to play Beethoven and Mahler (in 1973 as in 1960)',²¹ is still applicable forty years on. That two such statements were made more than a century apart, and both remain true today, is possibly because both Berlioz's and Nyman's texts, as is the case with most writings concerning notation and orchestration, are not widely studied by performers. Very few performance treatises give more than nominal historical information, and texts tend to focus on either common practice or 20th-century music, creating isolation between genres. I have yet to see a text which describes the history of cello technique in relation to the present day.²² Thus a relatively large space is given to historical discussion in this thesis.

The first Methods for cello were created nearly a century after the instrument emerged. If one draws a parallel with the new wave of techniques which emerged from the early 20th century, this thesis has good precedent.

Our exploration of the topic begins with a look at existing materials.

²¹ Nyman (1999), p. 116.

²² Chapters 11-13 of Stowell (1999) present possibly the most complete survey published to date.

Part I: Where Are We Now?

This is a broad overview of the material currently available to cellists who wish to further their knowledge of contemporary aesthetics and techniques. These are evaluated in terms of their relevance to the current demands of the profession, supporting the need for the creation of additional publications, further discussed in Part IV.

The materials surveyed below can be divided into three categories:

- a) **Performance Materials:** syllabuses, études
- b) **Performance Treatises:** books, academic papers, websites
- c) **History of the 20th Century:** books

While these form an important resource, a lack of practice-based material becomes evident. Just as there are few études pertinent to the development of contemporary techniques for the cello, so there are very few writings which can be of any practical assistance to a performing cellist today. The works discussed below have varying degrees of relevance to cellists as such, many of them written for other string instruments or for more general use. Full details of these publications can be found in the Bibliography.

PERFORMANCE MATERIALS

Syllabuses

As the number of music students expands and the need for clearly defined technical standards develops,²³ lists and collections of pieces have been assembled by specialists. The cello is thankfully no exception here, and many institutions have classifications of pieces selected by educational committees for their pedagogical value to students with a defined level of playing.

²³ This accompanies the increasing development of exam boards and the growing recognition of their grading systems.

Part I: Where Are We Now?

The Associated Board of the Royal Schools of Music (ABRSM) in the United Kingdom has commissioned and published the *Spectrum* series, which comprises several collections for various instruments, with CD recordings. The collection for cello was published in 2004 and features 16 pieces by living British composers which are ranked in order of difficulty. A valuable collection for the young or amateur player, this introduces several extended techniques and develops the ear to a non-tonal musical language. The ABRSM also lists in its syllabus works from *Fingerprints*, *Unbeaten Tracks* and the second of three volumes of the *Collection Panorama – Violoncelle*. The *Fingerprints* collection brings together 14 pieces by living composers, though these use more ‘popular’ compositional styles. *Unbeaten Tracks* features 8 pieces, ranked in order of difficulty, though only the concluding work written by Steven Isserlis incorporates non-traditional techniques (friction noise of the left hand sliding on the strings, tapping the cello, overpressure, Bartók pizzicato, harmonics glissandi, and *sub-ponticello*). The French *Collection Panorama* brings together 15 *oeuvres contemporaines* in three volumes.

Excerpts from James MacMillan’s *Northern Skies*, seven miniatures written for children, and Aaron Minsky’s *10 American Cello Etudes* are also listed in the ABRSM syllabus. A conspicuous lack of 20th-century masters are present though, extending only in the higher grades to the early 20th century with Bartók, Janáček, Ravel, Bloch and Prokofiev – many of the 20th-century works programmed in this syllabus are of different cultural traditions: fiddle music, Hungarian folksongs, bluegrass, TV/movie theme tunes, traditional Congolese, American jazz, and Latin.

The Royal Conservatory of Music of Canada and Trinity College London (TCL) also present interesting cello syllabuses. The latter, as does the ABRSM, only introduces the more celebrated names of the 20th century in the highest two grades. It is interesting to note that the ABRSM syllabus does not require any études, while TCL does for the first five grades, from their own publication *Cello Scales, Arpeggios & Studies from 2007*. This syllabus also lists études from Minsky’s *10 American Cello Etudes* and Dmitry Kabalevsky *Major-Minor Etudes for Violoncello, Op. 68*. TCL offers the possibility for students to perform their own composition at all levels and requires Grade 8

Part I: Where Are We Now?

compositions to feature ‘a variety of instrumental effects e.g. glissandi, *sul ponticello*, *col legno*, etc.’²⁴ This is an admirable effort but inconsistent in that the student has very little chance of learning these ‘effects’ if following the syllabus.

While the above-mentioned collections – which are commissioned, published and promoted by examination bodies – are exceptional tools, these are limited in scope as they cater to the younger or amateur pupil. While aiming to form the ear and extend the horizons of musical understanding, the study of these collections cannot prepare students to perform the larger and more substantial works of the modern repertoire.

Etudes

When considering traditional performance practice, the correlation between didactic materials and the performance of musical works of the same era seems to be indisputable – for example, the study of J. L. Duport’s études develops notions and techniques important to the performance of Beethoven’s works. While Methods evolved in the 18th century in parallel to the encyclopaedia as we now know it, études developed in the 19th century, in tandem with the rise of the virtuoso cellist. Dotzauer and Grützmacher were among the first renowned performers to publish volumes of short pieces intended for advanced students of the cello. These pieces intensively explored a specific technical notion in a musical context. There followed dozens of étude books throughout the 19th century, from the Russian, German, Belgian and French schools, the style of which mirrored the musical taste of the day.

As the 20th century saw a tremendous diversification of styles and approaches, the études written have come to represent their author’s particular idiom. This could be illustrated in a separate investigation of more recent étude collections which could be further evaluated, first individually then comparatively, in terms of their value to the étude literature, a cellist’s development both musically and instrumentally, and the understanding of the specific language of the composer in question.

²⁴ *Trinity Guildhall Strings Syllabus* (2009), p. 11.

A comprehensive list of 20th- and 21st-century études, a short discussion on the problems of nomenclature, and brief descriptions of the more significant étude collections can be found in ‘Appendix I: 20th-Century Etudes’ on page 283.

PERFORMANCE TREATISES

Materials with very different formats – books, academic papers, and websites – have been grouped into this section because of their similarities. Most of the works below are intended for both composers and performers (though generally there is more emphasis on orchestration, notation and context than on how to play something), which dilutes the information and focus of the text. All of these texts provide performance advice from only one source, the author(s), taking into account only one body-type and one particular cello.²⁵

Books

Several detailed instrumental treatises have been written. Though these works can be very interesting to the performer, their format renders them impracticable to the cellist wishing to acquire and refine new techniques. The works below are catalogues in which pedagogy is not a priority.

The earliest publication of this type for a string instrument is **Bertram Turetsky’s** *Contemporary Contrabass* (1974)²⁶ and is unfortunately no longer in print.

Gardner Read’s *Compendium of Modern Instrumental Techniques* (1993) presents a broad survey of instrumental techniques for all of the instruments of the Western musical tradition. Each section begins with a general introduction to the technique followed by examples specific to an instrument group, concluded by a vague prediction as to the role of this technique in future works. A separate section presents techniques idiomatic to each instrument. He differentiates between the different string instruments,

²⁵ This general absence in literature of comparisons between solutions by different players (with different body types) is an observation which arose in interview, when the sheer difference in physical size between N. Heyde and V. Welbanks became the obvious source of difference in their respective outcomes for technical solutions.

²⁶ Turetsky (1974).

listing examples specific to each one when appropriate. Both composers and performers would find this text a useful point of departure for further experimentation and reflection, however the information of each section is presented erratically; the techniques Read selects are chosen from existing and mostly obscure compositions, restricting the list to what has been done rather than what could be done. For the extensive examples, there is a lack of actual illustrative notation, and many of those provided are of poor printing quality, their purpose unclear. The book would be more pleasant to read if such editorial considerations had been taken, and if translations of the performance indications of his examples had been provided. Rather than fulfilling his intent of codifying instrumental techniques as he suggests in his opening text, Read provides an interesting, if superficial, introduction to the wide ranging transformation of technique over sixty years.

Patricia and **Allen Strange**'s textbook of modern techniques, *The Contemporary Violin: Extended Performance Techniques* (2001) is a work of colossal importance though with limited impact because of its textbook format. This manual of technique assumes (and necessitates) an already present interest and knowledge of modern music from its readers, "preaching to the converted" if one will allow the expression. Written for the violinist, many of the techniques are transferrable to the cello, though their most efficient means of execution, because of the sheer difference in the size of the instruments, would have to be devised by the player. The *Contemporary Violin*, as a self-proclaimed technical digest, provides a description of the widest possible range of extended techniques with little thought to classification or consistency of presentation. Much as in Read's book, contextual references are often limited to obscure American repertoire; in the absence of any supporting audio material, the notated examples are of limited use. P & A Strange dedicate a relatively large amount of space to obscure developments made to the actual instrument, to do with technology and extending the range of the instrument.

The most recently published book of this type is co-authored by **Irvine Arditti**, first violinist of the Arditti Quartet, and **Robert HP Platz**, a composer and conductor. *The Technique of Violin Playing* (2013) is a lighter publication, presenting articles by either

author in both German and English text. It is pleasant to read and dotted with pertinent anecdotes, but is, as with both previously discussed publications, primarily intended for the composer. The techniques presented are those which are most commonly used by Arditti himself. Notions of advanced interpretation, basic violin technique, and notation are conflated, though each topic is clearly presented. The book provides a lexicon of terms, a guide for writing double-stops, a chart of all possible harmonics for the violin, and a very well-crafted DVD of Arditti playing the examples printed in the book.

All of these works use existing repertoire as a basis for the presentation of unconnected techniques. These are all noteworthy resources for composers rather than performers.

An increasing wealth of educational texts is available to various other instruments. An insightful and wide-ranging summary of the principal works for flute, clarinet, and harp can be found in Ellen Fallowfield's introduction and literature review to her thesis *Cello Map*.²⁷ As she so sufficiently reviews what she calls 'the handbook of instrumental technique' as a genre – none of which exists in a comparatively systematic and pedagogically sensitive publication for the cello – I will only review performance treatises for bowed string instruments. The interested reader should consult the works of Robert Dick, Bruno Bartolozzi, and Carlos Salzedo.

Academic Papers

Several academic papers have been written concerning extended techniques for the cello. **Dylan Messina's** *Where Will it End? A Guide to Extended Techniques for the Violoncello* written for his studies at the Oberlin College and Conservatory presents a wider range of techniques than the two websites cited below, in a more structured approach than Read's compendium. Messina is both a cellist and composer but states in his opening paragraph that the paper is intended as a resource for composers. As such, the information is presented in clear, concise short articles with examples when necessary and basic information about the means of production of a certain technique.

²⁷ Fallowfield (2010), pp. 1-29.

Ashley Sandor's doctoral thesis *Extended Techniques for String Instruments As Applied to Twentieth-Century Cello Repertoire* has been reviewed but cannot be recommended as further reading. The study contains loosely verified historical information, and does not extend to any substantial acoustic information or personal insight.

The Cambridge Companion to the Cello, edited by Robin Stowell, includes an interesting chapter by **Frances-Marie Uitti** entitled *The Frontiers of Technique*.²⁸ Her article covers the various compositional currents of the past century and places the cello within their context. She also discusses some of the more radical changes in technique such as microtones, use of the voice, and electronics. Uitti is an invaluable exponent of modern music. A composer and cellist, she also collaborated with many of the century's greatest composers and developed the double-bow technique which allows for full polyphony on the instrument. Her plans of writing a book commissioned from the University of California Press on new cello techniques from 1915 (the year of composition of Kodaly's solo Sonata Op. 8) to the present day sadly have not yet come to fruition.

In comparison with the aforementioned works **Ellen Fallowfield's** *Cello Map* (2010) can be placed at the other end of the spectrum. It is very detailed, very thorough and very systematic, but does not lend itself easily to assimilation by a student. In her work, Fallowfield discusses as completely as possible the spectrum of sound production on the cello to cover all existing and anticipated future techniques, though without any musical context or priority towards classical technique so as to avoid any bias. While she makes clear differentiations between theoretical models of sound production and practical results, such a mix of knowledge requires the reader to 'hunt' for information. Indeed, much of the information is given very factually, leaving the practical extrapolations to the reader. Cellists would benefit from having access to her work in a re-structured format which, as we will see below, she is endeavouring to do.

²⁸ Stowell (1999), pp. 211-223.

Websites

The following websites have been classified as performance treatises because of their public-reaching efforts to present techniques in a pedagogical way. The quality of presentation and the means of delivery vary widely.

*Extended Techniques for Cello by Craig Hultgren*²⁹ takes the form of an academic paper, and is divided into four sections: vibrato, harmonics, double-stops and pizzicato. Hultgren develops each section starting from a very basic explanation, though his approach is somewhat erratic and incomplete. His additional remarks on the use of these techniques on the other bowed string instruments obscure the aim of his text. He clearly addresses the composer who is not a string player or is unfamiliar with string techniques, rather than addressing the amateur, student or professional cellist as do Rolan and Fallowfield. Pragmatic advice is provided on what to do and not to do when writing these techniques for string instrument along with some historically interesting short introductory information on the technique in question. Even though he is a performing cellist himself and a teacher, he offers no specific information about the physical production of any of these techniques. The videos of the examples cited are however very useful to both composer and cellist. His examples are mostly from music written in the early 1990s, with very few taken from the more widely accepted repertoire or recognized composers of the 20th century. This is surely a useful site for composers wishing to gain better understanding of contemporary uses of these four techniques, but the title is misleading as the text is extremely limited in the context of the full range of extended techniques – only the section on pizzicato reaches into this category, the other sections being limited to 20th-century uses of traditional techniques in orchestration.

*Modern Cello Techniques*³⁰ forms **Russell Rolan**'s project as DMus candidate at Northwestern University, for which he also submitted a supporting document entitled *Moderncellotechniques.com: An Internet Resource for Extended Cello Techniques*.³¹

²⁹ <http://www.lunanova.org/CelloET/index.html>

³⁰ <http://www.moderncellotechniques.com>

³¹ Rolan (2011). Kindly sent by Rolan to the author.

While he intends to continue expanding the website, it already covers a wide range of techniques in a systematic and pedagogically sensitive way. Rolen's work resembles a Method, very much based on those of the 18th- and 19th-century masters. To use his words, it addresses the 'proficient cellist' who wants to learn 20th-century techniques. Rolen also divides his work into four sections, the first two as left-hand techniques and the last two as right-hand: harmonics, quarter-tones, *ponticello* & *tasto*, and pressure techniques. Each section has multiple sub-headings, including a section with examples from the repertoire, taken from an interesting mix of common practice and 20th- and 21st-century repertoire. Each page is accompanied by practice tips, printable exercises (many of which are popular melodies), video demonstrations, examples, and diagrams. The video demonstrations are essential in fully understanding the examples given, and are generally very well played - as are Hultgren's and Fallowfield's. Though Rolen's website in its current form³² presents a somewhat narrow selection in terms of the full range of extended techniques, the material presented would provide a solid basis for acquiring confidence in the performance of modern music.

Fallowfield has also very recently rendered her thesis into a website. The main flaw in **Fallowfield's** *Cello Map*³³ is design; it lacks the clarity and simplicity of Rolen's. The pages are very long, the text is in a small font, and the language is – though very accessible – still very close to the language she uses in her thesis and not quite accessible enough yet for an instruction manual. There is also much repetition in her text. The many videos are a redeeming feature of the website, and show interesting experiments in the acoustic phenomena she discusses.

Fallowfield best summarizes her own work, explaining 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

³² Last accessed 11/2012.

³³ <http://www.cellomap.com>

information about how the cello works that can serve the imagination of performers and composers.³⁴

Because of this tactic, the information provided on her website is also applicable to standard technique, the relevance to modern music not always immediately obvious. But this basic information is indeed essential in understanding how to break the limits of traditional playing, to enter the realm of extended technique.

In contrast to Hultgren's website, both Rolén and Fallowfield steer clear of discussing any compositional use of the techniques they survey. While Rolén focuses entirely on the nuts-and-bolts execution of the techniques, Fallowfield emphasises the acoustic working of individual mechanisms of sound production, adding practical execution remarks when appropriate.

Violinist **Alex Targowski**'s website extendedtechniques.blogspot.co.uk³⁵ is worth mentioning as he presents a wider range of applied topics than the other websites. These are in the form of fifteen short blogs, in no particular order, and most are accompanied by short video demonstrations. This site is useful in providing a brief informal overview of a wide range of techniques.

HISTORY OF THE 20TH-CENTURY

Amateurs of music history have access to several interesting books on the evolution of music in the 20th century, such as **Michael Nyman**'s *Experimental Music* and **Alex Ross**'s *The Rest is Noise*, both seminal works covering a wide range of composers and their particular views and/or contributions to music. Such works are important in understanding how music which differs so greatly from the traditional Western music tradition can still be so closely connected to it, and the process which art underwent which led music to its present form. Those texts written from within the explosion of experimentation which the 60s and 70s saw, such as **Schwartz and Childs**' *Contemporary Composers on Contemporary Music*, provide equally valuable first-hand insight rather than historical objectivity.

³⁴ <http://www.cellomap.com/meta/about.html>

³⁵ <http://alex-targowski.blogspot.co.uk>

SUMMARY

It remains that for all of the didactic literature written in the 20th and 21st centuries, no material exists which can comprehensively and systematically guide a cellist in acquiring the skills needed to adequately perform modern music. To accomplish this, the required publication would need to be presented in a clear and appealing format. The strongest aspects of the abovementioned publications would ideally be combined: a wide range of the techniques most used in existing repertoire, presented in a logical progression with a balanced mix of historical, theoretical and practical information. Preparatory exercises would be followed by an opportunity to place a particular technique into a musical context – acquiring practical knowledge of a given technique can be achieved through executing it in isolation, but being able to apply a technique as a component of artistry is dependant of its understanding in various contexts. Parts II and III establish the foundations needed to accomplish these aims.

Part II: Defining & Codifying Extended Techniques

The 20th century saw such an explosion of traditional technique that an order, a system must be created on which to found a pedagogical approach. Every aspect of traditional playing has been pushed to an extreme or disassembled, and entirely new ways of producing sounds on the instrument have emerged. I will refer to this collectively as ‘extended technique’.

Extended techniques are intrinsically difficult to define; many date back to the earliest days of cello playing, others ‘arrived as accoutrement to the romantic virtuosi’.³⁶ It was, however, with the virtuosity of 20th-century cellists such as Rostropovich and Siegfried Palm that ‘the musical viability of extended techniques solidified; that they could act as gestures of expression in and of themselves, rather than be relegated to mere accessories of core technique’.³⁷ Rohan de Saram expresses an interesting view on the subject:

The so-called extended techniques of voice, string, woodwind, brass and percussion belong to these instruments as a matter of birthright, but because these instruments have been used in a musical language largely centred around keyboard thinking, these other aspects of their nature have remained mostly unexplored and unused.³⁸

To distinguish between modern and traditional technique – not to create a separation, but rather, to delineate an area of focus – the progression involved in learning the cello needs to be considered in its entirety. The personal development of a cellist mirrors the historical evolution of technique throughout the centuries, a useful archetype when placing modern music and its performance in context.

Learning to play an instrument is naturally not a linear process, but a rough time-line could be drawn between the first cello lesson and the point at which a cellist can comfortably play any common practice repertoire. The first few lines of the progression

³⁶ Messina (2009), p. 4.

³⁷ Ibid.

³⁸ Steinheuer & de Saram (2013), p. 175.

of traditional training could perhaps be described as such: pizzicato (mechanics) → open strings (geography) → notion of pulse (musicianship) → left-hand notes of the first position (mechanics and geography) → reading notation (musicianship) → basic rhythm, crotchets and minims (musicianship), and so on... The techniques needed to adequately perform repertoire written before the 20th century are what we will refer to as traditional technique. The portion of timeline between this point and the one where a cellist can play any repertoire from the 20th and 21st centuries is what this thesis covers; these are, in other words, extended techniques.

Figure 1: Timeline, connecting traditional training to modern technique



This division is of course purely academic, many extended techniques can be used quite early on in a cellist's progression by a sensitive pedagogue, for example *sul ponticello* can be introduced as soon as a pupil learns about bowing perpendicularly to the string; this trains the pupil to associate physical movement with sound result, *sul ponticello* being a particularly recognisable sound which changes immediately with the point of contact. This could be the subject of a different study addressing the earlier stages of learning.

There are many possibilities when considering the classification of such a vast body of knowledge. Several authors, such as Read, P & A Strange, and Rolen, have grouped their material according to left- or right-hand use. Fallowfield chose to order her research independently of traditional playing, shaping her work according to acoustic possibilities of sound production on the instrument. Katherine Jetter Tischhauser chooses to define extended techniques as those for which 'a composer creates a new notation in order to convey to the performers of his work his intention regarding a

Part II: Defining & Codifying Extended Techniques

different timbre, special sound, or effect’.³⁹ To summarize, the works reviewed in Part I classify techniques according to which part of the body is traditionally used, the mechanics of the instrument, or notation.

However, when considering extended techniques in the context of a 300-year history, two large categories naturally emerge. Adapted Techniques are those created by modifying traditional techniques, either by expanding their scope or isolating and rearranging their physical parameters. These form a bridge between traditional playing and Non-traditional Techniques, which involve using an instrument in ‘a manner outside of traditionally established norms’⁴⁰ and depart significantly from traditional cello playing. These two categories of technique are divided into eight and nine sections respectively, presented in Part II.

When looking to integrate extended techniques into the performance of modern music, a third category emerges, that of Musicianship. These seven sections are presented separately in Part III, since ear training, rhythm, idiom⁴¹, and the use of technology are skills transferrable to all musicians.

The rudimentary scheme outlined above Figure 1 mentions three aspects of learning the cello: mechanics, geography, musicianship. While all 24 sections of this thesis involve a combination of these three aspects, each technique tends towards one or the other. Hence Part II covers predominantly physical techniques, dealing with the mechanics of playing the cello and geography of the instrument, while Part III is dedicated to general musicianship skills.

All sections in Part II, both large and small, are based on the action / mechanics of performing a certain technique; the question of ‘how’ a technique is executed is the guiding concept. The result may be seen as a catalogue, but the underlying principles guide and shape it into a pedagogically sensitive framework: this is not a list of isolated special effects but rather the most basic expression possible of available means of sound

³⁹ Tischhauser (2002), p. 2.

⁴⁰ <http://www.newmusicbox.org/article.nmbx?id=4076>

⁴¹ Both in terms of an individual composer’s language and the styles associated to schools of composition.

Part II: Defining & Codifying Extended Techniques

production on the cello. The following techniques are presented as a linear projection of traditional playing, so that the student may feel that this is not something entirely new, but rather a continuation of skills that have already been acquired through years of study. The numbering of each section will continue throughout Parts II and III, to emphasise this sense of progression.

While every aspect of traditional playing can be transferred to the context of modern music, the reverse statement is not true. But this clear demarcation of old and new is what must be avoided. Another way of explaining the choice of content is that the techniques included below are those which have the capacity of altering the sound considerably in relation to common practice music and which necessitate added proficiency on the instrument. For example, while vibrato is as much a consideration in modern music as it is in traditional playing, a cellist with good vibrato control will have the necessary technical knowledge to adapt its use to new musical contexts. Vibrato is therefore not included, but extreme vibrato, which necessitates a different arm motion, is included.

Each section introduces a technique or aspect of playing modern music in terms of pedagogical aims. The presentation continues with provenance in musical literature⁴² or tradition (History), ergonomics (Theory & Practice) and specific uses in compositions (Applications). When a certain notation or notations are specifically associated to a technique, these are illustrated (Notation). In addition, exercises are distributed throughout the text. Set into the text so that they can be easily identified, these are prototypes of the preparatory exercises which will eventually assist students in integrating new notions to their playing (see p. 269). Examples from the solo and chamber repertoire are cited where possible in Appendix IV: Further Study, to provide a certain amount of context, although this is in no way comprehensive.

⁴² Often, the beginning of a technique will be linked to its first appearance in notation. In private correspondence with V. Welbanks, Peter Sheppard-Skaerved explains that prior to the mid-1700s, 'very few special effects were notated - and this seems to be a legacy of an improvising culture. The early violin virtuosi, Walther, Playford, Matteis, Biber, Ziani, etc., did not notate special techniques, but did notate imitative ones [for example the 28th and final piece from Johann Walthero's Hortulus Chelicus]. So I would suggest that what one would be looking for would be anything which asked for the evocation of, say, aeolian harps, organs, etc.'

While the relationship between performer and composer is an interesting one, the latter's role will be deliberately overlooked in this thesis. Notation is used throughout this thesis in a purely illustrative way; in general, the most visually engaging notation – rather than the most frequently employed – is used in examples, while the Notation sections demonstrate what a performer might encounter in a score. Many other publications have provided comprehensive lists of available notation and such a task lies well outside the scope of this work. Much of the difficulty in systemizing extended techniques lies in the fact that notation itself has not yet been standardized, despite several valiant efforts to do so. Many techniques are as yet nameless and remain a written description of either the action or the resulting sound by composers in their prefaces. Where possible, all terms in use are included in headings, but much of the terminology in this thesis has been created specifically for this text (this is indicated when this is the case).

The techniques below and their order of presentation are not biased in terms of use in solo, chamber and orchestral repertoire; rarely used techniques are on equal terms with those more frequently used. These are all, however, absent in traditional pedagogical material. Each technique is presented in as isolated a manner as possible as a 'digest', though in a musical context various techniques are often combined. As the combination of any number of these techniques can become a technique in itself, section '17. Independence of Hands' (p. 177) is dedicated to a few examples of mixed techniques which were separately surveyed in the previous sections. As students progress from one section to another, they are encouraged to combine previous sections to explore the full range of tonal possibilities on their instrument; for example, once the student has progressed to the bowing techniques developed in sections 3 and 4, these should be combined with harmonics, seen in section 1.

Many of these techniques are idiomatic and vary with the cellist's body type and the instrument itself, even producing widely varying results on each of the cello's four strings. The type of string⁴³ used is the most significant factor. While a variety of

⁴³ The material used for the winding and the core, the type of core (whether single or rope for the lower strings), and the thickness of the string all affect the sound.

Part II: Defining & Codifying Extended Techniques

players have been interviewed, and the different solutions they have offered described below, the author would encourage both teachers and students to re-explore each of these techniques on a particular instrument and to discover above all the scope of their own sounds. While the solutions presented are based on information obtained by the individuals' own experiences, the author would like to emphasise that other solutions have been or will be found by others.

While this thesis does not intend to be exhaustive, at the time of writing it is very nearly so. As seen in Part I, many works examine basic extended techniques, and others are in-depth presentations of a specific topic. This paper is unique as a comprehensive overview of extended technique in its entirety.

In presenting the material below, the author has endeavoured to follow one basic principle: the mechanisms of playing the cello in new music should remain as similar as possible to traditional playing.

ADAPTED TECHNIQUES

The following extended techniques are placed in the category of Adapted Techniques, as they are extreme applications of traditional means of sound production. Gardner Read begins the introduction of his *Compendium* with the judicious words:

Many so-called "new" instrumental devices have developed from well-established techniques; they are extensions of, or refinements of, procedures long considered part of a composer's repertorium of expressive devices. The newness, then, is not one of kind but of degree, a further and more extensive development of basic effects found in scores from the late nineteenth century to the present day.⁴⁴

Indeed, this reflection places contemporary techniques in relation to traditional cello technique. The sections in this category are:

- | | |
|---|-----------|
| 1. Harmonics | 39 |
| <ul style="list-style-type: none">• History• Theory & Practice: Stopped Harmonics (Artificial Harmonics), Intonation, Sound Production, Double-node Harmonics• Applications: Glissandi (Natural Harmonics, Natural Harmonics over a Stopped Note, Stopped Harmonics), Trills, Pizzicato Harmonics, Pitch Bending / Pulled Harmonics, Fawcett Harmonics• Notation | |
| 2. Pizzicato | 60 |
| <ul style="list-style-type: none">• History• Theory & Practice: Parameters of Pizzicato (Note Length, Point of Contact, Direction, Plectrum: Contact Area / Size, Plectrum: Material, Velocity, Force)• Applications: Articulation, Bartók / Snap Pizzicato, Multi-Stop Pizzicato, Jazz / Double-Bass Pizzicato, Nail Pizzicato, Pizzicato-Tremolo, Alla Chitarra / Quasi Chitarra, Touch Pizzicato, Left-hand Pizzicato, Sub-Ponticello Pizzicato & Pegbox Pizzicato, Other Plectra• Notation | |
| 3. Bowing the String: Point of Contact | 76 |
| <ul style="list-style-type: none">• History• Theory & Practice• Applications: Fixed Points of Contact (Sul Tasto, Sul Ponticello, Sub-Ponticello / Oltre Ponticello, Non-Resonating Sul Tasto, Under the Strings, Pegbox), Modifying Points of Contact (Arco: Sul Tasto – Ordinario – Sul Ponticello, Circular Bowing, Irising, <i>Spazzolato</i> / Vertical Bowing, The Helicopter Effect, Tremolo, Parallel Bowing) | |

⁴⁴ Read (1993), p. 3.

- Notation

- 4. Bowing the String: Speed & Pressure** **93**
 - History
 - Theory & Practice
 - Applications: Overpressure (Pitch Bending (with the bow), Overpressure Harmonics, Tone Distortion, Scratch Tone, Subharmonics & ALFs / Undertones / Pedal Tones, Nageln / Clicks / Crenelated Bowing, Vertical Nageln), Underpressure (Flautando, Air Noise / White Noise / Rauschen, Filtered Pitch)
 - Notation

- 5. Between the Notes** **107**
 - History
 - Theory & Practice
 - Applications: Glissandi, Pizzicato / Struck Glissando, Double Glissando, Glissando Trill, Turning the Peg, Extreme Vibrato
 - Notation

- 6. Stopping the String** **111**
 - History
 - Theory & Practice: Density, Pressure
 - Applications: Note Length, Italian Harmonic, Half-harmonics, Damping / Pizzicato Effleuré / Dead Pizzicato, Left-hand Nail, Rattling / Buzz Pizzicato, Pitch Bending (horizontal), Pitch Bending (pegbox & sub-ponticello), Sub-ponticello, Other Stopping Objects
 - Notation

- 7. Expanding the Register** **117**
 - History
 - Theory & Practice
 - Applications: Altissimo Register, Scordatura / Alternative Tuning, Unisons
 - Notation

1. HARMONICS

We begin our exploration of extended techniques from a territory which most performers feel is familiar, but in which only a rare few are comfortable. Harmonics are part of a longstanding tradition in string playing and have been present in the earliest Methods⁴⁵ and indeed in the early stages of our development as cellists. Many publications and exercises are dedicated to harmonics, and, to avoid lengthy duplication of their content, students will be strongly advised to read Caroline Bosanquet's *The Secret Life of Cello Strings: Harmonics for Cellists*⁴⁶ as a preparation to this section.

The study of harmonics will form the basis for many of the other sections in this thesis; understanding harmonics and their role in sound can be likened to a mechanic understanding the different components of an engine. Familiarity with the geography and mechanics of harmonics on the instrument is essential in understanding how sound is created and how timbre is modified with extended techniques, as well as how dissonance and tuning systems function. Extended techniques specific to harmonics are discussed later in this section (Applications, p. 53).

Some definitions are first in order as there is much misuse of vocabulary surrounding harmonics. The term 'harmonic partial' is shortened interchangeably to either 'harmonic' or 'partial'. This text will only use the word 'harmonic' for the sake of clarity, to define 'isolated harmonics'. The word 'overtone' will be used solely when referring to harmonics as a component of sound, as in the context of overtone exclusion or when describing timbre. An overtone is any component of a sound other than the fundamental, which is higher than the fundamental. This can describe either harmonic partials (whole-number multiples of the fundamental) or inharmonic partials (non-

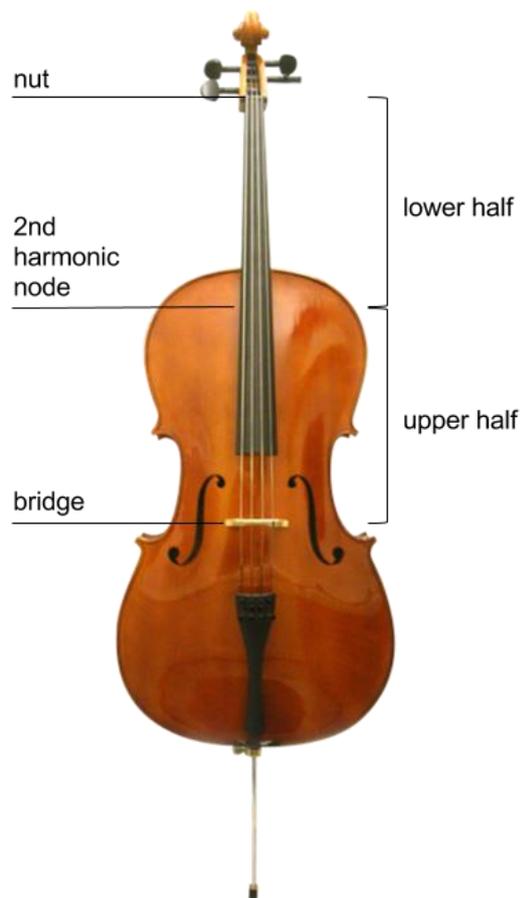
⁴⁵ While harmonics are mentioned in the Preface to Corrette's *Méthode* (1741) as integral parts of the sounds of an open string, the technique of isolating a harmonic is not discussed.

⁴⁶ Bosanquet (1996).

whole-number multiples, produced for example in cymbals or gongs). The numbering of overtones is different to that of harmonics⁴⁷ and will be avoided here.

The portion of string between the nut and the 2nd harmonic, or mid-way point, is called the lower half of the string. The portion between the 2nd harmonic and the bridge is called the upper half of the string. Based on J. L. Duport's introduction to harmonics⁴⁸ and Bosanquet's methodology, the upper half of the string will be taught first because this is where the harmonics sound at pitch.

Figure 2: Dividing the cello's string



⁴⁷ The 2nd harmonic partial = 1st overtone, the 3rd harmonic partial = 2nd overtone, and so forth. This is a common mistake because of the inherently confusing nature of having two numbering systems. An additional element of confusion is added with the German terminology *Oberpartialton* which is shortened to *Oberton* (which can be seen in the opening passage of Ligeti's *String Quartet No. 2*, where he labels certain harmonics). A cellist comfortable with the position and resultant pitch of harmonics can easily overlook this enduring discrepancy in terminology.

⁴⁸ Duport (1806), p. 46.

History

Though the theory of natural harmonics was known from antiquity, harmonics did not appear in notated music for bowed string instruments until 1738. Initially used in music for the violin, natural harmonics were first specified by Jean-Joseph Casseneau de Mondonville in *Les Sons Harmoniques: Sonates A Violon Seul Avec La Basse Continue, Op. 4* (see Figure 3 below),⁴⁹ in which he also provides performance indications and a diagram of the first 15 harmonics in the introductory notes. French and German violinists, however, were slow to integrate harmonics into their music.⁵⁰

Figure 3: First notated harmonics - de Mondonville *Les Sons Harmoniques* (1738)

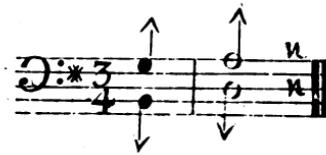


In comparing the sound of harmonics on the cello to that of the *tromba marina* in his formalized insult to the cello,⁵¹ Hubert LeBlanc at least proves that harmonics were in use by cellists by 1740. According to Walden, harmonics seem only to appear notated in published cello music from 1748 onwards, beginning with Berteau's set of six sonatas *Sonate da Camera a Violoncello Solo col Basso Continuo, Op. 1*. The publication includes a first page of instructions, very similar to those found in new scores today, explaining the notation of and giving performance indications for harmonics. In the final movements of his second sonata (variations 3 & 6) and third sonata, Berteau uses harmonics extensively, including in double-stops. Berteau's notation (see Figure 4 below) was still used in 1806 by Duport in his *Essai*.

⁴⁹ Several sources cite this information, including Sandor (2004), p. 5; Harvard Concise Dictionary of Music and Musicians (1999), 'natural harmonics'; Walden (1998), p. 194.

⁵⁰ Walden (1998), p. 194 & Stowell (1985), pp. 211-212.

⁵¹ Walden (1998), p. 194, LeBlanc (1740/R 1975), p. 85.

Figure 4: First notated harmonics for cello - Berteau *Sonate, Op. 1* (1748)

A noteworthy piece in the history of harmonics in the minuet composed circa 1763 by L'Abbé le fils (Joseph-Barnabé Saint-Sevin). Composed for violin, it is comprised entirely of natural harmonics, with the exception of a few stopped (3rd) harmonics.

Several words were used to denote harmonics, among them *allied tones*, *accessory tones*, *participating tones*, and the German *Beitones*.⁵² Rousseau's *Dictionnaire de musique* finally defines harmonics in 1768, providing a vague performance indication and an attempt at describing the resulting sound. In this lengthy entry on what he calls *Sons Harmoniques* or *Sons Flûtés*,⁵³ he references Berteau's use of harmonics.

Walden explains that harmonics had become standard playing technique by the turn of the 19th century. Bréval⁵⁴ and J. L. Duport both rationalize⁵⁵ in their respective treatises that harmonics were in fact currently less in use as they had ceased to surprise.

Nonetheless, Duport was 'apparently fascinated with the theoretical aspects of the overtone series'⁵⁶ and in addition to presenting a detailed scheme of natural harmonics, his *Essai* discusses stopped 4th harmonics as well.⁵⁷ Tricklir's extensive use of natural harmonics in his cello concerti⁵⁸ was followed by Romberg's extended passages in stopped 4th harmonics.⁵⁹ From this point onwards, in great part due to Paganini's extensive use of the technique, harmonics were an integral part of string playing.

⁵² G. Weber (1841), p. XIV, XLVI, 15.

⁵³ Rousseau (1768), p. 457. Cited in Walden (1998), p. 194.

⁵⁴ Bréval (1804), p. 134.

⁵⁵ Duport (1806), p. 56.

⁵⁶ Walden (1998), p. 196.

⁵⁷ Chapter 9 of Duport (1806) deals in great detail with the production of harmonics, pp. 46-56.

⁵⁸ Jean Balthasar Tricklir (1750-1813), 13 cello concerti survive.

⁵⁹ Romberg (c. 1799), bb. 189-197.

The use of harmonics as colouristic devices expanded at the turn of the 20th century, with, for example, the glissando on natural harmonics first orchestrated in 1895 by Rimsky-Korsakov in his opera *Christmas Eve*.⁶⁰

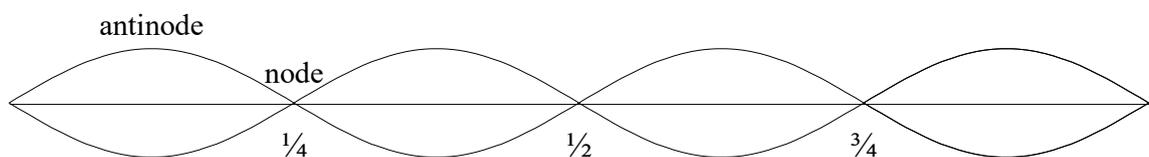
Figure 5: First notated natural harmonic glissando - Rimsky-Korsakov *Christmas Eve*



Theory & Practice

Harmonics occur by touching the string lightly with the finger at whole-number fractions of the string length: at the half-way point, at the $\frac{1}{3}$ and $\frac{2}{3}$ points, the $\frac{1}{4}$ and $\frac{3}{4}$ points and so forth. Touching the string at these points – called **nodes** – allows the string to vibrate on both sides of the finger (while fully pressing down the string dampens the portion of string which is not being bowed or plucked, see section ‘6. Stopping the String’, p. 111). The node is the point at which a vibrating string has zero amplitude and the **antinode** is the point at which a vibrating string has the greatest amplitude, or maximum displacement.

Figure 6: Nodes and antinodes of 3rd harmonic - string in motion (relative to resting position)⁶¹



⁶⁰ Read (1993), p. 53. The example is taken from Rimsky-Korsakov *Christmas Eve Suite* (1903).

⁶¹ The vibrations in a string can be compared to a wave. When the wave is deflected at either the nut or the bridge, it returns in the opposite direction. The points at which the waves intersect are the points of zero amplitude, or nodes.

Because harmonics rely on fractional divisions of the string, the same pitch can be found on every equidistant point. When differentiating between various positions of a harmonic on the same string, we will refer to, for example, the first node of the fourth harmonic ($1/4$) or the third node of the fourth harmonic ($3/4$). However, nodes that are shared between several harmonics always sound at the lowest pitch when played alone: for example the 1st node of the 2nd harmonic ($1/2$) is also the 2nd node of the fourth harmonic ($2/4$), the 3rd node of the 6th harmonic ($3/6$) and so forth, but will always produce the pitch of the 2nd harmonic when touched alone.

Below are the first 16 harmonics on each string of the cello, as they appear on the upper half of the string (the numbers under the notes indicate which harmonic is isolated). The diamond note-head indicates the position at which the finger should touch the string. These positions and the resulting pitches are written as closely as possible to 24-tone equal temperament (explained on p. 211). The 11th and 13th harmonics are almost exactly a quarter-tone sharp, while the 7th and 14th harmonics are close to a sixth-tone flat, and the 5th and 10th harmonics are approximately $1/15$ th-tone flat. These notions and the relevant accidentals are discussed in section 20. Microtonality (p. 208), but are not essential in understanding the exercises below, as the ear will guide the hand. Arrows indicate pitch deviations within eighth-tones on either side of a note and, where they are less than this, deviations are expressed in cents,⁶² if only to provide an order of magnitude.

⁶² Cents are used to express the distance between two notes (100 cents will always represent an equally-tempered semitone) whereas hertz are the measurement of frequency (defined on page 121), and are exponential. The term ‘cent’ was introduced in 1885 by Alexander J. Ellis’ *On the Sensations of Tone* (London, 1885), his translation of Helmholtz’ seminal work on acoustics.

Exercise 1: Harmonics 1-16 (upper half of the string)

- a) Play all of these notes by lightly placing the left-hand second finger at the pitch indicated by the diamond note-head. Play at a *mezzo forte* dynamic, taking care that the bow moves closer to the bridge as the notes get higher in pitch. All of these harmonics sound at the same pitch as indicated by the note-head.

The image displays four musical staves, each representing a different string on a cello: A-String, D-String, G-String, and C-String. Each staff is numbered 1 through 16, corresponding to the 16 harmonics. Diamond-shaped note heads are placed on the staves to indicate the finger placement for each harmonic. The A-String staff is in treble clef, while the D-String, G-String, and C-String staves are in bass clef. An 8va dashed line is shown above the A-String staff and below the D-String staff. Arrows point to specific notes on the 5th, 7th, 10th, and 14th positions of each string.

While more harmonics are possible on the cello, this thesis will use the first 16, which provides a four-octave range. These 16 harmonics complete a major scale (plus one note), a notion further discussed on page 198. The higher harmonics (16-64) are discussed in a theoretical sense on the same page.

Below are all of the possible single nodes for each of the first 16 harmonics presented above, on both the lower and upper halves of the A-string. The sounding pitch is given at the beginning of each staff and applies for the entire line.

Bow placement is crucial when isolating harmonics: the higher the harmonic is in pitch, the closer the bow must be to the bridge. This is a natural action when playing on the upper half of the string, but is counter-intuitive in the lower half. The student is therefore presented with two ways of reading the exercise below:

Exercise 2: Harmonics 1-16 (all nodes)

- Begin by playing the last bar of each line – this is the last node of each harmonic, which sounds at pitch, as seen in Exercise 1. Take note of the bow placement and maintain it while playing the other nodes of the same harmonic.
- Play the last bars of each line sequentially (upper half of the string), followed by the first bars of each line (lower half of the string), in order to feel the increasingly small distances between the nodes. This is an important aspect of understanding the geography of the harmonics on the string. The first nodes of the 10th-15th harmonics have very slight deviations in finger placement, by less than an eighth-tone. These have been indicated in cents which in this case, as with the arrows, serve only as approximate indication of finger placement. Special attention should be given to aural recognition of pitch placement when familiarizing oneself with the upper harmonic, as these will not correspond to the notes of the diatonic scale.

A-String

The image displays musical notation for the A-string harmonics, showing the first and last nodes for each harmonic. The notation is presented in six staves, each representing a different harmonic. The first node is indicated by a diamond symbol, and the last node is indicated by a diamond symbol with a downward arrow. The fraction below each node indicates the bow placement relative to the string length.

- 2nd harmonic:** First node at 1/2.
- 3rd harmonic:** First node at 1/3, last node at 2/3.
- 4th harmonic:** First node at 1/4, last node at 3/4.
- 5th harmonic:** First node at 1/5, last node at 4/5. Intermediate nodes are shown at 2/5 and 3/5.
- 6th harmonic:** First node at 1/6, last node at 5/6.
- 7th harmonic:** First node at 1/7, last node at 6/7. Intermediate nodes are shown at 2/7, 3/7, 4/7, and 5/7.

The image displays a musical score for the 8th through 16th harmonics. Each harmonic is represented by a single staff on a treble clef. The notes are diamond-shaped and placed on the staff lines. Ratios are written below the notes. Some notes have arrows pointing to them, and some are marked with 8^{va} and a bracket. Some notes are marked with a circled number and a 'c' (e.g., (-18 c), (-35 c), (+28 c), (+19 c)).

8th harmonic: Notes at ratios 1/8, 3/8, 5/8, 7/8.

9th harmonic: Notes at ratios 1/9, 2/9, 4/9, 5/9, 7/9, 8/9.

10th harmonic: Notes at ratios 1/10, 3/10, 7/10, 9/10. Includes a circled 18 with a 'c' and an arrow pointing to the 3/10 note.

11th harmonic: Notes at ratios 1/11, 2/11, 3/11, 4/11, 5/11, 6/11, 7/11, 8/11, 9/11, 10/11. Includes a circled 35 with a 'c' and arrows pointing to the 2/11, 3/11, 4/11, and 5/11 notes.

12th harmonic: Notes at ratios 1/12, 5/12, 7/12, 11/12.

13th harmonic: Notes at ratios 1/13, 2/13, 3/13, 4/13, 5/13, 6/13, 7/13, 8/13, 9/13, 10/13, 11/13, 12/13. Includes a circled 11 with a 'c' and arrows pointing to the 2/13, 3/13, 4/13, 5/13, 6/13, 7/13, 8/13, 9/13, 10/13, 11/13, and 12/13 notes.

14th harmonic: Notes at ratios 1/14, 3/14, 5/14, 9/14, 11/14, 13/14. Includes a circled 28 with a 'c' and arrows pointing to the 3/14, 5/14, 9/14, 11/14, and 13/14 notes.

15th harmonic: Notes at ratios 1/15, 2/15, 4/15, 7/15, 8/15, 11/15, 13/15, 14/15. Includes a circled 19 with a 'c' and arrows pointing to the 2/15, 4/15, 7/15, 8/15, 11/15, 13/15, and 14/15 notes.

16th harmonic: Notes at ratios 1/16, 3/16, 5/16, 7/16, 9/16, 11/16, 13/16, 15/16.

Stopped Harmonics (Artificial Harmonics)

More commonly known as artificial harmonics, stopped harmonics work on the same principles as natural harmonics. The difference lies in that the fundamental, or 1st harmonic, is a stopped note rather than an open string. This limits the other harmonics that can be touched to the player's hand-span. In the lower positions of the cello, the intervals between the fundamental (thumb or 1st finger) and the harmonic node (3rd or 4th finger), are the perfect-4th, perfect-5th, major-3rd and minor-3rd. This translates to, respectively, the first nodes of the 4th harmonic, 3rd harmonic, 5th harmonic and 6th harmonic. In the upper range of the instrument (again, depending on hand-span), the octave can be added to produce the 2nd harmonic.⁶³

Stopped harmonics can be produced with and without fully pressing down on the fundamental (see 'Double-node Harmonics', p. 51) and are notated as per the exercise below, with or without the sounding pitch in brackets or on an upper staff:

⁶³ Berlioz (1844), p. 21, includes stopped harmonics of a 4th, 5th, major-6th, major- and minor-3^{rds}, and 8^{ve}, although the major 6th produces the same resultant pitch as the major 3rd (in other words, the major 6th is the 2nd node of the 5th harmonic).

Exercise 3: Stopped Harmonics

- a) The upper staff indicates the sounding pitch – note that the resulting sounds are the same for each of the lowest four lines below.
- b) The fundamental (the lowest note in each example below) is first played with the thumb and the diamond note-head is lightly touched with the 3rd finger. Repeat the exercise using the 1st finger on the fundamental and the 4th finger on the harmonic.
- c) The scales can all be played either staying on one string or over two strings, as indicated on the second and third lines.

The musical notation for Exercise 3: Stopped Harmonics is presented in five systems. Each system consists of two staves: an upper staff showing the sounding pitch and a lower staff showing the stopped harmonic technique. The systems are:

- System 1:** Shows a scale of natural harmonics. The upper staff has notes on the 1st, 2nd, 3rd, and 4th lines. The lower staff has notes on the 2nd, 3rd, 4th, and 5th lines. A dashed line labeled "II" spans the first four lines of the lower staff.
- System 2: Stopped 4th harmonics.** The upper staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. The lower staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. A diamond note-head is on the 4th line. A dashed line labeled "II" spans the first four lines, and another labeled "I" spans the last two lines.
- System 3: Stopped 5th harmonics.** The upper staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. The lower staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. A diamond note-head is on the 5th line. A dashed line labeled "II" spans the first four lines, and another labeled "I" spans the last two lines.
- System 4: Stopped major-3rd harmonics.** The upper staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. The lower staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. A diamond note-head is on the 3rd line. A dashed line labeled "III" spans the first three lines.
- System 5: Stopped minor-3rd harmonics.** The upper staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. The lower staff has notes on the 1st, 2nd, 3rd, 4th, 5th, and 6th lines. A diamond note-head is on the 3rd line. A dashed line labeled "III" spans the first three lines.

Intonation

Understanding how finger placement and pressure affects the string's vibration is essential to accuracy in intonation, for both natural and stopped harmonics. Whereas a fully stopped note will allow the string to vibrate from the outer edge of the finger to the bridge, touching a harmonic node will allow the two string segments bisected by the finger to vibrate, from the middle of the finger. The result is that the finger placement for a harmonic will feel 'higher' up on the string than a stopped note, by half of the width of the finger's area of contact.⁶⁴ This 'correction' becomes particularly apparent when alternating or changing quickly from a stopped harmonic to a stopped note. Finger pressure also affects intonation, for example a very light left-hand finger on the stopped note will have less discrepancy with the harmonic. Because a finger-width is a constant value, the intonation discrepancy will be greater for the higher positions.⁶⁵

Sound Production

Various harmonics will react differently depending on string material and thickness.

Rolen offers the following suggestions:⁶⁶

- a) When activating the harmonic, the left-hand fingers should tap the string lightly to deaden the node immediately. Without this subtle articulation, the pitch is less likely to speak quickly.
- b) Move the bow closer to the bridge for the higher-numbered harmonics.
- c) At first, give a slight "ping" with bow speed to the front of each note. This also helps to activate the harmonic quickly.

Neil Heyde finds that, in terms of sound production, the most reliable node (for multiple node options) is the one nearest the bridge.⁶⁷ The highest nodes are generally more easily found because they are located at sounding pitch.

⁶⁴ This was tested with both N. Heyde and V. Welbanks; both players had the same results even though their finger-widths are very different.

⁶⁵ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

⁶⁶ <http://www.moderncellotechniques.com/left-hand-techniques/harmonics/open-harmonics/>

⁶⁷ Interview, 13/03/2013.

Finger pressure will affect the timbre of a harmonic. As it increases, so the harmonic's pitch sharpens because of the increase in string tension (see Pitch Bending / Pulled Harmonics, p. 58), and the overtone content weakens. In order to obtain a harmonic, the string's vibrations must pass the finger – when there is too much contact, a damping effect occurs in which overtones and excitation energy are lost. In the same way, a denser object or part of the finger, for example the fingernail, will reflect overtones and excitation energy more efficiently (see section '6. Stopping the String', p. 111). Arditti advises that harmonics will speak more clearly on new and clean strings, suggesting that layers of rosin will interfere.⁶⁸

Double-node Harmonics

Higher partials that have multiple nodes and which are within the hand-span will speak more quickly and reliably if touched on two of these points. The 7th harmonic is a common example, as is the 5th harmonic.

It is important to know all of the points on the string where each natural harmonic can be found. The context of the left-hand position for a given musical passage will determine which node is preferable, and experience will reveal that certain nodes are more reliable than others for different cellists and instruments. For example, Heyde prefers using the 2nd node of the 7th harmonic because it is at the neck joint of the instrument and more easily recognizable in terms of ergonomics. I prefer using the 6th node of the 7th harmonic because its location at the end of my fingerboard provides a visual point of reference.

⁶⁸ Arditti & Platz (2013), p. 57.

Exercise 4: Double-node Harmonics

- a) Play the sounding pitch, notated at the beginning of the line. Use the harmonic rather than the stopped note so that the intonation is precise.
- b) Play each double-node by lightly touching both harmonics on the same string to obtain the same pitch. Remember that finger spacing will remain constant for all the double-nodes on the same line.

A-String

5th harmonic

6th harmonic

7th harmonic

8th harmonic

9th harmonic

10th harmonic

11th harmonic

12th harmonic

13th harmonic

14th harmonic

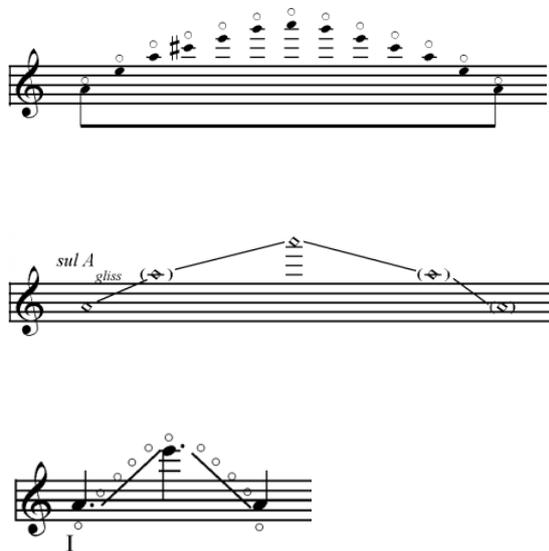
15th harmonic

16th harmonic

Applications**Glissandi**Natural Harmonics

Though the motion is the same in this technique as in a traditional glissando, a rapid succession of clearly heard harmonics is produced instead of one steadily descending or rising pitch. There are three conventional ways of notating this, as seen in the following excerpts:⁶⁹

Figure 7: Natural glissandi notation (Rolen)



To achieve a steady stream of ascending or descending harmonics, in pitch and in rhythm, the motion has to be faster between the larger intervals of harmonics (between, for example, the 2nd, 3rd, and 4th harmonics in the middle of the string) than in the extremities of the string. There must therefore be a deceleration (with the rising in pitch) and acceleration (while descending in pitch) of the hand motion to achieve a consistency or regularity in the sound. Whatever the effect desired, the main consideration in this technique is the range used.

⁶⁹ <http://www.moderncellotechniques.com/left-hand-techniques/harmonics/glissandi/>

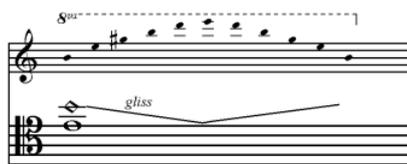
Exercise 5: Natural Harmonics Glissando

- a) Keeping the bow close to the bridge, glissando along the whole string from the nut to the end of the fingerboard, which will create a descending and ascending line (the 2nd harmonic, or middle, as the lowest point in the register). The left hand should start slowly, accelerating as it reaches the middle of the string, and then slowing down again as it gets further away from the middle.

Natural Harmonics over a Stopped Note

This develops expansion and contraction of the hand, useful in other techniques such as the double glissando (p. 109), but also in the general strengthening of the hand muscles. The exercise below is from Rolén's website.⁷⁰

Exercise 6: Natural Harmonics Glissando over a Stopped Note

Stopped Harmonics

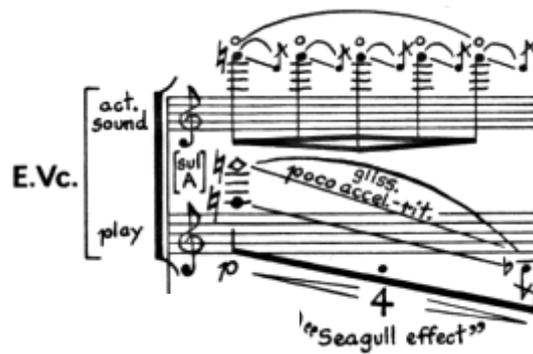
Constant glissando Maintaining the same musical interval between the fundamental (thumb/1st finger) and harmonic node ensures the resulting pitch remains relative to the position on the string. This requires control of hand spacing, which will contract as the hand moves towards the bridge.

Seagull effect Maintaining the same physical distance between the fundamental (most comfortable with the thumb in this case) and harmonic node produces different pitches of the harmonic series as the hand travels up or down the fingerboard. Rolén explains: 'The fixed finger spacing causes higher partials of lower fundamentals to be

⁷⁰ Ibid.

activated as the left-hand motion continues towards the scroll, which repeatedly restarts the glissando.⁷¹ Starting at the top of the fingerboard with the span of an octave produces the 'seagull' effect.

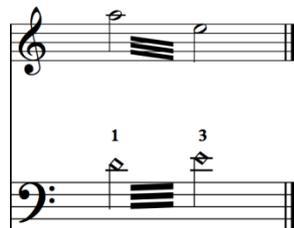
Figure 8: 'Seagull' effect - Crumb *Vox Balaenae*⁷²



Trills

Keyboard trill

The finger action is similar to a pianist playing a trill, each finger lifting to accommodate the note of the next finger. The two fingered harmonics are heard.

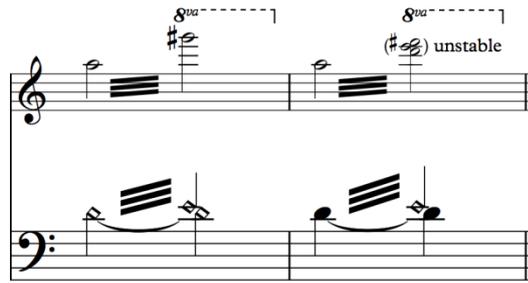


Traditional trill

As in a normally played trill on the cello, the finger playing the lower note is stationary. This produces a slightly unstable outcome of harmonics.

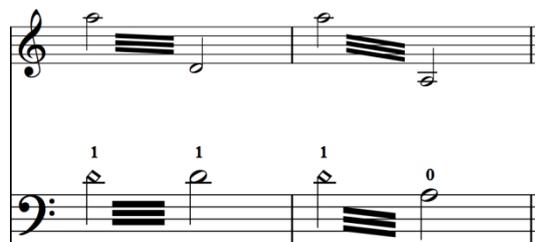
⁷¹ Ibid.

⁷² Crumb (1971).



One-finger trill

The finger action is similar to a pianist playing a single note rapidly. The harmonic and the stopped note are heard in alternation if the finger action is between touching the string and pressing it down to the fingerboard (also called a ‘pressure trill’). Alternatively, the harmonic and the open string are heard in alternation if the finger is lifted from the string.



Pizzicato Harmonics

The principles discussed on page 43 apply to all harmonics regardless of how the sound is produced (bowed, plucked or struck). We will, however, give special attention to pizzicato harmonics in this section, as the action is quite different to any other use of the left hand.

The finger on the harmonic node must be lifted as soon as the string is plucked. The success of this technique is contingent on the coordination between stopping finger and plectrum⁷³ – the difference between correctly and incorrectly timed finger action in pizzicato harmonics will drastically alter the resulting sound, much more so than for

⁷³ The term *plectrum* will be used here and for the remainder of the text to define any finger plucking the string and any external plectrum of any material, such as plastic, metal or glass. This is in keeping with Fallowfield’s terminology which aims to avoid any bias towards traditional playing technique.

arco and struck harmonics (for example in *col legno*). Correctly played, pizzicato harmonics will ring very clearly, and incorrectly, a dull thud will be produced with most of the nodes.

This excerpt from Fallowfield's website clarifies this effect: 'If the stopping finger is removed from a vibrating string, it interrupts the decay of a tone. Harmonics work in the opposite way: the decay duration of harmonics is maximised by removing the finger very soon after excitation.'⁷⁴ She goes on to explain that there is 'an optimum left-hand contact time at which decay duration and overtone content are maximal', which depends on the frequency of the harmonic. For higher harmonics, the finger must be lifted even sooner after the string is plucked than for lower harmonics.

A harp player producing harmonics with one single hand – the thumb on the node and the 3rd finger plucking – demonstrates how this action should be coordinated. This way of producing pizzicato harmonics is easily transposed to the cello and should be firstly explored on the 2nd harmonic node. This single-handed action can be useful for combined pizzicato (see '17. Independence of Hands', p. 178). The same action can then be performed using two hands, with any of the left-hand fingers on the node. Using both hands allows for greater resonance on higher nodes as the right hand can be placed closer to the bridge.

For pizzicato on open strings or with stopped notes, the fullest sound occurs if the string is plucked at the half-way point of the resonating portion of the string. For pizzicato harmonics, the most resonance occurs if the string is plucked near the nodes (near the bridge, the nut or the left-hand finger).

Longer string lengths (either side of the harmonic node) have more resonance. Pizzicato on a natural harmonic rings more clearly on the lower strings and on the nodes closer to the middle of the string. For stopped harmonics, the lower positions speak more easily, as do the stopped 5th harmonics rather than stopped 4ths.

⁷⁴ <http://www.cellomap.com/index/the-string/the-left-hand.html>

Pizzicato cannot be used for double-node harmonics (p. 51).

Pitch Bending / Pulled Harmonics

The pitch of a harmonic can be distorted upwards by pulling on the string sideways (towards the palm of the left hand). This technique can also be used to simulate vibrato. The pitch can be distorted considerably, based on the tension of the string; in general, the harmonics on the A-string can be pulled up by a semitone, while those on the C-string can be modified by a whole tone.

Fawcett Harmonics

This technique isolates harmonics with bow placement. A few references to this type of harmonic can be found both on the internet and in P & A Strange's book,⁷⁵ although both the origin of the technique and after whom it is named remain unclear.⁷⁶ The most information on Fawcett harmonics is to be found in an online comment posted by composer Philipp Blume.⁷⁷

All of the left-hand fingers are placed lightly on the string, as with a harmonic, to dampen the vibrations. The position of the 4th or uppermost finger will determine the fundamental and subsequent harmonic series. If the bow is drawn at the antinode of the targeted harmonic, it will be isolated. Drawing the bow half-way between the bridge and the left-hand finger will produce the fundamental; drawing the bow at the $\frac{3}{4}$ -point will produce the 2nd harmonic; the $\frac{5}{6}$ -point is the 3rd harmonic, the $\frac{7}{8}$ -point the 4th harmonic and so forth. Bow speed and pressure should be steady.

In his online post, Blume offers the following explanation:

The theory is that the bow, when drawn steadily at the given spot, can force an anti-node much as a resting finger can force a node. The reason this very delicate sound can emerge is because all other orderly behaviors of the string are suppressed: the light touch of the "fundamental" prevents the stopped string from vibrating clearly, while the additional fingers prevent ordinary "natural harmonic" behaviors.

⁷⁵ P & A Strange (2001), p. 134.

⁷⁶ In an email to P & A Strange (29 July 1999) which they reference (p. 288), Clemens Merkel specifies: 'Actually I never found out who R. Fawcett is (also never looked for it).'

⁷⁷ <http://www.moderncellotechniques.com/pressure-techniques-feedback/>

Notation

As Rolan explains on his website, while the notation for harmonics has not yet been standardized, several conventions are now widely accepted.⁷⁸ Here are ways of notating natural harmonics:

- a) A small circle above the note indicates a harmonic which has the same pitch as written on the staff. Notating the actual sounding pitch leaves the choice of node and string (when applicable) to the player.

Figure 9: Natural harmonics notation, concert pitch



- b) Diamond note-heads indicate finger placement on the string. These are sometimes left white regardless of the rhythm, and sometimes filled in. The sounding pitch may or may not be written above in a smaller font, in brackets or on a separate staff. The fundamental is also sometimes included.

Figure 10: Natural harmonics notation, fingered pitch



To show which node is being used, I suggest writing the fraction showing the position of the harmonic on the string either above or below the note, much as a fingering. The second harmonic is marked $\frac{1}{2}$, and the third harmonic is $\frac{1}{3}$ if it is in the lower half of the string and $\frac{2}{3}$ if it is in the upper half. The fourth harmonic is $\frac{1}{4}$ or $\frac{3}{4}$, and so on. The fundamental, or open string in this case, is the first harmonic and therefore '1', but this would easily cause confusion with the tradition of marking an open string as '0' and such a marking should be avoided.

⁷⁸ <http://www.moderncello.com/left-hand-techniques/harmonics/harmonics-overview/>

2. PIZZICATO

Pizzicato is our next subject in this journey, as it is a fundamental part of playing the cello. It is usually the first thing we learn to do as cellists and a very comfortable motion. Indeed, most string players begin their very first lessons with pizzicato, and continue to use the same technique throughout most of their lives without further developing the technique: pulling the string upwards with the thumb, or with the pad of the first or second finger while leaning the thumb against the fingerboard for stability. It is perhaps for the very reason that it is such a basic motion that generally, little thought is given to how pizzicato is produced, and to the nuances that can be achieved.

Berlioz' entry on pizzicato in his *Treatise on Instrumentation* is strangely still as applicable today as it was in 1844:

In the future the pizzicato will doubtless be used in even more original and attractive effects than here to fore. Violinists, not considering the pizzicato an integral part of violin technique, have given it hardly any serious attention...players will doubtless become familiar with [a wider range of] techniques in the course of time. Then composers will be able to take full advantage of them.⁷⁹

The following section begins to explore the richness of possibilities by first isolating the individual parameters involved in playing pizzicato, and then discussing the main applications as used by composers.

History

Gardner Read comments in his *Compendium* that pizzicato:

...was the first of a long historical succession of unorthodox techniques applied to bowed stringed instruments. From its first appearance in Claudio Monteverdi's *Il*

⁷⁹ Berlioz (R 1991), pp. 35-6. Cited in Fallowfield's introduction to her thesis. N.B. The closing remark of this passage is not present in the original French edition.

Combattimento di Tancredi e Clorinda of [1624],⁸⁰ however, up to the closing years of the nineteenth century, pizzicato was basically a one-dimensional device.⁸¹

Doubtless individual players develop their own way of varying the timbre of pizzicato though artistic sensitivity, but no exercise has ever been made to develop timbre or speed.

Walden notes that although pizzicato was overlooked by most 18th-century cello Methods, it was mentioned in 1752 by the flautist Quantz.⁸² The earliest example of pizzicato in solo cello literature is found in the 1st movement of French cellist Jean-Jacques Nochez' *Sonata III, Op. 1* (1765), where open strings have the indication *pincez*. It was the English cellist John Gunn who in 1789, formalized the practice of having beginners first pluck the notes rather than bow them.⁸³

Left-hand pizzicato, according to Read,⁸⁴ was developed in the 17th century,⁸⁵ allowing string players to pluck and bow the instrument simultaneously for displays of virtuosity.

It is only in 1828 that more extensive discussion and specific performance indications are provided for pizzicato; Baudiot advises using the fleshy part of the finger to achieve a round, soft sound.⁸⁶ He discusses single notes, double-stops (using thumb and index finger), block chords (one finger on each string pulling all the strings at once), strummed broken chords (with a back and forth movement using the fleshy inside part of the finger in a downwards motion on the strong part of the beat, and the nail on the upwards motion of the weak beat), alternating strings (placing the 3rd finger against the

⁸⁰ Read confuses the date of composition (1624) with that of *L'Orfeo* by the same composer (1607). Monteverdi's performance instruction to 'put down the bow and strike the string with two fingers' (trans. Nicola Moro) is not found in every edition, but is present in *Tutte le Opere di Claudio Monteverdi* (1927), Vol. 8.

⁸¹ Read (1993), p. 235.

⁸² Quantz (1752), p. 234. Cited in Walden (1998), p. 202.

⁸³ Gunn (1789), p. 10. Cited in Walden (1998), p. 202.

⁸⁴ Read (1993), p. 235.

⁸⁵ Left-hand pizzicato is also mentioned in Playford's *Musick's Recreation on the Viol Lyra-Way* (1652) for the *viola da gamba*. He uses the term 'Thump', which according to the website www.dolmetsch.com/defst2.htm is 'a short-lived, specifically English term for a "left-hand" pizzicato'.

⁸⁶ Baudiot (1828), p. 226. Cited in Walden (1998), p. 203.

outer side of the fingerboard, the player alternates thumb and index), and left-hand pizzicato (recommending the use of the 2nd or 3rd finger).⁸⁷ Dotzauer, Kummer, and Romberg's⁸⁸ Methods can serve as further study of 18th-century pizzicato technique.

Berlioz suggests in 1844 an alternative technique for violinists using the thumb and three fingers, supported by the 4th finger, approaching that used by guitarists, whereupon the notes could be played much faster. The brief exercise below is a transcription of Berlioz' *Traité*, originally intended for violin.⁸⁹

Exercise 7: Finger Dexterity in Pizzicato

a) The use of *p* (thumb), *i* (1st finger), *m* (2nd finger), and *a* (3rd finger) to label the fingers of the right hand is borrowed from the guitarist's terminology. See also p. 74.

Allegro non troppo
sempre pizz.

p i m a m i

Allegro

p i m i

Though this suggested new technique is intended for the violins and violas, surely the cellist of today could prove Berlioz' following remarks outdated:

The cello's pizzicato cannot be executed with much speed, and the method we have suggested to perfect the violin's pizzicato would not be appropriate to the cello

⁸⁷ Baudiot (1828), pp. 226-228. Cited in Walden (1998), pp. 203-205.

⁸⁸ Dotzauer (1824); Kummer (1839); Romberg (1840).

⁸⁹ Berlioz (1844), p. 28.

because of its size, the tension of the strings and their height above the table of the instrument.⁹⁰

The diversification of pizzicato was prompted by the Late-Romantic's search for colour, as Read points out.⁹¹

Theory & Practice

Sound is produced by a chain reaction, in which the first step will vary according to whether the string is bowed (see p. 76), struck (see p. 126), or plucked. Once the string is activated, an impulse is sent throughout the string, for which Fallowfield uses the term 'kink'. In pizzicato, the string is pulled by the plectrum and as it is released 'sends two kinks of vibration from the contact point, one in the direction of the bridge and the other in the direction of the nut'⁹² or stopped finger. The kinks are reflected between the two extremities of the string until the excitation energy runs out.

Parameters of Pizzicato

While many of the following parameters are basic considerations when playing with the bow, this section aims to encourage their exploration within pizzicato to broaden the control of this technique.

Note Length

This first parameter is actually controlled by the stopping finger, rather than the plectrum. For a given dynamic, the resonance of the note can be controlled by the stopping finger's pressure, the length of time it is on the string, and the speed at which it is lifted (slowly or quickly). This is an important aspect of pizzicato, as a note that rings on too long (especially a bass note or the open C-string) can affect the harmony. Left-hand pressure and placement is discussed later ('6. Stopping the String', p. 111).

⁹⁰ Idem., p. 32. Trans. V. Welbanks.

⁹¹ Read (1993), p. 235.

⁹² <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string.html>

Point of Contact

How close one should pluck to the bridge, or how far up on the fingerboard, is an important consideration for sound production in pizzicato. It is rare that any indication is given in the music other than for pizzicato *sul ponticello*. The sound is most resonant at the middle of the resonating portion of the string, as this is where the string oscillation has the possibility of greatest amplitude; while the strength of the overtones increases as the point of contact approaches the bridge, resonance decreases.

Theoretically, the same effect as pizzicato *sul ponticello* can be achieved by plucking near the nut or left-hand fingers; however in practical terms this is only the case in very quiet dynamics because the string is much closer to the fingerboard, which restricts the possible amplitude of the string and the angle at which the plectrum can approach the string.

The portion of string under the plectrum is the part of the string which is most displaced, which creates an antinode at this precise location. Harmonics that already have an antinode close to this point of contact will be very present in the sound. While the mid-point of a string has the potential for maximal physical displacement, plucking at this exact point will cut out or minimize every second harmonic in the sound, just as in does in bowing the string (see '3. Bowing the String: Point of Contact', p. 76). This is called **overtone exclusion**. In practical terms this means that if the plectrum's point of contact is between the 2nd and 3rd harmonic nodes, this will be the most overtone-rich sound possible. This is indeed the point at which cellists are taught to pluck the string for music of the common practice period, although without the accompanying theory.

Exercise 8: Overtone Exclusion

- a) Find the 2nd harmonic.
- b) Pluck the string exactly at this point, this 2nd harmonic should be completely absent from the sound but the fundamental should be very loud.
- c) Pluck the string at the mid-point between this harmonic node and the bridge (or, at the 3rd harmonic node), the 2nd harmonic should be very prominent in the sound as the 3rd harmonic is its antinode.

Fallowfield has an interesting schema to explain overtone exclusion, which presents a simplified model of a cello string up to the 13th partial. She precedes this with the explanation ‘excitation at any point affects every partial by either enabling or restricting its vibration. The pattern of the timbral response to each excitation point changes significantly throughout the string length.’⁹³

While there are many factors which influence overtone content (damping and string thickness can eliminate overtones; cello body response, room acoustics, and psychoacoustic⁹⁴ effects can add them), suffice to say here that overtone exclusion does not occur in a linear way – some points over the fingerboard are more overtone-rich than beyond the fingerboard. The cellist should develop sensitivity to which points on the string of their cello is richest, strongest, most piercing and so forth.

Direction

The direction in which the string is pulled affects the sonority; plucking the string either sideways in parallel to the fingerboard or up away from the fingerboard (or towards it for that matter) produces very different sounds. At its most extreme position, vertical pizzicato will produce a strident, percussive sound (see ‘Bartók / Snap Pizzicato’, p. 69), and horizontal pizzicato, will create a rounded sonority (see ‘Jazz / Double-Bass’, p. 70). Approaching the string from different angles also should be explored, particularly in chords.

Theoretically, the reason for such changes in colour would be due to a difference in how the bridge reacts, depending on whether the string is plucked upwards or sideways. This would explain the difference in attack, volume and decay. Fallowfield suggests that horizontal pizzicato would maximise volume and initial attack while vertical pizzicato would maximise decay duration, each at the expense of the other. Whether created by plucking or bowing, horizontal vibrations in the string cause the bridge to also oscillate from side to side (towards the f-holes), which is where a bridge is most efficient. If the bridge oscillates backwards and forwards with vertical pizzicato

⁹³ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

⁹⁴ ‘Psychoacoustic’ refers to the perception of sound.

(toward and away from the tailpiece), the excitation energy dissipates more slowly, thus increasing the duration of decay. She concludes with: ‘If this proposition is true, a mixed output is heard for excitation angles between these two extremes.’⁹⁵

Plectrum: Contact Area / Size

The amount of contact between the plectrum and the string also affects the sonority. More or less flesh of the finger can be used by slanting the right-hand finger to varying degrees of angle with the string. In this way, for example, the entire outer side of the first two phalanges of the first finger or of the first phalange of the thumb can be in contact with the string.

Figure 11: Finger



For a very consistent sound in rapid passages, a ‘finger-plectrum’ can be created with the thumb, reducing the size of the surface area used. This ensures that the same amount of contact is used for every note. Whether this can be used with the bow may depend on finger length; thumb and first or second finger can be used.

The smaller the plectrum, the more overtones will be in the sound, thus creating a brighter sound. This is because the portion of string under the plectrum doesn’t vibrate – the wider the plectrum, the more nodal points are prevented from vibrating, and therefore the less overtones are present in the sound.⁹⁶ The larger the plectrum, the longer the contact time is with the string.

To simulate a very wide plectrum, two plectra can be used. The distance formed between the outer edges of two plectra is equivalent to the outer edges of one single plectrum. Using two plectra doubles the volume. In practice, the resulting timbre of using two plectra can be unpredictable. Fallowfield specifies: ‘However, a clear change

⁹⁵ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

⁹⁶ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/with-what.html>

in timbre and volume is heard between plectra at fixed positions exciting the string in the same direction compared with plectra exciting the string in opposite directions.⁹⁷

Exercise 9: Plectrum Width

Try these possible combinations, at varying distances:

- a) R.H. 1st and 2nd fingers, in the same direction
- b) R.H. thumb and 3rd finger, in the opposite direction
- c) L.H. 3rd finger and R.H. 1st finger, in the same direction
- d) L.H. 3rd finger and R.H. 1st finger, in the opposite direction

Plectrum: Material

Plectrum material equates to density; different parts of the finger will yield different sounds. A more rounded sound will be obtained from using the fleshy pad of the finger while the tip of the finger or thumb will produce a more precise and focused sound; the sound made by the nail is even more overtone-rich and piercing. Plectra of other materials, such as metal, wood or plastic, will each also have a different sound. The denser the plectrum, the more overtones will be present, creating a brighter sound. This is because the angles at which the string vibrates are more pronounced, involving more overtones. The denser the plectrum, the shorter is the contact time with the string, thus damping is minimized.

Velocity

A sound will be more overtone-rich and louder if the string is plucked with greater speed. This can be modified in two ways:

Distance The distance from which the action is started can help the movement gain speed. This is very much like the subtlety of articulation achieved by a pianist, slowly depressing the key so

⁹⁷ Ibid.

that the hammer is close to the string when it hits, or starting well above the key and depressing it with the full weight of the arm to achieve a sharp front to the note. Flicking the string with the nail for example (high speed) will produce a clearly defined sound.

Preparation Pulling the string into position and then releasing quickly produces greater amplitude in the string movement. This is especially effective in Bartók pizzicato (see p. 69), but of limited use in rapid passages.

Force

The strength with which the string is activated: a small movement of the finger versus a movement made with the weight of the entire arm will affect the sound. A sound will be more overtone-rich and louder if the string is plucked with greater force.

Applications

While the aforementioned parameters belong comfortably to the realm of traditional pizzicato, an extreme variance of just one of these results in a considerably different effect. Several techniques resulting from such modifications are discussed here. As many pizzicato techniques as possible should be developed both with the bow in hand and without. While holding the bow during pizzicato can prove to be restrictive in the number of fingers used, the added weight of the bow enables a more resonant sound.

To develop the existing repertory of pizzicato, inspiration can also be sought by observing and listening to harpists, jazz bass players, classical and flamenco guitarists, banjo players, folk musicians and the virtuoso guitarists of rock music. Plucked string instruments have developed an extensive vocabulary to complement the array of techniques which are integral to their performance, some of which are used below.

Articulation

Articulation in pizzicato is controlled with the length of contact time between left hand and string. With short contact time, pizzicato can be *staccato*, for example, or qualified

of ‘dry’ or ‘secco’. A long pizzicato may be indicated by a tie or be accompanied by the indication to ‘let vibrate’ (‘l.v.’).

Bartók / Snap Pizzicato

To achieve this technique, the string is pulled directly upwards (away from the fingerboard), and released so that it hits the fingerboard and produces a percussive sound of metal against wood. The string should be plucked above the fingerboard, where there is the least tension – this technique will not work close to the bridge. The string can be held away from the fingerboard between the thumb and first finger, for greater reliability. One must be careful that the string does not slip from the finger’s hold and be released at the wrong moment, especially as this technique has a very piercing sonority, often used for its rhythmic characteristic. It is a common misconception that Bartók pizzicato can only be achieved in a loud dynamic however; it should be rehearsed in different dynamics.

The first use of this technique is by Ignaz Biber in *Battalia à 10, C. 61* (1673), where the bass instruments imitate the sound of musket fire. The composer instructs: ‘The battle must not be played with the bow, and the string must be snapped like a cannon with the right hand. Vigorously!’

The snap pizzicato was only next notated in 1905 in the *Scherzo* of Mahler’s *Symphony No. 7*. The string players are instructed in a footnote to a pizzicato written in a *fffff* dynamic to ‘pluck so hard that the strings hit the wood’.

Figure 12: Early use of snap pizzicato - Mahler *Symphony No. 7*



The snap pizzicato is now most commonly called the Bartók pizzicato in honour of the composer who used it so effectively in many of his works, beginning with his *Divertimento for String Orchestra*. Arditti suggests that Bartók was influenced by the

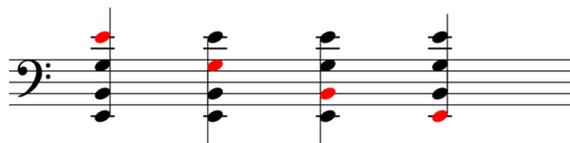
playing techniques of the *ütőgardon* ('ütő' meaning 'hit'), a Hungarian folk instrument which resembles a rudimentary cello.⁹⁸ It is played as a drum, with a combination of a wooden stick beating the strings and the left-hand pulling the string so that it slaps against the fingerboard, providing a rhythmic drone to ensemble music. This technique was also used from the earliest days of jazz, and is known as 'slap bass'.

Multi-Stop Pizzicato

This technique will deal with all strings plucked simultaneously, rather than strummed. Various combinations of fingers used in double-, triple- and quadruple-stopped pizzicato can be rehearsed. As do pianists when playing chords, balance between the notes of the chords must be sought. This can be achieved through experimenting with various angles of the right elbow, to achieve greater strength on a given note. The exercise below is adapted from P & A Strange.⁹⁹

Exercise 10: Voicing in Pizzicato Chords

- a) Play all four notes simultaneously, using the thumb and different fingers for each note. Begin by making each red note a Bartók pizzicato, taking care that the other notes are not.
- b) Then make the voicing more subtle by eliminating the snap and simply making the red notes louder than the others.



Jazz / Double-Bass Pizzicato

A cello pizzicato can sound surprisingly close to that of a double-bass. The string is pulled sideways (horizontally to the fingerboard), and the follow-through of the action leads the right-hand finger to rest on the adjacent string. Either the finger is turned almost parallel to the string or two fingers are used side-by-side, to increase surface

⁹⁸ Arditti & Platz (2013), p. 43.

⁹⁹ P & A Strange (2001), p. 63.

area. Guitarists use a similar technique, called *apoyando*, introduced by Francisco Tárrega (1852-1909).

Nail Pizzicato

The nail pizzicato was first notated by Béla Bartók in 1934, in his *String Quartet No. 5*.¹⁰⁰ In the second movement of the piece, the second violin is required to pluck the string with the fingernail, which produces much the same sound as a metal plectrum. The string can also be flicked with the fingernail.

Pizzicato-Tremolo

There are several ways to produce a rapid sequence of pizzicato notes. The maximum speed one can achieve using traditional methods of pizzicato will differ from one person to the next, but nevertheless this is generally quite limited as traditional pizzicato creates a circular motion when repeated. Here are three techniques which use a back-and-forth (rather than circular) motion:

- a) Alternating fingers (right hand): Two to five fingers of the same hand alternate cyclically. This is a basic technique for guitarists, called *Picado* in Flamenco music.
- b) Alternating fingers (different hands): Alternating fingers of the right and left hand is generally faster than traditional pizzicato but speed is still quite limited because of the difficulty in coordinating the alternation between both hands. The resulting range of timbre is greater however, because of the possibility for each hand to be on different points of contact.
- c) One finger: Pizzicato-tremolo is executed with either the right-hand thumb or first finger. If using the thumb, the action should come from the wrist; if using the first finger, the action should come from the knuckle-joint, the first finger fully extended and quite rigid. The cellist might find it more comfortable to also extend the second finger to provide strength to the first, using both fingers as a unit. In all of these cases, the thumb or finger should be as parallel as possible to the string so that the flesh rather than the nail comes in contact with the string. For the thumb, this means angling the hand upwards, and for the first finger, downwards. Flamenco guitarists use this back and forth motion with the thumb, *alzapúa*, on one or more strings.

¹⁰⁰ Bartók's *Music for Strings, Percussion and Celesta* (1936) is often cited as the first instance of notated nail pizzicato.

Alla Chitarra / Quasi Chitarra

As would a guitarist, this technique is produced by using a combination of thumb to strum the string from the lowest to the highest and first finger from the highest to the lowest. This is used for chords.

The Flamenco guitarist's idiomatic *rasgueado* can also be applied to the cello, although only three strings sound, and only when this strumming technique is done high on the fingerboard where the curve of the strings and fingerboard is minimal. While the thumb is leaning on the side of the fingerboard, each finger is flicked towards the string from the palm of the hand in one motion, and in this order 4-3-2-1. The return motion of all four fingers back into the palm of the hand also makes the chord sound.

Touch Pizzicato

Push the string down with the finger, then let go: the release of the string produces a soft sound, and is more effective if the finger is on the rosined part of the string, just over the fingerboard. This technique is useful for very fast but quiet pizzicato.

Left-hand Pizzicato

This technique, as discussed previously in the context of history (p. 60), is anchored in the tradition of the virtuoso. Here we will consider the relationship of left-hand pizzicato to point of contact. While an open string can be plucked along any point, if the left-hand is also stopping the string, the point of contact of the pizzicato will be quite close to the string's extremity. This is effectively a *sul ponticello* pizzicato (see p. 64). More distance can be achieved by stopping the note with the thumb and plucking the string with the third finger.¹⁰¹

Sub-Ponticello Pizzicato & Pegbox Pizzicato

It is useful to know what pitches are produced on the other side of the bridge of one's instrument (see 'Sub-Ponticello / Oltre Ponticello', p. 84); the same applies for the length of string between the peg and the nut, located inside the pegbox. Using these

¹⁰¹ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

short segments of string has the advantage of liberating either the left or right hand, and eliminates the difficulty of finding those particular pitches in a very high position.

Sub-ponticello pizzicato produces the same sound quality as its equivalent stopped pitch on the fingerboard, as string length and contact with the bridge is equal in both cases. Because there is no fingerboard, Fallowfield leans her left or right thumb on the side or upper face of the bridge so that the finger(s) doing the pizzicato action is stable. Because all four lengths of string *sub-ponticello* are equal, the pitches mainly correspond to string thickness and are therefore descending in pitch from the A to the C string.

The sound quality of pegbox pizzicato is slightly different than its equivalent stopped pitch on the fingerboard because of the distance between the vibrating string and the bridge. The middle two strings are longer in length than the outer two, therefore pitch is not only contingent on string thickness. Fallowfield recommends using the nail or other dense plectrum for a more overtone-rich sound.¹⁰²

Other Plectra

When looking to vary the timbre by using a plectrum or pick, imagination is the only limit of what can be used on the instrument. Plucked string instruments such as guitar and banjo have a variety of accessories that are easily available and can be used on the cello.

Finger and thumb picks come in a variety of sizes, while plectra can be made of materials as varied as synthetic polymers (nylon, various plastics), rubber, felt, tortoiseshell, wood, metal, glass, tagua and stone.¹⁰³ Arditti recommends using a soft to medium plectrum as these have better contact with the strings.¹⁰⁴

Many instruments from around the world use a plectrum, the techniques of which could yield interesting results on the cello with further research.

¹⁰² <http://www.cellomap.com/index/the-string/bridge-tailpiece-and-in-the-peg-box.html>.

¹⁰³ http://en.wikipedia.org/wiki/Guitar_pick

¹⁰⁴ Arditti & Platz (2001), p. 42.

Notation

Figure 13: Pizzicato notation

Term	Description	Notation / Abbreviation
Let vibrate (English) Laissez vibrer (French) Lasciare vibrare (Italian) Klingen lassen (German)	Long	<i>l.v.</i> <i>Klingen lassen</i>
Pizzicato staccato	Short	<i>pizz.</i> 
Pizzicato secco		<i>Pizzicato secco</i>
Bartók pizzicato	Percussive	<i>pizz.</i> 
Nail pizzicato ¹⁰⁵	Metallic	<i>pizz.</i> 
Pizzicato tremolo	Imitating a mandolin	<i>pizz.</i> 

¹⁰⁵ This notation was first used by Bartók in 1934 in his *String Quartet No. 5*.

Left-hand pizzicato	Normal	<p><i>pizz.</i> +</p> 
Sub-ponticello / Pegbox	Dry	See Section '3. Bowing the String: Point of Contact': Notation on p. 89.

The different fingers of the hand could be notated following the system established by guitarists, which has the advantage that none of these letters are used in notation for bowed string instruments: thumb (p), 1st finger (i), 2nd finger (m), 3rd finger (a), 4th finger (c).¹⁰⁶

¹⁰⁶ From the French names for each of the five digits: *p*ouce, *i*ndex, *m*ajeur, *a*nulaire, *a*uriculaire.

3. BOWING THE STRING: POINT OF CONTACT¹⁰⁷

The following two sections explore extreme variations of bow control. However, let us first define *ordinario* (also referred to as *normale* or *naturale*) as the default playing position. In other words, this is the range of bow positions on the string which yield a rich overtone content nevertheless subordinate to the fundamental...a beginner will be taught that this is roughly halfway between the edge of the fingerboard and the bridge, whereas an experienced player will have a heightened awareness of positioning and its effects. The *ordinario* sound is contingent on balancing three elements of bow control: point of contact, bow speed and bow pressure. The range of subtlety and expression within these parameters and within the *ordinario* sound we are trying to define are infinite, and are the basis of an extremely rich 300-year-old performance practice tradition.

A brief explanation of sound production is needed first, in order to better understand the nature of the extended techniques which stem from the traditional use of the bow. When the bow is drawn across the string, a cycle known as the ‘stick-slip’ mechanism occurs. This begins with the string ‘sticking’ to the bow and moving in the same direction, ‘sending a kink of vibration to the bridge, where it is reflected’.¹⁰⁸ The displaced string increases in tension, and as the kink, or impulse, of vibration returns from the bridge to the bow, ‘the string breaks free from the bow and ‘slips’ back to its rest position’.¹⁰⁹ This sends another impulse to the bridge, and when this comes back to the bowing point, the bow picks up the string and the cycle continues.

There is a certain range in which the relationship between the three factors of bow control can be modified before the sound quality changes to something essentially different. Any point of contact between the bow and the string which gives a noticeably different colour will be defined as an **alternate point of contact**. Any extreme use of bow speed and pressure will be discussed separately in the following section (p. 93).

¹⁰⁷ Alternate points of contact between the bow and other resonating parts of the instrument are discussed on page 87, in section ‘11. Bowing the Instrument’.

¹⁰⁸ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string.html>

¹⁰⁹ Ibid.

The prolonged use, rapid alternation and extreme locations of alternate points of contact in modern music now require from the player an in-depth understanding of sound production and bowing mechanism.

Points of contact are divided into general regions of the string and defined below as Fixed Points of Contact. Techniques in which several of these regions are used are discussed in the following category, Modifying Points of Contact. Unlike the parameters of pizzicato, each component of Fixed Points of Contact is a technique in its own right. Each part of the following two sections should first be practised on open strings and then with stopped notes.

History

Traditionally, alternate points of contact are divided into two areas: *sul tasto* (over the fingerboard) and *sul ponticello* (near or on the bridge). Sylvestro di Ganassi first described the differences of character produced by changing the point of contact on the *viola da gamba* in his *Regola Rubertina* (1542):

‘It is true that you can play occasionally close to the bridge or to the fingerboard, when you wish to produce a rough sound appropriate to the subject, or should you want the harmonies to conform to a sorrowful subject. Indeed, sadness leads to playing closer to the fingerboard and cruel sentiments are best rendered by playing near the bridge.’¹¹⁰

Baroque composers continued to use the broader range of colours available through alternate points of contact, and in the 18th century *sul ponticello*, or *alla gamba* (imitating the sound of the then more popular *viola da gamba*), were used by Austro-German performers as a matter of course to colour solo passages, and by the French in

¹¹⁰ Ganassi (1542/R 2004), p. 27. Trans. to French Jean-Philippe Navarre; trans. to English V. Welbanks.

rapid accompaniment figures.¹¹¹ In fact the term *alla gamba* survived into the turn of the 19th century, to Romberg's day, as can be seen in his second concerto.¹¹²

There is also some supporting pedagogical material for cellists surrounding this performance practice: Pierre Baillot provides an exercise for accompaniment figures in crotchets and double-crotchets in his *Méthode*¹¹³ written in 1804, Dotzauer mentions *sul ponticello* in the first page of his *Violonzell-Schule*,¹¹⁴ Romberg writes in his *Violoncelle-Schule*¹¹⁵ of 1840 that *sul ponticello / alla gamba* is especially effective in variations and pieces of 'popular genre', and Berlioz mentions points of contact in his *Traité*: 'The metallic and slightly bitter sounds obtained by the bow when it is closer to the bridge vary greatly from the soft, distant sounds which are borne of the bow when it is on the fingerboard.'¹¹⁶

Theory & Practice

Despite the longstanding tradition of using alternate points of contact in string playing, *sul tasto* and *sul ponticello* have always been executed with the same bowing mechanism as any other point of contact, but simply 'closer to the bridge' or 'over the fingerboard'. Neither has ever been considered a technique whose mechanism needs to be rehearsed.¹¹⁷

¹¹¹ Stowell (1999), p. 190.

¹¹² Romberg (c. 1799), bb. 159-166 and 170-179. The interested cellist should look at the Allegretto of Kraft's Duet I, Op. 3 for violin and cello (bb. 240-258), cited in Walden (1998), p. 209. Probably published in 1792, the work combines *sul ponticello* in the cello part with extreme dynamics of *pp* and *ff*, in a French-style accompaniment of rapid notes.

¹¹³ Baillot (1805), p. 135. Cited in Walden (1998), p. 209.

¹¹⁴ Dotzauer (1824), p. 1. Cited in Walden (1998), p. 276.

¹¹⁵ Romberg (1840), p. 97.

¹¹⁶ Berlioz (1844), p. 20. Trans. V. Welbanks.

¹¹⁷ This is perhaps a result of the terminology itself, which refers to the means of execution rather than the end product desired by the composer.

Two facets of bow control will be developed for use in modern music:

- a) Fixed points of contact: obtaining a different sound than is usually employed with *ordinario* playing by changing the overtone content in a sound.
- b) Modifying points of contact: moving rapidly from one point of contact to another.

It should be observed that all of the techniques below are highly dependent on bow speed and bow pressure – elements which are difficult to quantify and relate. Bow speed and pressure for the techniques below should initially be similar to those used in *ordinario*, as it is the imbalance in the relationship between bow speed, pressure, and point of contact which causes the greatest change in colour. Once this relationship is understood, bow speed can be altered while the relative proportions of pressure and point of contact are maintained; for example, one could try creating a *sul ponticello* sound as close to the fingerboard as possible...

Applications

Fixed Points of Contact

Ordinario is a relatively precise indication; inasmuch as one aims to produce a rich sound, most cellists will naturally find the point on the string where a rich overtone content is still subordinate to the fundamental. *Sul tasto* and *sul ponticello* are more ambiguous terms, leaving the choice of overtone content to the performer. Awareness of the possibilities and the capability of fully exploiting them enlarge the palette and therefore the artistry of the player.

Sul Tasto

As the term *sul tasto* somewhat erroneously implies if taken literally, bowing ‘over the fingerboard’ per se does not considerably alter the sound. The *sul tasto* sound is achieved by bowing on a harmonic node, thus cutting a portion of the harmonic spectrum from the sound to produce a different colour, which is traditionally described as ‘hollow’, ‘dull’ or ‘distant’. This is called overtone exclusion (see p. 64).

Theoretically, the most extreme example of this is bowing on the node of the 2nd harmonic (or $\frac{1}{2}$ -point), which should exclude every second harmonic (nos. 2, 4, 6, 8, 10, 12, 14, 16, etc.), therefore removing half of the potential overtones from the sound.¹¹⁸ Similarly, bowing at either node of the 3rd harmonic (the $\frac{1}{4}$ - or $\frac{3}{4}$ -point) excludes one quarter of the potential overtones (nos. 4, 8, 12, 16, etc.), bowing at one of the 4th harmonic nodes ($\frac{1}{5}$ -, $\frac{2}{5}$ -, $\frac{3}{5}$ -, or $\frac{4}{5}$ -point) excludes one fifth of the potential overtones (nos. 5, 10, 15, etc.), and so on. Several other acoustic factors come into consideration, but one of them – the point of contact – can be controlled by the player through bow placement and direction, and the amount of bow hair used.

Firstly, to ensure a consistent *sul tasto* sound, the bow must stay on the harmonic node throughout; the arm must therefore compensate in its movement to ensure a steady point of contact. Bow movement above the fingerboard is often uncomfortable as the natural tendency is to bend the elbow so that the arm becomes shorter and therefore higher up on the string. This adjustment redesigns the necessary arm movement, whereas a more familiar motion can be maintained by pulling the entire arm back, letting the shoulder relax while turning the upper body slightly towards the player's right. Secondly, the bow should be turned on its side to minimize the surface area of the bow hair in contact with the string.¹¹⁹ This is to ensure that the point of contact is more precise, ideally only touching one harmonic node. Harmonic nodes are spaced more closely at the extremities of the string – if all of the surface area of the bow hair is used in *sul tasto* sound production and/or the point of contact fluctuates, more than one node will be affected by the bow movement, thus creating variations in the sound. Hence, bow speed and contact must be maintained as in *ordinario* playing.

When playing *sul tasto*, the bow is most frequently placed near the $\frac{2}{3}$ -, $\frac{3}{4}$ -, or $\frac{4}{5}$ -point harmonics. For the open string, the $\frac{3}{4}$ -point harmonic presents the ideal position: it

¹¹⁸ For a more detailed explanation of the theory and use of nodes, please refer to: Fallowfield (2010), pp. 69-75.

¹¹⁹ For side hair, the bow is usually rotated so that the stick of the bow is further from the bridge. It is recommended that the rotation be in the other direction for *sul tasto* playing on the A-string, as this increases the distance between the stick and the upper corner of the bout, allowing greater freedom in bow placement.

produces a sufficiently different timbre (as opposed to the $\frac{4}{5}$ -point harmonic which is only slightly varied in colour from *ordinario* playing) but remains physically possible to play (as opposed to the $\frac{2}{3}$ -point harmonic on the open A-string, where the edge of the cello's body and the D-string prevent the bow from touching the A-string). To maintain the same point of contact relative to string length as the left hand moves up the fingerboard (thus making the string shorter), the bow must move closer to the bridge. This has the practical advantage of making the A-string accessible to the bow. This relationship of overtone reduction to bow placement relative to the string length is most evident on very short string lengths, where the stopped note is near the end of the fingerboard. In this scenario, should the cellist take the *sul tasto* indication literally, thus bowing next to the stopped note, an overtone-rich sound would be produced – quite the opposite effect from the intended indication!

Bow speed and bow pressure are both factors which greatly influence the colour of the sound. *Sul tasto* should be developed with an awareness of this once a firm understanding of node placement is gained, and practised with varying degrees of speed and pressure.

These above-mentioned notions are in fact very difficult to achieve in a precise way because of the constant variation needed in the point of contact, as the left hand moves to various ranges of the cello thus increasing and decreasing string length. What is important, however, is the knowledge of sound production mechanisms for *sul tasto*, so that cellists can use their own judgement and artistry to produce the desired colour.

It is important to be familiar with the point at which the diminishing height of the strings and the curvature of the bridge place the strings either below or at the same height as the neighbouring strings. This point can either prevent the bow from playing any higher up the string without touching another, or enable the player to sound three strings simultaneously with either added pressure of the bow or a with a stopped note on the middle string. This is an added consideration with the increasing demand for extreme versions of *sul tasto*, which are often more motivated by a desire for theatrics than an understanding of acoustic principles.

In order to produce a consistent *sul tasto* sound over string changes, bow placement must compensate for the fact that the number of possible overtones diminishes as:

- a) the thickness of the string increases (lower strings as well as higher stopping positions)
- b) the tension of the string decreases

These factors are explained in greater details below but effectively, the *sul tasto* sound is more pronounced on the lower strings.

Sul Ponticello

Similarly to the term *sul tasto*, the indication of *sul ponticello* can be misleading if the literal instruction of playing ‘on the bridge’ is followed arbitrarily or interpreted simply as ‘near the bridge’. While there is a wide range of results for the technique, this term implies a sound in which the overtones are anywhere from very present to dominant, to completely overtaking the fundamental.

Sul ponticello is more comfortable to bow than *sul tasto*, and presents less of a choice in terms of choosing and maintaining a point of contact. The closer the bow is placed to the bridge, the more present the overtones become in relation to the fundamental. A sound which is traditionally qualified as ‘metallic’ can be achieved by placing the bow a few millimetres from the bridge, while a most extreme placement of *sul ponticello*, with part of the bow hair on the bridge itself, will produce a sound with very little or no fundamental pitch consisting only of the pitch’s overtones. This placement, basically on the node of the fundamental (first harmonic), suppresses the fundamental in the same way as was described above for *sul tasto* bowing on the second, third, fourth or fifth harmonic nodes. This produces a different spectrum of overtones, as the second harmonic then becomes the fundamental (one octave higher). Fallowfield names this effect **overtone takeover**, explored further in the context of ‘Filtered Pitch’ (p. 103).

As in *sul tasto*, the point of contact is relative to string length; the relationship of the bow’s position to the overall string length can be expressed as a ratio. If one is to

maintain the ratio (in other words, the timbre), the point of contact must be nearer to the extremity of the string as the string gets shorter. Bow speed and pressure are considerable influences as well. With enough pressure, and *ordinario* sound can be achieved at the bridge but in a very loud dynamic, and an overtone-rich sound with little or no fundamental can be achieved near the fingerboard with enough speed and little bow pressure. Theoretically, a *sul ponticello* sound can be achieved by placing the bow at the other extremity of the string, near the nut or as closely as possible to the left-hand finger, though the shape of the cello often makes this impracticable.

In addition to these factors, in order to produce a consistent *sul ponticello* sound over string changes, the bow must move closer to the bridge as the thickness of the strings increases and the tension of the strings decreases. Concerning thickness, Fallowfield writes: ‘...increased string width in relation to string length limits higher partials. This is because the string can only vibrate at partials with wavelength greater than string width.’¹²⁰ The possible number of overtones is limited by string width therefore, and will remain constant regardless of string length. In effect, notes in higher positions will have fewer overtones; there will also be less possible colour range in the *sul ponticello* sound. Fallowfield comments that strings with higher tension will enable more pronounced angles in the vibration patterns of the string, hence the upper strings will have more overtone content than the lower strings.

As in *sul tasto*, tilting the bow to achieve a more precise point of contact can help by reducing the number of overtones blocked by the point of contact. Initially, a light and fast bow can also help in feeling the necessary imbalance between speed, weight and point of contact.

Sul ponticello is essentially an underpressure technique, and is related to ‘Filtered Pitch’ (see p. 103).

¹²⁰ Fallowfield (2010), p. 75. For a more detailed explanation of *sul ponticello*, please refer to pp. 75-76.

Sub-Ponticello / Oltre Ponticello

The notions of sound production described in the previous entries on *sul tasto* and *sul ponticello* can be applied to playing on the area of the string between the bridge and the tailpiece (for playing on the thread winding, see p. 148 in section ‘11. Bowing the Instrument’). This very short string segment described as ‘below the bridge’ (*sub-ponticello*) or ‘over the bridge’ (*oltre ponticello*) is subject to the same acoustic laws that apply to the string on the ‘normal’ side of the bridge; the same mechanisms as discussed above relating to overtone content apply here. However, because of the restricted string length, hence limited overtone content, relatively less tone variation can be found. A strong clear *ordinario* sound can be achieved by bowing between the bridge edge and the winding, using enough bow pressure. This section should be revised after the next section is studied (‘4. Bowing the String: Speed & Pressure’, p. 93). The spectrum of noise produced by the bow behind the bridge is much stronger than on the ‘normal’ side of the bridge.

The tuning of this portion of string will vary greatly between instruments, as it is dependent on string tension, itself dependent on the distance between the bridge and the tailpiece, and string thickness and density.

Though more of the composer’s concern than that of the performer, it is interesting to note P & A Strange’s observation that *sub-ponticello* allows for indeterminate pitch to be produced, and in larger ensemble settings it allows for indeterminate clusters, with the option of the performer being ‘able to respond quickly, without engaging in decision making’.¹²¹

Pizzicato *sub-ponticello* is discussed on page 72; stopping *sub-ponticello* is discussed on page 115.

Non-Resonating Sul Tasto

Bowing on the length of string between the nut and left-hand finger produces a very different sound quality, as the vibrations of the string are transmitted to the body of the

¹²¹ P & A Strange (2001), p. 9.

cello through the nut rather than the bridge. The sound has less overtone content, is quieter and faster to decay.¹²² Fallowfield explains:

...relatively more energy is lost through damping in the air or non-amplifying parts of the body (e.g., the fingerboard). In general, energy that is lost through damping inhibits the amplitude and decay-duration of higher partials more than those of lower partials.¹²³

Obtaining a specific fingered pitch is quite difficult as fingerings will occur in mirror image to traditional fingering. Intonation is a further challenge, as the player will have to play one finger-width closer to the bridge to get accurate pitch for a given note – the portion of the string vibrating is from the finger edge to the nut. The geometry of the cello's body and the curvature of the bridge is once more a largely limiting factor in this technique, which is in effect most easily rendered on the C-string or on multiple strings simultaneously.

Alex Targowski comments on his blog that he obtained a clearer sound by placing his bow near the nut, and that 'using quite a fair amount of bow pressure helped to create a pleasant tone'.¹²⁴ This is of course easier for a violinist, and most cellists would have to lean back or lower the end-pin for the bow to reach this part of the instrument. Bowing is made more comfortable by using a *viola da gamba* grip (underhand rather than overhand) as suggested by George Crumb in *Black Angels*.

Playing a non-resonating *sul tasto* while the left-hand finger is on a harmonic node eliminates the problems of accurate pitching and intonation, as the string naturally divides into equal portions. The tone colour remains different because of the change in relationship between bow, string and bridge.

¹²² <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

¹²³ Ibid.

¹²⁴ <http://extendedtechniques.blogspot.co.uk/2012/05/bowing-behind-lh-fingers.html>

Under the Strings

Bowing under the strings creates a different timbre because the relationship between the string and the bridge is altered. The A- and C-strings can easily sound simultaneously, whereas bowing only one of these strings is more challenging. The D- and G- strings cannot be played in this way. This is discussed further in the context of the double-bow (p. 155). The bow should be held as ‘normally’ as possible, using the entire arm (rather than wrist or forearm) to apply upwards pressure to the string.

Pegbox

Bowing on the part of the string between the nut and the pegbox is comparable to *oltre ponticello*. Similarly, the pitch obtained here is contingent on the distance between the nut and the pegs, and string tension, thickness and density. It isn’t necessarily possible on all instruments for the bow to access each of the four strings; this will depend on the angle of the join between the pegbox and the neck.

Modifying Points of Contact

Alternation between various points of contact requires control of the bow movement on two distinct planes – an amplified vertical movement is additional to the usual lateral movement of the bow – rendering the action of moving from one point of contact to the other a technique in itself.

Arco: Sul Tasto – Ordinario – Sul Ponticello

There are two ways of controlling these transitions in regular *arco* playing. Each has its advantages and will be more suited to a certain physique.

Rolen and the author of this thesis angle the heel of the bow towards the next point of contact on the string. Rolén suggests angling either the frog or the tip of the bow level with the point of contact being transitioned to. For rapid transitions he suggests a steeper angle to the bow, and for a slower transition, very little angle.¹²⁵

¹²⁵ <http://www.moderncellotechniques.com/bow-techniques/ponticello-tasto/bow-angles/>

Heyde always maintains a 90-degree angle between the bow and the string, choosing to change point of contact by opening and closing his right elbow. This means that the bow hold and bow motion can stay constant and familiar. This method is not necessarily possible for *ponticello* bow placement for players with shorter arms. It also is much more effective for players who use low elbow placement for arm weight rather than a higher elbow for leverage. The angle of the instrument (end-pin length) will also affect this. Heyde uses this movement for slower circular bowing, irisings, vertical bowing and tremolo.¹²⁶

Circular Bowing

A regular alternation between two points of contact is called circular bowing, which can be done at any speed and is in effect a continuous variation of both vertical and horizontal movement with the bow. Slower circular bowing involves more bow, and uses the cellist's normal arm mechanism. Faster circular bowing uses a very restricted amount of bow and is controlled by the fingers and wrist. The movement can be done in a clockwise (down-bow towards the bridge, up-bow towards the fingerboard) or anticlockwise direction. The faster the movement is – the faster the transition between *ponticello* and *tasto* – the more the noise content becomes dominant in the sound (see *spazzolato*, below).

Because the 'extremities' of the 'circle' created by the bow's trajectory have a distinct sound quality, a rhythmic period is created. The smaller or faster the 'circle' is, the faster the rhythmic pulse. A very smooth transition between tone colours will necessitate a slow movement where vertical and lateral movements correspond very precisely. The resulting colour of circular bowing will depend on what portion of the string length the bow movement covers. Alberman qualifies the result as a 'continuous change in timbre.'¹²⁷

¹²⁶ Interview, 13/03/2013.

¹²⁷ Alberman (2005), p. 45.

Irising

Irising involves going from *ordinario* to *sul ponticello* in a crescendo, rapidly bringing out the overtones of the note(s). This term is coined by violist Garth Knox in his work *Viola Spaces*.

Spazzolato / Vertical Bowing

Spazzolato, or ‘brushed’, is a term often used in crafts involving leather, wood and metal. This term is used by Sciarrino,¹²⁸ and indicates a vertical bow movement from the bridge to the fingerboard and back again. Any portion of the string length can be used. To keep the bow perpendicular to the string, with no horizontal movement, the entire arm – and absolutely no wrist or finger movement – must be used to move the bow.

The total lack of horizontal movement in the string means sound is generated in a very different way. Fallowfield explains this ‘is the opposite situation to a “normal” bow stroke; the string excites vibration in the bow hair, even though it is the bow that is moving’.¹²⁹ The pitch can be changed by altering the tension and length of the bow hair, while volume is controlled by the speed of the bow moving up and down the string. Tension can be adjusted with the nut of the bow, while the length of the bow hair can be altered by moving the bow hold up the stick and either pinching the hair with the left hand or pressing on the hair with the thumb. For very short hair lengths (higher pitch), the bow can be turned around so the frog provides bow pressure while the right hand ‘stops’ the hair. Tension can be neither too low nor too high for this technique to be effective.

This technique produces a clear pitch but with a dominant noise component. The result will be the same regardless of whether it is played on an open, stopped, or damped string. The same pitch will be achieved on all four strings, but the noise spectrum will alter slightly because of the thickness of the string.

¹²⁸ Knox cites Salvatore Sciarrino’s *Tre notturni brillanti* (1975) for solo viola in his notes to *Viola Spaces*.

¹²⁹ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

The Helicopter Effect

The vertical bowing, or *spazzolato*, described above is relatively limited in terms of speed. A much more rapid vertical bow movement can be achieved on a restricted portion of the string length by fixing the arm position; the amplitude of the movement is controlled with the fore-arm, fingers and wrist of the bow-arm. Arditti likens the movement to that of a windscreen wiper.¹³⁰ This technique is referred to as ‘the helicopter effect’. Wider amplitude can be achieved at the tip of the bow.

Tremolo

Changing the point of contact during tremolo bowing requires careful planning in bow angle and bow distribution. The position of the tremolo on the bow should be allowed to gradually move by approximately 1cm closer to the tip when moving towards the fingerboard or to the heel when moving towards the bridge. For example, to move from *ordinario* to *sul ponticello*, the heel of the bow will be angled down towards the bridge, and the finishing position of the tremolo on the bow will be 1cm closer to the heel.

Parallel Bowing

The bow can be turned 90 degrees so that the entire length of the hair is in contact with the string. The bow is in effect parallel to the string and creates high, irregular squeaks.

In her video demonstration, Fallowfield holds the tip of the bow with her left hand as well to bow vertically (or in effect diagonally but at a very narrow angle to the string).¹³¹ This change in bowing orientation is discussed on page 152.

Notation

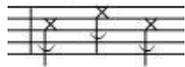
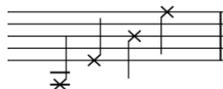
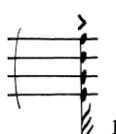
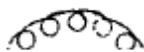
Points of contact are usually indicated with written instructions (sometimes abbreviated), which can be in different languages:

¹³⁰ Arditti & Platz (2013), p. 33. This comparison, however, is made for what Arditti describes as *spazzolare* bowing.

¹³¹ Example 28: <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

Figure 14: Points of contact notation

Term	Description	Language	Notation / Abbreviation
<i>Im Wirbelkasten</i>	In the pegbox	German	
<i>Estremamente sul tasto</i>	Very far up over the fingerboard	Italian	<i>est</i>
<i>Molto sul tasto</i>	Far up over the fingerboard	Italian	<i>mst</i>
<i>Sul tasto</i>	Over the fingerboard	Italian	<i>t. / s.t. / tasto</i>
<i>Sulla tasteria</i>		Italian	
<i>Sur la touche</i>		French	
<i>Am Griffbrett</i>		German	
<i>Poco sul tasto</i>	Close to the fingerboard	Italian	<i>pst</i>
<i>Normale</i>	Return to regular point of contact	Italian	<i>n. / norm.</i>
<i>Ordinario</i>			<i>ord.</i>
<i>Poco sul ponticello</i>	Near the bridge	Italian	<i>poco sul pont.</i>
			<i>psp</i>
<i>Sul ponticello</i>	Very near the bridge	Italian	<i>p. / s.p. / pont. / sul pont.</i>

<i>Au chevalet</i>		French	
<i>Am Steg</i>		German	
<i>Molto sul ponticello</i>	Hair on the bridge	Italian	<i>molto sul pont.</i> <i>msp</i>
<i>Alto sul ponticello</i> <i>Estremamente sul ponticello</i>	Hair on the bridge, no fundamental	Italian	<i>asp</i> <i>esp</i>
<i>Sub-ponticello</i>	Between bridge & tailpiece	Italian	<i>sub pont.</i>    
Circular bowing	Cyclical transitions between various points of contact	English	

¹³² Penderecki first used this notation in *Threnody to the Victims of Hiroshima* (1960).

¹³³ Saariaho uses a four-line staff in *Im Traume* (1980).

Figure 15: Less common notation for points of contact¹³⁴

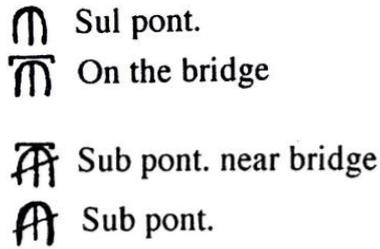


Figure 16: Modifying points of contact - Gubaidulina *Ten Preludes*, No. 5

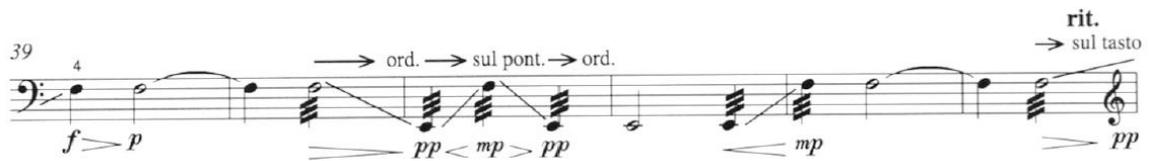
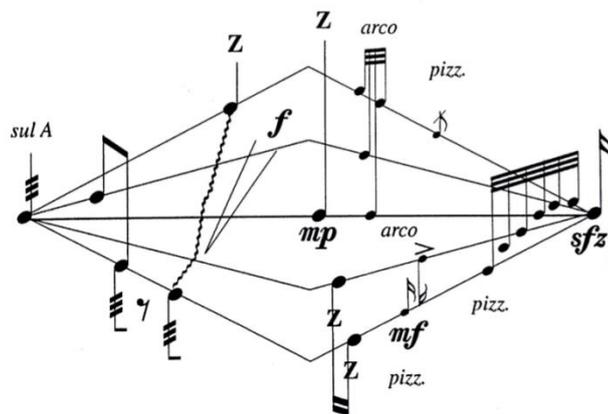


Figure 17: Modifying points of contact - *Strange Star Salon*



Allan Strange's *Star Salon Strikers* and *Slider's Last Orbit* (1973) for four percussionists and amplified string trio.¹³⁵ This excerpt of the violin cadenza presents a solution to rapid changes of point of contact, though there seems no possibility here to notate pitch. Played entirely

on the A-string, the two bottom lines represent varying degrees of *sul tasto*, the middle line represents *ordinario* placement, and the top two, respectively, *sul ponticello* and *molto sul ponticello*.

¹³⁴ Notation used by von Biel in *Quartett* (1964). Cited in P & A Strange (2001), p. 47.

¹³⁵ P & A Strange (2001), p. 7.

4. BOWING THE STRING: SPEED & PRESSURE

As mentioned in the previous section, a competent cellist aims to combine the optimal bow speed and bow pressure to create the fullest possible spectrum of overtones for a given point of contact, which we have named *ordinario*. Changing the point of contact while maintaining the bow speed and pressure used in *ordinario* sound will affect the overtone content, and thus the sound.

In this section we will see how, in changing the other two factors of bow control – bow speed and pressure – more colours can be developed. The extremes of these sounds will be explored.

History

Unlike the preceding three sections which find their roots in traditional performance practice, the concept of disassociating bow speed and pressure from point of contact is a product of the 20th century. With the exception of *flautando*,¹³⁶ which has nonetheless strong associations to *sul tasto* playing (and, historically, to harmonics), one isolated example exists. This is found in accounts of Niccolò Paganini's playing, the descriptions of which could be overpressure techniques, including Anomalous Low Frequencies (ALFs, see p. 97). Louis Spohr, condemning the great virtuoso, writes of his playing '[...] and in many tones quite unnatural to the violin, such as the bassoon tone, the voice of an old woman, etc., etc.'¹³⁷ ALFs were only first notated in 1971 by George Crumb, in the violin II and viola parts of his string quartet *Black Angels*.

Theory & Practice

For a string to make a sound, it must first be displaced. When a string is plucked or struck (see pp. 60, 126 and 132), the amount that the string is displaced is directly related to the energy used to displace it, known as excitation force. In the bowed string,

¹³⁶ A definition of *flautando* is published in 1825 by Danneley in his *Dictionary of Music*: '[Flautando] applies to instruments performed with the bow, and denotes that the tones, by a particular method of bowing, should correspond to the softest notes of the flute.'

¹³⁷ Spohr (1865), p. 280. Cited in Walden (1998), p. 277.

string displacement and excitation force are also interdependent, but can be individually controlled – this is why the bow is such a wonderfully expressive tool.

Roughly, bow speed correlates to string displacement and bow pressure to excitation force. In general, string displacement corresponds to volume (wider displacement creates a louder sound). An increase in bow pressure however creates more pronounced angles in the vibration pattern of the string, ‘allowing the string to vibrate in smaller sections’ and ‘as a consequence, [the] more overtones can take part in the vibration, thus overtone content increases.’¹³⁸ Though this relationship is made more complex by several other factors, including overtone content’s strong psychoacoustic influence on dynamics, the following simplified model isolates these two factors of sound production within the bow.

Bow speed	→	Horizontal	→	String displacement	→	Volume
Bow pressure	→	Vertical	→	Excitation force	→	Overtones

As the following techniques are strongly dependent on bow placement, it is advisable that the preceding section, ‘3. Bowing the String: Point of Contact’, be understood before the study of this section. While this section is most influenced by the string’s material and thickness, it is assumed that the small variants in bow speed and pressure necessary for the same colour across the different strings will be felt intuitively by the proficient cellist.

Vibrato increases the possible amount of bow pressure that can be applied to a string before the fundamental is replaced by harmonics. So while it allows the cellist to achieve a louder sound, it should be omitted for most of the techniques below where the absence of the fundamental is desired.

While the following text categorizes various types of sound, a musical context will often see several of these graded progressively within one gesture. The following categories

¹³⁸ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

will be qualified as pitched or non-pitched, to guide the cellist toward the sound intended.

Applications

Overpressure

The techniques below are graded in order of pressure needed, the last categories requiring the greatest bow pressure.

Generally, the more pressure is needed to achieve a certain sound, the less flexibility there is in dynamic range. To achieve overpressure techniques in a *forte* dynamic, there must be an increase in bow pressure relative to *ordinario* speed, whereas to achieve the same in a *piano* dynamic, there must be a decrease in bow speed relative to *ordinario* pressure.

Overpressure effects are more easily controlled on shorter, thicker strings.¹³⁹

Pitch Bending (with the bow)

(Pitched sound)

Increased bow speed and pressure for a given point of contact will make the sound louder and richer in overtones up to a certain point. Past this point, the pitch centre is altered; this can be most easily achieved on the open strings. This technique is more effective if the original pitch is heard first, so that the listener may have a point of comparison – otherwise the note tends simply to sound loud and the pitch alteration goes virtually unnoticed. The pitch centre returns to the original frequency as the excitation energy decays and the elasticity of the string returns it to its original tension.

Upwards pitch bending is produced by an increase in bow speed, for the same point of contact and bow pressure. Thus the bend is usually accompanied with an increase in volume. Strings with less tension will bend more easily and to greater intervals: for

¹³⁹ Ibid.

example, on an open string, a D-string Bel Canto chrome/steel core can bend to a semitone, while a lighter tension Pirastro Permanent can bend to nearly a whole tone. The lower strings usually have less tension and therefore a wider possible range.

Downwards pitch bending is produced by an increase in bow pressure, for the same point of contact and bow speed. This is also possible with harmonics, especially those lower in the harmonic spectrum. Fallowfield writes that the reason for downwards pitch-bends is unclear; she speculates that ‘high bow pressure restricts the movement of the kink of vibration in the string, occasionally preventing it from passing the bow and causing fewer cycles of vibration between bridge and finger/nut than normal, i.e., resulting in a lower frequency.’¹⁴⁰

Overpressure Harmonics

(Pitched sound)

Increased bow pressure while playing a harmonic will produce both the harmonic and an open string sound simultaneously. This is a simpler version of multiphonics, explored more fully on page 160, and should serve as a preparatory exercise to section 14. Overpressure harmonics are especially idiomatic to different instruments and strings. In interview, Neil Heyde discussed the 7th harmonic as especially conducive to this technique.¹⁴¹ Fallowfield also discusses using high bow pressure on harmonics to incorporate the open string into the sound.¹⁴² For harmonics in the upper-most range of the instrument, she places the bow behind the fingers.

¹⁴⁰ Ibid.

¹⁴¹ Interview, 13/03/2013.

¹⁴² <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds/other-multiple-sounds.html>

Tone Distortion

(Pitched sound)

An increase in bow pressure while maintaining bow speed and point of contact will create a distortion in the sound quality. While there are endless subtleties to this, it is a worthy experiment to determine for an individual cello and bow how much pressure can be added before the bow sticks to the string in an irregular manner, as with *nageln* (p. 100).

Scratch Tone

(Unpitched sound)

An additional level of discrepancy between high bow pressure and low bow speed for a given point of contact will suppress pitch and produce a dominant spectrum of noise. Rolén explains that as no pitch is required in this technique, scratch tones are often written on open strings (each open string produces a different spectrum however). Muting the string by lightly touching it with several fingers or the palm of the hand facilitates the production of a non-pitched sound;¹⁴³ placing the hand closer to the bridge also facilitates this by reducing the string length which needs to be activated, while bearing very little influence on the sound.

Short attacks with the bow can create different types of scratch tone and are particularly effective rhythmically.

Subharmonics & ALFs / Undertones / Pedal Tones

(Pitched sound)

Subharmonics and ALFs (Anomalous Low Frequencies) are fascinating subjects, little understood from a scientific point of view,¹⁴⁴ but the colouristic value of which is

¹⁴³ As suggested by Rohan de Saram in a private interview, 16/12/2014.

¹⁴⁴ In an article on Kimura, Gurewitsch (2011) explains: ‘...acousticians who have studied her techniques under laboratory conditions still find them deeply perplexing...’

gradually being recognized. The difference between subharmonics and ALFs will be explained below, but for the purposes of the present work, the bowing technique used to obtain both of these will be the focus of our study. These sounds are also collectively known as undertones or pedal tones, the latter being the term used by George Crumb.

Both subharmonics and ALFs are notes that sound below the fundamental, thus considerably extending the range of the instrument. These are achieved by using disproportionately slow bow speed in relation to pressure (or in other words, very high bow pressure in relation to bow speed). ALFs are by far more used than subharmonics, but are commonly mistaken for subharmonics.

Theoretically, subharmonics are produced by a division of the frequencies of the fundamental to produce a mirror sequence of the harmonic series; therefore bowing on the 2nd harmonic of the C-string will produce a C one octave lower than the open string. Bowing on the 3rd harmonic (producing a 12th / compound-5th above the open string, in this case a G) will produce a 12th / compound-5th below the open string (in this case an F). The sound produced with this technique is not a clear one.

ALFs are similar to subharmonics in that they are related to the fundamental, the frequency of which is divided to create a new fundamental, with a new series of harmonics, hence producing a sound which is resonant and clear. However, ALFs are not in the correct octave to be true subharmonics and can range from a minor third to a compound-5th below the fundamental,¹⁴⁵ with the most common intervals being 7^{ths} and octaves. The pitch obtained depends on the thickness, material and age of the string, and amount of rosin on the bow. The arm weight on the bow and bow speed can also affect the interval obtained. Indeed, ALFs can be ‘idiosyncratic to a particular player or instrument’.¹⁴⁶

With practice, the correct speed and weight can be controlled to produce a relatively clear and stable tone; due to the bow weight required, these notes are difficult to sustain.

¹⁴⁵ P & A Strange, p. 25.

¹⁴⁶ Idem., p. 28.

Point of contact is crucial, and will be closer to the fingerboard than *ordinario* playing; for an open string, positioning the bow on the 8th harmonic is a good point of departure.

Again because of the amount of bow pressure required, ALFs are most easily produced on the C-string, whose position closest to the bow arm, and on the outer edge of the bridge, allows for greater angling of the bow. This is the most useful string on which to develop the technique in terms of expanding the register of the instrument. Sustain is the most difficult parameter to achieve; the following are points of advice from performers who have mastered this technique:

- a) Mari Kimura recommends loosening the bow hair.
- b) Neil Heyde maintains a normal bow hold but angles his right elbow as high as possible for leverage.¹⁴⁷ Cellists with shorter arms may find the same leverage by elongating the first finger across the bow stick, leaning on the outer side (right side) of the hand.
- c) Neil Heyde also advises against using strings with a rope core (such as the *Thomastik Bel Canto* G- and C-strings), which produce more harmonics but are less efficient at producing ALFs. Strings with a single core, such as gut strings, are easier to control. *Thomastik Dominants* (nylon core) are even better for ALFs than gut strings, as they are very low tension (they take about a day to stop stretching, and are very zingy when first strung on).¹⁴⁸
- d) Mark Dresser draws the bow vertically, pressing up into the string, then changes the direction from a vertical to horizontal position to sustain the pitch.¹⁴⁹
- e) Hanson, Schneider & Halgedahl write: ‘It seems the most important factor in producing these low tones may be the knowledge that they actually exist; for a skilled player is not used to looking for a stable pitch amid the clutter and anguish of noise that he/she has worked with for so many years.’¹⁵⁰

The violinist Mari Kimura, who has mastered and popularised the technique, has written many works for violin incorporating ALFs and has been encouraging composers to do

¹⁴⁷ Interview, 13/03/2013.

¹⁴⁸ Ibid.

¹⁴⁹ Dresser (2000), p. 256.

¹⁵⁰ Hanson, Scheider & Halgedahl (1994), p. 11.

so as well. Kimura began developing subharmonics in the early 90s. She describes finding the sound during a *son filé* exercise, whereupon arm weight is applied to long bows to develop sound production; she tried this on the G-string and noticed she could produce a sound one octave lower. She refined this over some time and was eventually able to produce the note without the grainy noise usually associated with overpressure. She has also been able to control the speed and pressure of her bow to obtain an octave, third, second and fifth below the fundamental.

This excerpt from Fallowfield's website is a possible explanation of ALFs:

If the bow exerts high downward pressure on the string, the kink of vibration in the string is unable to pass the bow in the usual way. If this restriction is controlled such that the kink passes the bow at a frequency that is lower than the 'normal' frequency but nonetheless regular, the pitch of the vibrating string is lowered. This effect is very difficult to control (more so on the longer cello strings than on the violin); it is more easily sustained with very regular, quite slow bow speeds on short, thick strings. These pitches are rarely 'in tune' with the fundamental pitch and intonation varies with contact point: the pitch is sharpened as contact point moves towards the bridge. A high component is also present in the sound. This is possibly vibration between bow and bridge.¹⁵¹

Nageln / Clicks / Crenelated Bowing

(Pitched sound)

Applying an excessive amount of bow pressure will allow the bow to slip at irregular intervals, producing a 'pinging' noise. In other words, only the first half of the 'stick-slip' mechanism occurs. The result is a clear pitched sound, intermittently heard above a band of noise.

There are two ways in which to gain greater control of the frequency of the clicks, which enable the leverage needed to achieve the extreme bow pressure for this technique:

¹⁵¹ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

- a) Neil Heyde suggests leaning the 2nd joint of the right-hand thumb against the side of the end of the fingerboard which, although limits the amount of bow that can be used, provides the leverage needed for the extreme bow pressure and very slow bow speed. This also allows a quasi-regular bow hold.
- b) Many cellists, including this author (being of smaller build) and Fallowfield, choose to lean the tip of the thumb on the side of the fingerboard for control, and tilting the hand towards the right, protracting the first finger across the top of the bow stick for leverage. This slightly increases the amount of bow that can be used but drastically changes the bow hold.

The thumb and fingers in both these methods can also be fully extended to increase the amount of bow available. For Heyde, the slight increase in muscle tension in his hand in the first example is more viable in performance than the considerable increase in arm muscle tension which occurs in the absence of the techniques described above. Heyde's general approach to the bow hold in contemporary techniques is to maintain as much as possible the hand positions and muscles used as in traditional playing: 'Think of the hours that have gone into getting these things to be flexible and strong.'¹⁵² Some cellists choose to wrap their hand around the entire frog of the bow, holding it in the fist of the hand, the thumb under the frog – this author would strongly advise against this bow hold because of the huge reduction in bow-arm flexibility and increase in arm-tension. For this reason, this method does not provide the greatest leverage as it tends to block arm weight; brute force needs to be applied to compensate.

Following Fallowfield's suggestion,¹⁵³ the tension of the string can also be increased by pulling the string upwards with the left hand, which does however dampen the portion of string in contact with the left-hand finger(s).

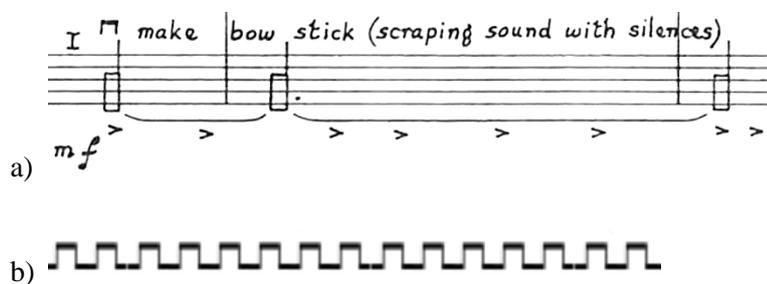
This technique also belongs to the category of bi-tones, as two pitches are produced. While this section discusses the physical aspect of producing *nageln*, acoustic properties are discussed further (p. 130).

¹⁵² Interview, 13/03/2013.

¹⁵³ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

The German verb *nageln*, ‘to nail’, colourfully described the resulting sound. The term *crenelated bowing* is inspired by the Arditti Quartet, in particular violist Levine Andrade, and describes one of the notational devices used by Helmut Lachenmann and Jonathan Harvey for this technique. P & A Strange list this technique in their Compendium as *son filé*, a confusing term which traditionally refers to sustained bowing. The first example below is from Harvey’s *String Quartet No. 2*; the second example¹⁵⁴ is of a ‘crenelated’ line, also used by some composers to express different sounds.

Figure 18: Notation example of *nageln*



Vertical Nageln

(Pitched sound)

Nageln are also produced at extremely high bow pressure in vertical bowing (see p. 88). Fallowfield provides an informative video demonstration of this technique on open strings,¹⁵⁵ in which she holds the bow with two hands. This technique produces two sets of bi-tones, and is further discussed on page 130.

Underpressure

The following techniques are graded in order of decreasing bow pressure; there are far fewer levels of grading in underpressure than in overpressure.

¹⁵⁴ <http://www.moderncellotechniques.com/bow-techniques/pressure-techniques/pressure-techniques-overview>

¹⁵⁵ Video 29: <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

Flautando

(Pitched sound)

This relatively traditional technique is achieved through a lessening of bow pressure relative to bow speed. The low excitation force cannot sustain the lower harmonics, while the upper harmonics are simultaneously prevented from sounding because of the less pronounced angles of the vibration pattern in the string. The *flautando* sound is therefore created by dominant mid-range harmonics.

Air Noise / White Noise / Rauschen

(Unpitched sound)

The sound of loud breathing or of air being blown can be achieved through a *flautando* bow combined with, as Rolén suggests,¹⁵⁶ placing several fingers or the whole hand lightly on the strings to prevent them from vibrating and so as not to activate a harmonic node (see ‘Damping / Pizzicato Effleuré / Dead Pizzicato’, p. 113). This is sometimes referred to in German as *Rauschen*, which can be translated as ‘murmur’.

Filtered Pitch

(Unpitched sound)

In the previous section, ‘3. Bowing the String: Point of Contact’, we discussed two ways of manipulating overtones with the bow, by varying its point of contact with the string:

- 1) *Sul tasto* – Placing the bow directly on a node, with the same bow speed and bow pressure as in *ordinario*, eliminates that node and every periodic recurrence of that node. This is called overtone exclusion.
- 2) *Sul ponticello* – Placing the bow near or on the bridge eliminates the fundamental and each subsequent harmonic. This is called overtone takeover.

¹⁵⁶ <http://www.moderncellotechniques.com/bow-techniques/pressure-techniques/non-pitched>

Filtered pitch however, involves reinforcing a specific harmonic component of the sound and can occur at many different points of contact on the string. Placing the bow on a node with reduced bow pressure will reinforce that harmonic so that it is heard simultaneously with the fundamental. It is difficult to target a specific harmonic: as bow pressure (excitation force) is progressively reduced, so the fundamental and then each of the lower overtones diminish from the sound, in ascending order. There is a point on the string where the first harmonic dominates (*ordinario*), then slightly closer to the bridge the second harmonics dominates, and then progressively closer to the bridge the third, fourth, fifth harmonics take over and so forth. Fallowfield provides an interesting video demonstration of this transition on her website.¹⁵⁷ She also explains that overtone takeover can take place further from the bridge on longer strings, with lower excitation force, and with a small and dense exciter (obtained by tilting the bow). This effect is more pronounced with bowing rather than plucking or striking, because the excitation of the string is continuous.

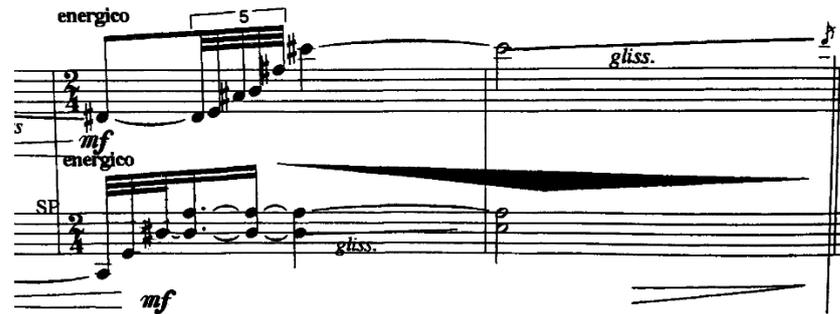
Filtered pitch could be considered a type of multiphonic, in that two harmonics (the one that is bowed, and the fundamental, or 1st harmonic) are heard almost equally. However, the mechanics of this are completely different to multiphonics, and it is for this reason that these are presented separately: whereas multiphonics (p. 160) involve several factors in both the right and left hands, filtered pitch uses only bow pressure.

Notation

Often words such as *overpressure*, *heavy pressure*, *scratch tone*, *hard scrape* and so forth are used.

Kaija Saariaho devised graphic notation for overpressure, in which the thickness of the line above the note indicates the relative increase in bow pressure.

¹⁵⁷ Videos 4 & 6: <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

Figure 19: Overpressure graphic notation - Saariaho *Mirrors* for flute and cello

Rolen cites the following example in his page on overpressure, of double down-bows and up-bow:¹⁵⁸

Figure 20: Overpressure notation - Romitelli *Professor Bad Trip*

Rolen also cites German-American composer Hans Thomalla's use of a different symbol for a similar technique in his 2010 string quartet *Albumblatt*. Thomalla refers to the technique as *too-slow bow*, in which Rolen explains that he 'distinguishes from overpressure by indicating that he does not want a "snoring sound", but a slight distortion of the sound with the tone still shining through. Here the "teeth" of that jagged line get smaller and closer together to indicate that the sound is closer to normal and the wider, larger portions indicate more distortion.'¹⁵⁹ This notation can easily be confused with the crenelated bowing described on page 100.

¹⁵⁸ <http://www.moderncellotechniques.com/bow-techniques/pressure-techniques/pressure-techniques-overview>

¹⁵⁹ Ibid.

Figure 21: Overpressure notation - Thomalla *Albumblatt*

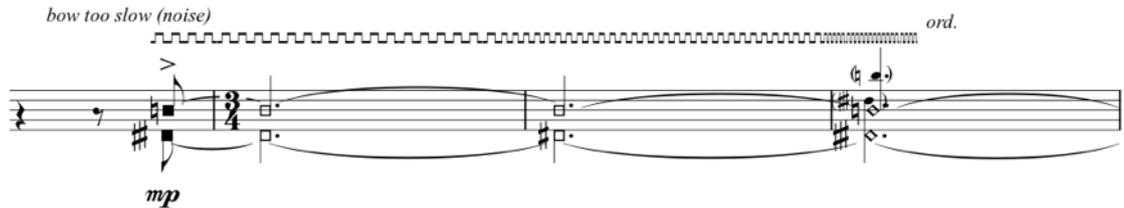
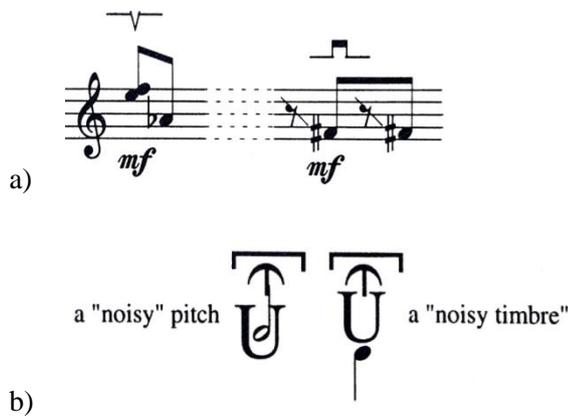


Figure 22: Overpressure notation - Miroglio *Projections* and von Biel *String Quartet*

Francis Miroglio indicates overpressure with modified up- and down-bows (a)¹⁶⁰ and Michael von Biel uses these two signs to differentiate between an overpressure sound where the fundamental is heard and an un-pitched sound (b):¹⁶¹



In notating ALFs, composers sometimes write the fundamental with a diamond note-head an octave underneath. This is a reasonable method but both composer and performer shouldn't necessarily expect to obtain an octave under the fundamental, as a 7th is more usual.

¹⁶⁰ P & A Strange (2001), p. 19.

¹⁶¹ Ibid.

5. BETWEEN THE NOTES

As the natural flexibility of the sound of string instruments continues to be explored, much of the music of the 20th and 21st centuries has broken past the confines of definite pitch centres.

Rohan de Saram reflects on the dual aspect of the increasing similarity between Western and non-Western music, as elements of the music of other cultures become integrated into Western art music:

This is certainly partly the case [that many of these developments in recent Western musical practice have been directly inspired by non-Western examples], but also the evolution of Western musical thinking in itself has independently arrived at a similar mode of thought, especially concerning the melody instruments, including the voice.¹⁶²

While it is not specific cross-cultural influences that interest us here – this would form an entire other study linking ethnomusicology to 20th-century extended techniques – this short section will focus on developing pitch recognition and familiarity when there is a blurring of definition of the twelve semitones of the Western classical music tradition, with the principal focus on extreme vibrato and different types of glissandi. Natural harmonic glissandi (see p. 53) are omitted here because they result in clearly defined pitches from the harmonic series, rather than constantly fluctuating pitch.

The motions which form the basis of the following techniques should all be recognizable in terms of traditional playing. These are, however, combined with new motions which require additional attention.

History

The distortion of pitch centre has been present since the earliest days of stringed instruments, in the form of vibrato. The use of vibrato on violins was mentioned as early as 1545, in Martin Agricola's second edition of his treatise *Musica instrumentalis deudsh*. Initially used ornamentally, vibrato eventually became an integral part of

¹⁶² Steinheuer & de Saram (2013), p. 176.

sound. Glissandi also appeared early on, but remained merely an effect into the 20th century. One of the first uses of the glissando was in 1627, by Carlo Farina in his *Capriccio Stravagante* for violin, two violas, cello, double bass and harpsichord.¹⁶³ According to Read, the glissando on stringed instruments was used by Mahler in his symphonies but 'came into its own' in Bartók's music, especially in his last four string quartets.¹⁶⁴

In addition to these ornaments – be it from Baroque composers adapting the dance forms of various countries¹⁶⁵ to Debussy taking inspiration from the gamelan music of Indonesia – Western music has always incorporated elements of 'exotic' music to extend the formal and colouristic pallet. Music of the post-war period is no exception; with the use of experimental techniques, many aspects of the music of other cultures can be emulated very accurately on Western string instruments. These influences range from different tuning systems and scales (see 'Equal Temperament other than 12/24-TET', p. 214), to non-chromatic use of the left hand.

Theory & Practice

The challenges presented in these techniques are very different for musicians with and without perfect pitch. It is often much more difficult for the latter to maintain a sense of reference when pitch is continuously fluctuating. Mapping out the notes of peaks and troughs, or arrival notes for example, can provide anchor points for the ear. Remembering the speed of the arm motion is also sometimes helpful, though all of these points are contingent on musical context. The following text will focus on the mechanics of specific techniques.

¹⁶³ Farina (1627). Cited in P & A Strange (2001), p. 79.

¹⁶⁴ Read (1993), p. 51.

¹⁶⁵ A fine example of this is the *Sarabande*, which either originated in Mexico or evolved there from a Spanish dance with Arab influence. It was prohibited in Spain in 1583 by Philip II because it was 'regarded as loose and ugly', but was adopted by the Italians only a few decades later and then spread to French courts. The slow version in triple time was preferred to the originally lively Spanish version. Bach used the dance form to great effect in his Suites for Unaccompanied Cello.

<http://www.britannica.com/art/sarabande> and

<http://www.oxfordmusiconline.com/subscriber/article/opr/t237/e8956>.

Applications

Glissandi

The traditional use of glissando is to delay the movement of pitch to just before the next note, a technique sometimes referred to as portamento.¹⁶⁶ More commonly in 20th- and 21st-century music, the glissando starts at the very beginning of the first note so that the effect is for the entire duration of the note.

Glissandi over two or more strings will not be perfectly continuous, but the break can be minimized by changing from the 1st to the 2nd, then 3rd, then 4th fingers while travelling up the string. This makes it possible to use the 1st finger again on the adjacent string – using an extension will minimize the gap in the sound.

Pizzicato / Struck Glissando

To be effective, the glissando movement needs to begin as soon as the string is plucked or struck (for example with *col legno*). The effect is accentuated in the higher registers

Double Glissando

This involves glissando in contrary motion: the hand either opens out or contracts. Practising this motion develops certain muscles of the hand.

Glissando Trill

This involves the combination of two motions: a rotation of the hand (trill) and a linear motion of the entire arm (glissando).

Turning the Peg

See section ‘17. Independence of Hands’, on page 178.

Extreme Vibrato

Because of the cello’s string length, extreme vibrato requires a different motion than all other types of vibrato. The motion is of a very small back-and-forth glissando of less

¹⁶⁶ P & A Strange (2001), p. 79.

than a semitone (whereas on the violin, the same action as normal vibrato can be used but to a more extreme degree).

In modern music, vibrato is often very prescriptive, with indications such as *vibrato*, *non vibrato*, *poco vibrato*, *molto vibrato*, extreme vibrato, slow / fast vibrato. Anything other than extreme vibrato, however, requires the same physical motion as in traditional playing. The use of normal vibrato in modern music belongs to the realm of musicianship, and is discussed further in section '24. Interpreting Notation & Style' and 'Appendix II: Components of Modern Notation & Style'.

Notation

The many subtle possibilities in a glissando have encouraged composers to be particularly creative with notation, notably with graphic notation. Most notations are self-evident, and that which isn't should be explained in a work's preface. Tischhauser provides a clear lexicon of notation related to glissandi.¹⁶⁷

¹⁶⁷ Tischhauser (2002), pp. 18-23.

6. STOPPING THE STRING

Timbre is very much affected by how the string is stopped. Traditionally, stopping is done with the left hand, but so as not to exclude any possible extended techniques, this text will refer to the ‘stopping object’, rather than the ‘left-hand finger’.

This section aims to develop awareness of the possible influence that the stopping object can have on sound.

History

Modifications to stopping techniques can be traced back to the earliest days of the violin, but seem limited to only a few documented examples. P & A Strange provide an interesting anecdote from Agricola’s *Musica instrumentalis deudsh*, whereupon a Polish violinist depressed the strings of his instrument with the nail of the finger rather than the flesh.¹⁶⁸

Nearly 300 years later, Romberg wrote that J. L. Duport:

...introduced a third species of tone, something between a firm note and an Harmonic [*sic.*]. This tone he produced, not by pressing the finger tightly against the Finger-board, but by bending the string sideways from right to left, by which means he produced a species of Harmonic. In this tone, he executed whole passages, and with the most delightful effect.¹⁶⁹

Theory & Practice

The stopping object determines how the impulses of vibration are reflected in the string. Timbre is therefore affected by the pressure and density of the stopping object.

¹⁶⁸ P & A Strange (2001), p. 71.

¹⁶⁹ Romberg (1840), p. 73. Cited in Walden (1998), p. 199.

Density

The denser the stopping object, the more overtones will be present in the sound and the longer the decay time. This is because ‘fewer overtones are lost to damping when vibration is reflected at the stopping [object].’¹⁷⁰

Pressure

For the purpose of generalized description, we shall divide stopping pressure into six categories, which are listed below in order of highest to lowest.¹⁷¹ Pressure will always be relative to string tension, and will vary between low and high positions and the upper and lower strings:

Figure 23: Gradations of stopping the string

Pressure (string height from the fingerboard)		Quality of Sound
High-pressure stopping	String in contact with the fingerboard.	Overtone-rich with a long decay time.
Low-pressure stopping	String in contact with the fingerboard.	Fewer overtones and rapid decay time.
High-pressure harmonic	String doesn't touch the fingerboard but is depressed.	Overtone-weak. Harmonics and stopped string sound are combined. See ‘Half-harmonic’, p. 113.
Medium-pressure harmonic	String doesn't touch the fingerboard.	Clear harmonics are produced if the point of contact is on a node.

¹⁷⁰ <http://www.cellomap.com/index/the-string/the-left-hand.html>

¹⁷¹ Figure 21 is based on the information provided by Fallowfield: <http://www.cellomap.com/index/the-string/the-left-hand.html>

Low-pressure harmonic	String doesn't touch the fingerboard.	Harmonics are combined with the open string. See '14. Multiphonics', p. 160.
Very low-pressure harmonic	String doesn't touch the fingerboard.	Harmonics, the open string, and a noise component are heard.

Applications

Note Length

Please refer to 'Note Length' on page 63 in section '2. Pizzicato'. The same notions can be applied to bowing and hitting the string.

Italian Harmonic

P & A Strange use this term to describe the left-hand stopping notes by pressing on the side of the string rather than pushing it down to the fingerboard. This produces a sound with defined pitch but less resonance.

Half-harmonics

These are produced by left-hand finger-pressure halfway between that needed for a harmonic and that needed for pressing the string to the fingerboard. Fallowfield discusses how this technique produces a harmonic simultaneously with the pitch of the stopped note (rather than with the open string of 'Overpressure Harmonics', p. 96).¹⁷² The pitch of the harmonic is slightly sharpened (see 'Pitch Bending / Pulled Harmonics', p. 58) and the overtone content is weak.

Damping / Pizzicato Effleuré / Dead Pizzicato

Damping – preventing the string from vibrating – can be used in many ways. Placing the palm of the hand, chin, or more than one finger on the string with a medium- to low-pressure harmonic ensures a harmonic node will not sound when using the bow (see 'Air Noise / White Noise / Rauschen' on page 103). For pizzicato, the left hand touches

¹⁷² <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds/other-multiple-sounds.html>

the string in the same way as for a harmonic, but is not located on a node, producing a damped sound, much like a ‘thud’. In the notes to his second string quartet, Ligeti describes the sound of such pizzicato as ‘hollow, wooden’.

Left-hand Nail

Using the nail to stop the string is much more easily achieved on a violin or viola, because of both the natural angle of the fingers to the strings, and the diameter of the strings. P & A Strange also discuss this technique, observing that the longer fingernails required for this technique are at odds with the short nails necessary for conventional playing.¹⁷³ For a cellist to create contact between nail and string, the hand needs to be turned diagonally by raising the left elbow; this is far more comfortable in the upper positions, where this technique is in fact most useful for pizzicato. The higher density of the nail versus the finger-pad allows high pizzicato to ring more clearly.

Rattling / Buzz Pizzicato

There are many different ways of producing this effect, where a hard surface or object creates a rattling or buzzing sound in addition to the pitch. Ligeti provides instructions for this in the second movement of his *String Quartet No. 2*: ‘Let the string strike the fingernail of the left-hand finger, which is placed beside the string.’ Ligeti’s instructions are the most effective, as the other options of placing the fingernail under or over the string make very little difference to the sound. A more delicate buzz can be made by letting the string vibrate on the right-hand nail once the string has been plucked.

This can also be combined with bowing or hitting the string.

Pitch Bending (horizontal)

The tension on the string can be increased, and thus the pitch raised, by pulling the string sideways with the stopping object.

¹⁷³ P & A Strange (2001), p. 71.

Pitch Bending (pegbox & sub-ponticello)

The pitch of an open string can be raised by increasing the tension on the portion of string beyond the nut or bridge. Applying pressure with a stopping object, regularly and quickly, simulates vibrato, and is most effective during a bowed note. The bridge-to-tailpiece segment of the string can be difficult to reach, while the pegbox segment of string is more comfortable for the left hand and won't detune the string as much.

Sub-ponticello

Although stopping the string on the other side of the bridge is very awkward to anyone without extremely long arms, leaning the left thumb on the side or upper face of the bridge can provide more stability and comfort.¹⁷⁴

Harmonics and stopped pitches are in a mirror image to those on the nut-to-bridge portion of the string: a clearer sound is obtained if the bow is nearer the bridge, the stopping object on the far side of the bow. A non-resonating *sul tasto* (see p. 84) is obtained with the stopping object nearer the bridge than the bow.

Other Stopping Objects

While this is only limited by the bounds of the imagination, some more commonly used objects include glass rods, available in a variety of lengths and diameters, metal coins, and plastic cards (such as a credit card).

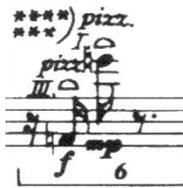
P & A Strange suggest placing metal sewing thimbles on the fingers to stop the string, to reproduce the effect of using the fingernail.

Notation

There is little notation devoted to aspects of stopping the string. The two most seen notational devices are found in the second movement of Ligeti's *String Quartet No. 2*.

¹⁷⁴ Videos 51 & 52: <http://www.cellomap.com/index/the-string/bridge-tailpiece-and-in-the-peg-box.html>

Pizzicato Effleuré / Dead Pizzicato



Rattling / Buzz Pizzicato



7. EXPANDING THE REGISTER

We conclude our survey of Adapted Techniques with another short section, which explores expansion in register, in both a vertical and lateral sense: vertical in pushing the limits of the lowest and highest registers, and lateral in the exploration of pitch and timbre on the different strings.

In the same way as playing in the upper positions of the cello for the first time is a daunting task for the young or amateur cellist, so too can be playing notes which lie outside the accepted range of an advanced or professional cellist.

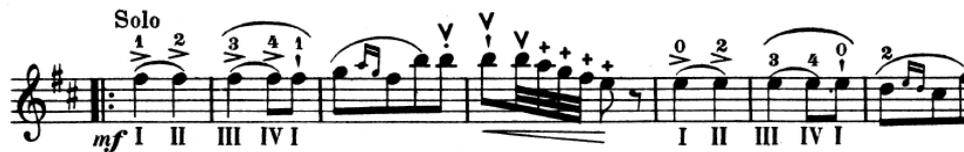
History

All instruments have seen an expansion of register throughout history. The cello's fingerboard has changed over time to accommodate this, with longer fingerboards being introduced in the 18th century. To allow higher playing on the C-string, Romberg introduced a fingerboard with a flattened side.

Scordatura dates back to the early 1600s,¹⁷⁵ and has mostly been used as a colouristic device and to enable chords otherwise not possible with regular tuning. Its function of expanding the register downwards is traditionally kept to a whole tone on the cello. The earliest surviving examples of *scordatura* date from around 1660, and are found in Thomas Baltzar's violin works. Like many of the Adapted Techniques which were present in the 17th and 18th centuries, *scordatura* is largely absent from the 19th century, save by Paganini and select virtuosos of the violin, and re-emerged with the exploration of colour in the 20th century.

There is a large capacity for effects which can be achieved by exploiting the idiomatic timbre of different strings. Antonio Bazzini's showpiece *Scherzo fantastique, Op. 25 'La Ronde des Lutins'* for violin and piano (1853) contains an iconic moment where the violin re-articulates four F#s on four different strings, followed by four E's:

¹⁷⁵ Walden (1998), p. 206 & Stowell (1985), pp. 232-239.

Figure 24: Bazzini *La Ronde des Lutins*

Colouristic techniques were used to great effect on the cello by, for example, Vivaldi, Handel, Bach in the Prelude of his 6th *Suite for Unaccompanied Cello*, and Haydn:

Figure 25: Haydn *String Quartet, Op. 50, No. 6 'The Frog'*, final movement

Theory & Practice

The three applications discussed in this section should be approached in the same way as a when learning a new, higher position. Familiar scale patterns and shifting exercises are the first steps towards establishing physical comfort in a new range.

Applications

Altissimo Register

The *altissimo* register will be defined here as the range of notes played beyond the fingerboard, although this will vary from one instrument to another, as fingerboard and stop lengths are not always consistent. This term is adopted from woodwind instruments, on which the notes in the *altissimo* register are produced with harmonics, obtained by overblowing.

As in *scordatura*, a sensitive cellist should adapt relatively quickly to the change in tension, caused here by the use of an unusually short segment of the string. The main consideration is the placement of the left-hand thumb, which has two possibilities:

Under the fingerboard¹⁷⁶ This can be more comfortable for players with longer arms than those with shorter arms. This also allows for a more resonant sound but requires heavy finger pressure.

On the string¹⁷⁷ Placing the thumb on the string prevents the portion of the string not being used from vibrating, effectively reducing the length of the string which is being handled and resulting in a clearer sound. Less finger pressure is necessary but some of the resonance can be lost.

Scordatura / Alternative Tuning

Scordatura, literally ‘detuning’ in Italian, can alter both the chord vocabulary, the timbre, and expand the range of the instrument – it is this latter function that will be discussed here. The string’s pitch can be either lowered or raised; adjustments to a change in string tension should be practised in the same way as one would to adjust to a new cello, new strings or a new set-up, which should present little difficulty to a cellist sensitive to general sound production. The range of *scordatura* will vary depending on the type of string, although raising the pitch has a very precise limit in that it will snap if the tension is too great (a whole tone is generally a safe limit).

Fallowfield’s *Cello Map* provides an interesting discussion of the acoustic properties of the lowered string in *scordatura*.¹⁷⁸ At smaller changes of string tension (such as a

¹⁷⁶ Tortelier occasionally advocated the use of this position, mentioned in Wilson (1998), p. 99. Heyde places the thumb under the fingerboard for much higher position playing. In addition to the comfort and flexibility this position offers in terms of vibrato and use of open strings, Heyde believes that the tradition of blocking the thumb across one or two strings is due to tonal structures, and hence not necessarily applicable in modern music.

¹⁷⁷ V. Welbanks prefers this positioning of the thumb as she is of smaller build.

¹⁷⁸ All acoustic information on this page is sourced from www.cellomap.com/index/the-string/string-tension.html.

semitone or whole tone) the difference in timbre is due to the cut-off point of overtones in a note: overtones with wavelengths of less than the width of the string will not participate in the sound. Therefore raising the pitch of a string will decrease the overtone content. The increased string stiffness means that the higher overtones are weak and out of tune with the fundamental. The string is less responsive but louder because of the higher force of the string on the bridge. Longitudinal vibrations¹⁷⁹ are also present in the string, and contribute high-pitched sounds.

Lowering the string's pitch presents a much broader array of sounds than raising it. Up to a certain point, lowering the fundamental increases the number of potential overtones. The string is also more responsive, although underpressure techniques are more difficult to achieve.

Past this point (which will vary for different strings), fewer overtones are present, as the lower tension encourages damping; the angles of the string at the bridge and nut are less pronounced, which discourages the reflection of energy back along the string. This more extreme *scordatura* lessens the effects of changing point of contact but increases the possibility of pitch distortion with the bow (see 'Pitch Bending (with the bow)', p. 95). The motion of the string also becomes more difficult to sustain and more noise is present in the sound. The more the tension decreases, the more the string's movement becomes torsional (as opposed to transversal), which lessens its response to excitation force, adds unpredictable pitch changes and a noise component. The range of variation in bow speed and pressure is reduced and volume is difficult to sustain. At the lowest possible tension, the pitch is obscured by noise content and the string vibrates against the fingerboard. This grading occurs more drastically on the lower strings.

When one string is detuned, the other strings 'pull'. The drastic change in string pressure on one part of the bridge 'affects the amplitude of the other strings [...which] increases and decreases in inverse proportion to tension'.¹⁸⁰ This mostly affects the use of *scordatura* during performance (using the pegs to alter the tuning of the instrument

¹⁷⁹ 'A wave that is propagated in the same direction as the displacement of the transmitting medium.' English Collins Dictionary (2015)

¹⁸⁰ <http://www.cellomap.com/index/the-string/string-tension.html>

while playing on open strings), which will be covered separately in ‘Re-tuning While Playing’ (p. 178).

Uitti provides an interesting list of various tunings achieved by the use of two or more of the same string (for example, using a second A-string instead of the D-string).¹⁸¹

Unisons

As timbre became a predominant feature of music in the 20th century, so were developed various ways in which maximum timbral effects could be achieved using a single pitch. Familiarity with harmonics and their various nodes will certainly broaden a cellist’s scope in this area. Often the microtonal variations between the same notes on different strings will be an integral part of the texture desired by the composer.

Enharmonic, or timbre trills – trills between two notes of the same pitch, on the same string or on two different strings – exploit this quality to great effect. The following exercise is adapted from Rolen’s website.¹⁸²

¹⁸¹ Stowell (1999), p. 216.

¹⁸² <http://www.moderncellotechniques.com/left-hand-techniques/harmonics/harmonics-trills>

Exercise 11: Enharmonic / Timbre Trills

- a) Two nodes of the same harmonic (same string). This can be played either as a keyboard trill or a traditional trill (see page 55) to exploit the double-node.



- b) The highest node of a harmonic and the fully stopped pitch at the same placement (same string).



- c) Two natural harmonics which produce the same pitch (different strings).



- d) Two stopped harmonics which produce the same pitch (different strings).



- e) A natural harmonic and a stopped harmonic which produce the same pitch (different strings).



In addition to instrument geography, unisons are an issue of colour awareness. Changes of timbre in the left hand are usually accompanied by changes in the bow.

Notation

Traditional notation is used. The *altissimo* register will most usually be written with an 8^{va} sign. *Scordatura* can be notated in one of two ways: at concert pitch, which is generally preferred by musicians with perfect pitch, and transposed, more convenient for those without perfect pitch. The first method shows which pitches are actually produced, while the latter indicates the position of the stopped notes on the string.

NON-TRADITIONAL TECHNIQUES

As demonstrated in the preceding seven sections (Adapted Technique), many extended techniques are deeply rooted in traditional playing. Listed below are the techniques whose definition most faithfully corresponds to the term ‘extended technique’: using an instrument in ‘a manner outside of traditionally established norms.’¹⁸³

In many compositions, personal expression through musical material becomes subordinate to the physical interactions between performer and instrument, explored throughout many of the techniques below. This category also includes techniques borrowed from other instruments and from musical traditions outside the Western classical tradition. Together with Adapted Technique, the following ten sections complete the time-line of technical progression on the cello, from the earliest days of the cello to the present.

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¹⁸³ <http://newmusicbox.org/article.nmbx?id=4076>

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8. BI-TONES

The next three sections are very much connected, and belong to the realm of percussion. Bi-tones have been isolated as their own category because of the specific acoustic mechanism involved, which can also be produced with certain non-percussive techniques.

In the traditional use of *arco* and *pizzicato*, the string or string segment vibrates in its entirety; there is one fundamental with its overtones. The term bi-tone will be used to describe the techniques (other than harmonics) in which the string is activated to create two vibrating segments of string, producing two fundamentals and two sets of overtones. To follow Fallowfield's terminology, the term 'hammer' will be used to describe the object used to initiate vibrations in the string, whether it is the finger, bow or other object.

This section aims to develop awareness of the various pitch components in a sound, and a further understanding of how sound is produced. Each of the sections below should first be practised on the open strings; using whichever hand is free, pluck both string segments on either side of the hammer (nut to hammer and hammer to bridge), to hear both pitches separately.¹⁸⁴ It is important to aurally identify both these pitches when the technique is played.

History

The techniques which produce bi-tones are relatively new. Because neither terminology nor notation has been standardized for these, their origin is difficult to trace. One could speculate that none of these techniques appeared prior to the 1960s.

¹⁸⁴ This technique of isolating the pitches before playing them is used by Fallowfield on her website, <http://www.cellomap.com>.

Theory & Practice

The mechanism of sound production for bi-tones is similar to that of a clavichord.¹⁸⁵

When the hammer strikes the string and stays in contact, vibration occurs on both segments of the string, between the outer edges of the hammer and each extremity of the string. These impulses of vibration are reflected back to the outer edges and continue, with decay, as long as the hammer remains on the string, producing two pitches. As the string only vibrates from the outer edges of the hammer, the portion of string under the hammer itself does not vibrate.¹⁸⁶

The mechanism of sound production when the hammer does not stay in contact with the string is quite different (see '9. Strike Tones', p. 132).

The portion of string between the hammer and nut will sound fairly strongly on an open string, as the vibrations travel through the nut to the cello body where they are slightly amplified. A stopped string will block the transmission of the vibrations of this portion of the string to the cello body, and will be inaudible.

Fallowfield explains that the longer string segment, or lower pitch, is usually louder.¹⁸⁷ But because the vibrations of the hammer-to-bridge segment are more easily transmitted to the body of the instrument, there is a slight discrepancy in this statement. At the mid-point of the string where both segments are equal, the hammer-to-bridge pitch will be louder. Both segments are equally loud approximately one semitone above the mid-point of the string. Beyond this, as the hammer approaches the bridge, the longer string segment is louder once again. The effect is of two pitches moving in contrary motion as the hammer moves from one end of the string to the other. The pitches cross over at approximately one quarter-tone above the mid-point of the string.

¹⁸⁵ Fallowfield (2010), p. 51.

¹⁸⁶ For a more detailed explanation of the sound production process of a hammer mechanism, please see: Fallowfield (2010), pp. 56-60, 66-68.

¹⁸⁷ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

The point of contact in bi-tones also affects timbre.¹⁸⁸ As the hammer nears the string's extremity, fewer harmonics are present in the sound of the shortest length of string. Material is also a factor: the denser the hammer, the more overtones are in the sound and the longer the decay time.

To obtain a bi-tone whose pitches are in tune with each other, the hammer will have to be higher than it would be for normal stopping – how much higher will depend on the hammer's width. A typical finger-tip, for example, spans approximately a quarter-tone in the lower positions. Therefore, to produce two notes in tune with each other, the finger needs to stop the string half its width higher. For two identical pitches, the middle of the hammer must align with the middle of the string; the resulting pitch (on an open string) will be approximately one eighth-tone flatter than the open string one octave below.

Applications

Con le Dita / Fingerschlag / Finger Percussion / Finger Tapping / Hammer On

This technique has various names; this text will use Gubaidulina's Italian term *con le dita* which translates literally as 'with the fingers'. This particular technique is often vaguely defined and called 'bi-tones', a term which we use in this text to define a much broader category of sound mechanism. The German *fingerschlag* 'finger strike', the English 'finger percussion' and 'finger tapping' are also used, as well as the guitarists' terminology 'hammer on' coined by Peter Seeger in 1948 in his banjo manual, though guitarists tend to use this technique to a different effect than cellists. These terms all designate the left hand striking the string at the position where it would press on the string to produce the given pitch on the staff. This technique leaves the right hand free.

This is effectively a new technique resulting from a properly executed traditional left-hand technique, but with exaggerated action. Practising *con le dita* also contributes to a general strengthening of the left-hand fingers. It is particularly well suited to the cello because of the string length.

¹⁸⁸ Ibid.

In addition to the mechanical action of this technique, intonation becomes an area of focus. The pitch in *con le dita* comes from the outer edges of the finger, as in regular stopping. This means that for the same finger placement as for regular stopping, the second pitch, the one created by the string length between nut and finger edge, will be about a quarter-tone flat in the lower positions. Played with only one finger hitting the string, these bi-tones will never be in tune relative to an open string. There are two solutions:

- 1) Eighth-tone adjustments: As suggested in the example above, placing the finger ‘half-a-finger-width’ higher (approximately an eighth-tone in the neck positions), will create whole-number ratios between the string lengths.
- 2) Widening the hammer: The length of the two string segments are determined by the width of the hammer. Therefore using two fingers side-by-side to hit the string will make the bi-tones in tune with each other and with the open string. One can experiment using two or more fingers simultaneously and with different spacing to alter the pitch of one or both of the bi-tones.

In order to produce only the pitch written on the staff, the string segment between the nut and the finger can be dampened with another finger or the free hand. In prolonged passages where the open string is not required, a cloth can be tied to the neck of the cello, to the same effect as electric guitar players use a hair tie or sock.

This technique should be rehearsed through a variety of pitch ranges, dynamics and lengths (*staccato* and *tenuto*).

The sound is brighter (more overtones) and lasts longer if the nail is used rather than the finger-pad. However the hand must be turned (left elbow angled very high or wrist placed at an acute angle) to ensure that the nail stops the string – this makes it more difficult to play in tune.

Dead Stroking

The term ‘dead stroking’ or ‘dead sticking’ is used by percussionists when the mallet is left on the instrument’s surface after it is struck. This has the effect of dampening the resonance. Using this technique with the bow on the strings of the cello however

activates the same sound mechanism as described above. Hitting the string with the bow with considerable force and leaving it on the string creates vibration on both segments of the string; therefore, pitch can be altered through different points of contact and leaving the bow on the string. This is most effective if the tip of the bow is used, as the tension between the stick and the hair, and the distance of the pivot point (right hand) allow for greater strike force. This can also be done with the wood of the bow.

Nageln / Clicks / Crenelated Bowing

The mechanics of this technique were discussed on page 100 (section '4. Bowing the String: Speed & Pressure') because of the relation to overpressure technique. *Nageln* are included in this section because the resulting sound is effectively a bi-tone. The string is activated by the bow and sends two kinks of vibration to either extremity of the string, which are reflected back to the bow edges. The portion of string under the bow does not vibrate because of the bow's high pressure. Fallowfield writes that the stopped-finger-to-bow pitch is prevented from being amplified by the body of the instrument and hence only the bi-tone generated from the segment of string between bow edge and bridge is heard. This author has found however that this is not the case on her instrument and that the lower bi-tone is always heard. This technique is most effective with bow placement between the end of the fingerboard and the bridge.

Vertical Nageln

The mechanics of vertical *nageln* were also discussed earlier (p. 102). Two sets bi-tones are produced in this technique, but the dominant tone of each combine so that effectively, two pitches are heard. As with regular *nageln*, the high bow pressure both bisects the string, and allows it to vibrate in two segments; the longer string length, or bow edge to nut, is the dominant tone. Simultaneously to this, the bow hair vibrates in two segments, the longer segments producing the dominant tone regardless of whether the point of contact is in the lower or upper half of the bow. This produces a mirror image of ascending and descending pitch, the highest being at the middle of the bow. The bow hair can be stopped (see p. 100).

Pitch Bending (vertical)

The pitch can be bent by increasing the pressure of the hammer on the string, while always keeping contact between the hammer and string. As above, this technique is most effective beyond the fingerboard, where the strings can be ‘pushed’ further than is needed for vibrations to stop under the hammer. This technique done quickly and with a regular pulse can produce a vibrato effect.

Col Legno Tratto

The ergonomics of this technique are discussed on page 151. A brief mention is made here as bi-tones occur in *col legno tratto* at a medium bow speed.

Other Hammers

Bi-tones can also be produced by using a ‘hammer’ other than the left-hand finger or bow hair and stick. While the possibilities have only creativity as a limit, one may begin to experiment using the nut of the bow. This is used by Lachenmann,¹⁸⁹ with the instruction *Mit Spannschraube*. Another example can be found in the violin and viola parts of Crumb’s *Black Angels*, in which metal thimbles are placed on the 1st and 2nd fingers of the right hand, which performs a tremolo up and down the string, from the bridge to the middle and back again.

Notation

The notation for bi-tones typically only indicates the note produced by the hammer-to-bridge segment, the second tone being implied. Because no specific notation exists, crossed note-heads or a performance indication, which varies from one composer to the next, is usually included. Ligeti uses the following notational device:

Figure 26: Bi-tone notation - Ligeti *String Quartet No. 2*



¹⁸⁹ Lachenmann, ‘Toccatina’ from *Studies for Playing Contemporary Music for Violin* (1986).

9. STRIKE TONES

Both bi-tones and strike tones are produced by a hammer striking the string – both techniques are very much linked acoustically. However, the physical mechanics involved in strike tones are very different: the hammer releases the string after striking it, rather than staying in contact.

As with bi-tones, this section aims to develop an awareness of pitch components in sound. Once this section is understood, the student should compare and combine bi-tones and strike tones, focusing on the change in pitch components.

History

Col legno battuto was used from the earliest days of bowed string instruments as a sound effect. The Romantics incorporated the sound of the wood of the bow in a colouristic way (examples on p. 140) but the specific pitches produced by the strike tones are even now only rarely asked for in any precise way.

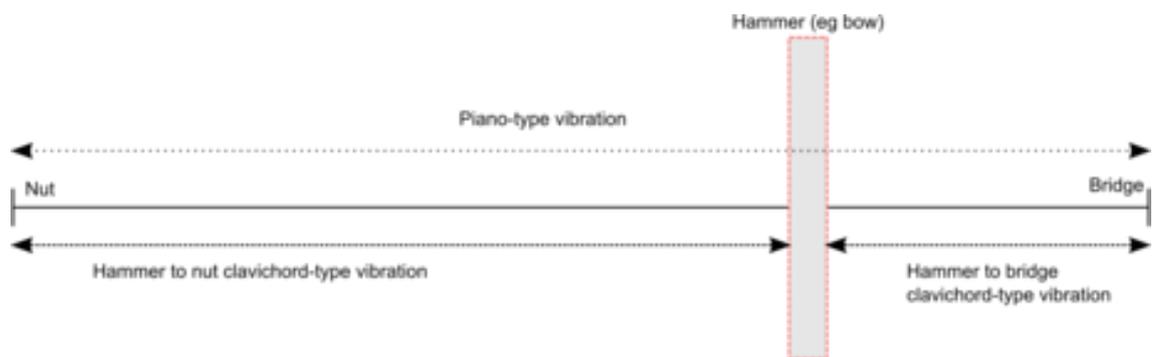
Theory & Practice

When the hammer is released after hitting the string, two pitches are heard: that of the entire string length (primary tone), and that of the much shorter length of string between the hammer and bridge (strike tone). This strike tone is the more prevalent of the two bi-tones produced by the hammer. There are in effect three pitches produced in this technique, but the primary tone and strike tone psychoacoustically mask¹⁹⁰ the weaker, nut-side bi-tone (secondary bi-tone), especially if it is close in pitch to the primary tone. The result is two pitches that are different than those of bi-tones proper. Fallowfield's diagram below clearly shows the three tones produced.¹⁹¹

¹⁹⁰ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

¹⁹¹ Fallowfield (2010), p. 60.

Figure 27: Bi-tones and strike tones



The same sound production mechanism as for bi-tones applies (section ‘8. Bi-tones’, p. 126), but additionally, when the hammer leaves the string, the vibration is able to travel along the entire length of the string. The vibration continues until the excitation energy dissipates. Fallowfield refers to this as a ‘piano-type’ vibration, as it is similar to the sound production mechanism in a piano.

The primary tone, or string length as determined by the open string, fingered note or harmonic, remains the same regardless of the position of the hammer. The strike tone changes according to the hammer’s point of contact with the string. As the bow travels from the bridge to the nut so the pitch descends. For an identical point of contact, the strike tone remains the same regardless of the position of the stopped note; this also applies to harmonics.

Fallowfield remarks that although the pitch of the primary tone sounds effectively after the strike tone, both notes are usually perceived as sounding simultaneously.¹⁹² She provides an exercise to understand how the string is bisected and to hear the difference between bi-tones and strike tones, reproduced below.¹⁹³

¹⁹² <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string.html>

¹⁹³ Ibid.

Exercise 12: Bi-tones vs. Strike Tones

- a) Placing the bow firmly on the string, pluck the string on either side of the bow to hear the pitches.
- b) Carefully maintaining the same point of contact, hit the string with the bow but don't lift the bow afterwards, keep it on the string. Listen for the two notes you just plucked.
- c) Now still with the same point of bow contact, hit the string but let it bounce back away from the string: you should hear the open string and the pitch of the portion of string between the bow and the bridge.

The primary tone can be heard very clearly if the hammer is on the farthest possible extremity of the string. This is most effective when playing harmonics, which are easily obscured by the strike-tone.

The sound production mechanisms of the plucked and struck string are very similar. The parameters below can be compared to those on page 63, which should be reviewed at this time. A more detailed explanation of these parameters and how they relate to contact area and damping, and therefore to overtone content, can be found on Fallowfield's website.¹⁹⁴

Point of Contact

In strike tones, as in pizzicato, the overtone content in a sound is determined by the point of contact, and the portion of string under the hammer is most displaced. The exercise on page 64, which is designed to hear overtone exclusion, should be repeated with strike tones.

Velocity & Force

A sound will be more overtone-rich and louder if the string is struck with greater force and speed. On the lower-end of the spectrum of force, the strike tone is as loud as the primary tone. With increasing force, the loudness of the primary tone increases at a faster rate than the strike tone, and becomes dominant at a moderate striking force. Past

¹⁹⁴ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/with-what.html>

this point, with strike force still increasing, – and as the force increases, so does the contact time between the hammer and the string – the strike tone then becomes louder than the primary tone. This does not apply to very short string lengths, where the amplitude of the stopped note is reduced significantly and the strike tone is dominant.¹⁹⁵

Size & Density

To reiterate, there are two acoustic mechanisms taking place in strike tones: that of the primary tone is similar to pizzicato and to the action of a piano, and that of the bi-tone is similar to the clavichord. Fallowfield summarizes the acoustic principle applicable to size and density: ‘In the case of the hammered string, thin, dense hammers maximise the overtone content of piano-type vibration and wide, dense hammers maximise the overtone-content of clavichord-type.’¹⁹⁶ Therefore dense materials will always provide greater overtone-content, but different widths of hammer will affect to various extent one or another of the pitch components of a strike tone.

Exercise 13: Widening the Hammer

- a) Notice the slight difference in sound between col legno at the middle of the stick, and using the flat side of the tip of the bow (the largest available surface of wood on the bow). Observe whether this produces a stronger or weaker strike tone in relation to the primary tone.
- b) Using two bows for col legno, observe the reduction in overtone content but the increase in volume. Repeat with various distances between the two bows. If the bow closest to the bridge stays at the same point of contact, there should be no variation in the pitch of the strike tone.

Notation

The open string or stopped note, which we have defined here as the primary tone, is usually the notated pitch. It is possible to notate the strike tone as well; if not precisely, an indication of melodic contour can be given:

¹⁹⁵ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/how.html>

¹⁹⁶ Fallowfield provides a more detailed explanation of this on: <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/with-what.html>

Figure 28: Strike tone notation - Crumb *Black Angels*, 'Sounds of Bones and Flutes'

Applications

Col Legno Battuto

Traditionally, *col legno battuto* is used in composition as a percussive effect, and for this reason is discussed in more detail in the following section (p. 141). However the pitch content of this technique shouldn't be neglected. In live performance the strike tone is easily accepted as tone 'colour' – the eyes and ears of the audience connect the 'click' of the wood of the bow to an indefinite pitch which colours the sound of the fingered note or open string. This is not so easily the case in recordings however, where the sound is heard for what it really is. Not taking care of the point of contact can produce an unwanted effect.¹⁹⁷ Exercise 14 (below) is adapted from P & A Strange's example, and demonstrates the effects of maintaining or changing the strike tone's point of contact.¹⁹⁸

¹⁹⁷ One can refer to V. Welbanks' recording of Elena Firsova's *Hommage to Canisy* (Meridian, 2015), in which the movement of the strike tones is inconsistent. It would have been preferable to alter the pitch of every strike tone.

¹⁹⁸ P & A Strange (2010), p. 107.

Exercise 14: Strike Tones Melodic Contour

Both staves are played entirely on the A-string. The lower staff shows the fingered pitches (primary tones), and the upper staff shows the hammer's point of contact on the string, which are also the pitches of the resulting strike tones.

- First play the upper staff *arco* to hear the notated pitches.
- Then, to hear the strike tones alone, place the palm of the hand over the strings to damp them and hit the string with the wood of the bow where the left hand would ordinarily be to stop the pitches.
- Play the exercise as written.

The musical score for Exercise 14 is presented in three systems, each with a treble and bass staff. The time signature is 4/4. The first system is labeled 'oblique' and shows a sequence of notes in the upper staff (treble clef) and lower staff (bass clef). The second system is labeled 'parallel' and shows a sequence of notes in the upper staff (treble clef) and lower staff (bass clef). The third system is labeled 'contrary' and shows a sequence of notes in the upper staff (treble clef) and lower staff (bass clef).

To eliminate the strike tone's pitch and truly obtain a '*col legno*' timbre, the bow should strike as closely as possible to the bridge.

Isolated Strike Tones / Legno Saltando

Strike tones can be isolated by damping the string between the hammer and the nut, using the palm of the hand for example. Damping the string at different points on the

string produces different secondary bi-tones. Lachenmann refers to this technique as *legno saltando*.¹⁹⁹

Battuto Con Crino

The information above in *col legno battuto* is applicable to *battuto con crino*. The same bowing technique is used but with the hair of the bow rather than the wood. Because the density of the hair is so much less than the wood, the sound of the strike tone is considerably muted.

Stopping with the Bow

These are ‘reverse’ strike tones of sorts. Two pitches are made by lightly pressing the bow hair onto the string and doing a left-hand pizzicato. The dominant pitch is the one between the nut and bow edge, and can be varied by moving the bow’s point of contact. Because the vibrations travel through the bow hair, the primary tone (open string, fingered pitch or harmonic) sounds as well. These two notes masks the secondary bi-tone (bow edge to bridge) in the same was as described above. Here, the pitch of the strike tone (nut to bow edge) is affected by the pitch of the primary tone, as opposed to the strike tones of *col legno* which are not.

¹⁹⁹ Lachenmann *Pression* (1969/2010).

10. CELLO PERCUSSION

Instrumentalists are occasionally asked to make percussive sounds on their instruments or with their bodies. Read remarks in the early 1990s that ‘Possibly no avant-garde string technique is more varied in production or more intriguing sonically than the concept – currently high in favor – of the bowed strings as percussion rather than lyric instruments.’²⁰⁰

Defining the various uses of the cello as a percussion instrument proves challenging in that official definitions seem neither comprehensive nor exclusive: regardless which category of percussion is being defined, each seems to have a caveat, be it in the Merriam-Webster, Oxford Music Online or the Cambridge Dictionary Online. If, as offers Samuel Adler, an idiophone can be ‘struck, scraped, shaken, or stroked’²⁰¹ (by which he also means bowed), then our own categorization of the cello as percussion will be defined as a struck or scraped idiophone.²⁰² Techniques where the cello is essentially a percussive chordophone²⁰³ have been discussed in sections ‘8. Bi-tones’ (p. 126) and ‘9. Strike Tones’ (p. 132).

Below we will look at different ways of producing percussive sounds – some pitched, others unpitched – by striking various parts of the instrument with the bow, hands, and objects. A brief discussion on body percussion will follow. This section will aim to develop familiarity with the sounds produced by these techniques and to coordinate their production with regular playing. These techniques provide fertile ground for improvisation, and should be explored and combined in this way one this section is understood.

²⁰⁰ Read (1993), p. 91.

²⁰¹ Adler (1982), pp. 437, 440, 443-444, 453. Adler’s term ‘stroked’ includes bowing, more specifically with the musical saw, vibraphone, and cymbals.

²⁰² The Merriam-Webster Dictionary defines an idiophone as: ‘any of a class of musical instruments whose sound is generated by striking, rubbing, plucking, or blowing the material of the instrument itself not under any special tension.’

²⁰³ Adler defines chordophones as instruments of the percussion family which ‘produce their sound by the vibration of their strings’ and are amplified by a resonator. He includes in this section the cimbalom, piano, harpsichord, harmonium (!), and organ (!). Adler (1982), p. 449.

A performer is occasionally asked to play another instrument while at the cello or in the middle of a piece. This sometimes requires knowledge of techniques specific to these instruments and lies outside the scope of this thesis; a professional percussionist will almost always be happy to offer advice.

History

The first percussive device used by stringed instruments was *col legno battuto*, and though this was used as early as 1605 (by Tobias Hume in *Musical Humors*), this remained rare in 18th- and 19th-century literature.²⁰⁴ Among the earliest examples of the technique, de Saram mentions a rare triple-stopped *col legno battuto* used in the first violin part of *Capriccio stravagante* for strings by Carlo Farina in 1627.²⁰⁵

Berlioz, who uses *col legno* in 1830 to great effect in his *Symphonie Fantastique*, mentions the technique in his *Treatise*.²⁰⁶ *Col legno* was used again in the early part of the 20th century in orchestral and quartet literature, namely in the music of the Second Viennese School.²⁰⁷

Other percussive devices appeared early on as well. In Biber's *Battalia*, stomping or hitting the side of the instrument with the wood of the bow is used in the first movement to represent soldiers' footsteps.

The re-emergence of interest in 'noises' possible on a stringed instrument could conceivably be attributed to 'the "*bruitism*" of the Futurists which used the sounds of the non-musical environment – namely noise'.²⁰⁸ Arnold Whittall provides interesting insight into 20th-century interest in percussion and noise: 'The battery of percussion [...] is the most obvious evidence of Varèse's experimentalism, the interest in new sounds as

²⁰⁴ Chopin writes *Col legno battuto* and *tratto* for the violins and violas in the third movement of his Piano Concert No. 2 (1830) but even today some orchestras ignore the indication, as if it were misguided.

²⁰⁵ Steinheuer & de Saram (2013), p. 225.

²⁰⁶ Berlioz (1844), p. 20.

²⁰⁷ Read (1993), p. 91.

²⁰⁸ Nyman (1999), p. 39.

such, since without new instruments the composer was forced to exploit new combinations and unusual selections of existing instruments.’²⁰⁹

This history of percussive sounds on plucked string instruments is perhaps richer, but lies outside the scope of this text. The interested reader should particularly investigate the flamenco guitar.

Theory & Practice

The Bow as Percussion

The bow is transformed into a beater, albeit a very sophisticated one offering such opposing textures as the hair and the wood, and varying weights as the tip and the frog.

Col Legno Battuto

(Pitched sound)

The term *col legno* designates that the wooden stick of the bow is to be used, while the term *battuto* informs the motion, instructing the player to strike the string. In many cases the bowing motion is very similar to the traditional *ricochet*, but the horizontal motion can be minimized or removed entirely to leave only a direct hit. As mentioned on page 136, *col legno battuto* produces two notes; in section ‘9. Strike Tones’, the technique was explored as a melodic device, and the ergonomics of the technique will be covered on page 151 in section ‘12. Changing Bow Hold’. This section discusses its qualities as a percussive device.

Several factors affect the sound in *col legno battuto*:

Density: The quality of the sound is contingent on the density of the wood of the stick. A clear *col legno battuto* sound will not necessarily come from a higher-quality bow, in the traditional sense.

²⁰⁹ Whittall (1977), p. 201.

- Weight: The different weights of each section of the bow, and of different bows, also give scope for variety in the sound. For example, a very quiet and delicate sound is produced at the tip of the bow. To achieve a *fortissimo* dynamic, cellist Anatole Liebermann suggests turning the bow around so that heaviest part – the wood above the frog – is used (see ‘Orientation’, p. 152).
- Force: Because the motion of a *battuto* bow stroke is perpendicular to the string, a greater angle between the bow and string increases the force of the strike. P & A Strange suggest acquiring less expensive instruments and bows, much as a percussionist ‘who must invest in a variety of instruments, each used for a different situation’.²¹⁰
- Point of contact: The position of the bow on the string will affect resonance of the strike tone in relation to the pitch of the string. *Col legno sub ponticello* ‘produces a much more percussive sound, pitch being almost absent.’²¹¹

Balzato / Ricochet / Saltato

(Pitched or unpitched sound)

This technique is a traditional component of string playing.²¹² However when applied to parts of the instrument other than the string, its function becomes primarily percussive. The parts of the instrument covered in section ‘11. Bowing the Instrument’ (p. 146), can all be used to varying effect.

²¹⁰ P & A Strange (2001), p. 97.

²¹¹ Idem., p. 105.

²¹² I would suggest refreshing this technique in a modern music context by studying Gubaidulina’s *Ten Preludes: No. 4 ‘Ricochet’*.

De Saram describes the *balzati* required ‘below the strings on the body of the cello as well as *balzati* in various positions along the face of the bridge’²¹³ as exactly the same bowing technique used for traditional *ricochet*.

Bow Whip

(Unpitched sound)

Moving the bow through the air in a whipping motion will produce a highly audible sound. The bow should be turned so that the hair is flat against oncoming air flow.

Hand Percussion

The same parameters as those outlined on page 63 of section ‘2. Pizzicato’ apply here.

Note length & point of contact: ‘Note length’ equates here to resonance and ‘point of contact’ to the part of the instrument used; in using the cello as a percussion instrument, these two parameters are interconnected. In addition to the strings, fingerboard, and the front and back of the body, the various parts of the instrument that produce a sound when hit are outlined in section ‘11. Bowing the Instrument’ (p. 146).

The front and back plates are omitted from section 11 because they don’t respond particularly well to being bowed, but they do however produce characteristic sounds when hit. A deeper and more resonant sound will come from the middle of the body, whereas a higher-pitched and dryer sound (much like a wood block) will be made near the ribs of the cello. The author suggests identifying three parts of the cello’s body which produce a relatively low, medium and high pitched sound, as it is the contrast of timbres which is usually sought with this technique.

Contact area & material: Contact area corresponds to how much surface area of the hand or fingers is used, and material to which part. Five parts of the hand can be used for percussion, each of which produces a different timbre:

²¹³ Steinheuer & de Saram (2013), p. 114.

- a) Fingertips
- b) Fingernails
- c) Knuckles
- d) Palm
- e) Heel

Flamenco guitarists provide inspiration in regards to tapping the top of the instrument with the finger tips, with the technique called *golpe*. A tremolo can be achieved using the finger tips.

Direction, speed & force: The movements made with the above-mentioned parts of the hand can be perpendicular (striking) or parallel (rubbing) to the string, and of course any combination of the two. The speed used in the approach of the instrument, and the force used on impact will affect the sound as well.

Strikes: Various amounts of force give different effects, from tapping, to slapping and knocking. Choosing to leave the hand on the string or instrument dampens the sound. To achieve a very sharp sound, snapping the fingers on the instrument gives the speed to the motion.

Rubbing: Combining this motion with contact area and material (palm of hand at one extreme and finger nails at the other) yields varying effects. Circular versus linear and slow versus fast motion should be explored. Rubbing the string with the fingernail is also in this category.

Tambourine Rub / Friction Rub

Press a rosined thumb,²¹⁴ fingertips or the palm of the hand on the back of the instrument, starting at the top of the body and moving quite rapidly downwards while maintaining steady pressure. The sound produced is similar to a tambourine roll. Percussionists use this technique on tambourines and drum heads.

²¹⁴ As per the suggestion by P & A Strange (2001), p. 54.

Body Percussion

It is possible to combine actions such as stamping and snapping fingers with playing the cello.

Objects

Sounds created with an object – glass, metal, rubber and wood – are subject to the same principles of sound production as the bow and hands. Discussing the wide variety of possibilities is beyond the scope of this thesis, but understanding the basic mechanisms of sound production should give the cellist enough tools to find the best way to use other objects on the cello.

Gubaidulina's 'friction stick' deserves special mention because of its unusual components and unique sound, which evokes the balalaika. She instructs to attach a piece of steel piano wire to a 3-4 centimetre rubber ball. This is dragged along the string and is most effective when amplified.

Notation

There is no standard notation, but crossed note-heads are often used and defined in performance notes.

11. BOWING THE INSTRUMENT

Bowing various parts of the instrument other than the strings produces very distinct tones, some pitched and some not. As with the previous section, the intent here is to develop a lexicon of possible sounds.

History

The use of these sounds belong very much to the 20th century. Frances-Marie Uitti writes about Germany's Darmstadt Summer School in the 1960s: 'There, for the first time, sound production from the whole instrument was accepted readily as valid material for the composer's use. The cello was played from the endpin to the scroll; it was treated as a percussion instrument...' ²¹⁵

Theory & Practice

The sounds below are divided into pitched and non-pitched, and are highly contingent on bow pressure and speed.

Non-pitched (Breathing): Light Pressure

In addition to the techniques described on page 103 (section '4. Bowing the String: Speed & Pressure'), there are several ways of emulating the sound of breathing with the bow. A certain amount of nuance can be achieved by increasing bow speed, which affects volume. The sound is created by the vibrations of the bow hair on a surface, rather than the vibrations of the instrument itself. All of the sections in this category require very little bow pressure and produce subtly different sounds.

On the Bridge

Bowing on the top of the bridge itself requires a great deal of control in order not to make the string vibrate. Rolén suggests bowing in the area between the strings, drawing the bow at a 45-degree angle with the bridge. ²¹⁶ Such bowing is more effective when the heel of the bow is pointing downwards, as the elongated arm can apply more leverage. This limits the cellist to using only the lower half of the bow, depending on

²¹⁵ Stowell (1999), p. 217.

²¹⁶ <http://www.moderncello.com/bow-techniques/ponticello-tasto/to-the-extremes>

the cellists arm length, but provides more accuracy in the type of sound produced and through this comfort, a more sustained sound.

A slightly ‘darker’ sound can be achieved by placing a wooden mute on the bridge and bowing on this.²¹⁷

Foot of the Bridge - Light Pressure

To bow the side of the foot of the bridge closest to the right hand, the bow should be parallel to the strings. This action is better achieved with the bow-tip pointing downwards so as to maximise the amount of bow used by the length of the arm.

Ribs / Tailpiece / Scroll

The bow should be parallel to its usual position for all of these parts of the cello. Of these, the ribs are the most accessible but there is a risk of wearing down the varnish. The tailpiece is perhaps the most convenient in terms of the movement and protecting the instrument, while the scroll is the most visually dramatic.

Pitched (Fog Horn): Heavy Pressure

There are several pitched sounds which can be achieved by bowing various parts of the cello. These techniques each produce one pitch, with very little possible nuance. For a sustained sound, the bow should be well rosined, bow speed very slow and bow pressure very high. The sounds are created by causing a certain part of the instrument to vibrate.

Bowing on the following parts of the instrument will produce powerful and unique sounds, which will vary from one instrument to another depending on the thickness, density and type of material used.

Foot of the Bridge - Heavy Pressure

Bowing with a considerable amount of pressure on the foot of the bridge should be done in the manner described in the entry above, ‘Foot of the Bridge - Light Pressure’.

²¹⁷ Alberman (2005), p. 43.

Thread Winding

Bowing on the thread winding of the strings, near the tailpiece, will produce a sound with a very dominant noise spectrum and very little pitch. Pitch content increases nearer the bridge, and decreases nearer the tailpiece. Each of the four strings has a different pitch.

Tailpiece / Sulla Cordiera

The tailpiece can vibrate at quite a low and pure frequency, and will not be damaged by high-pressure bowing. This technique is discussed by P & A Strange²¹⁸ and Samuel Adler.²¹⁹

End-pin

For certain types of end-pin, bowing in the middle segment (between the floor and the body of the cello) will produce a pitched sound.

Scroll

Bowing on the front of the scroll, or the narrowest part, produces a high-pitched note.

Pegbox, Pegs & Neck

These parts of the violin and viola resonate when bowed, but are normally too thick to resonate on a cello. It is nonetheless worth trying when exploring a particular instrument's possibilities.

Notation

While there is no standard means of notation for bowing on various parts of the cello, a wide variety of notational devices are used. A wide range of percussive techniques are indicated by crossed note-heads (x). It is often not specified whether bow pressure should be high or low, and thus whether the sound should be non-pitched or pitched.

²¹⁸ P & A Strange (2001), pp. 46-47.

²¹⁹ Adler (1982), p. 150.

Figure 29: Bowing the instrument, notation examples²²⁰

Area to be Bowed	Composer	Notation
Side of the bridge	Penderecki	
Side of the bridge	von Biel	
Tailpiece where the strings are connected	von Biel	
Tailpiece	von Biel	
Tailpiece	Penderecki	

²²⁰ Michael von Biel's notation is cited in P & A Strange (2001), p. 47. It is unclear whether the examples reproduced here refer to von Biel's *Quartett* (1964) for violin, viola, cello & bass or to one of Biel's string quartets. Penderecki's notation is cited on http://beststudentviolins.com/Reflexions_archive_page2.html, and is used in his *Threnody to the Victims of Hiroshima* (1960).

12. CHANGING BOW HOLD

As seen previously with ‘Modifying Points of Contact’ (p. 86), the rapid changes between various techniques are techniques in themselves. While an underlying principle of this thesis is that traditional playing position should be altered as little as possible, certain flexibility is required in the bow hand, even in traditional playing.

Through the examples in this section, students will develop ways of adapting to new challenges of bow technique. This challenge which will become explicit in section ‘13. Sustained Polyphony: New Uses of the Bow’.

The sections below cover techniques which are commonly alternated. Familiarity with all the individual techniques below will have been attained through the study of the previous sections.

History

Virtuosity has from the earliest days of the cello included rapid alternations of bowing patterns and articulations. This virtuosity extends into the 20th century through the means of alternating two or more timbres.

Theory & Practice

Passages with alternating techniques should first be divided so that all sections in one technique are rehearsed consecutively. Careful attention should then be made to the movements needed to most effectively pass from one technique to the other.

Applications

Pizzicato & Arco

As learnt from quite early on, pizzicato can be done either holding the bow in the fist, or by keeping the bow hold and extending a finger. Both of these should be rehearsed in alternation with *arco* playing.

Rotation

Rotating the bow to varying degrees allows the sonority of the wood of the bow to be involved in the sound. *Con crini tratto* to *col legno battuto*, *tratto* or *con crino* all provide a multitude of subtleties.

Con crini tratto is what we refer to as *ordinario* playing, with the hair of the bow.

Col legno battuto has already been discussed in terms of sound production mechanism (p. 136) and ergonomics (p. 141).

Col legno tratto involves bowing in a regular manner but using only the wood of the bow: the bow must be almost ‘up-side down’ as it were, or inclined enough so that the hair does not touch the string. In his notes to *Pro Musica Nova*, Palm suggests applying rosin on the stick of the bow to heighten the characteristic sound of bowing with the wood. Relatively fast bow speed is necessary in most cases as the sound produced is extremely quiet. Sound is partially produced here by the ‘stick-slip’ motion of the string (see p. 76), and more so if rosin is used, but mostly what is heard is the noise made by the wood on the string.

Col legno con crino is normal *arco* playing but with both the wood and the hair in contact with the string – this needs the bow to be fully on its side, the hair facing towards the bridge.

Positioning the bow for these techniques involves either rotating the position of the bow in the hand, or rotating the bow by bending or straightening the wrist and elongating the fingers. In both instances, the rotation is controlled by the thumb and 2nd finger, as in traditional playing.

Ordinario & High Pressure Arco

High pressure bowing, as needed for the techniques on page 95, sometimes requires a bow hold which allows for greater leverage than a normal bow hold can provide. Four possibilities exist, listed in order of resemblance to a normal bow hold:

- a) Angling the right elbow very high (necessitates long arms).
- b) Laying the first finger across the bow stick (tilting to the outer side of the hand).
- c) Placing the thumb under the frog.
- d) Holding the bow in the fist: *Faustgriff*.²²¹

Orientation

180°: The frog of the bow is heavier; therefore changing the orientation of the bow so that the tip is held can help, for example, to produce a *col legno battuto* in a *fortissimo* dynamic (see p. 141). Both hands are needed to make the transition. The bold hold should remain as near as possible to the normal bow hold.

90°: A 90° rotation with the bow's tip pointing upwards, as in 'Parallel Bowing' (see p. 89), sees the bow hold remain the same, while the arm's angle accommodates the change. Bowing at a 90° rotation with the bow's tip pointing downwards, as on the foot of the bridge (see 'Foot of the Bridge - Light Pressure', p. 147), requires the bow hold to stay the same, but 'upside-down' as it were.

Mirror image: Placing the bow under the strings, between the fingerboard and the bridge, allows the A- and C-strings to be played simultaneously (see p. 86). When going from bowing above the string to below it, it is easier to begin the bow stroke on an up-bow – this will reduce the possibility of hitting the strings or table when bringing the bow into position.

²²¹ Term coined by Lachenmann. Alberman (2005), p. 41.

13. SUSTAINED POLYPHONY: NEW USES OF THE BOW

This section introduces several ways in which polyphony can be developed on the cello, incorporating sustained triple- and quadruple-stopping. The first method involves adapting a cello bow, the second using two bows, and the third explores the use of a newly invented bow.

Very few cellists use these techniques currently, and practically no information is available concerning performance advice. This section intends to encourage students to pursue the personal exploration of these techniques which will be necessary to learn them.

History

Polyphony, or rather virtual or implied polyphony, has been used in much of the solo repertoire for solo string instruments, a tradition that Bach inherited and which continued into the 20th century. Paganini, in his endless exploration of the violin's capacities, detached the frog of the bow, placed the hair above the strings, the stick below the body of the violin and re-attached the frog in order to sustain four-part chords. Several unpublished pieces and fragments exist for this set-up, namely *Capriccio per violino solo* (1828) transcribed from the manuscript by Philippe Borer.²²²

Many efforts have been made throughout the 20th century to produce a curved bow so that three- and four-part chords could be sustained. Michael Bach attributes the beginning of this search to Albert Schweitzer, who claimed in 1905 that a curved bow must have existed to play Bach's music as it was written, rather than with broken chords.²²³

Uitti also experimented with a curved bow but eventually abandoned it for the simultaneous use of two bows. She discusses the technique briefly in the article *The Frontiers of Technique*:

²²² According to Michael Bach (Other Minds 13: Panel Discussion March 6, 2008).

²²³ <http://www.cello.org/Newsletter/Articles/bachbogen/bachbogen.htm>

In the 1970s, while involved with improvisation, I felt the need to be able to play four-part chords [...]. In 1972 I commissioned a curved bow to be made to my specification but found that it was too limited for my musical needs as it could only play on adjacent strings. This gave rise to a sound that, in my opinion, became monotonously thick, given the low timbre of the cello.²²⁴

In an interview with Ben Watson for *The Wire*,²²⁵ Uitti discusses working with Scelsi – the first to hear her two-bow technique – in Rome in the mid-1970s, and his subsequent encouragement.

Michael Bach's curved bow seems to be the most resilient invention of its kind to date. Bach first showed a prototype of his invention to John Cage in 1990. He continued to improve the design and showed a model to Rostropovich in 1997. Bach and Rostropovich introduced the latest model (BACH.Bow 34, discussed further below) to the public in 2001.

Theory & Practice

Each of the methods below has clear advantages and disadvantages, and is suited to different situations.

Applications

Removing the Frog

Four-part chords can be achieved by removing the frog from the bow, placing the hair above the strings, and the stick of the bow below the string and re-attaching the frog. Three parts could also be achieved by leaving out the A- or C-string. This achieves sustained polyphony without retraining the hand muscles and without having to purchase new equipment, but it takes time to set up. It also has no flexibility in terms of voice independence, number of voices, and articulation.

²²⁴ Stowell (1999), pp. 222-223.

²²⁵ <http://www.uitti.org/Interviews/Interview%20in%20The%20Wire.html>

Double-bow

Two bows are used simultaneously in the right hand. The double-bow technique devised in 1975 by Frances-Marie Uitti has been used by some of the foremost composers of the 20th century. One bow is held upside-down and under the strings while the other is held above. Very little information is available on this technique, especially as photos and videos of Uitti performing do not show her bow hold. However Uitti does provide, on her website²²⁶ and in her article *An Adventure*,²²⁷ an interesting list of musical possibilities (summarized below), and a helpful guide for composers outlining left-hand possibilities when writing for sustained polyphony. While this technique presents vast musical potential, the doubled weight of two bows in one hand is an additional challenge.

Strings	Any combination of strings can be played (single notes, two-, three-, or four-parts), except for the over-bow alone on the A-string (the under-bow scrapes the bouts of the cello). Specific combinations are provided below in Figure 27 on page 133.
Note length	Independent to a certain degree: the bows move in the same direction and at the same speed but one can be lifted while the other stays in contact with the string. Thus various rhythms, cross rhythms and articulation can be achieved (<i>staccato</i> can be combined with <i>legato</i> for example). Bounced bowings (i.e. double <i>spiccatti</i>) are more difficult to control, however, they can produce interesting rhythmic phasing.
Pressure	Independent dynamics are feasible. This makes possible the combination of various attacks such as accents. The volume of the instrument has the potential of being nearly doubled.

²²⁶ <http://www.uitti.org/Two%20Bows.html>

²²⁷ Zorn (2000), pp. 67-77.

Timbre	Uitti describes a difference in timbre between the over- and under-bows, because of the direction of pressure into the string. She says of the under-bow that it has 'a softer and sweeter sound resembling the <i>viola da gamba</i> . It can emphasize a "shadow tone" if desired, [...] useful for echos [<i>sic.</i>] and hocketing effects. It can be used melodically, but switching between upperbow and lowerbow for crossed string melodic work is somewhat clumsy to execute and uneven timbrically. (Playing in higher positions on the D string gives a more homogeneous effect than switching from A to D strings.)' ²²⁸
Point of contact	Independent: <i>sul tasto</i> and <i>sul ponticello</i> can be achieved by either bow, and transitions between them can be smooth.
Rotation	One bow at a time can be independently turned to achieve <i>col legno tratto</i> or <i>col legno con crino</i> , but for both bows to rotate, they must be repositioned.
Multiphonics	Several multiphonics of eight or more pitches can be produced and combined with normal notes.

²²⁸ <http://www.uitti.org/Two%20Bows.html>

Figure 30: String combinations with the double-bow²²⁹

	Over-bow	Under-bow
4 NOTES	D & G	A & C
3 NOTES	G & C	A
	A & D	C
	D & G	C*
	D & G	A* (*reliability may depend on the bridge curve)
2 NOTES	A & D	
	D & G	
	G & C	
	D	C
	G	A
		A & C
1 NOTE	D	
	G	
	C	
		A
		C

Several other cellists perform with two bows, namely Arne Deforce²³⁰ and Anton Lukoszevieze.

Curved Bow (BACH.Bow)

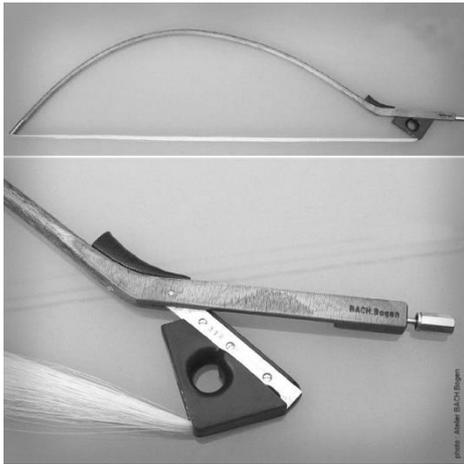
The BACH.Bow currently seems to be the most accepted invention of its kind, with several prominent cellists using it for improvisation or pieces written specifically for the

²²⁹ This table is adapted from Uitti's website: <http://www.uitti.org/Two%20Bows.html>.

²³⁰ His website <http://www.arnedeforce.com/gallery/> has a clear view of his bow hold.

use of this bow. It allows for a flexible use of single notes, two-, three-, and four-note chords on adjacent strings. Attack and timbre are the same for all the strings involved, but a certain amount of subtlety of voicing and dynamic can be achieved as with normal double-stops.

Figure 31: BACH.Bogen, entire bow (above) and frog mechanism (below)²³¹



Its inventor Michael Bach Bachtischa has made a substantial amount of information available online, including numerous videos which demonstrate the bow hold. While the grip itself is conventional, one needs to adjust the tension of the bow hair using a lever mechanism at the frog. This is done with the thumb, which extends outwards from its normal position to tighten the hair. Adjusting the tension on the hair has a double function: altering the number of strings in contact with the bow, and modifying the timbre. Loose hair allows for more strings to be played while tighter hair permits the use of only one string. Tighter hair on one string allows for a richer sound. For this new motion, Bach says some muscles need to be strengthened, namely the large muscles around the thumb (see Figure 32). These can be developed using exercises such as those prescribed by physiotherapists.

²³¹ Courtesy of Atelier BACH.Bogen.

Figure 32: BACH.Bogen bow hold with extended thumb²³²



Bach mentions a small difference in *spiccato* for the BACH.Bow: the sound is less percussive and the bow is not lifted off the string. But most crucially, he advises that most of the difficulty in four part polyphony lies with the left hand, which must play across four strings.

²³² Ibid.

14. MULTIPHONICS

Multiphonics, also known as split tones, are ‘the simultaneous sounding of two or more harmonics on a single string’.²³³ Vastly explored by wind and brass players, multiphonics are also possible on a string instrument but have to date been infrequently used in composition. Violinist and composer Tracy Silverman likens the sound of multiphonics on a stringed instrument to electronic feedback.²³⁴ Norwegian double-bass player Håkon Thelin, who has done extensive research on multiphonics for his instrument, comments that multiphonics are far more successful on longer strings,²³⁵ making the cello an ideal vehicle for this technique.

This section aims to provide a solid basis for the production of multiphonics, the exploration of which could be vastly expanded on the cello. Multiphonics are often thought to be unpredictable and idiomatic to a particular instrument or player, but only patient practice on various instruments and string types will reveal this to be true or false.

History

Wind players have a much better understanding and control of multiphonics, especially flautists and clarinetists. The first person to write about multiphonics on a bowed string instrument is double-bass player Bertram Turetzky, in 1974. While Tracy Silverman and P & A Strange have also contributed to the subject, Fallowfield’s thesis and website are the first in-depth explanation of multiphonics on the cello. Norwegian double-bass player Håkon Thelin has, simultaneously to Fallowfield, written extensively about multiphonics in several publications and his website. Neither of them seems to have seen the work of the other at the time of writing.

²³³ Fallowfield (2010), p. 108, and <http://www.cellomap.com/index/the-string/the-left-hand.html>.

²³⁴ P & A Strange (2001), p. 132.

²³⁵ <http://haakontheelin.com/multiphonics/multiphonics-on-the-double-bass/definitions/introduction-to-multiphonics-on-the-double-bass>

Theory & Practice

Multiphonics are created by manipulating harmonic nodes; it is therefore essential that section ‘1. Harmonics’ (p. 37) – and principally the location of harmonics in the lower positions – is understood before this section is studied. Filtered pitch (p. 103) should also be revised at this point, to develop the ear’s sensitivity to pitch components in a sound. Finally, ‘Overpressure Harmonics’ (p. 96) and ‘Half-harmonics’ (p. 113) should be reviewed as well, to refine sensitivity to variations in pitch content with increases in bow pressure in stopping pressure.

These techniques mentioned above and various combinations of altered bow speed, pressure and point of contact can produce multiphonic effects, such as light and fast bowing *sul ponticello*. This section however will be reserved for sounds in which harmonics that wouldn’t naturally speak together do, and, more specifically, to those multiphonics comprised of three or four clearly audible pitch components.

In *A Personal Pedagogy*, bassist Mark Dresser suggests that multiphonics are the result of ‘sending mixed signals regarding finger placement, bow placement, bow speed, and accent to the string’.²³⁶ Dresser continues by describing the effect: ‘the string will vibrate in simultaneously different modes, often producing clear triads’. Open strings, in other words the 1st harmonic, can also sound as part of a multiphonic. Fallowfield describes the effect as ‘a left-hand position, bow speed/pressure and point of contact that is “acceptable” enough to several harmonics to enable them to sound simultaneously’.²³⁷

Step-by-step

Of the three or four harmonics which sound, the stopping finger is placed on the harmonic node with the highest pitch. Both Silverman and Fallowfield have similar

²³⁶ Zorn (2000), p. 256. Cited in P & A Strange (2010) p. 134.

²³⁷ <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>

recommendations for beginning to learn how to play multiphonics,²³⁸ but the latter has a more detailed explanation.

- a) The upper harmonic component should first be played normally.
- b) Silverman slightly increases finger pressure, whereas Fallowfield decreases bow speed and increases bow pressure.
- c) The stopping finger then slides back to the multiphonic position (between two nodes).

Silverman maintains it is best to practise this *forte*, keeping *ordinario* bow pressure and point of contact to start with. Fallowfield however, believes that bow has more control than the left hand in producing multiphonics. She reasons: ‘Bowling conditions are more critical to harmonics, especially high harmonics, and it follows, therefore, that they are the controlling factor in multiphonics.’²³⁹

Parameters of Multiphonics

Stopping-hand Pressure

Silverman describes the left-hand finger pressure as between that of a harmonic and normal stopping (see Half-harmonic, p. 113). Fallowfield, on the contrary, uses light left-hand finger pressure.

Stopping-hand Point of Contact

Silverman, Fallowfield and Dresser all advise placing the finger between two closely located harmonic nodes, but Fallowfield is more precise, indicating that this needs to be

²³⁸ Silverman is paraphrased from P & A Strange (2010), p. 133, source not identified. Silverman’s opinions are included for the sake of comparison between two very personal experiences with multiphonics. The reader should remember that she is a violinist, and Fallowfield’s research was most likely done in a more systematic and comprehensive way.

²³⁹ <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>

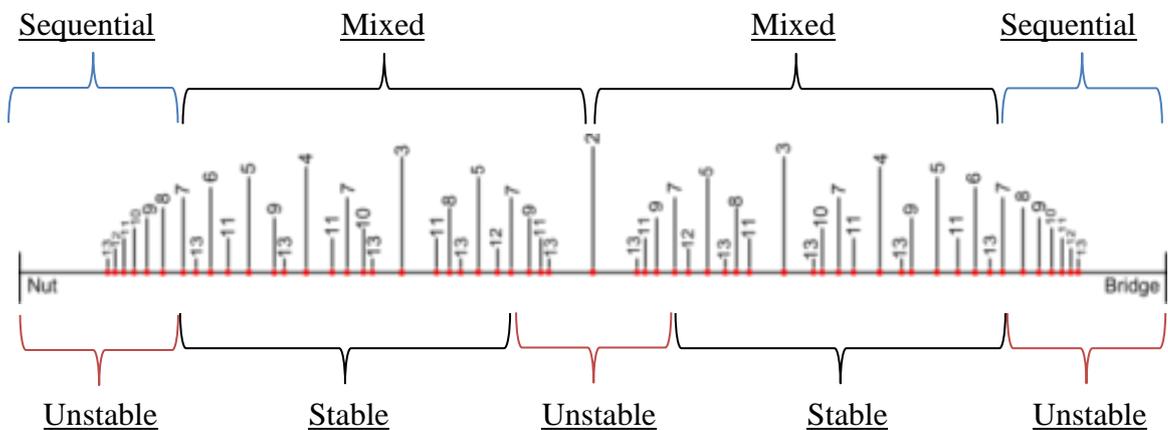
at points on the string where there are clusters of nodes. She observed that the harmonic nodes can be divided into two regions:²⁴⁰

Sequential: 13, 12, 11, 10, 9, 8

Mixed: 7, 13, 6, 11, 5, etc.

This second region, nearer the middle of the string, is where multiphonics speak most purely. These two regions are identified on Fallowfield's scheme of harmonics 2-13 below.²⁴¹

Figure 33: Sequential and mixed regions of harmonics



Just as harmonic nodes are found in multiple locations, all equidistant from the middle of the string, multiphonics are also found in the upper part and lower part of the string, in mirror image to the 2nd harmonic's node. Fallowfield indicates however that it is more difficult to produce multiphonics on the upper half of the string. She suggests placing the bow 'behind' the fingers for those multiphonic positions nearer the bridge. Using only the 2nd-13th harmonics in her research and string models, Fallowfield's has isolated 13 relatively reliable multiphonic positions. Many more multiphonics could be found but would be the subject of a more extensive study on the subject.

²⁴⁰ Further research could examine the smaller sequential region around the string's mid-point (7, 9, 11, 13). Fallowfield describes the multiphonics in this particular range as unstable, like those in the 'sequential' area.

²⁴¹ <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>

Fallowfield proceeded systematically using the scheme above and found in the **mixed** area of the string eight ‘pure’-sounding multiphonics, stable, and with well-balanced harmonic components. She found that tone colour and volume are relatively flexible in these.

Fallowfield isolated five more multiphonics in the **sequential** area of the string as well as around the string’s mid-point. These are more unstable, with less reliable pitch, extraneous noise and a ‘fluttering’ sound quality. She found that much higher bow pressure and slower bow speed is necessary for these, and that variation in tone colour and volume are far more restricted than for the ‘stable’ multiphonics.

As cello students quickly learn with natural harmonics, finger placement need not be precise for the lower harmonics; the 2nd and 3rd harmonics will speak even if the stopping finger is considerably far from the node. As the harmonics become higher in the spectrum, and as the vibrating segments of the string become smaller, the finger placement needs to be increasingly precise. This also applies to multiphonics: those in the sequential range are more affected by finger placement than by the bow.

Fallowfield recommends flattening the stopping finger and possibly turning the hand diagonally in the sequential range, to cover two or more nodes.

Stopping-hand Length of Contact

Fallowfield has found that multiphonics can also be produced by modifying the use of the left hand. Shorter contact time between the stopping finger and string than what would be optimal for a harmonic allows a second harmonic or open string to speak.²⁴² This allows multiphonics to be produced in pizzicato as well (see p. 167).

Bow: Point of Contact, Speed & Pressure

While Tracy Silverman maintains that the bow-hand activity is ‘normal’ and that multiphonics are a left-hand technique,²⁴³ Fallowfield’s approach requires bow-hand manipulations which will vary from one multiphonic to the other. Fallowfield places

²⁴² <http://www.cellomap.com/index/the-string/the-left-hand.html>

²⁴³ P & A Strange (2001), p. 132.

the bow closer to the bridge²⁴⁴ and uses a slower and heavier bow stroke than she would for normal playing of the highest harmonic component of a given multiphonic. She summarizes that multiphonics containing high harmonics require a lighter, faster bow stroke which is closer to the bridge than multiphonics containing only mid-range harmonics.

Fallowfield writes that the scope for variation of these factors in the bow is limited compared to normal playing of harmonics. These factors not only influence the volume and noise content of a multiphonic, they also affect which harmonics are part of the multiphonic. The following is paraphrased from the *Cello Map* website:

Increasing bow pressure increases volume, distorts sound. High bow pressure favours the lower harmonics (including the open string) and can restrict higher harmonics.

Decreasing bow pressure decreases volume, clearer sound. Low bow pressure can restrict lower harmonics.

Increasing bow speed increases volume and favours higher harmonics, eventually cutting out lower harmonics.

Decreasing bow speed decreases volume and favours lower harmonics, eventually cutting out higher harmonics.

Contact point quite near the bridge encourages noise content and favours lower harmonics, sometimes restricting high harmonics.

Contact point very near the bridge produces a clearer sound and favours high harmonics, sometimes restricting lower harmonics.

²⁴⁴ The website *Cello Map* presents a slight inconsistency in that Fallowfield's text places her bow farther from the bridge, while her videos consistently show her bow placement as closer to the bridge than for normal playing of the highest harmonic component.

Notation

Fallowfield has developed a precise system for notating the various components of a multiphonic, provided in four detailed charts.²⁴⁵ She notates the resulting pitches and the fingered pitch with cent deviations and provides alternative notation for the fingered pitch, using microtonal accidentals. This is the most precise notation from a theoretical standpoint, but in keeping with the system of notation in this thesis, the exercise below has a consistent use of accidentals.²⁴⁶

A noteworthy aspect of Fallowfield's notation is her labelling of multiphonics. Following the Roman numeral which traditionally denotes the string, she writes in brackets the numbers of the harmonic nodes which are the constituent parts of the multiphonic, in ascending order of their position on the string (nut to bridge). Because multiphonics have two locations which are symmetrical distances to the middle of the string, the numbers in brackets will be in reverse order for the same multiphonic on the upper half of the string.

²⁴⁵ Available for download: <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds/fingeringcharts.html>.

²⁴⁶ This exercise is the notated version of Fallowfield's video demonstrations on: <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>.

Exercise 15: Finding a Multiphonic

- Play the four harmonics, the resulting pitches are notated on the upper staff (these are the constituents of the multiphonic).
- Play the highest sounding of these four harmonics, in this case the 3rd node of the 11th harmonic. Use light left-hand pressure, and a slower bow stroke with higher pressure and closer to the bridge.
- To find the same multiphonic on the upper half of the string, first play the next four harmonics then follow the same instructions for the multiphonic.

1/3 2/7 3/11 1/4 I [4+11+7+3] 2/3 5/7 8/11 3/4 I [3+7+11+4]

I

Applications**Pizzicato Multiphonics**

As discussed in ‘Pizzicato Harmonics’ (p. 56), there is an optimal length of time the stopping finger should stay in contact with the string in order that a harmonic rings clearly in pizzicato. When this optimal time is made shorter, the open string or another harmonic is made to sound simultaneously with the fingered harmonic. Fallowfield finds that the lower harmonics are generally stronger in pizzicato than in bowed multiphonics and she observes that those above the 10th harmonic are inaudible. She also observes that the multiphonic effect is more noticeable on the lower strings.²⁴⁷

Double-Stop Multiphonics

Because the success of a multiphonic is strongly contingent on the factors of the bow, which are in turn largely dictated by the string’s length and thickness, multiphonics are difficult to achieve as double-stops.

²⁴⁷ <http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds/further-examples-of-multiphonics.html>

Stopped Multiphonics / Artificial Multiphonics

Contingent on hand-span, it is possible to generate the multiphonics which are located in the same range as the harmonics producible in stopped harmonics. Fallowfield observes that stopped multiphonics on the upper strings are more difficult to sustain than those on the lower strings.²⁴⁸ Creating a multiphonic in this way allows for other techniques such as glissando.

²⁴⁸ Ibid.

15. VOCAL & THEATRICAL EFFECTS

An area of performance neglected by conservatoires and instrumental departments, musicians are often uncomfortable with the vocal and theatrical effects demanded of them in performance. With the musical happenings of the 1960s and 70s, the development of multimedia, the Fluxus Movement and other experimental music (see p. 294), the role of the instrumentalist expanded. One assumes that such music is written by composers who do, or should, be aware that the instrumentalist might not necessarily have a gift for any of the additional skills required, except, to quote Read, ‘a minimum sense of dramatics and a willingness to participate’.²⁴⁹ This section is intended to provide an entry point into this much larger world, to which the author joins her wishes to those expressed by Patricia and Allen Strange in their preface, that ‘this area will be best served by its own complete study and would hopefully result in a text on “*The Performer’s Theater*”’.²⁵⁰

The cello is especially well suited for such ‘additional’ sounds or actions, which are often an integral part of the resulting music. ‘The player’s voice can be very precisely synchronized with played events, so various kinds of effects are possible including pure vocal accompaniment, coloration of the instrument’s timbre, masking of attacks, and flights of vocal theatre.’²⁵¹ The cello doesn’t impede use of the mouth as does a wind or brass instrument, or to a lesser extent, a violin or viola, nor does it limit the movement of the head, but it does however limit body movement and walking. This section therefore provides a repertoire of basic actions and sounds which can be combined with playing the cello.

History

The emergence of experimental currents such as the Fluxus Movement was key in developing this aspect of an instrumentalist’s performance. Korean-American composer Nam June Paik wrote his first performance pieces *Simple, Zen for Head* and

²⁴⁹ Read (1993), p. 129.

²⁵⁰ P & A Strange (2001), p. xii.

²⁵¹ Idem., p. 192.

Étude Platonique No. 3 in 1961, and he later wrote especially provocative works for cellist Charlotte Moorman, notably *Sextronique* (1967, for which she and Paik were arrested) and *TV Bra for Living Sculpture* (1969). P & A Strange cite Ashley's *Complete with Heat* (1962) for two or more string or wind instruments as one of the first examples of vocal writing for strings.²⁵²

This movement was pre-empted in 1913 by the futurist painter Luigi Russolo in his pamphlet *The Art of Noise*.²⁵³ He actioned his ideas by building noise-instruments.

Theory & Practice

Rohan de Saram explains Mauricio Kagel's expectation that 'it is not enough simply to follow a set of instructions on a page. What [Kagel] wanted above all was that the thought or emotion in the mind of the protagonist-player should be communicated to the audience.'²⁵⁴ This is a valuable lesson for all musical performance and an interesting exercise for an instrumentalist.

Nothing substitutes a mirror, a video camera or a friend's feedback. When learning a new language, for example, it is important to say words out loud and at full speaking voice, one shouldn't merely repeat words internally or in a whispered voice. Very much in the same vein, words, sounds and actions need to be fully rehearsed, at the appropriate volume, and for the length of time necessary. Even sitting still with no expression needs to be rehearsed.

Breath support is necessary to adequately perform the vocal effects below. It is a complex notion and its explanation lies outside the scope of this paper, but a tutorial with a wind or brass player or vocalist will be helpful to the cellist needing to develop projection or trying to eliminate dizziness.

²⁵² Ibid.

²⁵³ Cited by Ross (2007), p. 63.

²⁵⁴ Steinheuer & de Saram (2013), p. 120.

Notation

No standard notation exists. It is useful to write one's own breath marks when needed, as would a wind player.

Applications

The following are all actions or sounds which do not impede on playing the cello. Projecting any of these sounds into the cello's f-holes is effective, especially with amplification.

Vocal Interjections

The following list demonstrates the range of possible vocalizations:

- a) Speaking
- b) Whispering
- c) Muttering
- d) Shouting
- e) Screaming
- f) Hissing
- g) Grunting
- h) Groaning
- i) Laughing
- j) Singing
- k) Humming

Fricatives / Spirant

'A consonant [...] produced by the forcing of breath through a constricted passage.'²⁵⁵

In English, this includes the consonants *f*, *s*, *th*. These, in addition to projecting consonants such as *k*, *p*, *t* have a very percussive quality.

Whistling

Both men and women whistle at the same pitch, as pitch is the result of mouth volume. Changing the position of the tongue and the size of the embouchure modifies pitch and clarity. The lower range can be extended by dropping the jaw and pulling it back, and airflow should begin before the note sounds. Vibrato can also be incorporated. Because

²⁵⁵ <http://www.thefreedictionary.com/fricative>

of their excellent control of lip and tongue muscles, flautists are especially helpful when learning to whistle.

Audible Breathing / Snorting

Audible breathing can be used to amplify ‘breathing’ sounds made with the bow on the instrument (see pp. 103 and 146). In the long sounds of ‘*Sh*’, ‘*Ph*’, ‘*Heh*’, drawing air through one’s teeth, heavy breathing and panting, there is a risk of becoming light-headed or hyperventilating. Snorting is a short sound and presents less of a problem.

Facial Expressions

Performers who are not trained as actors should be encouraged to practise with a mirror or a video camera. Performing an action first in front of the mirror to get the desired effect, then away from it, allows for muscle recognition (how does it ‘feel’ to make this facial expression). This should then be followed by looking in the mirror to assess if the links between sensation and result are adequate.

16. MUTES & THE PREPARED CELLO

Prepared instruments have had their timbre changed by the addition of objects. This is a technique developed for the piano, where objects are placed on or between the instrument's strings.

This section discusses temporary, external sound modifications to the cello, all of which are non-electronic (for electronic sound modification, see '23. Live Electronics', p. 227). The aim of this section is to discuss some of the most commonly used objects which modify a cello's sound and how they do so. While the limits of preparing a cello are only bound by one's imagination, the basic suggestions in this section provide a point of departure.

History

Additions and modifications to the instrument are intimately linked to the development of the cello; the addition of the end-pin, the Tourte bow, the elongated fingerboard and the Romberg curve are but some examples of instrument modification, inseparably linked to the formation of cello technique and to the development of the music composed for the instrument. Walden's statement on technical developments in the 18th century is transferrable to today's search in the virtuosity of new sounds: 'The demands for ever-increasing virtuosity instigated changes to instrument and bow design, which in turn inspired performers to further development of technically difficult passage work.'²⁵⁶

Biber's *Battalia* from 1673 is a fine example of early instrument preparation. In his notes accompanying the score, Biber writes: 'where the drum appears in the bass one must affix some paper to the string, so that there is a loud noise, but only in the march'.²⁵⁷ This corresponds to bar 52 of the section entitled *Der Mars*.

²⁵⁶ Walden (1998), p. 134.

²⁵⁷ http://www.mymusicbase.ru/PPB/ppb10/Bio_1005.htm

Mutes are the most common example of sound-modifying devices, and have long been in use for string instruments, changing little in design. The most extensive discussion of mutes is found in Quantz' treatise of 1752: he describes the effect and musical rationale, the size and materials used (wood, lead, brass, tin and steel) and his opinion on the success of each, and he gives performance indications for the bow.²⁵⁸ While mutes are not much discussed by cellists of the 18th and 19th centuries, there is evidence in letters and private journals that they were used to provide greater contrast in the sound.

John Cage famously pioneered the technique of preparing a piano in *Bacchanale* which he wrote in 1940 for a dance piece choreographed by Syvilla Fort. The space was not big enough for a percussionist but did fit a grand piano – with the prepared piano, Cage obtained the percussive elements and variety of timbre he was looking for.

Applications

Mutes

Mutes alter the timbre of an instrument by amplifying and suppressing various portions of the harmonic spectrum. P & A Strange report on a small experiment on the violin, which demonstrates that mutes don't necessarily just decrease volume: whereas a three-prong aluminium mute significantly amplified the first four harmonics and caused 'an almost instantaneous suppression of the higher harmonics',²⁵⁹ a steel mute and Symmons Aluminium²⁶⁰ mute both showed different results, amplifying the lower registers and damping the upper harmonics to varying degrees. A more extensive experiment would provide guidelines for the various mutes available.

Mutes currently available for the cello:

- a) Round rubber, Tourte
- b) Polly Mute (currently only available in the U.S.A.)

²⁵⁸ Quantz (1752), section II, No. 29.

²⁵⁹ P & A Strange (2001), p. 186. Unfortunately, many of the mutes listed in their text are no longer available.

²⁶⁰ No longer commercially available.

- c) Roth Sihon slide-on brass, steel and rubber
- d) Chrome-plated brass (practice mute)
- e) Three-pronged ebony
- f) Four-pronged steel (practice mute)
- g) Four-pronged steel encased in rubber (practice mute)
- h) Five-pronged rubber (practice mute)
- i) Two-, three-, and five-pronged leather (practice mute)

Placing and removing objects from the instrument is considered in this Method as a technique in itself, and should be rehearsed within a musical context, even scales (see p. 177).

Metallic Buzzing

Placing a **metal coil** around the string creates a buzzing sound, which is affected by bow speed and pressure. Harmonics are brought out in the sound as the wire travels along the string, touching the nodes. While varying types of metal will create different effects (as will the thickness of the coil and its tightness around the string), a paper clip is the simplest thing with which to start experimenting.

Affixing a **hair pin** (bobby pin) to the string also creates a buzzing sound. This sound is more consistent because the pin doesn't travel along the string.

The **Scelsi resonator** was invented by Frances-Marie Uitti in the 70s at the request of the composer. It comprises a brass strip which vibrates against two adjacent strings when these are bowed. It attaches as would a mute, to the far side of the bridge. Platz compares the sound to that of the South African Mbira (thumb piano), and Arditti remarks that they 'can come flying off during performance', although he specifies that this is only during *sforzandi*.²⁶¹

Rattling

A pencil or knitting needle placed between the strings and perpendicular to them will create a rattling sound.

²⁶¹ Arditti & Platz (2013), p. 15 and accompanying video, track 1.

Notation

Figure 34: Placing and removing the mute

Description	Language	Term
Placing the mute	Italian	<i>con sordino</i>
	German	<i>mit Dämpfer</i> <i>Dämpfer auf</i>
Removing the mute	Italian	<i>senza sordino</i>
	German	<i>ohne Dämpfer</i> <i>Dämpfer ab</i> <i>Dämpfer weg</i>

17. INDEPENDENCE OF HANDS

As the complexity of what performers are asked to do increases, the coordination between both hands, and sometimes feet or vocal effect, must be developed to encompass differing activities. A seemingly straightforward action can sometimes become a difficulty and a hindrance if never rehearsed in a musical context. While the possibilities are endless, this section covers four of the more commonly requested actions. These should encourage students to reflect on ways of approaching and solving new challenges of coordination as they arise. This short section concludes our study of extended techniques, in which comfort should be attained by this point.

History

Perhaps the earliest combination of two seemingly disparate techniques is found in the music of Paganini and virtuoso cellists of the same era, such as Charles Baudiot. Their use of left-hand pizzicato in combination with *arco* playing created a sensational effect at the time and still does.

Theory & Practice

Very much as would a beginner pianist, the left-hand and right-hand motions should first be disassociated and practised separately, but not for long. Both hands should then be combined so that the two different motions become connected.

Applications

Playing While Placing / Removing the Mute

Playing continuously with the bow while placing and removing the mute with the left hand provides a good starting point for developing coordination of dissimilar motions. The bow must maintain a steady tone while the left arm extends beyond its usual playing position. The mute should be placed and removed as progressively and smoothly as possible to allow for a gradual opening and closing of the sound. The bow can also help this change of colour through an increase in bow pressure when the mute is removed, and a decrease in pressure when it is replaced. The Tourte rubber mute is recommended due to its flexibility; fingers should be held along the whole back of the

mute for more control. When the mute is placed, the bottom of the mute should first lean along the bridge to progressively dampen vibrations.

Two-hand Pizzicato

Various pizzicato effects can be combined by using both hands. While these will most frequently use open string, pitches can be added by using *con le dita* or pizzicato harmonics.

Re-tuning While Playing

Turning a peg to a specific pitch while playing requires familiarity with one's instrument, with the motion and force involved. The amount the peg needs to be turned to achieve a certain interval is contingent on the material of the string and its tension. Metal strings need less tightening for a given pitch than pure gut or gut core strings. A particularity of high-tension strings is that when one is detuned, the other strings 'pull' the other way, affecting their tuning. For example, if the C-string is tuned down, the G-string will go up in pitch. This is also discussed in *Scordatura / Alternative Tuning* on page 119.

Exercise 16: Turning the Peg

- First retune the string during the rest, using the left hand to turn the peg. Aim to change your playing position as little as possible.
- Then retune while playing, focusing on maintaining a steady bow stroke.

The musical notation for Exercise 16 is presented in four staves, all in a 4/4 time signature. The first staff is in bass clef and contains a sequence of notes: G2, F2, E2, D2, C2, B1, A1, G1. Above the first three notes are boxes labeled 'retune'. Above the last two notes is the marking 'sim.'. The second staff is also in bass clef and contains a sequence of notes: G2, F2, E2, D2, C2, B1, A1, G1. The third staff is in bass clef and contains a sequence of notes: G2, F2, E2, D2, C2, B1, A1, G1. Above the first three notes are boxes labeled 'retune'. Above the last two notes is the marking 'sim.'. Arrows indicate the transition between notes: G2 to F2, F2 to E2, E2 to D2, D2 to C2, C2 to B1, B1 to A1, and A1 to G1. The fourth staff is in bass clef and contains a sequence of notes: G2, F2, E2, D2, C2, B1, A1, G1. Arrows indicate the transition between notes: G2 to F2, F2 to E2, E2 to D2, D2 to C2, C2 to B1, B1 to A1, and A1 to G1.

Non-synchronous Bowing²⁶²

Several composers have experimented with the possibilities of notating different bowing patterns and rhythms for the bow than those notated for the left hand. The desired result is often one of far greater complexity than the actions of each individual hand. This type of writing originates in the music of the New Complexity school (see p. 294).

²⁶² This term is adopted from P & A Strange (2001), p. 40.

Part III: Musicianship

Twentieth-century technique not only encompasses the physiology and ergonomics of creating specific sounds, it extends to thought processes, aural sensitivity and mental agility, in other words, advanced musicianship skills. To use Palm's words in the explanatory supplement to his *Pro Musica Nova* collection: 'What the ear is accustomed to is easier to communicate to the hand.'

This part presents aspects of music which are either specific to or which require a deeper understanding to complete a full 'arsenal' of skills to perform modern music. While there is an element of ergonomics in all of these topics, the material covered here largely pertains to theory and can therefore be applied by all instrumentalists and vocalists. While most of the subjects below already have several dedicated publications, this text differentiates itself in that it exclusively addresses the performer.

I would like to acknowledge that while the extended techniques covered in Part II should provide enough information to assist students in their performance, the subjects of Part III require more extensive research to be effective. For this reason, the seven sections below will be presented as short articles which will hopefully form the basis of a fuller publication, which would be complementary to the study of extended techniques.

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Part III: Musicianship

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18. DISSONANCE

Dissonance is present in music of all eras, but its role in the context of atonality and non-functional harmony is quite different – it is not necessarily a question of tension and release, and often dissonance is used to generate colour, expressivity, or disturbance. This section and the two that follow – ‘19. Tuning Systems’ and ‘20. Microtonality’ – are quite connected, but these three concepts should remain distinct: sections 19 and 20 have elements of both dissonance and consonance, and consider the means of creating dissonance, while this section is concerned specifically with the results of dissonance. This section also forms a connection between the concepts of pitch as a continuum, which began to be explored in section ‘5. Between the Notes’ (see p. 107), and concludes with section ‘20. Microtonality’.

Dissonance is difficult to define, being largely contingent on the listener’s perception (itself contingent on convention and context). For our current purposes, however, a practical distinction must be made between dissonance and consonance. This differentiation will become clearer when studying section 19. The crucial point now is to differentiate between ‘out of tune’ and ‘dissonance’: to be truly effective, a dissonance must be in tune. The tools to recognize the difference are discussed below.

The use of vibrato in dissonance will be dictated by musical context; clusters, for example, often benefit from a homogeneous vibrato, while vibrato is undesirable in music where beating should be heard. All notions below should be practised first without, then with vibrato.

Melodic Intervals

Shifting between dissonant intervals, especially compound intervals, requires aural, physical, and visual recognition of interval placement, particularly for cellists without perfect pitch.

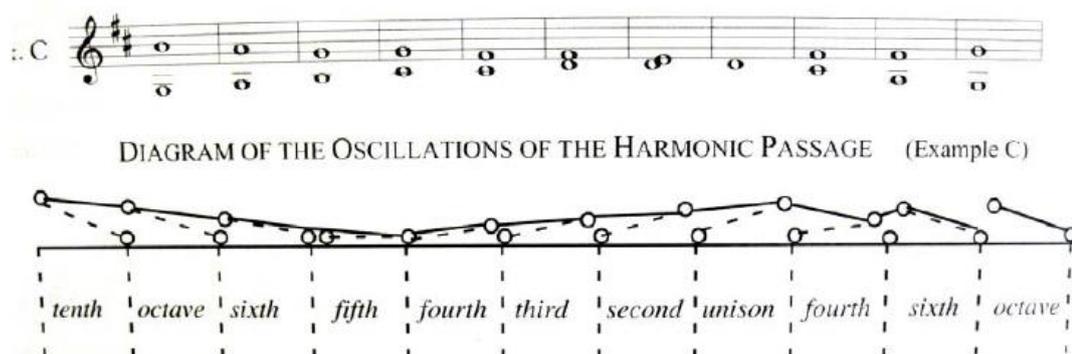
Dissonance can also be achieved by superimposing melodic lines, to achieve bitonality and polytonality.²⁶³ While this is the responsibility of the composer, the performer does need to ensure clear melodic relationships within their own parts when presented with such effects.

Harmonic Intervals

There is also a combination of physical and aural recognition in dissonant harmonic intervals, in terms of how two notes interact and affect the instrument's resonance. Dissonant intervals need to be even more rigorously in tune than consonant ones to be fully effective. Just as consonant notes in a harmonic context reinforce the overtones of other notes, enabling the chord to sound richer, so dissonant notes, when played in tune, allow certain acoustic effects to be heard at their maximum. These effects – sum and difference tones, and frequency beating – are discussed separately below.

Lucien Capet suggests that to obtain a well-balanced chord, bow weight on each note should be adjusted according to the interval: greater weight should be on the lower note of an interval of a 2nd and on the upper note for 7^{ths} and 9^{ths}.²⁶⁴

Figure 35: Relative weighting of the bow on each string of a double-stop (Capet)²⁶⁵



²⁶³ Bitonality is often used by Bartók. Polytonality dates back to Biber's *Battalia* (1673), bar 28 'Die liederliche gseltschafft [*sic.*] von allerley Humor', where eight different melodic lines play in different tonalities, the result quite similar to the music of Charles Ives.

²⁶⁴ Capet (1916), p. 39.

²⁶⁵ *Idem.*, p. 40.

While, from the earliest days of cello pedagogy, it was believed that the major triad found its source in the first five harmonics of a note (for example, the first five harmonics of the open C-string are C-C-G-C-E),²⁶⁶ so it has been argued that dissonance is also a natural part of sound, present in the upper harmonics of any given fundamental.²⁶⁷ Schoenberg and Boulez claimed that an inability to comprehend and enjoy dissonance was learnt, and could therefore be altered.²⁶⁸ History supports this argument in that the perfect 5th was not considered consonant in Europe in the 10th century, and the major 3rd was still rare in the 14th century and, generally, 'not fully accepted as consonant until the High Renaissance'.²⁶⁹ Indeed, there have been few definitions in music as fluid as that of dissonance.

Sum & Difference Tones / Heterodyne Frequencies / Combination Tones / Sidebands

It is at this point that the notion of frequency must be introduced. The frequency of a tone is expressed in cycles per second, now known as hertz (Hz). The term was suggested in 1930, in honour of the German physicist Heinrich Hertz (1857-1894) and almost completely supplanted the term 'cycles per second' (cps) by the 1970s. Hertz augment exponentially – for example the A-string of a cello is 220 Hz, the A one octave above it is 440 Hz and the A above that is 880 Hz.

When two notes are played simultaneously, they also produce the sum and the difference of their respective frequencies, which are called heterodyne frequencies (or in electronic music, sidebands). This is a psychoacoustic illusion which occurs when two notes correspond to the harmonics of an absent fundamental, which the ear imagines.²⁷⁰

Hermann von Helmholtz, the father of modern acoustics, shed light on, among many other aspects of acoustics:

²⁶⁶ Corrette (1741), p. B.

²⁶⁷ Ball (2011), pp. 68-69. Ball also mentions Jean-Philippe Rameau's 1772 *Treatise on Harmony*, in which he 'used the mathematics of the harmonic series to derive fundamental laws of musical composition based on what he saw as the natural relationship between notes.'

²⁶⁸ Idem., p. 167.

²⁶⁹ Ibid.

²⁷⁰ <http://www2.hmc.edu/~alves/microfestabstracts.html>

...the nature of beats and their role in consonance and dissonance, [...] the nature of combination tones, and “summation tones” (equal to the combined frequencies of the two notes in an interval), which supported his theory of the nonlinearity of the ear (that is, that through interaction with aural stimuli, the ear was capable of providing sounds that were not specifically generated).²⁷¹

For example, if C4 (261.6 Hz) is played at the same time as G4 (392 Hz), the **sum tone** of E5 will sound ($392 + 261.6 = 653.6$ Hz) and the **difference tone** of C3 ($392 - 261.6 = 130.4$ Hz) will sound as well:

Figure 36: Sum and difference tones



The resulting tones correspond to just intonation and will therefore sound out of tune in an equally tempered context (see ‘Twelve-Tone Equal Temperament (12-TET)’, p. 196).

Heterodyne frequencies are always the result of an interval relationship and will therefore remain at consistent intervals of the pitches played, regardless of range. Each part of the harmonic spectrum of the two notes will create a heterodyne frequency. The ability to hear heterodyne frequencies depends largely on the acoustic properties of the room, for example, these will be heard more easily in a small room.

Frequency Beating

Frequency beating is a regular pulsation heard in addition to the two notes of a dissonant harmonic interval. When the difference between the two frequencies is small

²⁷¹ Duffin (2007), p. 107.

enough,²⁷² the difference tone is too slow (low) to be an audible pitch. This is heard as a regular pulsation; the cycles per second (Hz) in effect become distinctly audible. Whereas difference tones apply to any interval, beating is the result of a dissonant interval.

Ball explains the phenomenon as the result of two sound waves interfering: one moment they reinforce each other to create more volume, the other they partly cancel each other, diminishing volume.²⁷³

Awareness of, and sensitivity to the phenomenon is most important; rarely is an instrumentalist asked to calculate the beating exactly. Should this be required, the simplest way to achieve this calculation is simply by subtracting the lower frequency from the higher one, the resulting number of Hz indicating the cycles per second.

A simple example of this is provided by Duffin: a note at 400 Hz and a note at 401 Hz will create one beat per second. A note at 400 Hz and a note at 402 Hz will create two beats per second.²⁷⁴

Duffin also underlines an important consideration in terms of tessitura: because the value in Hz increases exponentially as pitch rises, higher notes beat at a faster rate for the same interval discrepancy.²⁷⁵ For example, let us compare the difference in the equally-tempered semitone A to G# at two different octaves:

A4-G#4 440Hz - 416Hz = 24Hz, or 24 beats per second²⁷⁶

A3-G#3 220Hz - 208Hz = 12Hz, or 12 beats per second

²⁷² According to Ball (2011), p. 167, this is limited to a difference of about 20 Hz, or, 20 beats per second. Over this, the beating is too rapid for the ear to detect, and the ear perceives 'roughness', to use Ball's vocabulary.

²⁷³ Ibid.

²⁷⁴ Duffin (2007), p. 33.

²⁷⁵ Idem., p. 30.

²⁷⁶ This may produce a difference tone, depending on the environmental acoustics. The lowest notes of a piano, for example, is 27.5 Hz.

The result is that for the same interval, lower notes sound more dissonant than higher notes.²⁷⁷

De Saram suggests the following exercise to identify the beating frequencies in a dissonance and how the cycles per second get faster as the interval broadens. Starting with a unison interval on two different strings ‘gradually [move] away from the unison in order to produce beats. The further one goes away from the unison, the faster the beats per second...’²⁷⁸ Duffin summarizes this effect more precisely, stating that the wider the discrepancy from a just interval, the faster the beating will be.²⁷⁹

Certain composers indicate the desired number of beats over a dissonant interval as a precise way of notating harmonic microtones. De Saram observes that this use of microtones is often as a colouristic device. It is not so much the pitch itself that the composer requires, as much as the specific timbre and effect of frequency beating.

Further work on frequency beating could be inspired from the techniques used by pre-20th century piano/keyboard tuners. The following publications are suggested points of departure:

- Jorgensen, Owen. *Tuning the Historical Temperaments by Ear: A Manual of Eighty-Nine Methods for Tuning Fifty-One Scales on the Harpsichord, Piano, and Other Keyboard Instruments* (Northern Michigan University Press, Marquette, ca. 1977)
- Jorgensen, Owen. *Tuning: Containing the Perfection of Eighteenth-Century Temperament, the Lost Art of Nineteenth-Century Temperament, and the Science of Equal Temperament, Complete with Instructions for Aural and Electronic Tuning* (Michigan State University Press, East Lansing, 1991)

²⁷⁷ Ball (2011), p. 169.

²⁷⁸ Steinheuer & de Saram (2013), p. 115.

²⁷⁹ Duffin (2007), p. 30.

19. TUNING SYSTEMS

Throughout musical history, tuning systems have been the subject of mathematical and aesthetic theory, and occasionally ardent debate. Today's versatile musician should be able to adapt to any requests or be able to select the optimal tuning for a given context.

While tuning systems are generally seen to have historical implications, the understanding and application of tuning systems has an equal place in modern music. Whereas it is advantageous to use equal temperament in music with non-functional harmony or in dodecaphonic and atonal works, other styles, such as spectralism (see p. 295) and the Just Intonation movement spearheaded by Harry Partch, require intonation 'virtuosity'. Composers occasionally choose to specify a tuning system so that the intervals produced have a certain colour; often it is possible to express these requests with microtonal notation, but standard notation is also expected to accommodate different pitch placements which are guided by the ear. The sensitive musician will adjust with no great difficulty between equal temperament and just intonation within a tonal context; this section aims to provide the information necessary to find various pitch placements and interval colouring through the theory associated with particular tuning systems. From this theory, aesthetic decisions can be made.

This section will provide a solid basis for the following section '20. Microtonality' (p. 208), which explores equal-tempered environments other than 12-tone equal temperament (henceforth abbreviated as 12-TET).

Historical perspective is an important part of understanding our current use of tuning systems, and for this Ross W. Duffin's *How Equal Temperament Ruined Harmony (and Why You Should Care)* is strongly recommended. It provides a particularly clear insight into extended sixth-comma meantone temperament, effectively the most natural way a string player can place intonation in functional harmony (Duffin writes specifically in regards to common practice music). The main subjects of tuning history are notably omitted here – meantone and well temperaments – as they pertain largely to traditional harmony.

Though temperaments and systems in general are too difficult to achieve in an exact way on a fretless stringed instrument, where we are continually adjusting, the following text provides some technical explanations and calculations to allow the reader to differentiate between actual tuning theory, the pseudo-theory that many performers and composers hold,²⁸⁰ and the demands involved in the practical application of these theories. While many publications are far more complete, none that this author has found so far cater to the performing musician as such (or the string player for that matter, with the notable exception of Duffin's third chapter of the aforementioned book) leaving tuning theory quite separate from performance. It is in this light that the following materials are expounded.

Throughout history hundreds of systems²⁸¹ have been developed to tune the notes of a scale, in Western music just as in the music of other cultures. Most of Western classical music's systems are constructed on mathematical principles, and historically, some extended these foundations into philosophical concepts. Of all these systems, only three will be discussed as directly relevant to the contemporary performance of the cello: 12-TET, Pythagorean Tuning, and Just Intonation. Additionally, the intonation of harmonics which we will call 'spectral intonation' will be discussed and compared to these three systems.

Understanding these systems should also help in the application of tuning theory to traditional repertoire as well. Meantone temperaments are easily understood in terms of correcting the deficiencies of the systems discussed below, or of applying equal temperament to selected portions of a scale. Indeed, all tuning systems are flawed, Ball summarizes the issue: 'it is mathematically impossible to find any intonation scheme

²⁸⁰ Ball (2011), pp. 69-70, chides composers including Partch, Messiaen, Schoenberg and Hindemith for taking ill-digested science to support artistic theory. He moderates his view by adding that this pseudo-science doesn't invalidate the artistic merit of these composers' works. Another example of erroneous theory is found in Stowell (1999), p. 216, where Uitti writes that Rădulescu bases his tuning on Pythagorean tuning which is equivalent to natural harmonics. As will be seen below, this statement is incorrect.

²⁸¹ Duffin (2007), p.16 cites J. Murray Barbour's *Tuning and Temperament: A Historical Survey* (1951) as detailing about 150 historical tuning systems in the Western tradition alone.

that can be modulated to any key while retaining simple frequency ratios for intervals such as the perfect fifth and fourth and the octave'.²⁸²

As we have seen, pitches can be expressed in three ways:

- 1) In cents (c) - an absolute value, regardless of register, expressing the relationship between two pitches
- 2) In hertz (Hz) - a physical measurement of frequency, which augments exponentially
- 3) As a ratio – the relationship between two pitches

All three values will be used here at different times according to context. Writings on microtones and various tuning systems use cent values most frequently as expressions of absolute relationships, regardless of register. Whereas cents are units of measurements, much like metres or litres, Hz indicate a precise location, like geographical coordinates. It is for this reason that the pitches in this text are expressed in Hz. Indeed, it is more practical for an instrumentalist to locate subtle pitch placement in Hz, with the help of an electronic tuner,²⁸³ especially when these pitches are the result of mathematical calculations rather than intuitive placement within a melodic or harmonic context. The Hz frequencies in this text have been rounded to the nearest tenth, to reflect the accuracy of an electronic tuner.

The ratios indicate the placement of a note in relation to a fundamental, or root note; in other words, they represent ascending intervals. To express a descending interval, the ratios would be inverted: for example 16:15 indicates one semitone higher, and 15:16 indicates one semitone lower. This is important to decode the notation that certain composers, including Partch, use to express just intonation. This notation uses either a combination of traditional notation with ratios to express the 'colour' of a certain interval, or, only ratios with a melodic contour to facilitate reading.

²⁸² Ball (2011), p. 62.

²⁸³ The interval created by two notes expressed in either Hz or a simple ratio can be converted to cents on this site: <http://www.sengpielaudio.com/calculator-centsratio.htm>, which uses this formula: cents = 1200 × log₂ (upper frequency ÷ lower frequency).

Exact ratios apply to an ‘imaginary’ string, without accounting for density, thickness and tension. P & A Strange remark that marking the string to only mathematical measurements (i.e. exactly $\frac{2}{3}$ of the string length to find a perfect fifth) will yield consistently sharp notes: ‘when a string is pressed against a fingerboard, the string is lengthened (stretched) and its tension is increased, both of which factors affect its pitch’.²⁸⁴ To add to this imprecision, pitch will fluctuate with several other factors, including bow speed and pressure.

The intention here is to train the ear to identify certain colours, or effects of pitch placement.

Pythagorean System

The first recorded tuning system in Western music combined mathematical as well as philosophical principles – it is named in honour of the Greek philosopher and mathematician Pythagoras, who is said to have discovered the principles for the diatonic scale in the 6th century BC as well as how octave pitches relate to each other.²⁸⁵

Pythagoras’ followers believed that proportion and numbers ‘constituted the fundamental ingredients of the universe’ and that music had as such a ‘structure that was embedded in nature’.²⁸⁶

The particularities of Pythagoras’ scale are described in further detail below, but suffice to say here that it was because of its perceived imperfections that ensuing tuning systems were developed in the 16th century. The following excerpt from Philip Ball summarizes this transition between true harmonic ratios and simplified ratios:

The Pythagoreans deemed there to be an intrinsic ‘goodness’ in the juxtaposition of notes whose frequencies are related by a simple ratio. In the Middle Ages only octaves, fifths and fourths were regarded as consonances of this sort. But by the fifteenth century, music had become increasingly polyphonic [...]. In particular, the intervals of a third [...] and a sixth [...] became permissible and were deemed relatively consonant. But the Pythagorean ratio for a third (81:64) was far from

²⁸⁴ P & A Strange (2001), p. 150.

²⁸⁵ Ball (2011), p. 62.

²⁸⁶ Idem., p. 48.

simple. To restore the mathematical simplicity that was meant to characterize a consonance, this ratio was modified very slightly to 80:64, which simplifies to 5:4. Likewise, the sixth was altered from 27:16 to 25:15, or 5:3.²⁸⁷

The intervals in Pythagorean tuning are based on a root note to which all other notes relate through whole-number ratios. This is known as an open system, where (theoretically) an infinite number of notes are produced. Each ‘note name’ appears only once, or in other words, every time it re-appears in the cycle there is a small variance of frequency which can be expressed by an enharmonic note name. To enable periodic recurrences of each series of notes within each octave, a certain number of pitches are selected and certain compromises are made with, for example, the octave. A Pythagorean scale is built of intervals of pure fifths (3:2) and octaves (2:1), but the basic problem is that no amount of compiled fifths will ever equal to any amount of octaves.

Let us first look at one facet of the theory behind this system: the circle of fifths. The Pythagorean system of compiling pure fifths starting from a root note generates all the notes of the chromatic scale, which if starting on A,²⁸⁸ is composed of these:

Ascending fifths: A-E-B-F#-C#-G#-D#-A#

Descending fifths: A-D-G-C-F

To play all these notes sequentially, all the notes above the first fifth (B and above) must be divided by a power of 2 and all the notes below the root note must be multiplied by a power of 2. The resultant frequencies of these fifths, folded as it were into the range of an octave in order of ascending pitch, are in the chart ‘Comparing Tuning Systems’ (p. 202).

These notes are the result of the acoustically pure fifth, a ratio of 3:2, or, one third of an open string; the pure fifth is ever so slightly wider than the 12-TET fifth. The notes of

²⁸⁷ Idem., p. 58. This is an interesting contextualization, but Ball would have us think from his text (p. 70) that these modifications are arbitrary, when in fact they have a clear mathematical foundation.

²⁸⁸ All our pitch centres (root notes) in this section will be A3 (220 Hz), so that intonation exercises can begin on the A-string of the cello.

the scale in the Pythagorean system are always in relation to a root note; where this becomes apparent is in the fifths which exceed the notes of the chromatic scale:

Ascending fifths: A - E - B - F \sharp - C \sharp - G \sharp - D \sharp - A \sharp - E \sharp - B \sharp - F \times - C \times - G \times

Descending fifths: A - D - G - C - F - B \flat - E \flat - A \flat - D \flat - G \flat - C \flat - F \flat

Here we enter the realm of ‘microtonal’ tuning, where there is a clear difference between notes which would otherwise be considered enharmonically equivalent in the 12-TET system: here, a G \times is not an A...it is a G \times . Theoretically, the farther the ascending fifths are from the root²⁸⁹ the sharper the note becomes, and the farther the descending fifths are from the root the flatter the note becomes. In effect the semitones in this tuning system are nearly equal. But 6 whole tones (9:8) equal 2.027, or slightly more than an octave. Indeed, pure octaves (2:1) do not naturally exist in the circle of fifths, and because there are no octaves, each note only appears once.

The microtonal differences in the sharps and flats have been historically straightjacketed by fixed-pitch instruments, a difference which can now begin to be re-explored.

The difference between the A and the G \times (which is twelve perfect fifth, or seven octaves, away) is called a Pythagorean comma. This is the same value as we reached previously by moving through six whole tones above the root note. This value can be expressed either as $3^{12}:2^{19}$, as $\frac{531441}{524288}$ or as 1.0136432648, and is roughly equivalent to one quarter of a Pythagorean semitone. As we will discuss further in a moment, the 5^{ths} in equal temperament are lowered by $\frac{1}{12}$ of a Pythagorean comma to accommodate enharmonic notes.

The notes of the scale in the Pythagorean system of intonation are therefore the result of true ratios between the notes of a scale: these ratios, some of them quite far from simple, are nonetheless all multiples of 3:2 (the ascending perfect 5th) and of 2:3 (the descending perfect 5th).

²⁸⁹ Often we speak of tonal contexts when discussing intonation, but here we will refer to ‘intonation root notes’ given the often atonal context of new music.

The music built on the Pythagorean system integrated the octave in a consonant way by never using notes outside the chromatic scale, thus avoiding the ‘enharmonic’ notes, and by staying in the tonality of the root note or those closely related to the root note. In the music of our era, it is important to understand the theory behind Pythagorean tuning: when we have a choice of placing certain pitches in a way which will considerably alter the harmonic colour, often these choices must be made outside a tonal context which would otherwise guide our decisions. The pure intervals (octaves, fourths and fifths) are instinctively the string-player’s choice, rather than the tempered intervals. The practical implications of narrowing the octaves becomes apparent in string quartet playing, where there can be up to 6 octaves difference in range between the cello and violins.

Just / Pure Intonation

Just Intonation (henceforth referred to as J.I.) is comprised of intervals which relate by simple, whole-number ratios. Many of these intervals are also present in the harmonic series. While the position of harmonics have been expressed in fractions (a harmonic is related to its fundamental in a ‘part-to-whole’ relationship), J.I. is expressed as a ratio (two values are compared). Many composers have tried to notate J.I. by means of ratios or microtonal accidentals.

J.I. is a closed, or circulating, system wherein a finite number of notes are produced and repeated cyclically to accommodate enharmonic note values. A frequently used tuning system in 20th-century music, J.I. is achieved through simplified ratios of the Pythagorean system. These ratios can be compared in the table on page 202 ‘Comparing Tuning Systems’.

Many systems were developed under the banner of J.I. using simplified ratios. These were favoured by many of the Renaissance theoreticians because of their simplicity, believed to reflect the natural movements of the celestial bodies. The mathematician and astronomer Johannes Kepler advocated this system and expounded the theory of the Harmony of the Heavens in his treatise *Harmonia mundi*.

In 1588, the Italian Gioseffo Zarlino formalized this system of simplified ratios into what is known as Syntonic-Diatonic Just Intonation. The value of the modification carried out on Pythagorean intervals is called a syntonic comma, expressed by the ratio 81:80, or 1.0125, discussed in further detail below. This is equivalent to the ratio between the two J.I. whole tones. The theory behind this can in fact be traced back the 2nd century, to Ptolemy's tetrachord, constructed from a larger whole tone (9:8) a smaller whole tone (10:9) and a semitone (16:15).²⁹⁰

The simplified ratios of J.I. may have been more pleasing to the ear and more 'morally' sound,²⁹¹ but it created problems of transposition, explained below. As part of the continual search for a tuning system which could accommodate the greatest number of justly tuned intervals and key changes, theoreticians created keyboards with extra notes, with the addition of split keys, extra keys, or pedal mechanisms. Two such examples are Zarlino's harpsichord, designed in 1588, which had 16 pitches per octave, and the Londoner Charles Claggett's Telio-chordon, a fortepiano with a 39 subdivision of the octave, an instrument which Haydn greatly admired.²⁹² Other inventions of this sort are mentioned in pages 214-219, because of their equivalences with equal temperaments other than 12/24-TET.

Sebastien de Brossard was the first to define microtones, at the turn of the 18th century in his Dictionary of Music. Describing the comma as the smallest identifiable interval, he states that a whole tone is comprised of 9 comma, or 4 comma for a minor semitone and 5 for a major semitone (which identifies Brossard's comma as a syntonic comma).²⁹³

Like the Pythagorean system, all notes relate to a root note. But for two different root notes, the difference in pitch between two notes of the same name is much more pronounced, and is equivalent to a syntonic comma.

²⁹⁰ http://en.wikipedia.org/wiki/Ptolemy%27s_intense_diatonic_scale

²⁹¹ Pun not intended.

²⁹² Duffin (2007), p. 84.

²⁹³ de Brossard (1703), p. 21.

For example, the open strings of the cello as pure 5^{ths} are:

A	D	G	C
220 Hz	146.7 Hz	97.8 Hz	65.2 Hz

An E which is in tune with the open C-string (compound major 3rd, or 5:4) will be 163 Hz while the same E which is in tune with the open A-string (perfect fourth, or 4:3) will be slightly higher at 165 Hz. The difference between these two values is a syntonic comma.

P & A Strange observe that just intonation is not ‘an attempt to generate necessarily consonant intervals. There are many instances of just intervals that are far more dissonant than any interval found in 12-TET.’²⁹⁴

Twelve-Tone Equal Temperament (12-TET)

The most widely accepted tuning system in Western classical music is currently 12-TET, where the octave is divided into twelve equal semitones. In 12-TET, a semitone is equal to 100 cents and an octave 1200 cents, values which mean all the notes of the chromatic scale will always be in the same place regardless of the tonality or harmonic context.²⁹⁵ The result is that intervals are not ‘in-tune’ (at least not according to the terms set in our previous section) and do not have the most acoustically stable resonance on a cello. However, because this system is used so frequently, the ear needs to be trained to hear such intervals.

Historically, the protagonists of tuning theory have been keyboard instruments, unavoidably shaping conception of harmony. Equal temperament, through its systemized use in keyboard instruments, has been the accepted form of tuning for most of the 20th century. But a string player will rarely resort to playing in equal temperament unless the context demands it (for example when playing with a piano or

²⁹⁴ P & A Strange (2001), p. 147.

²⁹⁵ This refers to any given tuning environment, for example with A4 being tuned at 440 Hz. The tuning environment can be changed of course, for example to an A442 Hz, and the placement of all the notes would be altered by the same increment.

an orchestra, versus playing unaccompanied music or in a string quartet). It is usually assumed that standard notation accommodates 12-TET; rarely is any other indication given concerning pitch placement.

The idea of 12-TET (essentially 11th-syntonic comma meantone temperament, or exactly 12th-Pythagorean comma meantone temperament) emerged quite early on. The concept of equal temperament was first documented by the Greek philosopher Aristoxenus in the 4th century B.C.²⁹⁶ Theorists clung however to the idea that intervals should correspond to simple ratios. Vincenzo Galilei (Galileo's father), among many others, attempted to find a solution to this paradox. The solution to 12-TET was discovered almost simultaneously in both China and Holland: the only factor that gives a precise doubling of frequency and can be multiplied by itself twelve times is $2^{1/12}$. This system was first published in 1584 by the prince and scholar Chu Tsai-Yü and contemporaneously put forward in 1585 by the Flemish mathematician Simon Stevin.²⁹⁷ This number however is in direct conflict with all preceding philosophies of harmony, in that it is an irrational number and cannot be expressed as a whole number. The concept of 12-TET was advocated as early as the 17th century by the French mathematician and monk Marin Mersenne and continued to be discussed for the greater part of 300 years. Equal temperament was seen as too much of a compromise in the consonance, or rather the euphony, of intervals until the turn of the 20th-century when it became the standard tuning system.

Several piano and organ builders commercialized their 12-TET instruments from the middle of the 19th century, but these were probably closer to 9th-comma meantone. Without the technology of accurately detecting frequencies we have today, instrument tuners relied on interval and chord colour recognition. Both P & A Strange and Duffin cite Owen Jorgenson as an expert on historical temperaments. The first successful

²⁹⁶ Macran (1902), p. 62.

²⁹⁷ http://en.wikipedia.org/wiki/Well_temperament: Kenneth Robinson attributes the invention of equal temperament to Zhu Zaiyu (Robinson 1980, vii) and provides textual quotations as evidence (Robinson and Needham 1962, 221). Fritz A. Kuttner is critical of his theory (Kuttner 1975, 163) and proposes that neither Zhu Zaiyu or Simon Stevin truly achieved equal temperament, and that neither of the two should be treated as inventors (Kuttner 1975, 200).

attempt at tuning a keyboard in 12-TET was in 1907 by Jerry Cree Fisher,²⁹⁸ but it was with the publication of William Braid White's *Modern Piano Tuning and Allied Arts* in 1917 that 12-TET was applied with mathematical precision.²⁹⁹ White developed a system of counting beats and using 'checks', or comparative intervals. To return to our statement of connecting tuning systems with philosophical principles, Duffin observes that the turning point for 12-TET coincides with the Russian Revolution – 'history's ultimate expression of the triumph of "social equality"!'³⁰⁰

As with J.I., 12-TET is a closed / circulating system. Because there are only 12 set pitches in 12-TET, there is no differentiation between enharmonic values, with, for example a C♯ and D♭ being the same pitch.

As 12-TET is now the norm, we often think of and compare alternate pitch placement in relation to it. Statements such as 'the just major third should be narrower' are relative to 12-TET.

Spectral Intonation

Spectral intonation is the term we will use to relate the natural pitch placement of the harmonic series. All values are expressed in simple, whole-number ratios, and are therefore sometimes also found in J.I. Indeed, many theoreticians have tried to connect the intonation of harmonics with the modes of Western classical music, such as major and minor scales, analysing similarities and rationalizing discrepancies. For our purposes, spectral intonation will be considered distinct from the other three systems we have discussed, in that it is the result of an acoustic phenomenon rather than a series of pitches selected for their mathematical or acoustic properties.

The following table illustrates de Saram's explanation of the harmonic series up to the 64th harmonic, a range which encompasses six octaves.³⁰¹ The ratios in this table are incremental, each value relating to the one preceding it. The ratios allow comparison

²⁹⁸ P & A Strange (2001), p. 288.

²⁹⁹ Duffin (2007), p. 112.

³⁰⁰ Idem., p. 140.

³⁰¹ Steinheuer & de Saram (2013), pp. 230-231, 237.

between the intervals present in the harmonic spectrum and those found in the tuning systems of the table on page 202.

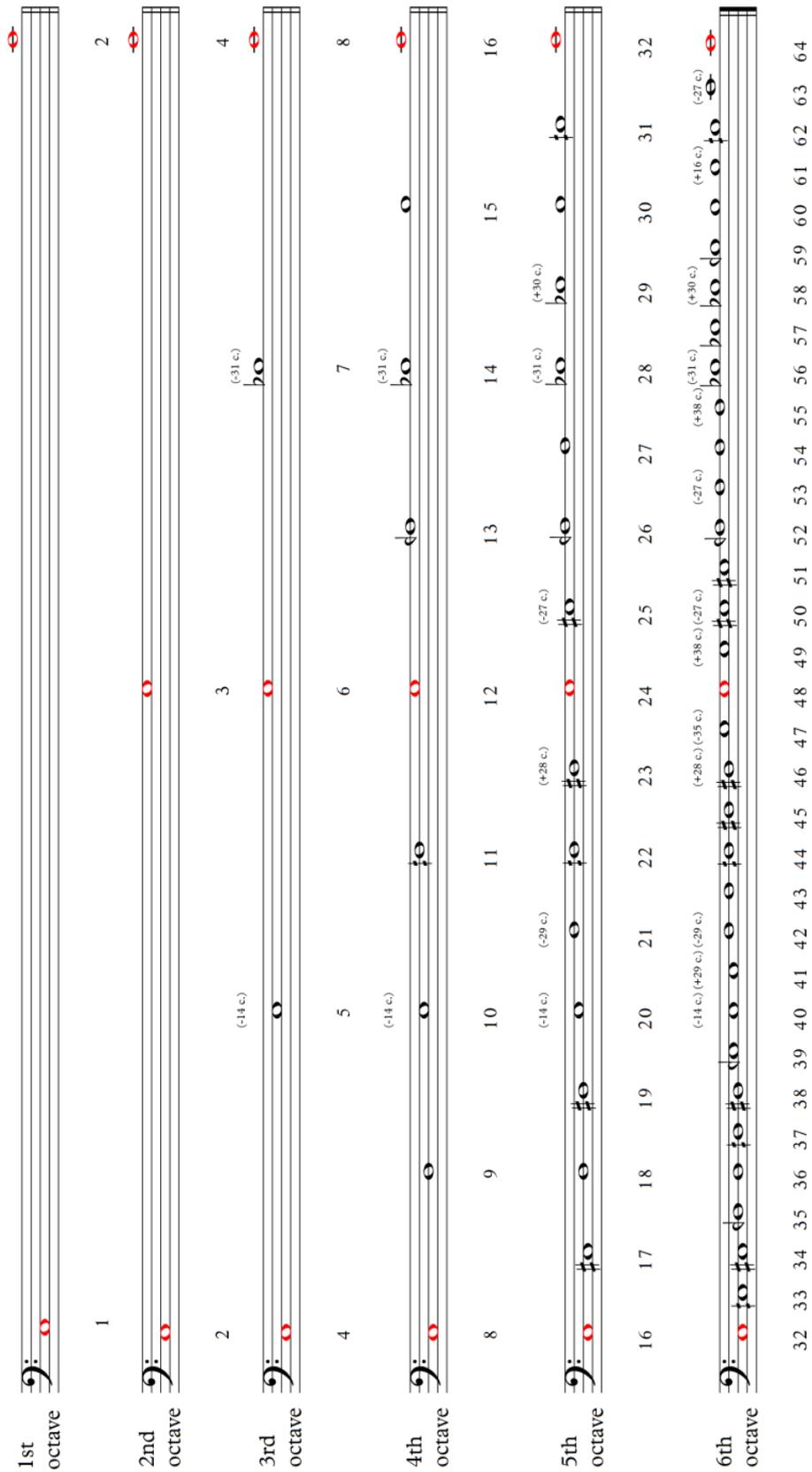
Figure 37: Harmonics 1-64

Octave	Harmonic	Ratio	Interval between harmonics	Note	Hz
1 st	1	1:1	Unison	C (open)	65.4
2 nd	2	2:1	Octave	C	130.8
	3	3:2	Fifth	G	196.2
3 rd	4	4:3	Fourth	C	261.6
	5	5:4	Major third	E	327.0
	6	6:5	Minor third	G	392.4
	7	7:6	Between minor 3rd & whole tone	B \flat	457.8
4 th	8	8:7	Between minor 3rd & whole tone	C	523.3
	9	9:8	Large whole tone	D	588.7
	10	10:9	Small whole tone	E	654.1
	11	11:10	Between whole tone & semitone	F \sharp	719.5
	12	12:11		G	784.9
	13	13:12		A \natural	850.3
	14	14:13		B \flat	915.7
	15	15:14		B	981.1
5 th	16	16:15	Semitone	C	1,046.5
	17	17:16	Increasingly smaller semitones	C \sharp	1,111.9
	18	18:17		D	1,177.3
	19	19:18		D \sharp	1,242.7
	20	20:19		E	1,308.1
	21	21:20		F	1,373.5
	22	22:21		Increasingly smaller third-tones	F \sharp
	23	23:22	F \sharp		1,504.3
	24	24:23	G		1,569.7
	25	25:24	G \sharp		1,635.2
	26	26:25	A \natural		1,700.6
	27	27:26	A		1,766.0
	28	28:27	B \natural		1,831.4
	29	29:28	A \sharp		1,896.8
	30	30:29	B		1,962.2
31	31:30	Increasingly smaller quarter-	B \sharp	2,027.6	

6 th	32	32:31	tones	C	2,093.0
	33	33:32		C [♯]	2,158.4
	34	34:33		C [♯]	2,223.8
	35	35:34		D [♭]	2,289.2
	36	36:35		D	2,354.6
	37	37:36		D [♯]	2,420.0
	38	38:37		D [♯]	2,485.4
	39	39:38		E [♭]	2,550.8
	40	40:39		Increasingly smaller fifth-tones	E (-14)
	41	41:40	E (+29)		2,681.7
	42	42:41	F (-29)		2,747.1
	43	43:42	F		2,812.5
	44	44:43	F [♯]		2,877.9
	45	45:44	F [♯]		2,943.3
	46	46:45	Increasingly smaller sixth-tones	F [♯] (+28)	3,008.7
	47	47:46		G (-34.5)	3,074.1
	48	48:47		G	3,139.5
	49	49:48		G (+38)	3,204.9
	50	50:49		G [♯] (-27)	3,270.3
	51	51:50		G [♯]	3,335.7
	52	52:51		A [♭]	3,401.1
	53	53:52		A (-26.5)	3,466.5
	54	54:53		A	3,531.9
	55	55:54		A (+38)	3,597.3
	56	56:55		B [♭] (-31)	3,662.7
	57	57:56		B [♭]	3,728.1
	58	58:57		B [♭] (+30)	3,793.6
	59	59:58	B [♭]	3,859.0	
	60	60:59	B	3,924.4	
	61	61:60	Increasingly smaller eighth-tones	B (+16)	3,989.8
	62	62:61		B [♯]	4,055.2
	63	63:62		C (-27)	4,120.6
64	64:63	C		4,186.0	

Transposed into the same octave, these values can be notated approximately as such:

Figure 38: Perspective view of harmonics 1-64



De Saram comments on how the notes are distributed: as can be seen in the notated example above, the 1st octave is empty, the 2nd has one note in between, the 3rd has three notes (forming a dominant-seventh), the 4th has seven notes (resembling the diatonic scale), the 5th has fifteen (resembling the chromatic scale), and the 6th has thirty-one. There is no equal division, but there is a constant frame of a fifth and fourth, shown above by the red notes. De Saram adds: ‘The prime numbers constitute one of the most interesting features, since they always come at a point where they divide an interval of the preceding octave into unequal parts. [...the overtone series] could be compared to perspective in the visual field.’³⁰²

The portions of the harmonic spectrum contained in the 4th, 5th and 6th octaves can be transposed to the lower positions of the cello and serve as microtonal exercises. This will form a preparatory exercise before moving on to study sequences of equally spaced microtones in the next section. Harry Partch coined the words Otonal and Otonality to identify scales constructed from harmonics.

As mentioned in the very first section, only the first 16 harmonics can be played on the open string in any practical sense. Although the next harmonics, up to the 40th, are said to ‘contribute significantly to the sound of the open C string’,³⁰³ the interest of reproducing essentially unplayable harmonics in a lower range is in the colour of the intervals and the resonance on the instrument. While natural harmonics are the theoretical basis for spectral intonation, in practice the upper harmonics (from approximately the 9th harmonic) are slightly out of tune with their theoretical values.

Comparing Tuning Systems

The following table places the values of the four tuning systems described above in parallel, for the same root note A = 220 Hz. More precise comparisons between each system are made below.

³⁰² Idem., pp. 230-231.

³⁰³ <http://www.cellomap.com/index/the-string/plucking-striking-and-bowing-the-string/where.html>

The formula for converting the cycle of fifths into ratios and their corresponding values in Hz is given for each note of the Pythagorean system. As there are many values in J.I., only a selection have been given, each reflecting the syntonic comma deviation in relation to the Pythagorean values (for example, the minor 6th 8:5 and the semitone 25:24 are commonly cited in J.I. but do not relate by a syntonic comma). Similarly, only a selection of notes has been given for spectral intonation. All of the ratios in this table relate to the root note (as opposed to the ratios on page 198, which relate to the preceding note).

Figure 39: Comparing tuning systems

12-TET		Pythagorean					Just Intonation			Spectral Intonation	
Name	Hz	FIFTH No.	Name	Ratio	Formula	Hz	Syntonic Comma ³⁰⁴ (81:80)	Ratio	Hz	Ratio	Hz
A	220.0	0	A	1:1	$\frac{1}{1}$	220.0	equal	1:1	220.0	1:1	220.0
		12	G♯	531441:524288	$\left(\frac{3}{2}\right)^{12} \times \left(\frac{1}{2}\right)^7$	223.0					
A♯	233.1	-5	B♭	256:243	$\left(\frac{2}{3}\right)^5 \times 2^3$	231.8	lowered raised	135:128	232.0	17:16	233.8
		7	A♯	2187:2048	$\left(\frac{3}{2}\right)^7 \times \left(\frac{1}{2}\right)^4$	234.9					
B	246.9	-10	C♭	65536:59049	$\left(\frac{2}{3}\right)^{10} \times 2^6$	244.2	lowered equal	10:9	244.4	9:8	247.5
		2	B	9:8	$\left(\frac{3}{2}\right)^2 \times \frac{1}{2}$	247.5					
C	261.6	-3	C	32:27	$\left(\frac{2}{3}\right)^3 \times 2^2$	260.7	raised	6:5	264.0	19:16	261.3
		9	B♯	19683:16384	$\left(\frac{3}{2}\right)^9 \times \left(\frac{1}{2}\right)^5$	264.3					

³⁰⁴ To raise a ratio by a syntonic comma, it is multiplied by (81/80); to lower a ratio by a syntonic comma, it is multiplied by (80/81).

C#	277.2	-8	D \flat	8192:6561	$\left(\frac{2}{3}\right)^8 \times 2^5$	274.7	lowered ↗	5:4	275.0	5:4	275.0
		4	C#	81:64	$\left(\frac{3}{2}\right)^4 \times \left(\frac{1}{2}\right)^2$	278.4					
D	293.7	-1	D	4:3	$\frac{2}{3} \times 2$	293.3	equal ↘	4:3	293.3	21:16	288.8
		11	C#	177147:131072	$\left(\frac{3}{2}\right)^{11} \times \left(\frac{1}{2}\right)^6$	297.3				11:8	302.5
D#	311.1	-6	E \flat	1024:729	$\left(\frac{2}{3}\right)^6 \times 2^4$	309.0	lowered ↗	45:32	309.4	23:16	316.3
		6	D#	729:512	$\left(\frac{3}{2}\right)^6 \times \left(\frac{1}{2}\right)^3$	313.2					
E	329.6	-11	F \flat	262144:177147	$\left(\frac{2}{3}\right)^{11} \times 2^7$	325.6	equal ↗	3:2	330.0	3:2	330.0
		1	E	3:2	$\frac{3}{2}$	330.0					
F	349.2	-4	F	128:81	$\left(\frac{2}{3}\right)^4 \times 2^3$	347.7	lowered ↗	405:256	348.1	13:8	357.5
		8	E#	6561:4096	$\left(\frac{3}{2}\right)^8 \times \left(\frac{1}{2}\right)^4$	352.4					
F#	370.0	-9	G \flat	32768:19683	$\left(\frac{2}{3}\right)^9 \times 2^6$	366.3	lowered ↗	5:3	366.7	27:16	371.3
		3	F#	27:16	$\left(\frac{3}{2}\right)^3 \times \frac{1}{2}$	371.3					
G	392.0	-2	G	16:9	$\left(\frac{2}{3}\right)^2 \times 2^2$	391.1	raised ↘	9:5	396.0	7:4	385.0
		10	F#	59049:32768	$\left(\frac{3}{2}\right)^{10} \times \left(\frac{1}{2}\right)^5$	396.5				29:16	398.8
G#	415.3	-7	A \flat	4096:2187	$\left(\frac{2}{3}\right)^7 \times 2^5$	412.0	lowered ↗	15:8	412.5	15:8	412.5
		5	G#	243:128	$\left(\frac{3}{2}\right)^5 \times \left(\frac{1}{2}\right)^2$	417.7					
A	440.0	-12	B $\flat\flat$	1048576:531441	$\left(\frac{2}{3}\right)^{12} \times 2^8$	434.1	raised →	2:1	440.0	2:1	440.0

Below are key observations from the chart above, which can be corroborated by practical experience:

Pythagorean vs. Just Intonation vs. 12-TET

- Fifths** The equally-tempered fifth is only 2 cents narrower ($\frac{1}{48}^{\text{th}}$ of a semitone) than the just fifth (3:2), a negligible amount. (The real compromise of 12-TET is in the thirds.) If one chooses to tune the open strings of the cello in Just or Pythagorean fifths (3:2), then certain adjustments may need to happen, particularly in string quartet playing. For example, if tuning to an A440 and this is the temperament root, then the open G- and C-strings of the cello will be $\frac{1}{5}$ of a semitone flat. In the string quartet, if all the instruments tune their open strings to pure fifths, the open E of the violins and the open C of the cello will be a Pythagorean Major 3rd (81:64) which will sound out of tune (see below). It is more practicable to establish a just major third between the outer strings of the quartet; to achieve this, the open strings must be even narrower than in 12-TET.
- Major thirds** The 12-TET major third is 14 cents ($\frac{1}{7}^{\text{th}}$ of a semitone) wider than the just major third (5:4). Because the minor and major third occupy the space of a fifth, the discrepancy with the minor third is inversely small as seen below. Pythagorean major thirds are even wider than those in 12-TET, and have a very ‘rough’, dissonant sound quality.
- Minor thirds** The 12-TET minor third is 16 cents narrower than the just minor third (6:5). Pythagorean minor thirds are also ‘dissonant’.
- Major sevenths (as leading tones)** The just seventh (15:8) is 12 cents narrower than the tempered seventh. The string-player’s tendency to raise the leading note in a tonal context is not based in either of these

tuning systems; this is often referred to as ‘expressive intonation’ and actually corresponds more closely to Pythagorean tuning.

- Major seconds While Pythagorean whole tones are all equal to 9:8, those in J.I. are either 9:8 (A→B, D→E and F♯→G♯, for a root note of A), or 10:9 (B→C♯ and E→F♯). The smaller major second (10:9) and the larger major second (9:8) in J.I. correspond to C ♭ (10 fifths below the root) and B (2 fifths above the root) of the cycle of fifths. When added, these two intervals form a just major third (10:9 x 9:8 = 5:4).³⁰⁵ The 10:9 is 18 cents narrower, and the 9:8 is 4 cents wider than the 12-TET whole tone.
- Minor seconds The semitones between the 3rd-4th degrees and the 7th-8th degrees of the J.I. scale are 16:15. This is 12 cents wider than the 12-TET semitone. The ratio of Pythagorean semitones is 256:243, which is 10 cents narrower than the 12-TET.
- Octaves Octaves in the Pythagorean system can be calculated in two ways: 1) as a ratio of 2:1, in which case the tonic stays consistent but the other notes of the scale do not, and 2) six whole tones (9:8) equals 2.02728652954, which divided by 2 is 1.01364326477, i.e. the Pythagorean comma.
- Enharmonic notes In 12-TET there are only twelve notes, with absolute values, therefore a C♯ and D ♭ will be placed at exactly the same frequency. In the Pythagorean system, there are no enharmonic values.
- Sharps & flats The natural tendency of string players to raise sharps and lower flats corresponds to the cycle of fifths, and therefore the

³⁰⁵ P & A Strange (2001), p. 269.

Pythagorean system. This also subscribes to the notion of 'expressive intonation'.

All intervals

In theory, Pythagorean intervals are evenly spaced as they are derived from equally spaced fifths.

Resonance

The cello is most resonant when notes corresponding to the overtone content of a string are played. In double-stops or in harmony with other instruments, these create difference tones that are perfectly in tune (see p. 184).

20. MICROTONALITY

Microtones are usually defined as any interval which is smaller than a semitone. For our purposes, this definition will extend to include any interval which lies outside the twelve semitones of the chromatic scale. Section ‘5. Between the Notes’ (p. 107) served as preparation for this section, in disassociating pitch with chromatic notes, and section 18 (‘18. Dissonance’, p. 182), developed sensitivity to heterodyne frequencies and frequency beating. The previous section (‘19. Tuning Systems’, p. 188), established that microtones were an integral part of the earliest tuning systems, in the form of the Pythagorean and syntonic commas.

On a fundamental level, microtonality could be considered an intrinsic component of all music; vocalists and instrumentalists playing non-fixed-pitched instruments will let their ear guide them in the pursuit of harmony or expression, or in reaction to acoustics. Perhaps because of this natural flexibility, the exploration of dividing the octave into more than 12 notes was in fact incentivized by fixed-pitch instruments; pre-20th-century efforts of adding enharmonic notes to the octave of a keyboard circumvented to a certain extent the problem of comma discrepancies. This exploration, however, was sporadic for the greater part of 400 years, even within given composers’ and theoreticians’ own output. For this reason, the history of microtonality before the turn of the 20th century has been included in the previous section, with relevance to particular tuning systems. Equal temperaments other than 12-TET were also discussed prior to the turn of the 20th century, because of their relationship to established temperaments (usually meantone) and always with a view to achieving greater consonance in tonal music. When this is the case, this information is included below. All this paved the way for modern microtonal explorations. The text below will focus on the development of microtonality independently of tonal contexts.

P & A Strange write that a trained musician can differentiate pitches separated by 3 cents,³⁰⁶ although this will vary widely with timbre, context, and acoustics. Nevertheless, if this were possible, it would mean that 400 intervals are available within an octave, all of which would, again theoretically, be possible on a string instrument.

³⁰⁶ Idem., p. 141.

As early as 1636, Marin Mersenne acknowledged this possibility: ‘because it carries no frets, [the violin] contains all the intervals imaginable’.³⁰⁷

The goal in this section, to use Garth Knox’ example in his introduction to his études, is to train the ear to develop ‘the feeling that it is neither a C natural nor a C sharp which is out of tune, but a note in its own right.’ The playing of microtones necessitates first and foremost an understanding of the tonal colour of intervals that lie outside the chromatic scale, which can then be followed by a study of the ergonomics of the technique. For our purposes, quarter tones will form the focus of our study as these are the most frequently used in modern music and can easily relate to the chromatic scale. Guiding information for other equal divisions of the tone or octave will be given briefly as well.

Another way of approaching microtonality is offered by de Saram: ‘However, something that does interest me very much is the extent to which these microtones can be thought of as independent pitches in their own right or as subordinate adjuncts or satellites, if you like, of more important fundamental pitches.’³⁰⁸ Whether a microtone is perceived as an ornamental note in relation to a diatonic or chromatic note, or whether it is a note in its own right will depend entirely on context. In this text, microtones will be considered distinct to pitch bending (discussed in various sections according to the technique which is used to achieve this effect, see pp. 58, 95, 114, 115, and 131); the latter should be heard as a deviation to a pitch, whereas the former is a different note entirely.

Late 19th-century efforts can be traced back to two physicists, the Hungarian Josef Petzval (1807-1891, inventor of opera glasses) and Japanese Shohé Tanaka (1862-1945). In terms of composers, ‘Busoni, Schoenberg, and Webern all flirted with the idea of using microtones, and while none of them made real use of non-12-TET tunings, all three had significant influence on other composers’.³⁰⁹ In 1906 Richard H. Stein

³⁰⁷ Mersenne’s *Harmonie Universelle* is cited in Walden (1998), p. 242.

³⁰⁸ Steinheuer & de Saram (2013), p. 123.

³⁰⁹ <http://www2.hmc.edu/~alves/microfestabstracts.html>. Ball (2007), p. 63 cites Busoni’s *Sketch of a New Aesthetic of Music* (1907).

published a piece using quarter-tones. ‘Willi Möllendorf patented a quarter-tone keyboard which made a great impact on both Alois Haba and Ivan Wyschnegradsky.’³¹⁰

Although microtonality was the subject of theory for some time,³¹¹ the story of microtonality effectively begins in 1895 with the experiments of Mexican theorist and composer Julián Carrillo (1875-1965). His publication *Sonido 13* (1900), in which he systemizes microtonality, is of great importance; Carrillo also applied his system in his own compositions.³¹² The Czech Alois Hába (1893-1973) followed suit a few decades later, his string quartets are particularly good examples of his use of microtones. In addition to his renown for building microtonal instruments which could produce microtonal pitches with accuracy, American composer Harry Partch (1901-1974) experimented with various systems of microtonality and influenced several generations of composers who adopted his techniques. Other contributors include Charles Ives, Easley Blackwood, Lou Harrison, John Eaton, and Ben Johnston. Rolén traces the earliest use of a quarter-tone in music for cello to Ernest Bloch’s *Schelomo*, written in 1916; this single quarter-tone is very clearly labelled.³¹³

The notation for microtones has not yet been standardized. This is quite likely the area of new music notation which has the most varied and least systemized notation. However, most music involving microtones will be accompanied by a notation chart explaining their meaning in the context of the work.

³¹⁰ Ibid.

³¹¹ In addition to the many historical examples cited in this section, Busoni’s theories are noteworthy. Nyman (1999), p. 39, cites Busoni as having ‘invented 113 different scales using the chromatic octave, and proposed scales based on thirds and sixths of a tone’.

³¹² Many of Carrillo’s works for cello are cited by Uitti in Stowell (1999), p. 216.

³¹³ <http://www.moderncellotechniques.com/left-hand-techniques/quarter-tones/qts-examples-from-the-repertoire/>

Figure 40: Most common microtonal accidentals (Rolen)³¹⁴

$\frac{1}{4}$ -sharp	$\frac{3}{4}$ -sharp	$\frac{1}{4}$ -flat	$\frac{3}{4}$ -flat
♯ _↑ ♯ _↗ ♯	♯ _↘ ♯ _↓	♭ _↓ ♭ _↘ ♭ _↗ ♭	♭ _↘ ♭ _↓ ♭ _↗

The accidentals with arrows are often used as ‘slightly sharper or flatter’, without necessarily designating an exact quarter-tone.

This sign is used by George Crumb, and is placed above a note with a flat, a sharp, or no accidental at all. ♯_↑

In an equally tempered environment, the $\frac{3}{4}$ -tone accidental is essentially redundant, in that it can always be expressed by a $\frac{1}{4}$ -tone sharp or $\frac{1}{4}$ -tone flat depending on context. For this reason, it should only be used in a melodic line, where it most clearly indicates an ascending or descending sequence of quarter-tones.

Figure 41: Ascending and descending quarter-tones³¹⁵

24-TET (Quarter-tones)

Interval size: 50 cents.

This is the most commonly used form of microtonality. Rolen says of quarter-tones in his introductory page:

Over many years of ardent practice we develop a refined sense of good intonation in our ears and in our fingers, and this technique can therefore be especially frustrating to practice and to master. At first the notation feels foreign and

³¹⁴ <http://www.moderncellotechniques.com/left-hand-techniques/quarter-tones/quartertones-overview/>

³¹⁵ Ibid.

requires additional mental steps, and it is difficult to know whether or not you're in tune.³¹⁶

Often a cellist will equate the playing of a quarter-tone with placing the fingers as closely as possible in the lower positions, but as each individual's finger width varies, it is important that the student is able to hear a quarter-tone, as an individual note and in a harmonic context. The natural placement of quarter-tones within the harmonic series will be the first step in aural recognition. Thus the 11th and 13th harmonics are used as a reference point for stopped notes in different ranges of the instrument.

Quarter tones can also be heard by stopping a note in the fourth position, and playing the length of string between the nut and the finger (see 'Non-Resonating Sul Tasto', p. 84).

The next step is familiarization with new fingering systems. Beginning the study of microtones with quarter-tones allows for finger patterns which involve semitones, which can be used as reference for correct intonation. The fingering style I have used below adheres to that printed in Lutosławski's *Cello Concerto*,³¹⁷ edited by Rostropovich, where the large numbers correspond to the notes of 12-TET and small numbers to the quarter-tones. This system becomes particularly useful in passages using both semitones and quarter-tones.

³¹⁶ <http://www.moderncellotechniques.com/left-hand-techniques/>

³¹⁷ Performed with the Goldsmiths Sinfonia on 21 March 2014, Great Hall, Goldsmiths College London (conducted by Ian Gardiner), as 3rd-year performance evaluation (via concerto competition) to support this thesis.

Exercise 17: Quarter-tone Scale (four octaves)

- a) Play all of the notes with a 'big' fingering, including the open strings. This will produce a chromatic scale with shifts in unfamiliar places.
- b) Learn the following fingering pattern as you would in a chromatic scale (12-TET). Shifts are always onto a familiar note. When you shift, take note of which position you are in. At first, stop and compare familiar pitches with the open strings.
- c) As you become more comfortable with finger spacing and shifting, take note of the colour and resonance of each quarter-tone.

The musical notation for Exercise 17 is as follows:

Staff 1 (Bass Clef): 0 1 2 3 1 2 1 2 3 4 1 2 3 4 0 1 2 3 1 2 1 2 3 4

Staff 2 (Bass Clef): 1 2 3 4 0 1 2 3 1 2 1 2 3 4 1 2 3 4 0 1 2 3 1 2

Staff 3 (Treble Clef): 1 2 3 4 1 2 3 4 1 2 3 4 *sim.*

Staff 4 (Treble Clef): 1 2 3 4 *sim.* 1 2 3 4

Staff 5 (Treble Clef): 4 3 2 1 *sim.*

Staff 6 (Treble Clef): 4 3 2 1 *sim.* 4 3 2 1 4 3 2 1

Staff 7 (Bass Clef): 4 3 2 1 3 2 1 3 2 1 0 4 3 2 1 4 3 2 1 2 1 3 2 1 0 4 3 2

Staff 8 (Bass Clef): 4 3 2 1 1 4 3 2 1 2 1 3 2 1 0 4 3 2 1 4 3 2 1 2 1 3 2 1 0

Quarter-tone trills should be done with the same arm action as vibrato, rather than articulating the upper finger.

Equal Temperament other than 12/24-TET

Below are brief descriptions of equal temperaments other than 12-TET and 24-TET. In each case, intervals are obtained by dividing the octave into equally spaced intervals.

For divisions of the scale in which no pitch except the octave corresponds to the twelve tones of the chromatic scale, such as 19-TET, de Saram advises using white tape on the fingerboard, on which the intervals can be marked after being calculated with a tuner.³¹⁸ De Saram says of the process: ‘That is how I started, but then the intonation turned out to be so characteristic that my ear guided me to a large extent, as I got used to the scale.’³¹⁹

Graphic chart tape can also be used, and easily removed, to mark the fingerboard. It comes in a variety of widths which is useful if one prefers to feel just a line under the finger, or have a wider band on which the entire finger is placed. Fretting a cello is different to a guitar or viol, where the finger is placed behind the fret. Cellists tend to use the middle of their finger for geography, even though the pitch is determined by the outer edge of the finger. Therefore the fret should be placed in the middle of the finger for greater accuracy.

5/15-TET

Interval size: 240 cents in 5-TET / 80 cents in 15-TET.

³¹⁸ It is interesting to reflect on how technological progress has made this type of work universally accessible: whereas de Saram previously needed access to electronic equipment at the City University of London, an electronic tuner or tuning app on a smart phone is now adequate.

³¹⁹ Steinheuer & de Saram (2013), pp. 94-95.

This is often compared to the Indonesian gamelan's *slendro* scale, which is also made up of 5 equally spaced tones.³²⁰ There is relatively more repertoire written for guitar in 15-TET.

Figure 42: Easley Blackwood's notation system for 15-TET³²¹



7-TET

Interval size: 171.4 cents.

Each interval is slightly smaller than a whole tone (a whole tone is 200 cents), or approximately half-way between the ratios of 11:10 and 10:9. These pitches cannot be written exactly, and must therefore be learned aurally, the written score serving as a guideline to pitch placement. Ethnomusicologists have found that certain music of Vietnam (Morton, 1974) and Uganda (Haddon, 1952) is tuned in this system.³²²

16-TET ($\frac{3}{4}$ -tones)

Interval size: 75 cents.

This system divides a 12-TET minor 3rd into four equal intervals.

17-TET

Interval size: 70.6 cents.

The musician and theorist Safi al-Din al-Urmawi's compendium of contemporary musical knowledge, the *Kitab al-Adwār* written in the 13th century, describes a seventeen tone tuning system. In 1863 Alexander J. Ellis presumably refers to this

³²⁰ In Stowell (1999), p. 216, Uitti erroneously identifies the *slendro* scale as an equal division of the octave into 6, which is in fact a whole tone scale.

³²¹ http://en.wikipedia.org/wiki/15_equal_temperament

³²² Cited in P & A Strange (2001), p. 166, and http://en.wikipedia.org/wiki/Equal_temperament.

specific tuning, describing the Arabic scale as a system of seventeen tones based on perfect fourths and fifths.³²³

Figure 43: Easley Blackwood's notation system for 17-TET³²⁴



18-TET ($\frac{1}{3}$ -tones)

Interval size: 66.7 cents.

19-TET

Interval size: 63.2 cents.

The interest in 19-TET can be traced back to the Renaissance. The intervals are based on the natural discrepancy between an octave and four just minor thirds (6:5), which forms a comma to the ratio of 648:625, or 62.565 cents, also known as a greater diesis.³²⁵ This system also approaches extended $\frac{1}{3}$ -comma meantone temperament. The result is especially consonant 3rds and 6ths.

The French composer Guillaume Costeley wrote a four-part song called *Seigneur Dieu ta pitié* in 1558 using 19-TET.³²⁶ Other advocates of this system include music theorist Francisco de Salinas who proposed this form of tuning in *De Musica* (1577),³²⁷ French thinker Marin Mersenne who built a 19-TET harpsichord in the early 17th century, and

³²³ Ellis (1864), pp. 404-422.

³²⁴ Blackwood (1991), pp. 166-200.

³²⁵ A diesis is the difference between a major and minor semitone, and will vary in size according to the amount that the fifth is tempered. A smaller diesis is the difference between an octave and three just major thirds, which forms the ratio of 128:125, or about 41.1 cents.

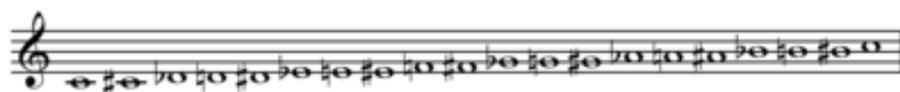
³²⁶ http://en.wikipedia.org/wiki/Guillaume_Costeley. The article references Kenneth J. Levy, 'Costeley's Chromatic Chanson', *Annales Musicologiques: Moyen-Age et Renaissance* 3 (1955, pp. 213–61). Levy writes that Costeley specified that a 19-key keyboard tuned in equally tempered $\frac{1}{3}$ -tones would be necessary for his microtonal 'chanson'. There is a discrepancy in this statement, in that equally tempered $\frac{1}{3}$ -tones would equate to 18-TET.

³²⁷ Salinas' 19-tone division of the octave was an irregular tuning, where whole tones are equal and minor semitones are half the size of major semitones.

Wesley Woolhouse, an English actuary with wide-ranging scientific interest, who suggested 19-TET as a more practical alternative to meantone temperament in his *Essays on Musical Intervals, Harmonics, and the Temperament of the Musical Scale* (1835).

In this division, no pitch except the octave corresponds to the twelve tones of the chromatic scale. De Saram comments that this type of intonation is similar to that of Indonesian gamelan, more particularly of the gongs and other percussive instruments, and that it approaches the intonation of the higher overtones, between the 8th and 16th (see p. 43).

Figure 44: Easley Blackwood's notation system for 19-TET³²⁸



In the above example, flats and sharps are different notes, while B[#] / C and E[#] / F^b are enharmonically equivalent.

31-TET ($\frac{1}{5}$ -tones)

Interval size: 38.7 cents.

This system equates to extended quarter-comma meantone temperament, producing very pure major 3^{rds} (5:4). The Italian music theorist and composer Nicola Vicentino (1511-1575/6) was an advocate of this system, and built the *archicembalo* with 31 notes to the octave. One such instrument survives today, built in 1606 by Vito Trasuntino of Venice. In 1618 Fabio Colonna (1567-1640) built a 31-TET instrument with eight keyboards, which he named *Sambuca lincea* and the French Marin Mersenne included 31 notes per octave in his keyboard design of the 1630s. Dutch polymath Christiaan Huygens (1629-1695) built a 31-TET harpsichord and fellow countrymen Adriaan Fokker (1887-1972) and Henk Badings (1907-1987) were both influenced by this tuning; the former built an organ with this tuning, which he called the 'tricesimoprimal

³²⁸ Skinner (2007), p. 52.

organ' (for some reason it didn't catch on) and the latter used the system in his compositions.

36-TET ($\frac{1}{6}$ -tones)

Interval size: 33.3 cents.

In 1875, a three-octave generalized keyboard organ with 48 notes per octave was tuned to Hermann von Helmholtz' approximate just intonation (schismatic temperament), or 36 notes per octave tuned in quarter-comma meantone selected by means of draw stops.

43-TET

Interval size: 27.9 cents.

This system is very close to extended fifth-comma meantone temperament. Partch favoured an unequal 43-tone scale, based on 11-limit³²⁹ just intonation.

53-TET / Pythagorean Intonation / Indian Shruti

Interval size: 22.6 cents.

If one follows the Pythagorean logic of building a scale out of pure fifths (and omitting any use of the octave), the result is 53-TET. In 1873, a $4\frac{1}{2}$ -octave harmonium tuned in 53-TET, with 84 keys per octave, was built by T. A. Jennings and in the same decade, the Bosanquet harmonium, also with 84 notes per octave, was built for the English scientist and music theorist Robert Holford Bosanquet. Bosanquet was also interested in the use of this system in Indian classical music. This uses 22 of these 53 notes, called *shruti* (also transliterated as *śrutis*), which correspond to perfect-5^{ths} ascending eleven times and descending ten times. In this unequal division of the scale, 'the microtones are essentially decorative to the main notes of the particular raga being used'.³³⁰

³²⁹ The term 'limit', or 'prime limit', was coined by Partch and refers to the highest factor of the ratios of each note in relation to the root note. For example, the Pythagorean System is 3-limit intonation because the prime factors of the ratios are no higher than three; J.I. is 5-limit intonation.

³³⁰ Steinheuer & de Saram (2013), p. 123.

55-TET

Interval size: 21.8

This system is comparable to extended sixth-comma meantone temperament, a system very suited to string playing in the context of functional harmony, because of the placement of the 3^{rds}.

21. PHASING & REPETITION

This short section and the next lead us progressively into section ‘24. Interpreting Notation & Style’, and to aspects of musicianship specific to certain styles of modern music (as opposed to sections 18 and 19, which explore general issues of musicianship).

The techniques of phasing and repetition are linked here to process-based minimalist music (see p. 294). Often referred to simply as ‘minimalist’ music, – best exemplified by the works of Philip Glass, Steve Reich, and Tom Johnson – this style now occupies a firm place in 20th- and 21st-century music. It is often under-rehearsed by professional classically-trained ensembles because of its perceived simplicity in terms of structure and harmony. For this music, no less than perfect intonation, metronomic stability of pulse and of rhythmic figures, and sensitivity to harmonic progression must be displayed by the musicians. A single wrong note will not go unnoticed! Ultimately, as these are qualities one would assume are present in all good musicians, concentration is the most determining factor in the success or failure of a minimalist music performance. Reich says of his own ‘phase’ pieces:

This music is not the expression of the momentary state of mind of the performers while playing. Rather the momentary state of mind of the performers while playing is largely determined by the ongoing composed slowly changing music. By voluntarily giving up the freedom to do whatever momentarily comes to mind we are, as a result, free of all that momentary comes to mind.³³¹

It is in this context that the techniques of phasing and repetition are discussed here.

Rhythmic phasing is a compositional technique where two or more musical lines begin a repetitive cell in rhythmic unison and gradually pull apart, while maintaining individual structural integrity in each part. Often the parts phase in a full cycle and return to a final iteration in unison. The phasing can occur by adding or subtracting a small rhythmic element to one part, or by discrete differences in each part’s tempo. Phasing was first developed by Reich in his electronic music on tape. Ross describes Reich’s happy accident in 1965: when misaligning two tape decks with the same

³³¹ Nyman (1999), p. 154.

material, he eventually produced the work *It's Gonna Rain*.³³² Reich then transferred the effect to live, instrumental music with *Piano Phase* in 1967. The melodic patterns and contours of phased material led Reich to develop his instrumental style of imitating speech pattern and intonation, as in, for example, *Different Trains*.

Philip Glass developed and refined rhythmic addition, subtraction, and repetition. Developing comfort in repeated figures is an important aspect of playing without fatigue or injury. Arpeggios and repeated figures should be rehearsed for accuracy of rhythm and intonation, as well as for bringing out what Nyman describes as the 'independent rhythms [and melodies] which arise naturally out of the regular quaver movement.'³³³

Minimalist music generally tends towards traditional harmonies. Very little (but constant) vibrato, or no vibrato, is optimal, in order to remove any of the performer's personal expression.

Intonation will depend on context, as with all other music, although just intonation is usually preferable, with careful consideration to the placement of 3^{rds} and 5^{ths}. Duffin presents an interesting approach to intonation with regards to the common practice period, which can be applied to minimalism. He differentiates between 'expressive intonation' (wide major thirds and seventh, or roughly Pythagorean tuning) and what he suggests calling 'harmonic intonation.'³³⁴ The latter is based on a flexible sixth-comma meantone system and requires fifths that are narrower than 12-ET, whole tones that are smaller than 12-ET, and lowered sharps and raised flats (i.e. a C# is lower than a Db). The practical implications are narrower major thirds and wider minor thirds, and differentiating between diatonic semitones (larger: C-Db) and chromatic semitones

³³² Ross (2009), p. 543.

³³³ Nyman (1999), of Glass' music, p. 151.

³³⁴ Duffin (2007), pp. 151-152.

(smaller: C-C#).³³⁵ According to Duffin, the ear seems to tolerate greater variance in minor thirds than major thirds.³³⁶

The foremost consideration is to let the music exist with as little interference from the emotions of performer and composer as possible. Rebecca Turner writes:

The performer is no longer the admired skilled virtuoso but the enabler of a sonic event, coaxing different sounds out of their instrument and challenged to become almost invisible in the experience. Minimalist-inspired music is commonly characterized by hypnotic repetition and is often constructed from elemental materials, sometimes cells or arpeggio fragments repeated in ostinato. Though this style of writing does not tend to require hours of work in the practice room it raises other challenges, for example, the repeated patterns and modules not only require immense concentration in counting bars, but can often produce almost trance-like states and this can be disconcerting for the performer.³³⁷

The study of minimalist music should in effect strengthen the tenets of good musicianship.

³³⁵ Duffin's book provides a full explanation of this system.

³³⁶ *Idem.*, p. 29.

³³⁷ Turner (2011), p. 29.

22. COMPLEX RHYTHM

To Steinheuer's prompting of 'Rhythm is probably the musical parameter that has gained particular significance during the last century in European music', Rohan de Saram replies that rhythm indeed 'plays a prominent role in works which communicate strongly to contemporary audiences. Rhythm is undoubtedly the most universal of the three main ingredients, namely melody, harmony and rhythm.'³³⁸

Our concern here will be twofold: metre and division of the beat. Metric modulation, a combination of these two aspects of rhythm, will also be discussed. While changes of pulse or frequent tempo changes can be remembered through the character of the musical material in solo and chamber music, and are the responsibility of the conductor in orchestral music, all areas of musical activity, and most of all ensemble music, necessitate a thorough understanding of metre and subdivision. Change of pulse is quite often the result of the aspects of rhythm discussed below.

Throughout history, the rhythm and metre of Western classical music remained at a relatively rudimentary level, while those of Eastern European folk music, Indian classical music and much of African music, for example, evolved to be the most complex aspects. With the exception of the Renaissance, which saw a rhythmic complexity unrivalled until the 20th century, the common practice period holds but a few examples, all from the 19th century and pertaining to asymmetric metre.³³⁹

Often in modern music, texture, dynamics and pitch (in this order of importance) are subordinate to rhythm. Stravinsky and Bartók were instrumental in shifting this focus in music, the latter having brought the isorhythms of folk music into his own music. Elliott Carter's *Sonata* for cello and piano (1948) marks another turning point, where

³³⁸ Steinheuer & de Saram (2013), p. 235.

³³⁹ Perhaps the earliest example is seen in Anton Reicha's *36 Fugues for the Pianoforte* (1803), where Fugue No. 20 is written in an additive meter of 3/8 and 2/8. Not only does he provide a written explanation to ensure that the quavers are played regularly, accompanied by notated examples, Reicha draws on examples from folk music in his introduction to support his use of a meter in 5. Chopin also notates the third movement of his *Piano Sonata No. 1* (1828) in 5.

the composer introduces metric modulation. This technique became a hallmark of Carter's style.

Metre

Asymmetric / Irregular / Complex

Asymmetric metre involves an odd number of beats and can therefore not be subdivided equally. For example, these time signatures are asymmetrical: 5/8, 7/4, 11/16. With the exception of a slower 5/4 or 5/2, asymmetric metre indicates larger beats which are to be grouped. This involves a mixture of beats in simple (divisible by 2) and compound time (divisible by 3). Below are some examples with some more commonly seen beat groupings:

5/4	3 + 2	2 + 3
7/8	2 + 2 + 3	3 + 2 + 2
11/16	3 + 3 + 3 + 2	2 + 2 + 2 + 2 + 3

Additive / Imperfect

Some subdivisions of metre necessitate unequal divisions of the bar, but could otherwise be written in a simple or compound metre. In this case, the subdivisions are often included in the time signature itself. These could be simplified to a simple or compound metre, but this would be either misleading in terms of pulse or necessitate constant alternation between two repeating time signatures: for example, Bartók uses a 4+2+3/8 in his *String Quartet No. 5*, inspired by Bulgarian folk music. This could be written in 9/8, which would be misleading in terms of pulse, or a constantly alternating 4/8 and 5/8, which would in turn be misleading in terms of tonic accent, or stress pattern.

Mixed

Music in mixed metre, or alternating between different time signatures, usually maintains a certain note value as a constant. For example, if one bar is in 2/8 and the next is in 3/16, the first bar should be subdivided into 4/16 so that the semi-quaver remains constant throughout both bars. This is a simplified form of metric modulation.

Irrationals

This is a misleading term used by musicians³⁴⁰ to describe non-dyadic ratios (ratios which cannot be divided by 2).³⁴¹ These are used to indicate a number of beats in relation to a previous time signature.

Dividing the Beat

The Suzuki method of teaching beat subdivisions to children can be extended into more complex subdivisions. Using words that have the same number of syllables as the subdivision, millions of children around the world have muttered while playing ‘busy, busy, stop, stop’ (four quavers and two crotchets), ‘Timothy, Timothy’ (triplets) or ‘caterpillar, caterpillar’ (eight semiquavers) to great success. A quintuplet easily becomes regular on the word ‘university’, a septuplet on ‘listen to these seven notes’ or ‘seven is a funny beat’, and so forth.³⁴²

With simple divisions that span several beats, regularity can be achieved through finding the lowest common multiple of the ratio. For example, three against two (3:2) is divisible into 6 parts, therefore each crotchet beat under a 3:2 in a 2/4 bar is equal to two triplet quavers. Four against three (4:3) can be divided into 12 parts, as can three crotchet beats (3/4 bar), and so forth.

Metric Modulation

This is ‘a method of notating the gradual passing from one tempo to another’. Uitti describes the effect of this technique: ‘relating all the movements in a coherent

³⁴⁰ See, for example, Arditti & Platz (2013), pp. 82-94.

³⁴¹ In mathematics, an irrational number is one which cannot be expressed as a ratio of whole numbers.

³⁴² http://piano.about.com/od/lessons/ss/Musical-Tuplets-101_5.htm and

<http://www.trumpetherald.com/forum/viewtopic.php?t=31740&sid=fe8e2ccdadd02b93bd0708bcc2e50f00>

conception. Speeds are always in a state of flux, interweaving permutations throughout all the movement.³⁴³

Metric modulation relates to rhythmic subdivision through changes of metre and pulse. The notions visited in this section regarding division of the beat are the basis of metric modulation; the subdivision of one pulse becomes the basis of a new pulse.

³⁴³ Stowell (1999), p. 212.

23. LIVE ELECTRONICS

It is now a matter of course that contemporary performers play using live electronics, at least occasionally. Working with a sound engineer is an equal partnership, in that the engineer will often have as much, if not more, control over the resultant sound than the musician. Especially as we are often paired with engineers who have very little knowledge about bowed string instruments, it is important for performers to know at least a few basic things to retain full control of their own timbre and sound quality.

This section broaches the two main aspects of live electronics – **amplification**, and **signal processing**. Technologies which can be used in live performance are briefly mentioned below. Pre-recorded media (still sometimes known as ‘tape’) will not be discussed, as the main issue that a performer faces in this case is amplification, diffusion and balance.³⁴⁴ Aspects of technology and performance which do not relate directly to live performance are also omitted here, namely recording and editing.

Due to the expense of obtaining equipment for private use, this section will only involve written explanations which can be applied when doing a sound-check before a performance. As rapid progress and innovation continue to be made in technology, information that relates to current technical possibilities, rather than concepts, will quickly become out-dated. Hopefully the principles discussed below and the same pursuit of understanding will be applied to the available technology by future readers.

It is important to remember that the equipment listed below is produced by various companies, and comes in all ranges of quality, complexity, and price. Much of the equipment and many of the techniques described below are currently available in both analogue and digital formats (see p. 232), but the principles remain the same. The format itself – from black-box with pedal, to elaborate console, to computer software – and how the technology is run, are the domain of the sound engineer and remain beyond the scope of this thesis. But in the same way that a musician will greatly appreciate a sound engineer’s understanding of basic performance considerations, so a sound

³⁴⁴ The musical difficulties of playing with tape are much the same as in chamber music; in this case the ‘partner’ is a particularly inflexible one.

engineer will appreciate a performer's basic understanding of their craft. Often, communication is simply impeded by a lack of vocabulary common to both set of skills.

In addition to the technical challenges of playing with live electronics, there are many musical ones.³⁴⁵ Turner cites Bahn, Hahn and Trueman's argument that there is an imbalance between sound and physical presence in live performance.³⁴⁶ These authors suggest that exaggerated gestures and over-amplification can emphasize this disconnect, which can be remedied by aligning the physical gesture 'with the sonic feedback', to use Turner's words.³⁴⁷ There are many publications that discuss the changing role of the performer in regards to electronics, however, and this will not be discussed here.

In addition to the considerations below, there is now a quasi-historical aspect to performing 20th-century electronic works – most of the technology integral to the seminal works of the 20th century is now superseded. Much like in historical performance practice, the performer must decide whether to a) replicate the original version as closely as possible, even by sourcing the original equipment, or b) use current technology to create a version which is an improvement by current standards.³⁴⁸

Perhaps the infancy of string instrument amplification can be traced back to the 1930s, when the swing blues fiddler Cliff Bruner used a Victrola needle in his bridge to amplify his violin,³⁴⁹ although experiments with pickups had been undertaken as early as 1925 by George Beauchamp. Beauchamp and his associate Adolph Rickenbacker founded a company which was the first to commercialize electric instruments. The

³⁴⁵ Many of which are discussed by Turner (2014), p. 14.

³⁴⁶ Bahn, Hahn, Trueman (2001).

³⁴⁷ Turner (2014), p. 19.

³⁴⁸ Pre-recorded media issued by a third party (as opposed to made by the performer), often dates back to analogue technology – for example, the tape (now CD) used for the performance of Reich's *Different Trains* has a characteristic lack of definition. This can be improved by equalizing certain frequency bands, but the performer must decide whether this is desirable.

³⁴⁹ Phillips (1994), p. 33. Cited in P & A Strange (2001), p. 201.

Rickenbacker International Corporation released in 1935 the first fully electric guitar as we know it today, and also designed electric violins, violas, cellos and double basses.³⁵⁰

Electronics and live performance came into their own in the 1960s and 70s, when composers began integrating amplification, pre-recorded media, and live sound processing into their compositions. Recent interests in cross-genre and cross-media performances have given live electronics ever increasing importance.

Amplification

P & A Strange's words aptly describe amplification's function in the context of modern music: 'Amplification allows the musician's sound to be put under a sonic microscope.'³⁵¹ Gardner Read's observation is more precautionary: 'Although one of the primary reasons for instrumental amplification is to produce a certain distortion of the instrument's normal tone, amplifying its sound often creates unwanted falsification of timbre as well as conspicuous dynamic imbalance.'³⁵²

This section deals with the volume control of the instrument in live performance. There are three steps between the sound made by the cello and the amplified result:

- 1) The microphone converts sound waves of the cello into electronic signals, by detecting variations in pressure and converting them into electronic signals between 2-10 millivolts. These are called low-level signals.
- 2) These signals are too weak to be used by a power amplifier, so they go through pre-amplification. This usually happens within the mixer (see p. 232).
- 3) A power amplifier then delivers a strong signal to the speaker.

Pre-recorded media is already in electronic signals (high-level signals of around 1 volt) and does not require pre-amplification.

³⁵⁰ http://www.rickenbacker.com/history_early.asp

³⁵¹ P & A Strange (2001), p. 202.

³⁵² Read (1993), p. 128.

Microphones

There are three kinds of device that amplify sound:³⁵³

Contact mic Also known as a piezo crystal pickup, a crystal is attached to the instrument or built into the bridge. This is a high impedance device (low output signal) so the signal needs to be pre-amplified. Feedback can be a problem. Clipping a mic directly onto the bridge will change the acoustic sound of the instrument, like a mute. Some devices use one crystal for the sound as a whole, and some devices have four crystals, one for each string.

Magnetic coil pickup These are more commonly used by electric guitars. A magnetic field is produced by a central magnetic core which is wound with wire. Sound vibrations break the magnetic field and corresponding electric voltage is produced. Contact mics / pickups do not respond to changes in air pressure and can therefore be used to amplify at much higher levels before feedback is produced (see p. 233).

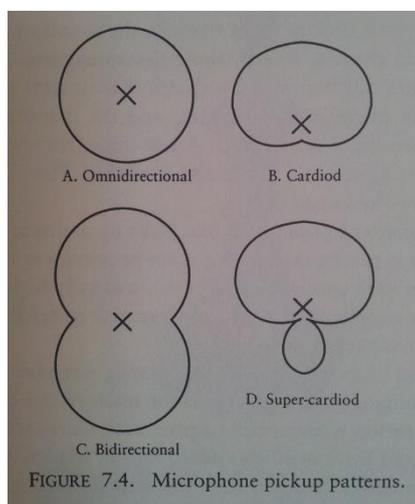
Air microphone This is what would generally be recognized by the layman as a microphone, with its usually conical or spherical shape. Air microphones respond to changes in air pressure, because they receive sound waves after they have left the instrument. Air microphones can be placed at varying degrees of distance from the instrument (on a mic stand or hung from the ceiling), and miniature versions exist that can be clipped onto the instrument. These are high impedance devices with more risk of feedback, but have the advantage of being truer to the timbre of the instrument. There are two categories: dynamic and condenser. Dynamic microphones are mostly used for speaking or singing, and condenser microphones are preferable for a cello. Air

³⁵³ P & A Strange (2001), pp. 203-206.

microphones have various polar patterns (this is the way the microphone responds to the direction of the incoming sound waves):

- a) Omnidirectional: receive sound equally from all directions.
- b) Cardioid: most sensitive to the sound coming from the front.
- c) Bi-directional: most sensitive to the sound coming from the front and rear, while rejecting sounds coming in from the side.
- d) Super-cardioid: the qualities of the cardioid are accentuated, with a frontal lobe which is more sensitive to sound. These are also able to reject sound coming from the sides of the microphone more efficiently than the cardioid, making them more effective for distant sound sources.

The diagram below by P & A Strange illustrates these four types of air microphone:³⁵⁴



³⁵⁴ Idem., p. 206.

The more directional the mic, the lower the risk of feedback. Microphones can be combined for their respective qualities, for example the Kronos Quartet ‘gets clean sound from one set of mics, and loudness from another.’³⁵⁵

Diffusion

The diffusion of sound, or how the sound is projected into the performance space, is an important consideration. Surround sound and multichannel speakers present more complex options, but sound location is often simply a matter of left and right panning. Audio panning is the spread of a sound signal into a new stereo or multi-channel sound field.³⁵⁶ Speaker placement will affect how the sound is received by an audience. The Kronos Quartet, for example, always has a speaker at the centre of the stage, to ensure the audience associates the sound to the source.³⁵⁷

Mixers & Levels

Mixers also go by the name of mixing console, audio mixer, mixing desk, audio production console, or soundboard. This electronic device modifies audio signals to produce one combined output signal. Every microphone will have its own channel into the mixer; the most basic models with only a couple channels and the most elaborate recording studio mixers may have up to 72.

Mic/Balanced input This has already been routed through a pre-amp stage, therefore a high-level signal is received.

Line input This has not been pre-amped, as the source is already a high-level signal.

Most mixers have balanced and line inputs for each channel, with input gain control which can be adjusted. If the sound is harsh and distorted, it is most likely the input gain is set too high. Certain types of mixers can mix analogue and digital signals. Both types of signal are used to transmit information about the sound through electric signals.

³⁵⁵ Brian Mohr, private correspondence with the Ligeti Quartet (March 2012).

³⁵⁶ [http://en.wikipedia.org/wiki/Panning_\(audio\)](http://en.wikipedia.org/wiki/Panning_(audio))

³⁵⁷ Ligeti Quartet in conversation with David Harrington (January 2012).

Analogue signal	Information is translated into electric pulses of varying amplitude.
Digital signal	Information is translated into binary format where each bit is representative of two distinct amplitudes. Digital signals are more protected from interference than analogue signals. This will require phantom power in the mixer input.
Phantom power	Also identified on a mixer as “+48v”, phantom power provides an additional 48 volts of power to the microphone via an XLR cable. Phantom power is necessary for all condenser microphones and can also be supplied in the form of batteries in the microphone itself.
XLR cables	These connect the microphone to the mixer and supply phantom power.

Particularities of Amplification

Depending on the desired result, these can be either problems or welcome effects!

Feedback	This occurs when amplified sound is ‘fed back’ into the microphone, creating a sound loop. This is usually because the microphones are pointing towards the speakers. The result is a sustained pitch.
Distortion / overdrive	This occurs when the amplifying circuitry is driven beyond designed tolerances, ³⁵⁸ when gain is too high. The effect is of additional harmonic and inharmonic overtones.
Proximity effect	P & A Strange describe the effect of placing a microphone less than two feet away from a sound source: ‘the higher frequencies tend to be cancelled, which appears to boost the bass frequencies. “Proximity effect” occurs at frequencies between 50 and 500 Hz;

³⁵⁸ P & A Strange (2001), p. 218.

at its peak, between 100 and 200 Hz, the bass can seem to be boosted as much as 16 decibels.³⁵⁹ This can also boost the amplification of extraneous noise on the cello, such as shifting and left-hand articulation.

Signal Processing

Amplification is only the process of making a sound louder, or converting it into electronic signals that can be manipulated. Signal processing, changing the parameters of sound, is where art meets technology. This is generally the area of the sound engineer, but the cellist may have some control through a pedal, as explained below. ‘Appendix III: Basics of Signal Processing’ (see p. 296) presents a few basics of signal processing which are useful for a cellist to understand.

Other Equipment

- Pedals** These are small metal units that initiate signal processing. Pedals can also be used to trigger pre-recorded media. Analogue pedals will generally be designed for a specific effect, which is usually controlled with a series of dials and an on/off button large enough to be operated by foot. Digital pedals are more versatile, as they will activate a function specified by a computer program.
- Monitors** A monitor is a speaker aimed at the performer instead of the audience, which allows the performing musician to hear either the overall result as would the audience, or a segment of the amplified sound. The content, or ‘mix’, of individual monitors can be unique, and are controlled from the mixing desk. **Wedge** monitors are speakers which usually sit on the floor, and **in-ear** monitors fit directly into the ear.
- Click track** A metronome or other track can be used to achieve rhythmic accuracy or coordinate disparate events. Only to be heard by the

³⁵⁹ *Idem.*, p. 206.

performers and played in from a separate unit at the mixing desk, click tracks are most commonly used with in-ear monitors for discretion.

In an article on Kimura, Gurewitsch's words can be cited as a fitting conclusion to both live electronics in general, and the entirety of extended technique: '...it affects expression in ways impossible to quantify.'³⁶⁰ This leads us to our final section, in which we develop an approach to specific scores, harnessing technique for musical purpose.

³⁶⁰ Gurewitsch (2011).

24. INTERPRETING NOTATION & STYLE

The final section in this compendium of modern music broaches the subject of process in approaching a new score. Whereas the information in this thesis alone is not enough to produce a fully developed interpretation, it has hopefully equipped cellists with enough understanding to begin learning any modern music, in any style. There are no obstacles to learning a new technique if one is able to deconstruct it into its constituent parts (physical actions, and basic principles of sound production); this applies to traditional as much as modern techniques.

As a complement to this chapter, ‘Appendix II: Components of Modern Notation & Style’ briefly presents graphic notation, improvisation, and some of the more prominent compositional currents which developed from the mid-twentieth century: Aleatoric / Indeterminate Music, New Complexity, Fluxus / Intermedia, Minimalism, and Spectralism.

The recital which supported this thesis was a demonstration of the notions herein, an extended learning process refining technical approaches. ‘Appendix V: Practical Component - Recital’ contains details of the programme.

This chapter assumes familiarity with the preceding twenty-three sections of this thesis, which sought to instruct ‘what to do’. This section focuses on ‘how to know what to do’. In this section, I present two case studies, of works for solo cello which have already become ‘standard’ pieces through their numerous performances and recordings,³⁶¹ and could hold a significant role in the pedagogy of new music. These serve only as examples of possible analytical approaches to performance issues, acknowledging that many solutions are conceivable.

Specific techniques and aspects of musicianship used in these two pieces will only be discussed when first presented in each work, and will reference all applicable parts of

³⁶¹ For example, Orning (2012), p. 28, counts three videos of Lachenmann’s *Pression* on YouTube at the time of publication. There are presently twelve (as of July 2016).

this thesis. The aim of the text below is not to explain particular techniques, but rather to explore contextual issues as examples of process when studying modern music.

The two following pieces are complementary in terms of pedagogy: Saariaho's *Sept Papillons* needs the performer to decide 'how' to make the sounds which are written with descriptive notation, whereas Lachenmann's *Pression*, using mainly prescriptive notation, requires the performer's judgement regarding the resulting sound.

Two slightly different approaches are taken below. For Saariaho's work, the student is encouraged to look at each movement in succession, as the piece is such that the material is cumulative, the final movement a synthesis of sorts. For Lachenmann's, each technique or aspect is discussed individually. While some examples have been provided in both case studies, the reader should refer to the original scores.

Saariaho - Sept Papillons

These seven short movements by Saariaho are études in all but name, and it is for this reason that we will look at them here.³⁶² The frequent use of overpressure, rapid variations in point of contact, and harmonics are all techniques that are part of a widely used, or ‘standard’, vocabulary in modern music, and an integral part of Saariaho’s own musical idiom. This piece should be assigned to a student to solidify these particular notions of technique, and to develop a sense of timbral colour.

The preparatory work for *Sept Papillons* should consist of a brief revision of Popper’s Etude No. 40 (2nd-6th, 8th, 10th-11th harmonics on the upper half of the string), using the lower half of the string instead. *Bariolage* should also be revised with the following études: J. L. Duport No. 7, Piatti No. 12, and Grützmacher No. 6. These preparatory exercises by Russell Rolén should also be studied: Open Harmonics, Harmonic Trills, Ponticello/Tasto Bow Angles, and Overpressure and Distortion.³⁶³

Written in 2000 and approximately 11 minutes in length, *Sept Papillons* exploits the harmonic content of the cello’s sound. Every aspect of this music – pitch, timbre, rhythm – is in constant flux, with several gradients overlapping. Vibrato can be used as a way of augmenting resonance, but is mostly unnecessary. Anssi Karttunen advocates a very free use of pulse to create a musical sense of a butterfly’s movements.³⁶⁴ This musical style corresponds to *spectralism* (briefly discussed on page 295).

The notation of the harmonics indicates the position of the left hand. The resultant pitches are not written and are often ambiguous because these will vary with the bow’s pressure and point of contact. A summary of the harmonics used is provided below for each movement.

All glissandi start at the beginning of the note so that transitions of pitch and timbre are gradual.

³⁶² Brief notes on this piece are found in Appendix V: Practical Component - Recital, in the context of the recital which supported this thesis.

³⁶³ The exercises can be downloaded as PDF files through:
<http://www.moderncellotechniques.com/download/>

³⁶⁴ <https://www.youtube.com/watch?v=FRp5nAP5P1s>

Part III: Musicianship

The following is an overview of the technical demands of each movement.

No. 1 – Dolce, leggiero, libero

Techniques: Harmonics: Theory & Practice – upper / lower halves of the string (p. 43)
Double-node Harmonics (p. 51)
Harmonics: Trills (p. 55)
Fixed Points of Contact: Sul Ponticello (p. 82)
Arco: Sul Tasto – Ordinario – Sul Ponticello (p. 86)
Overpressure: Scratch Tone (p. 97)
Stopping the String: Gradations of stopping the string (figure 23, p. 112)
Changing Bow Hold: Ordinario & High Pressure Arco (p. 151)
Appendix II: Graphic Notation (p. 291)

The image shows a musical staff with two systems of notes. The top system is labeled 'Lower Half' and the bottom system is labeled 'Upper Half'. The notes are: Lower Half (F#4, G#4, A4, B4, C5, D5, E5, F#5); Upper Half (G#5, A5, B5, C6, D6, E6, F#6). Below the staff, the word 'Harmonic' is written. Underneath the notes, fingerings are indicated: Lower Half (I, I, II, III, IV, II, III, II, III); Upper Half (II, I, I). A page number '365' is at the bottom right.

The trill in bars 1-3 and 8 (between the 2nd node of the 5th harmonic and 1st node of the 6th harmonic) is beyond many players' hand-span (see Example 1). It can be played using the thumb and fourth finger,³⁶⁶ or by replacing the 2nd node of the 5th harmonic with the 1st.³⁶⁷ Saariaho's notation doesn't specify whether the trills are keyboard trills

³⁶⁵ Notes in brackets indicate alternative nodes for the same harmonic, either for players with smaller hands, or which are to be played as double-nodes to enable the harmonic to speak more quickly. The asterisk (*) indicates a harmonic which is approximate if written without microtonal notation – the finger placement on a C-natural, for example, is close to both the 6th or 7th harmonic depending on context. This is discussed more below, as these issues occur.

³⁶⁶ <https://www.youtube.com/watch?v=pg7SCpMX7yQ>

³⁶⁷ In this suggested fingering, the placement of the first finger may cause the 7th harmonic to speak. In order to hear the 5th and 6th harmonics, the fingers would be placed in an unintuitively narrow semitone.

Part III: Musicianship

or traditional trills; both have different effects and the performer should choose which option has the most timbral variation.

Example 1 - bar 1³⁶⁸ (left, original) and suggested fingering (right)

The image shows two musical staves in bass clef. The left staff is labeled 'Original' and shows a trill starting on a note with a sharp sign (F#) on the second line. A wavy line above the notes indicates the trill. Below the staff is a wedge-shaped graphic labeled '1' that tapers from left to right. The right staff is labeled 'Alternate fingering' and shows the same trill. Above the notes, the numbers '2' and '1' are written above the first and second notes respectively, indicating the suggested fingerings. Below this staff is a similar wedge-shaped graphic labeled '1'.

The 2nd node of the 5th harmonic on the C-string is sometimes slow to speak, depending on the type of string; it can be helped by fingering a double node (1st and 2nd nodes of the 5th harmonic simultaneously), and/or lightly tapping the string with the left-hand fingers as they make contact:

Example 2 - bar 9 (left, original) and suggested fingering (right)

The image shows two musical staves in bass clef. The left staff is labeled 'S.P.' and shows a double-stop with two notes on the same string. A slur is over the notes. Below the staff is a wedge-shaped graphic labeled 'mp' and '6'. The right staff is labeled 'S.P.' and shows the same double-stop. Above the notes, the numbers '4', '2', and '1' are written above the first, second, and third notes respectively, indicating the suggested fingerings. Below this staff is a similar wedge-shaped graphic labeled 'mp' and '6'.

The double-stop in bar 13 (see Example 3) is notated as stopped notes, but given the large, rapid shift, can be found using harmonics. The lower note should then be stopped in preparation for the glissando, but the upper note can either be stopped for the trill, or left as a harmonic in preparation for the following bar.

Example 3 - bar 13

The image shows a single musical staff in treble clef. It is labeled '13' at the beginning. The staff shows a double-stop with two notes on the same string. A slur is over the notes. Below the staff is a wedge-shaped graphic labeled 'gliss.'. The staff ends with a note on a higher string, indicated by a circle above the note.

³⁶⁸ All excerpts from *Sept Papillons* by Kaija Saariaho, © 2002 Chester Music Ltd. are reproduced by permission.

Part III: Musicianship

Despite the absence of a time signature, the piece is notated as a 4/4 through the use of dotted bar lines, save bars 3 (though the minim could be dotted to match bar 7), and 9. This observation is only to facilitate reading, however, and the sense of fluidity should be maintained.

The first modification of point of contact with the bow is very rapid and should be led by angling the frog. The angle will depend on the direction of the bow stroke: if the first bar is on an up-bow, the frog is towards the bridge, and if the second bar is on a down-bow, the frog is also toward the bridge. If the first two bars are in one up-bow, the frog must be towards the bridge, then away from it in the second bar. For the passages with a fixed point of contact (bars 3-5, 7, 9-10, and 12-14), the bow should move as a unit, staying perpendicular to the string.

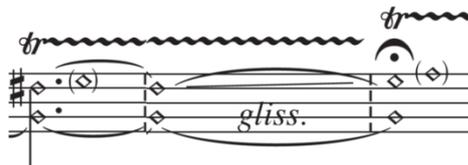
Saariaho introduces overpressure graphic notation in bars 13-14 (see Example 4); given this is in *sul pont.*, in an *mf* dynamic, the bow speed should be drastically reduced in addition to the added bow pressure.

Example 4 - overpressure



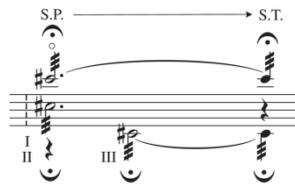
To enable the glissando in bar 10 (see Example 5), the first finger should be on the lower note in bar 9, and the second finger on the upper note – for this the hand will be angled.

Example 5 - bars 9-11



The final triple-stop (see Example 6) can be achieved more comfortably if the thumb doesn't fully stop the string (medium- to high-pressure harmonic). The final S.T. (*sul tasto*) indication can be read as *molto sul tasto*.

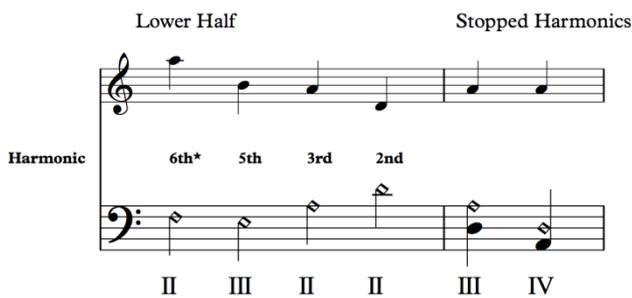
Example 6 - bar 15



No. 2 – Leggiero, molto espressivo

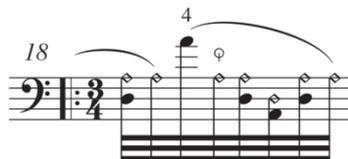
Techniques: Unisons (p. 121)

Stopped Harmonics (p. 48)



Entirely in *bariolage* between two, three, and four strings, this movement exploits a very restricted area of the fingerboard, expanding the pitch range by combining stopped notes with natural and stopped harmonics. Saariaho doesn't indicate the string for the stopped 4th harmonic in bar 3; Natasha Farny very skilfully plays it by shifting back to first position on the G-string,³⁶⁹ but it may be more comfortable to play on the C-string (in this case, the first joint of the first finger must be bent to touch the 2/5 harmonic). Bar 16 to the end sees a development of unisons (see Example 7).

Example 7 - bar 18



³⁶⁹ <https://www.youtube.com/watch?v=pg7SCpMX7yQ>

Part III: Musicianship

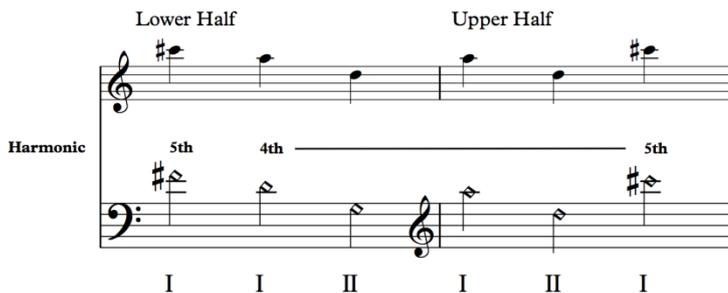
The notation in bars 14-15 could accommodate either the 6th or 7th harmonic (see Example 8), but it is more likely the 6th, as the ‘larger’ interval of a minor-sixth between the harmonic and the A (first finger) is generally more comfortable for the left hand. That Saariaho chooses to use chromatic notation rather than microtonal might indicate that it is acceptable for either harmonic to sound.

Example 8 - bar 15



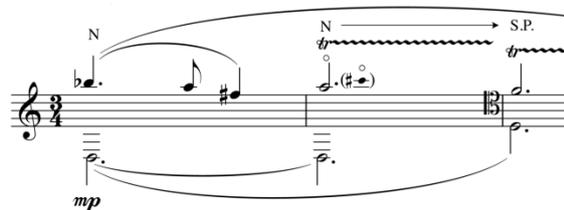
No. 3 – Calmo, con tristezza

Techniques: Modifying Points of Contact: Tremolo (p. 89)



This is the most traditional of the seven movements, in terms of technique. Alternate points of contact, and the compound intervals created by the open D-string (see Example 9) create Saariaho’s trademark textures.

Example 9 - bars 1-3



Part III: Musicianship

This movement introduces alternate points of contact (both fixed and modifying) in the upper range of the instrument. Points of contact will be closer to the bridge because of the shorter string lengths. In tremolo passages (bars 7-8, and 11 to the end), there should be a clear start and finish point on the bow. For instance, in bar 12 (see Example 10), the *sul pont.* is achieved by angling the frog towards the bridge – thus the point of contact moves a few centimetres closer to the frog.

Example 10 - bar 12



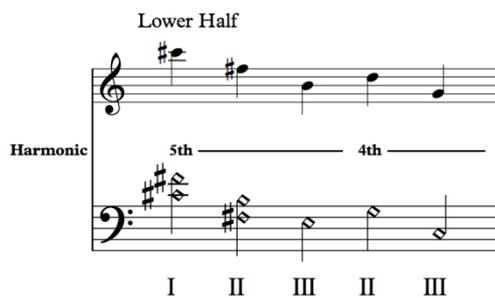
No. 4 – Dolce, tranquillo

Techniques: Harmonics: Intonation (p. 50)

Left-hand Pizzicato (p. 72)

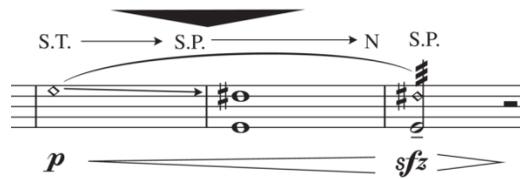
Spectral Intonation (p. 198)

Pythagorean vs. Just Intonation vs. 12-TET: Major thirds (p. 205)



Here, Saariaho makes greater use of her overpressure graphic notation (always in *sul ponticello*). The use of left-hand pressure is refined, gradually transitioning from a harmonic to a stopped note through a glissando, and back to a harmonic again (see Example 11). Bar 22 sees the first use of a *forte* dynamic.

Example 11 - bars 4-6

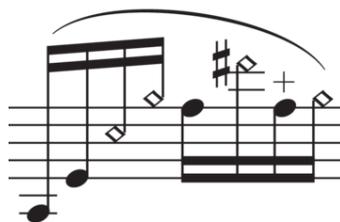


As in No. 1, there is no time signature but the music is presented with solid bar lines and can be read as a 4/4, this time with no exception. Again, no indication of metre should be given by the performer.

The discrepancy in finger placement between the 1st node of the 5th harmonic and the stopped note is especially apparent throughout this movement, when comparing with the finger placement of 12-TET. The finger must slide slightly lower for the harmonic, in going from bars 2-3, 5-6, 10-11, and 22-27, and in bar 14 if substituting the 1st node for the 2nd node for the ease of the left hand. In bar 18, the third beat (an A) should be stopped on the D-string.

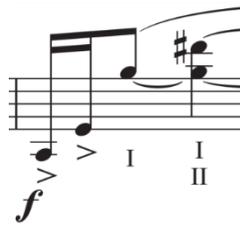
The middle section (bars 12-21) introduces left-hand pizzicato. The relatively rapid alternation of open strings with harmonics in this section (see Example 12) requires a refined sense of *ordinario*. The optimal *ord.* position for an open string is of course very different to that of harmonics – bow speed and weight will have to compensate.

Example 12 - bar 16



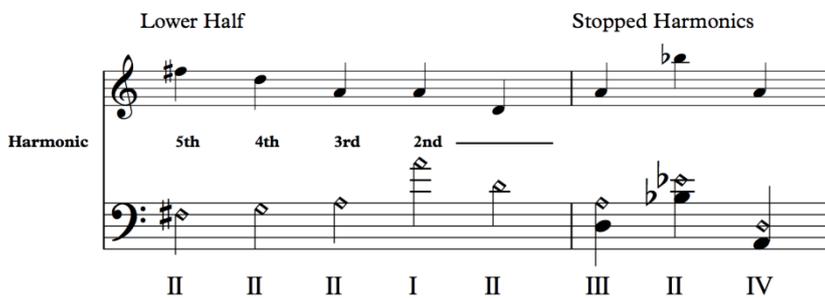
Saariaho indicates that the B in bar 22 be played first on the A-string (see Example 13). The shift between these two positions should be done as ‘cleanly’ as possible – a glissando should be avoided.

Example 13 - bar 22



No. 5 – Lento, misterioso

Techniques: Altissimo Register: for thumb placement (p. 118)



This movement combines many of the techniques explored in the previous movements, and indeed, much of the same musical material returns.

The following fingering will enable the glissando in bar 20:³⁷⁰

Example 14 - bars 18-20



The thumb can be placed under the fingerboard for the last two bars (see Example 15). Karttunen recommends exploiting the natural tendencies of the bow, letting it jump during these two bars, if this is what occurs naturally.³⁷¹ The effect amplifies the

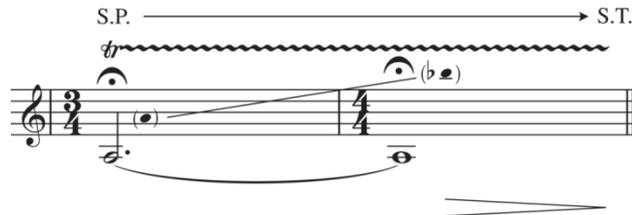
³⁷⁰ Fingerings are added by V. Welbanks.

³⁷¹ <https://www.youtube.com/watch?v=FRp5nAP5P1s>

Part III: Musicianship

percussive content of the sound, and creates a coherent transition to the following movement. Karttunen suggests the performer hold the interest, and hence the audience's attention, during this transition.³⁷²

Example 15 - bars 22-23



No. 6 – Sempre poco nervoso, senza tempo

Techniques: Strike Tones (p. 132)

Hand Percussion (p. 143)



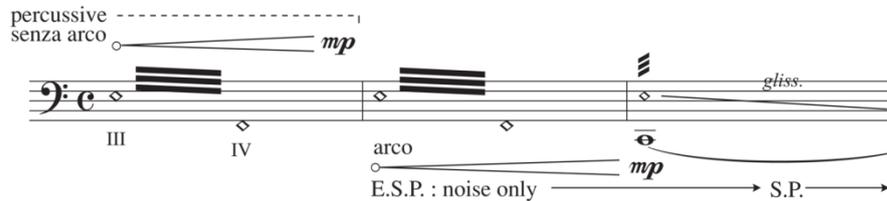
This movement stands alone in the piece, in the sonorities used; it is purely timbral, with no melodic content. The left-hand tremolo in the first bar is essentially a percussive device, created by strike tones (see Example 16). The finger pressure matches that of harmonics, as shown by the use of diamond note-heads. The thumb/first and fourth fingers tap the string at the place indicated by the note-heads, alternating as quickly as possible. The hand needs to remain loose, creating a sound which may, in many environments, only be heard by the cellist. A similar percussive technique is used in bars 8-9, where the open strings can be allowed to resonate, and in the last bar, where all the fingers and the thumb can be used to create the effect over several strings at once. The notation in bar 2 is more ambiguous (the dotted line should continue over it).

³⁷² Ibid.

Part III: Musicianship

Karttunen confirms³⁷³ that the left hand continues the percussive tremolo established in the first bar while the bow, itself not tremolo, starts from *niente*, creating air noise on the bridge which transitions to an overtone-dominant sound *sul pont.*

Example 16 - bars 1-3



The gradation of dynamics is extremely refined, the upper-end an *mp*. The gradation of point of contact is equally subtle, from *estremamente sul pont.* to *sul pont.*

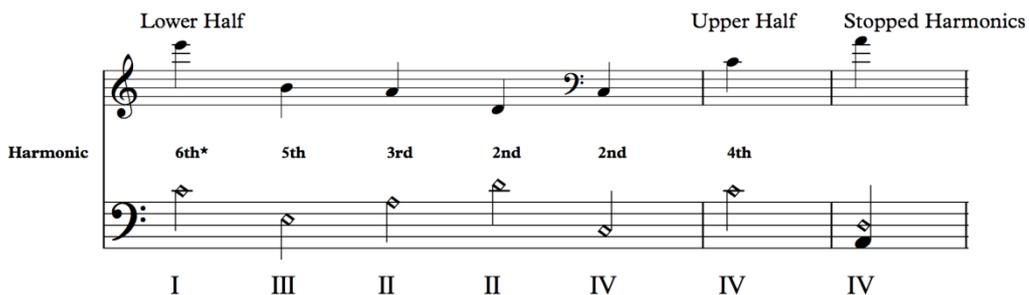
As mentioned previously, changes in left-hand finger placement will occur to accommodate intonation, in bars 4-7. Though not indicated, bar 11 is entirely in harmonics.³⁷⁴

No. 7 – Molto espressivo, energico

Techniques: Bi-tones: Col Legno Tratto (p. 131)

Strike Tones: Col Legno Battuto (p. 136)

Changing Bow Hold: Rotation (p. 151)



This movement is a fitting conclusion, with the dynamic range exploding to an *fff*. For the opening *bariolage* to speak, a fair amount of bow pressure must be used.

³⁷³ <https://www.youtube.com/watch?v=T32QIOAxrlo>

³⁷⁴ Ibid. Karttunen discusses this bar in particular.

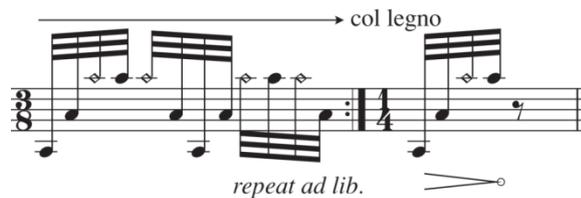
Part III: Musicianship

Col legno appears at the very end (see Example 17). The passage can be played in two ways:

- a) entirely on the C-string, the thumb on the 2nd harmonic, mirroring the unison/octave doublings of nos. 1, 2, and 5;
- b) as a *bariolage*, in which case the D-string can be lightly pushed down in the final bar, so that the bow doesn't catch it. This is perhaps more in keeping with her notation, but introduces the 6th harmonic into the sound, which as seen above, is a less stable harmonic.

In this context, one could play either *battuto* or *tratto*, but the former is perhaps more in keeping with the musical sound world. The transition to *col legno* must be made progressively, rotating the bow while playing. The bow stroke emerges from a slight *détaché* in *arco normale*.

Example 17 - bars 21-22



The many recordings and videos available online and commercially demonstrate the extent to which this piece is performed, particularly as an exam piece.

Lachenmann - *Pression*

Composed in 1969, Helmut Lachenmann's *Pression for one Cellist*³⁷⁵ was written for Werner Taube, and revised in 2010 with Lucas Fels. Lachenmann feels the revised notation brings more precision to the new edition, which is 'not a compositional revision of my work, but rather a new design of the notation, one which takes into consideration the knowledge and experience gained in regards to the performance of the score since its first publication, over 40 years ago.'³⁷⁶ Beyond the immediate improvements given by advances in music typesetting, clarity is gained by the addition of bar lines and time signatures (instead of 'division lines'), a more compact layout of each gesture, and a reduction of the spacing. There are several changes in dynamics, often more extreme in the revision, and the written instructions are more frequent and generally more precise. The addition of more traditional elements of notation lends familiarity to the score; however, the musical material and its experimental qualities remain almost identical to the first edition.

The title of this nine-minute piece describes the primary action – pressure – of both the left hand and bow. On first glance, *Pression* is an almost complete departure from tradition. However, with the new perspective I hope this thesis provides, the performer can observe this piece to be very much rooted in traditional technique and musical form; to deny this is to eliminate one of the work's great pleasures, subversiveness.

The challenges presented by Lachenmann – the levels of virtuosity required – are very different than those associated to traditional music. One could, for example, introduce this piece to a student who is about to begin playing in the upper regions of the instrument but who already has a certain amount of tone control in the neck positions. This would develop comfort with the larger gestures of playing in the upper half of the cello (developing arm motions first, instead of the traditional focus on finger placement). For a more advanced cellist, perhaps an undergraduate, this piece could

³⁷⁵ Lachenmann (1969) and (2010).

³⁷⁶ Lachenmann (2010), preface.

greatly assist in both loosening the shoulder and upper back muscles,³⁷⁷ while demystifying graphic notation and breaking down its barriers. A chamber musician should study *Pression* before approaching Lachenmann's string quartets, assimilating his arsenal of sounds in order to provide a solid foundation for group work. In all cases, the piece should be learnt from the beginning from memory, using the score as a 'cue sheet'.

There are many texts describing the function of this particular piece of music, over a dozen articles (mostly in German), on its role in history and the redefinition of aesthetics.³⁷⁸ Tanja Orning is the main source of information in English. As a performer herself, having studied the piece with Lachenmann, her essay *Pression – a performance study*³⁷⁹ covers Lachenmann's aesthetic, the theory behind and role of *musique concrète instrumentale*, notation, theory of the relationship between composer, score, performer and audience, and performance considerations including amplification and performance theory in theatre. Her other essay, '*Pression*' Revised,³⁸⁰ compares the revised edition with the original.

One of the differences between this piece and Saariaho's *Sept Papillons* is that there is now a quasi-historical performance practice associated to the ambiguity (or tradition) of certain notations being read in a different way than Lachenmann intended. The revised edition is his reaction to this discrepancy. Indeed, the new edition of the score leaves

³⁷⁷ The gestures in this work often need full stretches of both arms to play on the tailpiece or play pizzicato sub-ponticello. In such a piece where almost every sound and gesture must be learned anew, deeply-rooted concerns of 'correct' bow-hold and so forth can be overridden.

³⁷⁸ Structural analyses have been made by Jahn, Hans Peter. *Pression - Einige Bemerkungen zur Komposition Helmut Lachenmanns und zu den interpretatorischen Bedingungen*, in *MusikKonzepte* 61/62, 1988 and Mosh, Ulrich. *Das Unberührte berühren – Anmerkungen zur Interpretation von Helmut Lachenmanns Werken* *Pression und Allegro sostenuto*. In J. P. Hiekel (Ed.) *Musik heute. Veröffentlichungen des Instituts für Neue Musik und Musikerziehung Darmstadt*, 46, Mainz: Schott, 2006, pp. 25-46. Cited in Orning (2012), p. 15.

³⁷⁹ Orning (2012).

³⁸⁰ Orning (2013).

very little ambiguity, partly thanks to the ‘Practical Performance Instructions’ and English translation of the text, provided as supplements.³⁸¹

This case study will assume the student is using the new edition, referring to the first edition in the same way a Beethoven scholar might, to shed light on the compositional process. It is important that a student studies the first edition after learning to read the second one fluently; they will come to realize how the same sound can be represented differently on paper.

Below is an examination of individual aspects of the score, to demonstrate how the piece should be approached as an introduction to modernist repertoire. Each notion or sound should first be explored independently of the context, first in an almost improvisatory manner, then in rhythm or with the designated length. Then, special consideration should be given to transitions, connecting the gestures.

The bar numbers are not printed in the score and have been added for convenience, following Orning’s example.

Scordatura

The strings of the cello are tuned as follows:

Example 18 - bar 1³⁸²



See ‘Scordatura / Alternative Tuning’ (p. 119) for more information about this technique. Some care should be taken, as the lower tension of the strings slightly increases the risk of the bridge being pushed over in some of the techniques below.

³⁸¹ Beyond a few mistranslations and a small omission in the score, which are clarified below, the only ambiguity in *Pression* is found in bar 40: a quaver-like sign at the beginning of the 3rd line with downwards-pointing stem, on the IV string could possibly be a left-hand pizzicato.

³⁸² All excerpts from *Pression* by Helmut Lachenmann, © 1972 by Musikverlage Hans Gerig, Köln, 1980 assigned to Breitkopf & Härtel, Wiesbaden, are reproduced by permission.

Part III: Musicianship

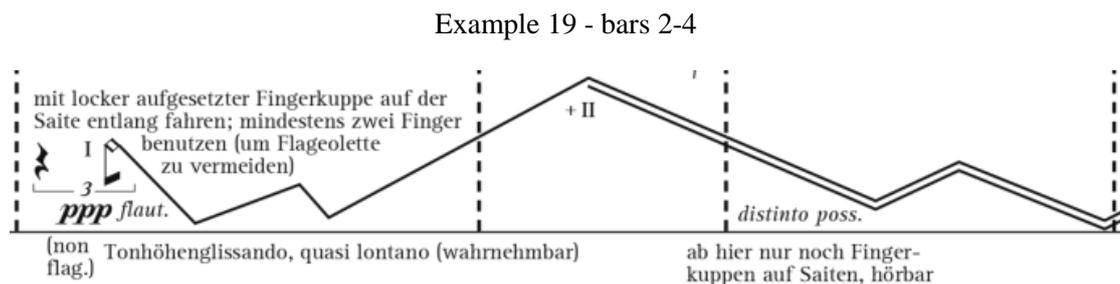
Graphic Notation

The graphic elements of the notation are what initially give the performer a sense of unfamiliarity. Lachenmann coined the term *musique concrète instrumentale*,³⁸³ which he uses to describe this piece – ‘music that emphasizes the way sound is produced rather than how it should be heard, thus reversing traditional hierarchies.’³⁸⁴ The notation is designed mainly to reflect this concept. For example, note stems pointing upwards indicate the position of the bow on the instrument, while downwards pointing stems correspond to the left hand. There are also several drawings throughout the music and other indications to guide the player, which will be discussed as applicable below, as well as extensive use of the pitch contour line.

The written indications are a crucial component of the notation, and inform both the technique and the resultant sound. See ‘Graphic Notation’ (p. 291) in Appendix II.

Friction Noise

Left-hand finger friction is used on the string, the bow and the body of the instrument. Lachenmann’s techniques stem from ‘deconstructed’ traditional techniques. In the case of friction noise, it is the glissando; hence we are left with only one aspect of a technique which traditionally is comprised of several, both left- and right-hand motions. These technique ‘components’ are also applied to unusual parts of the instrument.



³⁸³ He based this term on Pierre Schaeffer’s term *musique concrète*, which he first used in 1948 to describe his technique of recording ‘everyday (concrete) sounds and noises as material for electronic composition’ (Orning 2013, p. 95).

³⁸⁴ Orning (2012), p. 12.

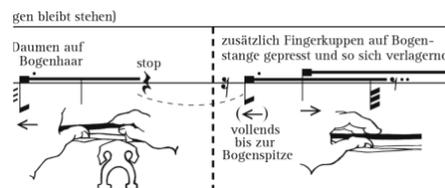
Sound is created by sliding the finger-pads³⁸⁵ on the string (see Example 19). To this sound are added punctuations of the thumbnail sliding on the string (see Example 20). The dynamics are manipulated by varying the speed of the gesture.³⁸⁶

Example 20 - bar 5



Similarly, sound is produced by the friction of the fingers moving on the bow, in a sweeping motion from the frog to the tip (Example 21). By leaning the metal clip of the bow (ferrule) on the bridge, this sound is amplified by the body of the instrument. The left-hand thumb (use the outer side, to have mostly flesh) travels along the hair of the bow. The bow may need to be tightened slightly more than usual, to accommodate the thumb. This same motion is repeated with the thumbnail; with the left-hand fingertips also pressing into the stick (the resultant sound is louder); and with only the left fingertips on the outermost edge of the bow hair. The thumbnail can then be left on the bow hair for the duration of the intervening arco note in bar 17.

Example 21 - bars 12-13



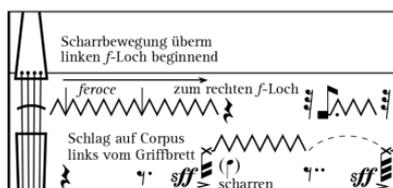
The same principle applies to the friction of the fingers on the surface of the instrument (Example 22). The player is instructed to hit the body of the instrument (to the left of the fingerboard) with a flat hand (see 'Hand Percussion', p. 143), and follow the motion

³⁸⁵ Lachenmann uses both *Fingerkuppen* and *Fingerspitzen*, both translated as 'fingertips' in the 2nd edition, which overlooks the subtlety that one refers to the fingerpads while the other, the fingertips.

³⁸⁶ There is an error in the English translation: Page 1, system 1 *crescendo durch Beschleunigung* should be translated as 'crescendo through acceleration'. The acceleration refers to sliding the thumbnail along the 2nd string, rather than the bow, which is motionless.

with a rapid back-and-forth ‘scratching’ motion. Lachenmann does not indicate whether the scratching should involve only the fingertips, or the nails as well – the latter would create a more interesting sound, but is unadvisable as it could damage the varnish of the instrument. In bar 50, the same scratching is applied to the surface of the strings at shoulder height.³⁸⁷

Example 22 - bar 45



‘Slap the fingerboard with an open hand, followed by a back and forth wiping motion centred around the point of attack on all four strings.’³⁸⁸ This technique is used to varying degrees, and sometimes only in upwards glissando.

Also in bar 45, the bow must ‘scratch’ the belly of the instrument, from the left f-hole to the right. This is in effect a vigorous tremolo.

Bowing: Points of Contact – On and Off the String

In this work, Lachenmann explores almost all possible points of contact on the string. He uses the term *sul pont.* to designate bowing literally on the bridge (see ‘On the Bridge’, p. 146), and *al pont.* when the bow needs to be extremely close to the bridge (see ‘Sul Ponticello’, p. 82). A ‘bridge clef’ represents the entire string length from the tailpiece to the scroll:

³⁸⁷ Though not specified, one can assume this refers to the shoulder of the instrument, rather than the shoulder of the instrumentalist!

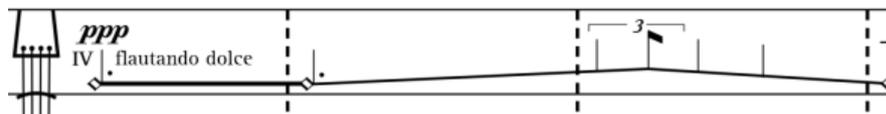
³⁸⁸ Translation in the 2nd edition.

Example 23 - bridge clef³⁸⁹



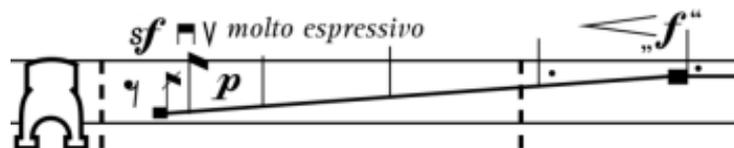
In *sub-pont.* (see ‘Sub-Ponticello / Oltre Ponticello’, p. 84), Lachenmann indicates which strings must be played, using the bridge clef, as well as how far the bow should be from the bridge, using a pitch contour line (see Example 24). The same contour line guides the bow placement to transition from *sub-pont.* to *al pont.* in bars 58-59, with the effect of a pitched sound becoming unpitched as the bow travels over the bridge. Light bow angling should be used for this progressive transition into *ord.* in bar 82, and a more pronounced angle should be used (frog towards the bridge on a downbow) for the faster transition back to *al pont.* in bar 88 (see ‘Arco: Sul Tasto – Ordinario – Sul Ponticello’, p. 86). The even faster *col legno* ‘wipe’ in bars 110-114 would need a still more pronounced angle.

Example 24 - bars 55-57



Lachenmann explores the sounds made by the bow through *saltandi* on various parts of the instrument (more information below, see ‘Strike Tones’ on p. 260). He begins along the face of the bridge. A diagram and pitch contour line guide bow placement, from the foot of the bridge to the top near the strings:

Example 25 - bars 28-30



³⁸⁹ Lachenmann (2010), p. 10.

Part III: Musicianship

Saltando continues on the left edge of the face of the bridge, on the body of the instrument in front of the bridge, and on the strings from underneath (see ‘Under the Strings’, p. 86). In this last instance, the *saltando* becomes a gentle circular motion in bar 41 (see ‘Circular Bowing’, p. 87); Lachenmann leaves the direction of the motion to the player. Example 26 demonstrates how Lachenmann combines these various points of contact:

Example 26 - bars 35-39

The image shows a musical score for Example 26, bars 35-39. It consists of two staves. The top staff is a standard musical notation with a treble clef and a 2/4 time signature. The bottom staff is a diagram of a cello body with various contact points labeled. The labels include: (Bogen unter den Saiten), Stegfläche, Bogenspitze (heller) / Bogenmitte (dunkler), arco salt., Corpus oberhalb Stegwand, (heller) / (dunkler), and espressivo. The score includes various bowing techniques such as saltando, arco salt., and espressivo.

In bars 47-54, the cellist reaches down to bow the tailpiece (see ‘Tailpiece / Sulla Cordiera’, p. 148), starting at the top and slowly moving towards the bottom, with light pressure so as only to hear the friction of the bow rather than the actual vibrations of the tailpiece.³⁹⁰

Mirroring the momentum of the left hand, the bow should follow through the motion of the glissando in bar 22 to ‘propel’ the bow over the bridge.

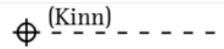
The ‘squeak’ in the attack of the second note in bar 17 is more effective *al pont.*; the bow can then sustain the pitchless note *sul pont.*

Stopping the String

A wide range of sounds in this piece are obtained by varying the ways in which the string is stopped. Touching the string with two or more fingers (see Example 19) produces a lightly pitched glissando with no harmonics. New to the revised edition, this sign is used throughout the piece to indicate damping (what the strings should be dampened with – left hand or chin – is indicated in parentheses, so that no open strings sound sympathetically):

³⁹⁰ Lachenmann is said to abhor the ‘comically birdlike sounds’ produced by overpressure on the various parts of the instrument. Alberman (2005), pp. 43-44.

Example 27 - damping



The placement of two of these signs, one above the other, (Example 28) at the beginning of the piece and near the end (b. 110) is somewhat unclear, and may indicate that the strings can be dampened with either the left hand or the chin as the bow is placed on the strings (see ‘Damping / Pizzicato Effleuré / Dead Pizzicato’, p. 113). If using the left hand, I would suggest damping the strings with flattened fingers in bar 1, halfway up the fingerboard, to prepare the first left-hand gesture. In bar 110, I would suggest damping near the nut, to prepare for playing in the pegbox.

Example 28 - alternate damping



This same sign is also used as a note-head in bars 58-78 and 89-91 (see Example 29) to designate damping with the left-hand thumb from under the string, adjacent to the bow hair, which is itself *al pont*. This creates white noise. In this particular passage, pitch is created by releasing the thumb. The passage is dotted with instances in which the thumb must slide to another string during damping.³⁹¹

Example 29 - bar 62



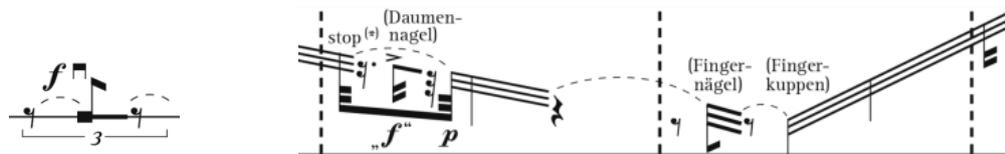
Bar 22 has a similar note-head to the damping sign, but to a different effect. It indicates pulling the strings up with several fingers while bowing *fff*. Though not explained in the part, this technique has the effect of increasing string tension to facilitate *nageln*.

³⁹¹ There is a small omission in bar 89, the pitchless note and left thumb are on/under string I.

Part III: Musicianship

Throughout the piece, dotted slurs are used over silences, for both the right and left hands (see Example 30). Though no explanation is provided, one can assume that in addition to connecting the gestures over the silences, these designate damping of sorts – preventing any resonance by applying pressure with the bow on the string, or stopping the movement of the left hand and leaving it in contact with the string. These slurs are almost all additions to the second edition.

Example 30 - bars 7 (bow) and 10-11 (left hand)



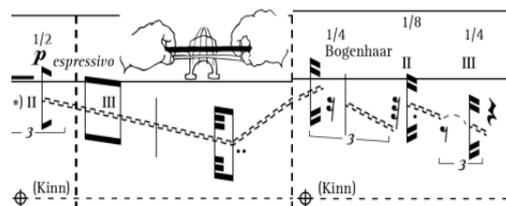
Another type of stopping is obtained by pinching the string between the thumb and index finger, in bars 79-83. This is perhaps more for theatrical effect as the same sound can be obtained with finger pressure, although it provides added control and consistency across the entire fingerboard for the very fast pinch and release motion required.

Because the motion has to be continued to both extremes of the string, the left hand should first be angled so that the tips of the fingers point downwards. As the glissando goes towards the nut (I suggest before the F#, the final note of bar 82), cellists with shorter arms could quickly reverse the angle of the hand so that the fingers point upwards.

Vertical bowing

From bar 19, the bow hair is ‘stopped’ at various lengths: $\frac{1}{2}$ the bow length, $\frac{1}{4}$, and $\frac{1}{8}$ (see ‘*Spazzolato / Vertical Bowing*’, p. 88):

Example 31 - bars 19-20



Strike Tones

As discussed above, *saltando*, *legno saltando*, and a combination of both, are used extensively in this piece, on various parts of the instrument (see ‘Battuto Con Crino’, p. 138, and ‘Isolated Strike Tones / Legno Saltando’, p. 137). *Saltando* returns in bar 92 (*al pont.*, with the left-hand on natural harmonics glissando), and *legno saltando* in bars 98 (double-stop quickly travelling from the fingerboard to the bridge), 109 (striking string IV and after plucking the upper three strings with the left hand, letting the wood of the bow roll onto each string), and 114 (the bow stick lies on the string, and a *saltando legno* from the middle of the string to the bridge is initiated by a Bartók pizzicato).

In these *saltandi*, Lachenmann asks that the strings are dampened with the palm of the left hand, and recommends holding the bow in the fist, a technique that he elsewhere calls *Faustgriff*.³⁹² He asks that no up-bow or down-bow movement is made when under the strings, however small up-bow movements are needed on the face of the bridge and the belly. The pitch gets higher as the bow moves closer to the tip (for example, bar 44 is essentially a down-bow).³⁹³ These indications of ‘brighter’ and ‘darker’ sounds do not also apply to the *legno saltando* on strings I and II in bars 32-36, which should be in the middle of the bow, with no lateral movement.

Pressure with the Right Hand – Bow

In bars 22-27, Lachenmann asks for overpressure bowing with minimal bow movement. Though not explicit, the extensive use of a crenelated line could imply the sound tends towards *nageln* (see ‘Nageln / Clicks / Crenelated Bowing’, p. 100):

³⁹² See ‘Ordinario & High Pressure Arco’ on page 152. This is, however, not necessary and more dexterity is achieved with a normal bow hold.

³⁹³ The indication of *Bogenspitze* (*heller*) and *Bogenmitte* (*dunkler*) in bar 36 is in slight opposition to the previously established notation in bar 29, in which the ‘lower’ notes are near the foot and the ‘higher’ notes near the strings. Perhaps those two indications of location on the bow should have been written in the following bar, for the *saltandi* on the belly.

Example 32 - bar 27



Mostly, Lachenmann exploits underpressure techniques, for various pitchless breathing sounds (see ‘Air Noise / White Noise / Rauschen’, p. 103).

Pizzicato

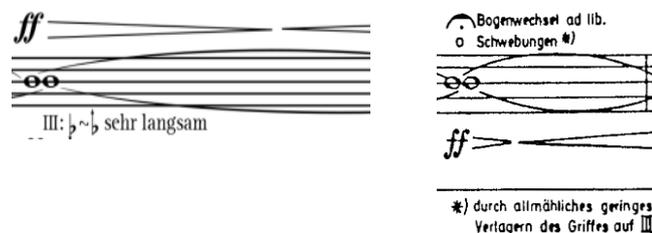
Most of the pizzicato in this work is played in the pegbox (*Wirbelkasten*) and *sub-pont.* (see ‘Sub-Ponticello Pizzicato & Pegbox Pizzicato’, p. 72). All pizzicato is played with the left hand, including a final chord at bar 109, and a Bartók pizzicato in the final gesture (see ‘Bartók / Snap Pizzicato’, p. 69).

In preparation for the left-hand *sub-pont.* pizzicato in bars 23-26, the nail glissando in bar 22 should propel the hand past the fingerboard so that the left-hand thumb leans on the face of the bridge.

Beating

The only *ordinario* sound in this piece is quickly transformed into a microtonal interval, in which attention should be drawn to the frequency beating (see ‘Frequency Beating’, p. 185). Lachenmann’s desired result becomes unarguably clear when the instructions in both the first and second editions are combined: the Db stopped on string III should be very slowly displaced between a slightly lower Db, and slightly higher Db:

Example 33 - bar 86 (second edition) and p. 8, system 1 (first edition)



Amplification

In the second edition, Lachenmann retracts his suggestion that the cello may be amplified. While one can understand the reasoning behind this increased precaution (we can safely assume more than one performance of this piece has been distorted by over-amplification), there are nonetheless certain situations which would benefit from skilful amplification, namely performances in bigger halls and recordings.

There are a considerable number of audio and video recordings available both commercially and online, the latter offering widely varying ranges of quality. Because *Pression* benefits from being viewed, and does not lend itself particularly well to editing, the optimal recording would be ‘live’, with as natural a sound as possible (mics placed far enough away from the cellist that only the natural resonance of the body, tail piece, bow and so on is picked up, as opposed to having pick-up(s) directly on the cello).

The sound source (speaker/s) should be near the cello, thus merging with the acoustic sound of the instrument – one of the main aspects of this piece is how the sound is made, so having the sound source come from somewhere else in the room would cause a disconnect.³⁹⁴ See ‘Amplification’, on page 229.

Theatre

The first impression of this piece when seeing it performed is of its theatrical nature, expressing ‘the physical relationship between instrument and performer.’³⁹⁵ Almost a parody of playing the cello, noise becomes music, and the single ‘normal’ sounding tone (bars 83-87) is shocking.

In the second edition, Lachenmann retains his original suggestion that the piece be performed by memory if possible, or at least in a way that bypasses page turns and leaves a clear view of the cello and bow for the audience. In this way he acknowledges the theatrical elements of the piece, even though they are implicit rather than explicit.

³⁹⁴ Orning (2012), pp. 27-28, provides an example of how not to amplify this piece.

³⁹⁵ Orning (2013), p. 95.

Section ‘15. Vocal & Theatrical Effects’ (p. 169), can be revised, to reflect on the importance of immobility in one hand or the other, and the control required when transitioning from one gesture to the other. There is indeed a theatrical effect resulting from the ‘freezing’ motion created by the slurs discussed above, sometimes seemingly in mid-gesture. In terms of the rhetoric of each gesture, the cellist should decide which movements are exploratory, hesitant, and which are assertive, or confident. Applicable here is Alberman’s view that ‘...the music that Lachenmann produces using these techniques is often warm, gentle and expressive. Interpreters forget this at their, and the music’s, peril.’³⁹⁶

Orning’s account of her studies with Lachenmann shows that he is as concerned with musicality, phrasing and pacing than any other composer.³⁹⁷ The piece is often misleadingly viewed in terms of its differences with traditional music, rather than its similarities. This is how it should be heard by the audience – new, radical, elusive – rather than how it should be performed. The performer, after many hours of practice, should feel the full comfort of history and tradition.

Perceived differences between ‘descriptive’ and ‘prescriptive’ notation have perhaps led to a false dichotomy; there are no more possible outcomes in Lachenmann’s notation than there are in Beethoven’s, and just as much freedom of expression in both. Any inadequacies, or imprecisions, with the ‘action notation’ in Lachenmann’s score should be considered temporary because of unfamiliarity.

It is the author’s hope that this study allows the performer to place emphasis on what Orning calls ‘an extreme idiomatic approach’ which extends ‘beyond the instrumental idiomatic virtuosity’ to the specific interaction between cello and cellist.³⁹⁸ She suggests that this piece uncovers the importance of the performance as an object, in opposition to the traditional ‘cult’ of the score, or *Werktreue*. I would like to add to this that emphasising the importance of the performer and their relationship to the score and

³⁹⁶ Alberman (2005), p. 47.

³⁹⁷ Orning (2012), p. 21.

³⁹⁸ Orning (2012), p. 15.

instrument, as well as their reaction to the audience and performance space allows us to revisit the Western Classical tradition with a deeper understanding, connecting past and present and acknowledging the tradition of breaking boundaries.

Part IV: Looking Ahead

We have now established that there is a gap in the pedagogy of modern music, and have discussed why it is important that this gap be filled. By looking at didactic literature from the 18th and 19th centuries and analyses by notable experts on the history of the cello, we can assert that there is indeed a historical precedent for the systemization of new techniques and that the results have been positive. We can also affirm that 20th- and 21st-century technique is firmly rooted in, and can be taught as a natural extension to, traditional performance practice.

The overview in Part I of available books, treatises, theses, and articles demonstrates that this thesis is unique in its presentation of the skills needed for the performance of modern music; this presentation is equally unique in its modelling of a Method. Whereas most of the larger works examined in Part I take existing examples of extended techniques from the repertoire and build a collection of special effects, the process used to create Parts II and III was to systematically analyse all aspects and means of sound production on a cello then associate them to existing techniques. Those techniques which have not been used in composition, but which could be, were given a name. This large body of material was presented in twenty-four sections, covering both physical extended techniques and advanced musicianship skills, and structured as a linear progression, or extension, to traditional technique. Though the techniques in this thesis are presented in as isolated a way as possible, it is ultimately important to keep in mind William Pleeth's words:

“Technique” in its fullest sense, means discovering and developing the physical means for bringing into existence a piece of music. Thus it follows that technique per se cannot exist apart from the music it is meant to serve. This fanaticism about “technique” as an end in itself severs the thread between the physical means and the music, and creates a separateness which is contrary to the nature of things.³⁹⁹

Hence the purpose of section 24 was to consolidate theoretical and practical knowledge, setting foundations for a methodology in the interpretation of modern music.

³⁹⁹ Pleeth (1982), cited in Stowell (1999), p. 208.

To conclude our survey of modern techniques, let us now look at how advanced students of the cello currently learn to play modern music, and what a thorough pedagogical framework for learning 20th- and 21st-century techniques should look like. Three educational resources are proposed below, which would create a systematic framework in which to learn and master the rich array of techniques developed over the past century.

CURRENT APPROACHES

Rolen's observations into the current process of learning the basics of extended techniques in the introduction to his thesis summarize my own thoughts and those of anyone who feels the gaps present in the pedagogy of modern music. Rolén remarks that many techniques are taught on a case-by-case basis, a symptomatic treatment as it were. He cites for example the stopped harmonics in Saint-Saëns' *Concerto in A minor*, or the quarter-tones in Bloch's *Schelomo*, which are taught only when a student studies these pieces.

Sul ponticello and *sul tasto* markings are often encountered first in orchestra parts, leaving it to the conductor or a stand partner to explain where to place the bow and how to achieve that sound. These techniques even receive the special label "extended techniques", defining them as outsiders, apart from the normal order.⁴⁰⁰

Because the techniques in this thesis are seen as 'outsiders', one could easily infer that they are superfluous to traditional performance study, or that there is already enough to do with 'mastering the traditional criteria of excellence – left-hand dexterity and accuracy, beauty and flexibility of tone color, and a controlled, variable vibrato'.⁴⁰¹ It is my opinion that the study of modern music benefits traditional playing, as it pushes a musician to go to the extreme limits of their playing. Certainly, bad playing of modern music will damage traditional playing, just as bad playing in general will damage bowing technique and intonation.

⁴⁰⁰ Rolén (2011), pp. 5-6.

⁴⁰¹ Idem., p. 6.

SUGGESTED PEDAGOGICAL AVENUES

The nature of learning an instrument and the advances in communications technology suggest that the three following projects would be most appropriate to disseminate the information contained in this thesis. Musical skill is transmitted from one individual to another, whether in the form of one-on-one lessons or through performing with musicians who are more proficient. Information is now primarily communicated through online formats – websites, blogs, videos – which makes the internet at once a limitless pool of knowledge and a platform for mediocrity. The three-pronged approach suggested below would ensure a solid framework for adequately learning to perform modern music.

Curriculum Development

It is my hope that the structure of this thesis will serve as a basis for future curricula. Certain specialist programmes for contemporary music are currently included in select conservatoires and universities, for example the Post-Masters' Degree in Contemporary Music from the Royal Conservatory in Ghent, Belgium. However these are few and far between and none are presently located in the UK. The specialist period music departments that have had much success in recent years could perhaps provide a model for the development of specialist modern music departments.

Parallel work could also be done in terms of introducing certain techniques to the earlier stages of development on the instrument. A grading system could accompany the contents of this thesis to assist teachers in finding the right point in a student's progression in which extended techniques would be particularly beneficial. For example, singing while playing should be taught at the very beginning stages, alternate points of contact (especially *sul ponticello*) when the student is learning to bow perpendicularly to the string, *con le dita* when the left-hand fingers and ligaments need strengthening, and so forth.

The traditional model of teaching can, with the right support, easily encompass modern techniques.

Online Database (www.extendedstrings.com)

The contents of this thesis will form the basis of an online audio-visual database of techniques, intended as a resource for both performers and composers. Each technique will have a one-minute video in which each instrument of the string quartet (violin, viola and cello) will demonstrate on all four of their strings. This will be followed by a short excerpt from accessible (published) string quartet repertoire to contextualize each technique. A clear image and audio demonstration, with close-up images of the hands, fingers, or bow will be a crucial addition to this type of resource, the most successful of which so far are Russell Rolan and Ellen Fallowfield's websites. Rolan's serves as a solid preparatory resource, and Fallowfield's provides a more advanced, deeper understanding of the acoustic mechanisms behind sound production. Hence www.extendedstrings.com would form a link between the two.

The videos will have no verbal explanations – to avoid language barriers – or if this is occasionally necessary (for example when a technique involves parameters that are difficult to see or hear such as bow weight and speed), explanations will be scripted or written concisely to accompany the video.

Rolan rightly says in the abstract of his thesis: 'The Internet-based format of this project is a critical aspect of the resource's reach and pedagogical approach.'⁴⁰² He continues with this logic in his introduction: 'In order for the utility of such a resource to be at its greatest, its format would need to be widely accessible and conducive to multimedia presentation of the material.'⁴⁰³ I join Rolan in his opinion that the considerable advantage of a website format is the potential for content and audience growth.⁴⁰⁴ The website format would also render the content approachable independently of any new-music specialist.

⁴⁰² Idem., p. 2.

⁴⁰³ Idem., p. 7.

⁴⁰⁴ Idem., p. 8.

The Contemporary Virtuoso

Far from implying the repetition of what has been, tradition presupposes the reality of what endures [...] tradition thus ensures the continuity of creation.

- Stravinsky⁴⁰⁵

A collection of contemporary concert études, or caprices, modelled on those of Paganini's *24 Caprices for Solo Violin*, will be published under the likely title *The Contemporary Virtuoso*. Each étude will explore one of the 24 techniques surveyed in this thesis. The études will be composed by a wide range of composers, who will be commissioned for their profound understanding of the particular technique for which they are writing. As a genre, the étude is an ideal laboratory for both instrumental techniques and compositional idiom, creating an accessible point of introduction between composer and performer.

As opposed to the online database, which aims to demonstrate techniques in an isolated way (as per the contents of this thesis), the goal of the études is to integrate both physical skills and musical ideas. Rolen reflects in his introduction that during traditional training:

...scales, exercises, études, caprices [and standard repertoire] [...] should lead [the student cellist] to establish a solid foundational technique and firm understanding of traditional Western classical styles. This is a time-tested system of instruction. The best teachers in this tradition help their students become musicians capable of great artistry and technical facility.⁴⁰⁶

In this same tradition, these études would convey understanding of modern music. It is envisioned that 20th- and 21st-century techniques will become more accepted as an extension of the traditional training progression and will be more accessible in the familiar format that is the étude collection.

⁴⁰⁵ Delivered at Harvard 1939-40, published in original French 1942, translated by A. Knodel & I. Dahl, N.Y. 1947.

⁴⁰⁶ Rolen (2011), p. 5.

Over the past century, unfamiliar idioms and technique have been approached in educational musical texts in three ways:

- a) Introducing new idioms through traditional technique. These are generally stylistic études.
- b) Introducing modern technique in a traditional, tonal context. These are usually preparatory exercises, and can take the form of scale patterns, or simple, familiar tunes.
- c) More rarely, introducing modern technique in the context of modern music. To have educational value, these must be presented in graded difficulty.

‘Appendix I: 20th-Century Etudes’ demonstrates the large quantity of études which have been written for the cello since 1905, the vast majority of which correspond to category (a). *The Contemporary Virtuoso* proposes an amalgamation of categories (b) and (c). Each étude will be accompanied by preparatory exercises, some of which are included in this thesis and also provided as a separate copy to demonstrate the potential of such a publication. The numbering and order of the categories above will be mirrored in the order of the corresponding études and series of exercises which will be developed. This is to emphasise a sense of progression.

The techniques surveyed in this text are not necessarily special effects: to join in Rolén’s statement which concludes his introduction, they ‘expand the range of human and musical expression’.⁴⁰⁷ The ‘perceived difficulty of new music’, to use Rolén’s words again, is a limiting factor for both performing musicians and audience members. Hopefully, together with Rolén and Fallowfield’s efforts, these three complementary resources will ‘contribute to the demystification of this repertoire and encourage more cellists to challenge themselves and embrace contemporary music’.⁴⁰⁸

By connecting three hundred years of tradition surrounding the mastery of the cello with the modern explosion of colour, subtlety and drama, a new virtuosity will be born.

⁴⁰⁷ Idem., p. 10.

⁴⁰⁸ Ibid.

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<https://www.youtube.com/watch?v=FRp5nAP5P1s> (accessed 15/02/2016)

Carnegie Hall: *Extended Techniques for Strings: Kaija Saariaho and Anssi Karttunen Workshop*

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Appendix I: 20th-Century Etudes

An étude is ‘a piece of music for the practice of a point of technique, a composition built on a technical motive but played for its artistic value.’⁴⁰⁹

Below is a timeline of études written for the cello during the 20th and 21st centuries (treatises and Methods are excluded as they present technical information without musical context). This list only includes works that are presented as études in name and intent. Nomenclature presents something of a challenge in this compilation, because many of the works below are ‘compositional études’, or compositional exercises (for example Cage’s *Etudes Boreales*), or pastiches of traditional études. The pieces that would have true value in developing an aspect of contemporary music are often simply part of the repertoire; indeed, many pieces listed in ‘Appendix IV: Further Study’ are better suited to the purpose of an étude as defined above. But the self-awareness involved in naming a work ‘étude’, the pedagogical intent behind this gesture, is of particular interest to this list.

Both this section and ‘Appendix IV: Further Study’ could be used as a basis to develop a syllabus to guide students and teachers. However, in terms of creating a model for the type of étude discussed in ‘The Contemporary Virtuoso’ (see p. 269), most works below have considerable shortcomings and it would be preferable to follow the format of the 18th- and 19th-century étude.

The following works are listed chronologically by year of composition. Following this are brief descriptions of the more significant étude collections of the 20th and 21st centuries.

Year of Composition	Composer’s Dates	Composer	Title of Work	Publisher
1905	1843 –	David	High school of cello playing, Op.	Hofmeister (1st edition)

⁴⁰⁹ <http://www.merriam-webster.com/dictionary/etude>

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	1913	Popper	73	G. Schirmer Barenreiter International Music Company Alfred-Kalmus Ricordi
1907			Ten Medium Difficult Studies, Op. 76	International Music Company
1908			Easy Studies for Cello, Op. 76a	International Music Company
c.1927	1875 – 1965	Julian Carrillo	70 Etudes for solo violin in quarter-tones (or vla, vlc, db)	Not known
1930	1897 – 1975	Stephen Deak	Modern Method For The Violoncello Volume 2 (26 Studies Of Medium Difficulty)	Theodore Presser Company
Not known	1872 – 1947	Mikhail Bukinik	4 Concert Etudes for Cello Solo	Schott
1949	1890 – 1962	Jacques Ibert	Etude-Caprice pour un tombeau de Chopin for solo cello	Alphonse Leduc
1953	1897 – 1976	Enrico Mainardi	Etudes and Studies from 1923 to 1953	Schott
1954	1923 – 1980	Don Banks	Three Studies for Cello and Piano	Schott
1961	1904 – 1987	Dmitry Kabalevsky	Major-Minor Etudes for Violoncello, Op. 68	Hans Sikorski
1961	1897 – 1976	Enrico Mainardi	Sette Studi Brevi	Schott
1969	1901 – 1985	Heinrich Litinsky	12 Etudes for Solo Cello	Not known
1971	1922 – 2006	Jacques Wildberger	Study for violoncello solo	Breitkopf & Härtel
1974	b. 1931	Sofia Gubaidulina	Ten Preludes for Violoncello Solo (1st ed. Ten Etudes)	Hans Sikorski, revised 1999
1974	b. 1947	Salvatore Sciarrino	Due studi	Ricordi
1974	b. 1947	Douglas Young	Studies for Virages	Not known
1975	1914 – 1990	Paul Tortelier	Etude No. 5: Pishnetto, for cello and piano	Chester Music
1976	1925 – 2014	Heiner Reitz	12 Caprices, Op. 5	Edition Kunzelmann
1977	b. 1953	Joel Hoffman	Concert-Study (Fantasie) for solo cello	Onibatan Music
1978	1912 – 1992	John Cage	Etudes Boreales	Edition Peters

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1980	1901 – 1992	William van den Burg	67 Etudes for the Cello on the Beethoven Quartets	Erickson Editions
1983	b. 1953	Tod Machover	Electric Etudes (amplified cello, live & pre-recorded computer electronics)	United Music Publishers
1984	1919 – 2000	Niels Viggo Bentzon	16 Etudes for solo cello, Op. 464	Wilhelm Hansen (www.musicroom.com)
1985	1927 – 2005	Siegfried Palm	Pro Musica Nova, Studies in Playing Contemporary Music	Breitkopf & Härtel
1986	b. 1961	Daron Hagen	Higher, Louder, Faster, an editorial étude	http://www.daronhagen.com/store/higher-louder-faster
1988	Not known	Aaron Minsky	Ten American Cello Etudes	Oxford University Press (distributed by: www.allegro.co.uk)
1990			Three Concert Etudes	Oxford University Press (distributed by: www.allegro.co.uk)
1991	b. 1946	Daniel Kessner	11 Studies for solo violoncello	Theodore Front Musical Literature
1993	1917 – 1995	Isang Yun	Sieben Etüden Für Violoncello Solo	Bote & Bock
1994	b. 1960	Claude Ledoux	12 Studies - First book for cello solo	http://users.skynet.be/ledouxcl/ledoux-oeuvres.html
1995	b. 1963	Benjamin Boone	Buffing the Gut: A Jazz Etude for Cello Solo	Latham Music
1999	b. 1969	Robert deMaine	Twelve Études-Caprices for solo cello Op. 31	Not known
2004	b. 1954	Wolfgang Devine	Four Studies for Cello and Piano	imslp.org
2005	b. 1947	Hristo Tsanoff	Seven concert études for solo violoncello, from the series concert études ‘Play of the mind’	Unpublished, contact the composer: http://www.tsanoff-classic.com/violoncello.etudes.php
2006	Not known	James C. Burke	Etude for Solo Cello	http://imslp.org/wiki/File:PMLP93085-Burke_-_Etude_for_Solo_Cello.pdf
2012	b. 1947	Hristo Tsanoff	Concert étude for violoncello and organ in f-dur	Unpublished, contact the composer: http://www.tsanoff-classic.com/violoncello.etudes.php

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Sofia Gubaidulina's *Ten Preludes for Violoncello Solo* (1974) were originally named *Ten Etudes for Violoncello Solo*; the original title best reflects the potential of this collection as formative pieces. Each short movement explores a particular technique, or transition between two techniques, rendering the action of alternation a technique in itself:

Movement	Technique	Page
No. 1: staccato – legato	n/a	n/a
No. 2: legato – staccato	Glissandi	109
No. 3: con sordino - senza sordino	Playing While Placing / Removing the Mute	177
No. 4: ricochet	n/a	n/a
No. 5: sul ponticello - ordinario - sul tasto	Fixed Points of Contact: Sul Tasto	79
	Fixed Points of Contact: Sul Ponticello	82
	Modifying Points of Contact: Arco: Sul Tasto – Ordinario – Sul Ponticello	86
	Modifying Points of Contact: Tremolo	89
	Glissandi	109
No. 6: flagioletti	Stopped Harmonics (Artificial Harmonics)	48
	Glissandi: Natural Harmonics	53
	Glissandi: Stopped Harmonics	54
	Glissando Trill	109
	Graphic Notation	291
No. 7: al taco - da punta d'arco	n/a	n/a
No. 8: arco – pizzicato	Multi-Stop Pizzicato	70
No. 9: pizzicato – arco	Stopped Harmonics (Artificial Harmonics)	48
	Glissandi: Stopped Harmonics	54
	Pizzicato / Struck Glissando	109
	Graphic Notation	291
No. 10: senza arco, senza pizzicato	Pizzicato-Tremolo	71
	Glissandi	109
	Stopping the String: Left-hand Nail	114
	Bi-Tones : Con le Dita / Fingerschlag / etc.	128
	Graphic Notation	291

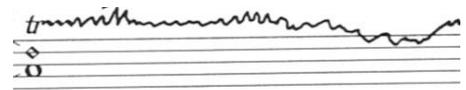
In addition to the Adapted and Extended Techniques listed above, Gubaidulina also addresses issues specific to her own musical language: staccato in a range of dynamics and as components of a larger phrase (no. 1), use of silence within and between

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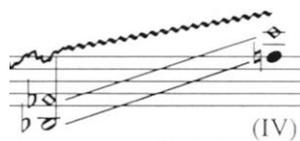
phrases,⁴¹⁰ rapid chromatic meanderings of the left hand (nos. 1, 7, 8 and, to a slightly lesser extent, nos. 2 and 10), asymmetrical note groupings and bow divisions, large melodic intervals connected through glissandi, and controlled ricochet (of up to 7 notes) in both up- and down-bows (no. 4).

The graphic notation that is often seen in Gubaidulina's works is found in nos. 6, 9, 10. Prelude No. 6 in particular warrants a deeper look. Much of the notation used here is not explained in the published part, presuming a certain amount of knowledge and experience from the performer. The various rests used outside the measure, for example, are explained in a notation chart included in Gubaidulina's Quartet No. 3⁴¹¹ and in *Sonnengesang*.⁴¹² Rather more self-

explanatory is the graphically notated pitch contour



extending a trill, found in bars 6, 11, 13-14 and 22. Somewhat mysterious however are the artificial harmonics of bars 21-22, 43 and the double-stop in bar 41, only possible



for players with larger-than-average hands. These three dilemmas can be resolved by playing up the octave, but still stopping on the prescribed pitches in bars 22 and 45.

Please see page 314 in 'Appendix V: Practical Component - Recital' for more information relating to Gubaidulina and this work, which was performed in its entirety as part of the practical component of this thesis.

Though not specifically created with pedagogical intent, **John Cage's *Etudes Boreales for cello and/or piano*** (1978) present an important summary of American experimental music. Frances-Marie Uitti discusses the work in her essay *The Frontiers of Technique*,⁴¹³ and describes the technical difficulties of shifting accurately to erratically

⁴¹⁰ Gubaidulina's music often requires that direction and intent of phrasing incorporates notated silence. The importance of silence in Gubaidulina's music is reflected in the range of relative time indications she uses throughout her music.

⁴¹¹ Brief notes on this piece are found in Appendix V: Practical Component - Recital, in the context of the recital which supported this thesis.

⁴¹² Performed as part of the (M)other Russia Festival on 29 April 2012, Great Hall, Goldsmiths College London (conducted by Alexander Ivashkin), as 2nd-year performance evaluation to support this thesis.

⁴¹³ Stowell (1999), p. 221.

placed notes on the fingerboard, playing without vibrato, and performing the parameters of pitch, colour, duration and dynamic that apply to every note. The four études in this collection are a counterpart to Cage's *Etudes Australes* for piano (1975) and *Freeman Etudes* for violin (1990), all of which are indeterminate compositions.

Siegfried Palm's *Pro Musica Nova, Studies in Playing Contemporary Music* (1985) aims to provide a 'bridge between the inexperience with contemporary instrumental techniques and the demands made by contemporary composers in their works.'⁴¹⁴ This collection assembles twelve études and short pieces edited by Palm, and many commissioned by him specifically for this publication. A very helpful booklet of brief explanations for each piece is included. The contents are as follows:

- Günther Becker - *Study to 'Aphierosis'* (1968)
- Hans Ulrich Engelmann - *Mini-music to Siegfried Palm, op. 38* (1970)
- Wolfgang Fortner - *Study to 'Zyklus'* (1964)
- Michael Gielen - *Passages from 'Die Glocken sind auf falscher Spur'* (1969)
- Mauricio Kagel - *Siegfriedp* (1971)
- Milko Kelemen - *Preparatory Study for 'Changeant'* (1969)
- Konrad Lechner - *Drei kleine Stücke* (1971)
- Nikos Mamangakis - *Askisis* (1969)
- Krzysztof Penderecki - *Cadenza from 'Concerto for violoncello and orchestra no.1'* (1967/72)
- Jacques Wildberger - *Study* (1969)
- Isang Yun - *Study from 'Glissées'* (1970)
- Bernd Alois Zimmermann - *Four Short Studies* (1970)

The difficulties in these works are wide-ranging: from graphic and aleatoric notation, the cello as percussion, theatre, microtones, and scordatura, to harmonics, pizzicato, point of contact on and off the string, bow speed and pressure, dissonance, stopping the string, between the notes... to list these comprehensively is beyond the scope of this short section. The collection contains a richness that is rivalled by no other publication to date, but lacks any strategic or structural logic. The pieces are presented alphabetically rather than in order of difficulty, many of them covering the same issues; to a student or teacher inexperienced in new music, it would be difficult to know in

⁴¹⁴ Palm (1985), preface.

which order, and at what level, these should be approached. The level of virtuosity renders these works best suited to the very advanced student, and would be most helpful in gaining greater understanding of the compositional styles predominant in Germany in the 60s and early 70s, much of which developed at Darmstadt.

Isang Yun's *Sieben Etüden für Violoncello solo* (1995) were created so that Korean music students would discover a more contemporary idiom.⁴¹⁵ A cellist and teacher himself, Yun's music reflects his lifelong attempt to consolidate Korean and Western musical traditions, or as Keith Anderson explains in his liner notes 'developing essentially Korean ideas through Western instruments and avant-garde techniques.'⁴¹⁶ Yun's études are, however, quite difficult to evaluate in terms of the Western musical tradition; there is neither rhythmic cohesion, except in the first étude, nor structure (which could however be labelled through-composed). In terms of their function as études, they contribute nothing specifically new to the repertoire regarding technique, nor do they deepen the understanding of style and aesthetics in this cultural cross-pollination. Excessive trills and *glissandi* can easily sound affected, whereas they are most probably intended to mimic elements of traditional Korean music. They seem to be designed for intermediate students of the cello, with no use of the upper register of the instrument.

The main characteristics of this particular musical heritage are that notes begin with a grace note and once established, vibrato is added to open the sound, which is ended with an ornament. However these elements only seem present in some isolated forms (note shaping throughout No. 1 and intermittently in No. 2, note 'prefixes' in No. 5) and in a vaguely more complete form in No. 6. It seems unfortunate that no further stylistic elements of Korean music such as microtones or rhythms are incorporated into the compositions, leaving the idiom somewhat bland. These stylistic études certainly don't provide 'a concentrated study of contemporary techniques and styles' as claims Ko,⁴¹⁷

⁴¹⁵ Jee Yeoun Ko's paper *Isang Yun and his Selected Cello Works* (2008) provides some insight into Yun's compositional style and the reasoning behind his études.

⁴¹⁶ Anderson (2006).

⁴¹⁷ Ko (2008), p. 45.

but, very much like Gubaidulina's *Ten Preludes*, do provide a stepping stone into the composer's sound world, which he established over a long and fruitful career.

Garth Knox's collection of études for the viola entitled **Viola Spaces** (2009) are briefly mentioned here as a benchmark, for this is the publication which most closely resembles this thesis' objective, in its intent, approach and format. Each of the eight studies focuses on a specific technique: *Sul ponticello*, *Sul tasto*, Glissando, Pizzicato, Tremolo, Harmonics, Quarter-tones, Bow directions.

The two collections of études mentioned in Syllabuses (p. 20) – **Minsky's 10 American Cello Etudes** (1985) and **Kabalevsky's Major-Minor Etudes for Violoncello, Op. 68** (1961) – are representative of their author's compositional style, rooted in the folk music of their respective countries. These are only two examples of many similar collections from the 20th century, most of which are limited in scope in terms of 20th-century performance practice. Most of these compositions do not deviate in terms of harmony and technique from the 19th-century étude. Both of these collections cater to the early-intermediary stages of learning the cello, exploring thumb positions, dotted rhythms and syncopations, pizzicato chords, and compound time signatures. The simplicity of Kabalevsky's writing in his études leave much room for expressivity, in contrast to Yun's, where the heavy use of markings present a separate difficulty.

The final publication mentioned here is a Method of sorts, but deserves further introduction because of its unprecedented, and as yet unsurpassed, contribution to the pedagogy of harmonics. *The Secret Life of Cello Strings: Harmonics for Cellists* (1996) by **Caroline Bosanquet** combines theoretical, historical and practical information and both introductory exercises and practice exercises through simple tunes. In addition to a systematic survey of natural harmonics, Bosanquet also covers stopped harmonics of a perfect fourth, fifth, major third and minor third, double-node harmonics, the 'seagull' effect and trills.

Appendix II: Components of Modern Notation & Style

The past century has seen a vast array of notational devices, reflecting the need for expressing different timbre and various gestures. Ideally, this thesis would also attempt to standardize notation, but this is a much larger undertaking which has been attempted many times by prominent authors. The fact remains that often there is neither dedicated nomenclature nor notation for a given sound, and the performer often must either rely on personal contact with the composer or the guidance of written instructions.

Hence, composers often offer a description of how the sound is to be made, rather than of the desired result. This is categorised as ‘prescriptive notation’, versus ‘descriptive notation’ which indicates the resultant sound in terms of pitch, rhythm, dynamic and timbre. It is important for performers to be aware of this potential trap, in which the notation’s focus is unintentionally on technique rather than the result.⁴¹⁸

Here follows short presentations of issues of notation and style in modern music.

Graphic Notation

Though graphic notation belongs very specifically to modern music, it should not be considered a performance issue in and of itself, as it is essentially a substitution of one system of notation for another with no resulting difference in the sounds that are produced and the way they are produced. Inasmuch as notation is a means of communication between composer and performer, graphic notation’s greatest attributes are found in the influence exerted on the psychology of the performer⁴¹⁹ and in the freedom allocated the performer, subjects which lie outside the scope of this thesis. Ultimately, notation is the responsibility of the composer and editor – ideally

⁴¹⁸ A simple example is of a *forte* dynamic in a passage marked *sul tasto*, without knowing whether the resulting sound should be ‘strangled’ (normal bow speed), quasi-pitchless (slow bow speed), or essentially *ordinario* but slightly louder than a *sul tasto* sound would usually be (fast bow speed).

⁴¹⁹ It is interesting to observe one’s own personal reaction to typeset versus hand-written graphic notation. In the latter, every detail takes significance, the movement of the lines or shapes on the page have direct correlations to the sound being produced, and often, to the physicality of creating the sound. John Zorn’s combination of typeset and hand-written notation is especially interesting to study in this regard.

performers who have the technical know-how on the instrument can use their own taste and artistic judgement where notation is ambiguous.

Graphic notation is also known as ‘action notation’ or ‘prescriptive notation’, though these terms also encompass traditional notations, for example the mute, diamond-head harmonics, fingerings, and bowings. Also synonymous is ‘tablature’ notation – in reference to the notation used in the Renaissance for fretted instruments and flutes, which indicated where to put your fingers (that is, notation specific to a particular instrument).⁴²⁰

Improvisation

Of the many types of improvisation, free or experimental improvisation will come more easily to the cellist who is well-versed and comfortable in the techniques covered in this thesis. The other important aspects of improvisation however – form and style, which extend to tonal music and jazz as well as to many types of music throughout the world – are beyond the scope of this thesis and should be studied separately.⁴²¹

Gubaidulina’s thoughts on her years of improvising in Russia with her group of fellow composers reflect the aspects of musical development which improvisation brings: ‘Astraea was therefore important for me in three respects; expanding my imaginative range in the realm of sound, developing spontaneity, and learning from purely psychological experiences.’⁴²²

Compositional Currents

Just as the vast array of techniques and notational devices are in constant flux, so is musical idiom, or style. An understanding of the techniques above will greatly aid in the performance of the many styles and schools of composition, but each composer necessitates a fresh approach. The same considerations as one would apply to music of

⁴²⁰ Orning (2012), p. 21.

⁴²¹ de Saram discusses his own approach to free improvisation, coming from a score-based instrumental background, and offers some advice in Steinheuer & de Saram (2013), pp. 201-213.

⁴²² Kurtz (2007), p. 158.

different epochs – such as vibrato, dynamic range, and consistency of articulation – apply here.

The term ‘experimental music’ is often used for various styles of modern music.

Nyman provides a complete overview of experimental music in his book *Experimental Music, Cage and Beyond*, in which he writes:

...Cage's and Wolff's indeterminate scores of the early sixties not only demanded considerable technical expertise in performance, but also the ability to comprehend quite sophisticated abstract musical concepts and to unravel a complex notational sign-language; early experimental music was only available to a small dedicated elite of professional musicians...⁴²³

This can be said of all the currents discussed below, all of which are now easily within reach of any musicians with a willingness to push the boundaries of traditional performance practice. Five currents are outlined below, as an introduction to the principal styles a student needs to be aware of when first studying modern music. Brief thoughts are included in each section, reflecting on the place of each style in music today.

Aleatoric / Indeterminate Music

This is half-way between a written score and improvisation; Rohan de Saram qualifies works of this type as ‘guided improvisations’.⁴²⁴ There are two fundamental aspects of aleatoric music: time and pitch. These are often a result of the convention established by means of graphic notation between a composer and the performer. Whittall expresses his view of this style of music, which ‘allows the interpreter a more positive role than he has in much other modern music, where the technical difficulties are such that the most he can hope for is an approximate reproduction of the “correct” pitches and durations’.⁴²⁵

⁴²³ Nyman (1999), p. 110.

⁴²⁴ Steinheuer & de Saram (2013), p. 203.

⁴²⁵ Whittall (1977), p. 208.

New Complexity

New Complexity is highly institutionalized, or to use Richard Taruskin's terminology, it is music which is produced under the aegis of the 'new patronage' which has high academic expectations. This post-war trend resulted in music that is very much rooted in intellectual concepts. This doesn't necessarily lessen the artistic merit of such pieces, but the instrumentalist should be aware that often the predominant features of this style of composition are the gesture and interaction of the musician with the instrument and the score, and the underlying psychology of this process.

Fluxus / Intermedia

This music has a high content of theatricality and influence from other art forms. In development since the 1960s, the wit and often politically or philosophically charged undercurrents continue to be effective, though the initial shock value has now lessened. The musical material of such works is often subordinate to the overall effect, or message, with written instructions guiding the performer.

Minimalism

Definitions in this area of composition are often unclear. Minimalism is one of the several schools of composition which emerged as counter-currents to two movements which largely dominated the mid-20th century: the Fluxus movement, which almost removed the composer from the equation and sought to give the performer a greater part in the creative process, and New Complexity, in which the score is ever exerting control over the performer. Minimalism aims to remove both the musical material and the performer, to place musical process at the forefront.

The term 'minimal music' was first coined by Michael Nyman in a 1968 review in *The Spectator*. He used this term in reference to the current of 'minimalism' in visual art, to qualify the music of composer Hennig Christiansen and other unnamed pieces played by Charlotte Moorman and Nam June Paik, at the Institute of Contemporary Arts in London.⁴²⁶

⁴²⁶ http://en.wikipedia.org/wiki/Minimalism#Minimal_music

It is a current that has found appeal to both classical and pop audiences, and is used frequently in film music. The term ‘minimalism’ as we now understand it encompasses many different styles of music.

Spectralism

Spectral music is based on the harmonic series, or harmonic spectrum, of a sound. This style of music developed in the mid-1970s, in tandem with the development of technologies at IRCAM in Paris. Timbre is at the forefront of the spectral composition, with time as ‘a constituent element of sound itself.’⁴²⁷ The composer Gérard Grisey explains that spectralism is not so much a system, as an attitude, which provides ‘a formal organization and sonic material that came directly from the physics of sound, as discovered through science and microphone access.’⁴²⁸

⁴²⁷ Grisey & Fineberg (2000), p. 2.

⁴²⁸ Idem., p. 1.

Appendix III: Basics of Signal Processing

These are listed in an isolated manner, following the format of the rest of this text; they can, similarly, be combined and in this case, be re-applied to the resulting sounds *ad infinitum*.

Signal processing can be applied after the sound has been recorded, or in real-time, during a performance. Real-time processing algorithms have added a new genre of ‘interactive performance’ that was impossible until recently.⁴²⁹ Analogue technology is better for real-time processing, as it uses less bandwidth.

Equalization (EQ)

This is the raising or lowering of specific areas of a sound signal’s spectrum.

Graphic equalizer So-called because the console looks like a graph. Sliding dials divide frequencies into specific ranges, where the decibel levels of each spectral area can be brought up or down. An equalizer can also attenuate traffic noise, ventilation or other environmental frequencies where the lower frequency ranges available for manipulation exceed those produced by a cello. The upper frequency ranges affect the harmonic spectrum, and hence timbre of a sound.

Parametric equalizer Frequency ranges are more general, and are divided into low, mid and high. Dials control these rough areas. These are usually integrated into mixers.

Filtering

Filtering is essentially selective amplification.

Low-pass filter This removes or reduces frequencies above a certain threshold. The two parameters are ‘cut-off frequency’ and ‘Q’ (feedback /

⁴²⁹ P & A Strange (2001), p. 202.

resonance: amplification of the cut-off frequency). A virtual sine-wave can be created by cutting off all of the frequencies above the second harmonic. P & A Strange remark that ‘if a low-pass filter with high Q were swept from high [frequencies] to low [frequencies], one would very clearly hear each harmonic as the filter passed over it.’⁴³⁰

High-pass filter This removes or reduces frequencies below a certain threshold. The same considerations as a low-pass filter apply here.

Band-pass filter This is a combination of both low-pass and high-pass filters.

Filter tracking This maintains the cut-off frequency at a constant interval to any given note, unlike a regular filter which blocks any frequency above a set point. For example, if the cut-off point with a filter tracker is the third harmonic of a note, the third harmonic will remain for all subsequent notes, thus conserving the timbre.

Compression

If a pre-amplified signal is too strong (hot) for a device and produces unwanted distortion, it can be compressed by decreasing the level of the louder signals and increasing the level of the quieter signals, to average the decibel levels of the signals. However, this will greatly reduce the possible dynamic range of an amplified cello.

Noise Gating

This device blocks signals which fall below a certain amplitude level. It is often used to eliminate the background noise which can be amplified by the use of a compressor or by another form of processing. Of particular interest to a cellist, noise gating can decrease extraneous noise of the left hand on the string. The following parameters can be controlled:

⁴³⁰ Idem., p. 212.

- Hold time (sustain) This determines how long the signal should remain below the threshold.
- Attack time The length of time during which the signal is faded up from the gated state is designated.
- Release time This determines how long the signal should remain above the threshold.

Modulation

Modulation can occur with several parameters of the sound, and creates sum and difference tones (see p. 184), known in electronic music as sidebands. Whereas the sidebands created acoustically by a cello are limited to the combination of pitches which can be played simultaneously on the instrument (or by several instruments or voices), modulation can be used to access sidebands which are otherwise impossible to create. The result of the carrier pitch and sideband is a drastic alteration of timbre.⁴³¹

Amplitude modulation This is the electronic equivalent to tremolo; it is a continuous variation of a signal's amplitude.⁴³² One set of sidebands is produced.

Frequency modulation This is the electronic equivalent to vibrato; it is a continuous variation in a signal's pitch frequencies. As modulation rate and index (amount of change in pitch or loudness) increase, more sets of sidebands are created. When the index reaches a very high level, the carrier pitch (the original note) is eliminated.

Ring modulation Also known as 'full-balanced modulation' or 'double sideband modulation', two signals are multiplied together. This process is related to the amplitude modulation process described above,

⁴³¹ Idem., p. 215.

⁴³² Idem., p. 214.

except that the modulated carrier pitch is eliminated. This creates 'a complex spectrum of acoustic signals', which produces a pulsating thick and distorted sound.⁴³³ Stockhausen has used ring modulation in several works since 1956.

Effects

Reverberation

Known as 'reverb', this adds the illusion of space to the sound; it is the multiple reflection of a sound. P & A Strange explain that sound in a natural acoustic will 'bounce off virtually everything in the environment and arrive at the listener's ears at time intervals that are spaced in microseconds. Acoustically, reverb is the time it takes for the sound to decay from its initial attack to a level 60 decibels lower.'⁴³⁴ A reverb effect can either simulate a natural acoustic or amplify it.

Echo / delay

A more pronounced version of reverb, the time between repetitions is longer and discernible by the ear. If the delay is fed back into the microphone at regular intervals, a rhythm emerges. A tempo can also be derived from repeated delay; for example a 1000 millisecond delay (1 second) is equal to m.m. = 60.

Chorus effect

This is a variance on reverb, which 'adds continually delayed signals that are varied between 40-60 milliseconds at a rate of about 0.25 Hz.'⁴³⁵ The result is of another instrument trying to play along in unison.

Flange effect

Less pronounced than the chorus effect, the delay is about 5 milliseconds. The result is of the sound pulsating.

⁴³³ Idem., p. 216.

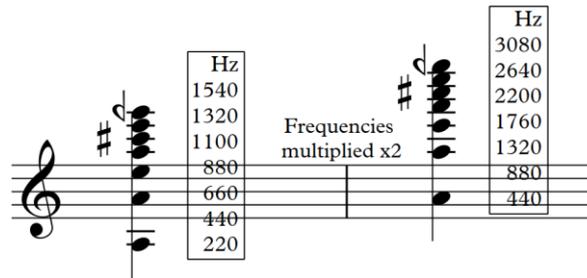
⁴³⁴ Idem., p. 212.

⁴³⁵ Idem., p. 213.

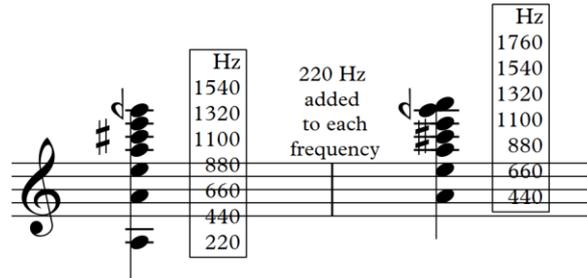
Phasing	Here the time delay is shorter than the reverb effect, and is no longer than the period of the sound wave which is being processed. Sound-cancelling effects are produced.
Loops	This is the repetition of a segment of music, which will continue until told to stop. Current looping units can repeat segments of millisecond length up to 20 minutes or more. Bowed instruments can create ‘infinite’ notes by starting and ending loops within a bow and on the same pitch.
Vocoding	A carrier pitch is modified by having the harmonic spectrum of one sound imposed on another. Two sounds with ‘the same general range and with similar spectral components’ are used for this. One tracks the ‘loudness of various areas of [one] signal’s spectrum and transfer[s this to] control the loudness of another sound’s spectrum.’ ⁴³⁶ The effect will vary according to the tessitura used on the cello.
Pitch-shifting	This is the process of shifting the fundamental note of a sound up or down in pitch, which also affects the timbre of the sound. Acoustically, a sound with its entire harmonic spectrum is multiplied or divided when it is played in another range, conserving all of the interval relationships between the components of the sound. Electronically, transposition occurs by adding or subtracting a frequency, therefore changing the interval relationships of the fundamental and harmonics and thus affecting the timbre. In the example below, the first bar of each line shows the natural harmonic spectrum of a note (up to the 7 th harmonic), and the second bar shows the new spectrum after electronic transposition:

⁴³⁶ *Idem.*, p. 216.

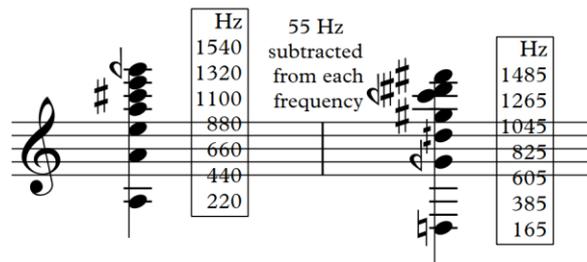
a) Acoustic transposition, up one octave:



b) Electronic transposition, up one octave:



c) Electronic transposition, down one fifth:



Tunnelling This is done by adding ‘recursive delay to a pitch shift’, which creates a pattern such as a scale or arpeggio. A pitch is shifted, delayed, and then ‘fed back into the shifter, where the cycle is repeated’.⁴³⁷ Usually the interval remains the same every time the signal is fed back in, but some ‘intelligent shifters’ can generate more complex effects in real time.

⁴³⁷ Idem., p. 217.

Appendix IV: Further Study

The pieces listed here are examples of works written in the 20th and 21st centuries, in which the technique in question is a prominent feature. Only published works are listed, with a few exceptions, to ensure that the materials are accessible to the reader. The works are listed chronologically in each section, by year of composition, rather than publication.

1. Harmonics

p. 37

- David Popper *High School of Cello Playing, Op. 73: Étude No. 40* (1905) solo cello (Bärenreiter)
- Igor Stravinsky *The Firebird* (1910) orchestra (Dover Publications)
- Maurice Ravel *Chansons madécasses* (1926) voice, flute, cello and piano (Durand)
- Dmitri Shostakovich *Sonata for Cello and Piano in D minor, Op. 40* (1934) cello and piano (Edition Peters)
- Dmitri Shostakovich *Piano Trio No. 2 in E minor, Op. 67* (1944) violin, cello and piano (Boosey & Hawkes)
- György Ligeti *String Quartet No. 1* (1954) string quartet (Schott)
- Paul Zukofsky 'On Violin Harmonics,' *Perspectives of New Music* 6.2 (1968, pp. 174-181)
- George Crumb *Vox Balaenae* (1971) flute, cello and piano (Edition Peters)
- Mauricio Kagel *Siegfriedp'* (1971) solo cello (Universal Editions)
- Sofia Gubaidulina *Ten Preludes: No. 6 'flagioletti'* (1974) solo cello (Edition Sikorski)
- Gerald Warfield 'The Notation of Harmonics for Bowed String Instruments,' *Perspectives of New Music* 12.1 (1974, pp. 331-343)
- Mathias Spahlinger's *Adieu M'amour, Hommage a Guillaume Dufay* (1983) violin and violoncello (Peer Musikverlag)
- Stefano Scodanibbio *Visas* (1987) string quartet (www.stefanoscodanibbio.com)
- Jo Kondo *Near and Far* (1993) cello and piano (University of York Music Press)
- Bright Sheng *Seven Tunes Heard In China* (1995) solo cello (G. Schirmer)
- Caroline Bosanquet *The Secret Life of Cello Strings: Harmonics for Cellists* (1996) solo cello (SJ Music)
- Kaija Saariaho *Sept Papillons* (2000) solo cello (Chester Music)

2. Pizzicato

p. 60

- Claude Debussy *Sonate pour violoncelle et piano 'Pierrot fâché avec la lune'* (1915) cello and piano (Henle Verlag)

- Béla Bartók *String Quartet No. 4* (1928) string quartet (Universal Editions)
- Hans Werner Henze *Serenade* (1949) solo cello (Schott)
- Paul Tortelier *Trois P'tits tours: Burlesque (Le Pitre)* (1950) cello and piano (Editions Combre / Henry Lemoine)
- Sulkhan Tsintsadze *Five Pieces on Folk Themes* (1950) cello and piano (Faber Music / Anglo-Soviet Music Press)
- György Ligeti *String Quartet No. 1* (1954) string quartet (Schott)
- Benjamin Britten *Cello Suite No. 1, Op. 72* (1964) solo cello (Faber Music)
- Iannis Xenakis *Nomos Alpha* (1965) solo cello (Boosey & Hawkes)
- Earle Brown *String Quartet* (1965) string quartet (Edition Peters)
- György Ligeti *String Quartet No. 2* (1968) string quartet (Schott)
- Isang Yun *Glissées* (1970) solo cello (Boosey & Hawkes)
- Sofia Gubaidulina *Ten Preludes: No. 8 'arco - pizzicato'* (1974) solo cello (Edition Sikorski)
- Sofia Gubaidulina *Ten Preludes: No. 10 'senza arco, senza pizzicato'* (1974) solo cello (Edition Sikorski)
- Paul Tortelier *Etude No. 5: Pishnetto* (1975) cello and piano (Chester Music)
- Aaron Minsky *10 American Cello Études: No. 9 'The Crack of Dawn'* (1985) for solo cello (Oxford University Press)
- Helmut Lachenmann *Reigen seliger Geister* (1989) string quartet (Breitkopf & Härtel)
- Sofia Gubaidulina *String Quartet No. 3* (1990) string quartet (Boosey & Hawkes)
- Bright Sheng *Seven Tunes Heard In China* (1995) solo cello (G. Schirmer)
- Steven Mackey *String Theory* (1998) amplified string quartet with delay (Boosey & Hawkes)

3. Bowing the String: Point of Contact

p. 76

- Krzysztof Penderecki *String Quartet No. 1* (1960) string quartet (Schott Music)
- Michael von Biel *Quartett* (1964) violin, viola, cello, double-bass (Universal Edition)
- Francis Miroglio *Projections* (1967) string quartet (Universal Edition)
- Jack Fortner *Quartet No. 7* (1968) string quartet (Jobert)
- Krzysztof Penderecki *Capriccio per Siegfried Palm* (1968) solo cello (Schott)
- George Crumb *Black Angels* (1970) string quartet (Edition Peters)
- Helmut Lachenmann *String Quartet No. 1 'Gran Torso'* (1972) string quartet (Breitkopf & Härtel)
- Sofia Gubaidulina *Ten Preludes: No. 5 'sul ponticello - ordinario - sul tasto'* (1974) solo cello (Edition Sikorski)
- Kaija Saariaho *Im Traume* (1980) cello and piano (Chester Music)
- Iannis Xenakis *Tetras* (1983) string quartet (Salabert)
- Jonathan Harvey *String Quartet No. 2* (1988) string quartet (Faber Music)

- Thomas Ades *Arcadiana* (1994) string quartet (Faber Music)
- Kaija Saariaho *Sept Papillons* (2000) solo cello (Chester Music)
- Helmut Lachenmann *String Quartet No. 3 'Grido'* (2001) string quartet (Breitkopf & Härtel)

4. Bowing the String: Speed & Pressure

p. 93

- Helmut Lachenmann *Pression* (1969) solo cello (Breitkopf & Härtel)
- Robert Ashley *String Quartet Describing the Motions of Large Real Bodies* (1972) string quartet (Alga Marghen – score included in ‘digipack CD edition’, catalogue number: nmn030CD)
- Jonathan Harvey *String Quartet No. 2* (1988) string quartet (Faber Music)
- John Zorn *Cat O' Nine Tails* (1988) string quartet (Hips Road)
- Steve Mackey *On All Fours* (1990) string quartet (Boosey & Hawkes)
- Jonathan Harvey *Advaya* (1994) cello, electronic keyboard and electronics (Faber Music)
- Kaija Saariaho *Mirrors* (1997) flute and cello (Chester Music)
- Fausto Romitelli *Professor Bad Trip: Lesson Two* (1998) flute, clarinet, trombone, electric guitar, electric bass, percussion, piano, violin, viola, cello (Casa Ricordi)
- Kaija Saariaho *Sept Papillons* (2000) solo cello (Chester Music)
- Hans Thomalla *Albumblatt* (2010) string quartet (<http://www.hans-thomalla.com/sitebuildercontent/sitebuilderfiles/albumblatt.pdf>)
- Bluegrass fiddlers have developed a rhythmic technique called ‘The Chop’, which has also been used by folk and jazz cellists to great effect. The interested reader has many YouTube videos which can be referenced.

5. Between the Notes

p. 107

- Luciano Berio *Sincronie* (1964) string quartet (Universal Edition)
- Toshiro Mayuzumi *Bunraku: Adaptation of Samisen techniques to a Western instrument* (1964) solo cello (Edition Peters)
- Iannis Xenakis *Nomos Alpha* (1965) solo cello (Boosey & Hawkes)
- Isang Yun *Glissées* (1970) solo cello (Boosey & Hawkes)
- George Crumb *Black Angels* (1970) string quartet (Edition Peters)
- George Crumb *Vox Balaenae* (1971) for flute, cello and piano (Edition Peters)
- Sofia Gubaidulina *Ten Preludes: No. 9 'pizzicato - arco'* (1974) solo cello (Edition Sikorski)
- John Mayer *Six Ragamalas* (1981) cello and tanpura (http://www.johnmayercomposer.co.uk/?page_id=196)
- Younghi Pagh-Paan *AA-GA I* (1984) solo cello (Ricordi)
- Jonathan Harvey *String Quartet No. 2* (1988) string quartet (Faber Music)
- Sofia Gubaidulina *String Quartet No. 3* (1990) string quartet (Boosey & Hawkes)

- Param Vir *Flame* (1997) solo cello (Novello)
- Akira Nishimura *Threnody* (1998) solo cello (Schott)
- Tôn Thất Thiêt *Voyage* (2007) solo cello (Jobert)
- Toshio Hosokawa *Chant* (2009) cello and orchestra (Schott)
- Param Vir ...*beyond the reach of the world...* (2009) solo cello (<http://www.paramvir.net/contact.html>)

6. Stopping the String

p. 111

- György Ligeti *String Quartet No. 2* (1968) string quartet (Schott)
- Helmut Lachenmann *Pression* (1969) solo cello (Breitkopf & Härtel)

7. Expanding the Register

Altissimo Register

p. 118

- Jonathan Harvey *String Quartet No. 2* (1989) string quartet (Faber)

Scordatura / Alternative Tuning

p. 119

- Zoltán Kodály *Sonata, Op. 8* (1915) solo cello (Universal Edition)
- George Crumb *Vox Balaenae* (1971) flute, cello and piano (Edition Peters)
- Luciano Berio *Sequenza XIV* (2002) solo cello (Universal Edition)

Unisons

p. 121

- György Ligeti *String Quartet No. 2* (1968) string quartet (Schott)
- Luciano Berio *String Quartet No. 3 'Notturmo'* (1993) string quartet (Universal Edition)
- Kaija Saariaho *Sept Papillons* (2000) solo cello (Chester Music)

8. Bi-tones

p. 126

Gubaidulina's Prelude No. 10 deals extensively with *con le dita*, through a wide range of pitch and dynamics, and is particularly useful in preparing for Gubaidulina's *String Quartet No. 3* in which this technique is required for a long period of time.

- Krzysztof Penderecki *Capriccio per Siegfried Palm* (1968) solo cello (Schott)
- György Ligeti *String Quartet No. 2* (1968) string quartet (Schott)
- Sofia Gubaidulina *Ten Preludes: No. 10 'senza arco, senza pizzicato'* (1974) solo cello (Edition Sikorski)

- Younghi Pagh-Paan *AA-GA I* (1984) solo cello (Ricordi)
- Sofia Gubaidulina *String Quartet No. 3* (1990) string quartet (Boosey & Hawkes)
- Luciano Berio *Sequenza XIV* (2000) solo cello (Universal Edition)

9. Strike Tones **p. 132**

- George Crumb *Black Angels* (1970) string quartet (Edition Peters)

10. Cello Percussion **p. 139**

- Krzysztof Penderecki *String Quartet No. 1* (1960) string quartet (Schott)
- Krzysztof Penderecki *Capriccio per Siegfried Palm* (1968) solo cello (Schott)
- Helmut Lachenmann *Pression* (1969) solo cello (Breitkopf & Härtel)
- George Crumb *Vox Balaenae* (1971) flute, cello and piano (Edition Peters)
- John Zorn *The Dead Man – Thirteen Specimens: No. 5 meditation (the blue of noon)* (1990) string quartet (Hips Road Edition)
- Sofia Gubaidulina *String Quartet No. 4* (1993) string quartet (Edition Sikorski)
- Sofia Gubaidulina *Sonnengesang* (1997) cello, percussion and chamber chorus (Edition Sikorski)
- Luciano Berio *Sequenza XIV* (2000) solo cello (Universal Edition)

11. Bowing the Instrument **p. 146**

- Krzysztof Penderecki *String Quartet No. 1* (1960) string quartet (Schott)
- Krzysztof Penderecki *Capriccio per Siegfried Palm* (1968) solo cello (Schott)
- Steven Montague *String Quartet No. 1* (1993) string quartet, live electronics and tape (United Music Publishers)

12. Changing Bow Hold **p. 150**

- Alban Berg *Lyric Suite* (1926) string quartet (Universal Edition)
- Iannis Xenakis *ST 4-1, 080262* (1962) string quartet (Boosey & Hawkes)
- Krzysztof Penderecki *Capriccio per Siegfried Palm* (1968) solo cello (Schott)

13. Sustained Polyphony: New Uses of the Bow

Double-bow p. 155

Many pieces were written exploiting Frances-Marie Uitti's abilities to improvise using the double-bow technique, including Randy Raine-Reusch's *Sparrow's Wing*,⁴³⁸ Barry

⁴³⁸ Raine-Reusch *Sparrow's Wing* (2007) solo cello two bows (Asza; Canadian Music Centre)

Appendix IV: Further Study

Truax's *Étude*,⁴³⁹ and Jonathan Harvey's *Philia's Dream*.⁴⁴⁰ These are either graphic scores or not notated and are therefore not included in the list below.

- Giacinto Scelsi *Riti: il Funerale di Carlo Magno (AD 814)* (1979) cello and percussion (Salabert)
- Luigi Nono *Quando Stanno Morendo. Diario Polacco No. 2* (1982) four female voices, bass flute, cello and live electronics (Ricordi)
- Toshio Hozokawa *Sen II* (1986) solo cello (Schott)
- György Kurtág *Ligatura – Message to Frances-Marie (The Answered Unanswered Question), Op. 31/b* (1989) cello, two violins, celesta (or) two celli, two violins and celesta (or) two organs, and celesta / upright piano (Editio Musica Budapest)
- Richard Barrett *Dark ages* (1990) solo cello (United Music Publishers)
- Richard Barrett *Praha* (1991) solo cello (United Music Publishers)
- Jay Alan Yim *Orenda* (1997) solo cello and live electronics (Shinkyoku Edition)

Unpublished:

(N.B. All of these scores are available through the composer.)

- Sharon Kanach *Stone: 3* (1982) solo cello (http://www.centre-iannis-xenakis.org/writing_protocol:sharon.kanach@gmail.com)
- Clarence Barlow *Fruitti d'Amore* (1988) cello and live electronics (b@rflow.org)
- Dominique Schafer *Rebounds* (2004) solo cello (dom@dominiqueschafer.com)
- Lisa Bielawa *Roman Holiday Blues* (2011) solo cello (www.lisabelawa.net/works)

Curved Bow (BACH.Bow)

p. 157

In addition to being an inventor, luthier, and cellist, Michael Bach Bachtischa is also a composer and has written numerous pieces for the BACH.Bow. He provides a more complete list of works written for polyphonic bow on his website: <http://www.bach-bogen.de/compositions.html>.

- John Cage *ONE8* (1991) solo cello (Edition Peters)
- Dieter Schnebel *Mit diesen Händen* (1992) voice and cello (Schott)
- John Cage & Michael Bach Bachtischa *ONE13* (1992) solo cello (Edition Peters)

⁴³⁹ Barry Truax *Étude* (1984) solo cello two bows and two sound tracks (the stereo tape part is in Mr. Truax's audio archive; he can be contacted through the Canadian Music Centre).

⁴⁴⁰ Harvey *Philia's Dream* (1992) for cello and synthesizer.

Unpublished:

- Walter Zimmermann *Geduld und Gelegenheit* (1989) cello and piano (www.worldcat.org)
- Amnon Wolman *STOP* (1993) cello and electronics
- Laurence Crane *Raimundas Rumsas* (2002) solo cello
- Joseph Kudirka *Vincas/81* (2011) solo cello
- Larry Goves *the clouds flew round with the clouds* (2012) cello and soundtrack (larry@larrygoves.com)

14. Multiphonics

p. 160

- Håkon Thelin *A new world of sounds*:
<http://haakontheelin.com/multiphonics/multiphonics-on-the-double-bass/definitions/introduction-to-multiphonics-on-the-double-bass>
- Ellen Fallowfield, video demonstrations of the eight pure multiphonics:
<http://www.cellomap.com/index/the-string/multiphonics-and-other-multiple-sounds.html>

15. Vocal & Theatrical Effects

p. 169

- George Crumb *Black Angels* (1970) string quartet (Edition Peters)
- Jack Fortner *Quartet* (1970) string quartet (Editions Jobert)
- George Crumb *Vox Balaenae* (1971) flute, cello and piano (Edition Peters)
- Mauricio Kagel *Siegfriedp'* (1971) solo cello (Universal Editions)
- Gerald Plain *Racoon Song* (1973) solo cello (out of print, Oxford University Press)
- Brian Ferneyhough *Time and Motion Study II* (1976) singing cellist and live electronics (Edition Peters)
- Pēteris Vasks *Grāmata čellam* (1978) solo cello (Schott)
- Louise Andriessen *La Voce* (1981) solo cello (Boosey & Hawkes)
- James Tenney *Ain't I a Woman?* (1992) cello and chamber orchestra (Canadian Music Centre)
- Giya Kancheli *Nach dem Weinen* (1994) solo cello (Boosey & Hawkes)

16. Mutes & The Prepared Cello

p. 172

- Giacinto Scelsi *Triphon* (1956) solo cello (Durand-Salabert-Eschig)
- Giacinto Scelsi *String Quartet No. 2* (1961) string quartet (Durand-Salabert-Eschig)
- Giacinto Scelsi *Khoom* (1962) soprano, horn, string quartet and two percussionists (Durand-Salabert-Eschig)
- Mauricio Kagel *String Quartet No. 1* (1965) string quartet (Universal Edition)
- Mauricio Kagel *String Quartet No. 2* (1967) string quartet (Universal Edition)

- Sofia Gubaidulina *Ten Preludes: No. 3 'con sordino - senza sordino'* (1974) solo cello (Edition Sikorski)

17. Independence of Hands

p. 177

- Iannis Xenakis *ST 4-1,080262* (1962) string quartet (Boosey & Hawkes)
- Theodore Antoniou *Jeux, Op. 22* (1963) cello and string orchestra (Bärenreiter)
- Iannis Xenakis *Nomos Alpha* (1965) solo cello (Boosey & Hawkes)
- Bernd Alois Zimmermann *Intercomunicazione* (1967) cello and piano (Schott)
- George Crumb *Vox Balaenae* (1971) flute, cello and piano (Edition Peters)
- Sofia Gubaidulina *Ten Preludes: No. 3 'con sordino - senza sordino'* (1974) solo cello (Edition Sikorski)
- Klaus K. Hübler *String Quartet No. 3: Dialektische Fantasie* (1984) string quartet (Breitkopf & Härtel)
- Alfred Schnittke *Cello Concerto no. 1* (1986) cello and orchestra (Boosey and Hawkes)
- Chinary Ung *Spiral* (1987) cello, piano, and percussion (Edition Peters)
- Sofia Gubaidulina *Sonnengesang* (1997) cello, percussion and chamber chorus (Edition Sikorski)

18. Dissonance

p. 182

- Giacinto Scelsi *Diathome* (1957) solo cello (Durand-Salabert-Eschig)
- Iannis Xenakis *Nomos Alpha* (1965) solo cello (Boosey & Hawkes)
- Ronald Herder *Tonal/atonal: Progressive Ear Training, Singing and Dictation Studies in Diatonic, Chromatic and Atonal Music* (Continuo Music Press, New York, 1973)
- Sofia Gubaidulina *Ten Preludes: No. 9 'pizzicato - arco'* (1974) solo cello (Edition Sikorski)
- Alvin Lucier *Navigations for Strings* (1991) string quartet (Material Press)

19. Tuning Systems

p. 188

- Per Nørgård *Between* (1985) cello and orchestra (Edition Wilhelm Hansen)
- Horațiu Rădulescu *String Quartet No. 4* (1987) nine string quartets (Lucero Print)
- Lydia Ayers *In the Throne Room of the Mountain Gods* (1987) string quartet (American Composers Alliance)
- Tristan Murail *Attracteurs étrangers* (1992) solo cello (Henri Lemoine)

20. Microtonality

p. 208

- Alois Haba *String Quartet No. 2* (1920) string quartet (Universal Edition)

- Julian Carrillo *Cuarteto in 1/4 de tono* (1925) string quartet (Jobert)
- Ton de Leeuw *String Quartet No. 2* (1964) string quartet (Donemus)
- Giacinto Scelsi *Triology: Triphon* (1957), *Diathome* (1957), *Ygghur* (1964) solo cello (Durand-Salabert-Eschig)
- Witold Lutosławski *Cello Concerto* (1970) cello and orchestra (Chester Music)
- Witold Lutosławski *Sacher Variation* (1975) solo cello (Chester Music)
- Henri Pousseur *Racine 19e de 8/4* (1976) solo cello (Centre Belge de Documentation Musicale, Brussels)
- James Tenney *Koan* (1984) string quartet (Canadian Music Centre)
- Giacinto Scelsi *Quartetto No. 5* (1985) string quartet (Durand-Salabert-Eschig)

21. Phasing & Repetition

p. 220

- Philip Glass *String Quartets Nos. 1-7* (1966-2014) string quartet (Dunvagen Music Publishers)
- Steve Reich *Clapping Music* (1972) two musicians clapping (Universal Edition)
- Arvo Pärt *Fratres* (1977) eight cellos / cello and piano (Universal Edition)
- Arvo Pärt *Spiegel im Spiegel* (1978) cello and piano (Universal Edition)
- László Sáyry *For violoncello or viola: Hommage à Philip Glass* (1980) cello solo (Editio Musica Budapest)
- Steve Reich *Different Trains* (1988) amplified string quartet and tape (Boosey & Hawkes)
- David Lang *Bitter Herb* (1992) cello and piano (G. Schirmer)
- John Tavener *Lament for Phaedra* (1995) soprano and cello (Chester Music)
- John Tavener *Chant for Cello* (1995) solo cello (Chester Music)
- Steve Reich *Cello Counterpoint* (2003) amplified cello and multichannel tape (Boosey & Hawkes)

22. Complex Rhythm

p. 223

- Maurice Ravel *Piano Trio in A minor* (1914) violin, cello and piano (Durand)
- Alban Berg *Lyric Suite* (1926) string quartet (Universal Edition)
- Béla Bartók *String Quartet No. 5* (1934) string quartet (Universal Edition)
- Elliott Carter *Sonata* (1948) cello and piano (G. Schirmer)
- Jonathan Harvey *String Quartet No. 2* (1989) string quartet (Faber)

23. Live Electronics

p. 227

- Rolf Gehlhaar *Solipse* (1974) cello and tape delay (MusicaNeo)
- Brian Ferneyhough *Time and Motion Study II* (1976) cello with delay tapes, modulation and amplification (Edition Peters)

- Tod Machover *Electric Etudes* (1983) amplified cello, live and pre-recorded computer electronics (Ricordi)
- Jonathan Harvey *Ricercare una Melodia* (1985) cello and quadrophonic tape (Faber Music)
- Steve Reich *Different Trains* (1988) amplified string quartet and tape (Boosey & Hawkes)
- Kaija Saariaho *Petals* (1988) cello and live electronics (Chester Music)
- Tod Machover *Begin Again Again* (1991) hypercello (Boosey & Hawkes)
- Sofia Gubaidulina *String Quartet No. 4* (1993) string quartet (Edition Sikorski)
- Jonathan Harvey *Advaya* (1994) cello, synthesizer and computer (Faber Music)
- Carl Vine *Inner World* (1994) amplified cello and tape (Faber Music)
- John Adams *John's Book of Alleged Dances* (1994) string quartet and loops (Boosey & Hawkes)
- Steve Mackey *String Theory* (1998) string quartet (Boosey & Hawkes)
- Steve Reich *Cello Counterpoint* (2003) amplified cello and multichannel tape (Boosey & Hawkes)
- Peter Sculthorpe *Captain Quiros* (2006) brass, percussion and strings, with amplified cello (Faber Music)
- Richard Barrett *nacht und träume* (2008) cello, piano and electronics (United Music Publishing)

24. Interpreting Notation & Style

Graphic Notation

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- Morton Feldman *Projection I* (1950) and *Intersection IV* (1953) solo cello (Edition Peters)
- John Cage *59 1/2 Seconds for a string player* (1953) solo string instrument (Edition Peters)
- Earle Brown *Music for Cello and Piano* (1955) cello and piano (Associated Music Publishers Inc.)
- Cornelius Cardew *Treatise* (1967) any number of musicians with any instruments (Edition Peters)
- Siegfried Palm *Pro Musica Nova: No. 1* (Becker, 1968), *No. 2* (Engelmann, 1970), *No. 6* (Kelemen, 1969) solo cello (Breitkopf & Härtel)
- Raine-Reusch *Sparrow's Wing* (2007) cello two bows (Asza; Canadian Music Centre)

Compositional Currents

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Aleatoric / Indeterminate Music

- Franco Evangelisti *Aleatorio* (1959) string quartet (Edition Tonos)
- Henri Pousseur *Ode* (1961) string quartet (Universal Edition)
- Witold Lutosławski *String Quartet* (1964) string quartet (Chester Music)
- Roman Haubenstock-Ramati *String Quartet No. 1* (1973) string quartet (Universal Edition)

New Complexity

- Brian Ferneyhough *Time and Motion Study II* (1976) singing cellist and live electronics (Edition Peters)
- Richard Barrett *Ne songe plus à fuir* (1986) amplified cello (United Music Publishers)
- Klaus H. Hübler *Opus Breve* (1987) solo cello (Breitkopf & Härtel)

Fluxus / Intermedia

- John Cage *4'33* (1952) Tacet (any instrument or combination of instruments) (Editions Peters)
- György Ligeti *Poème symphonique* (1962) 100 metronomes (Boosey & Hawkes)

Minimalism

See above 'Phasing & Repetition'.

Spectralism

- Kaija Saariaho *Sept Papillons* (2000) solo cello (Chester Music)
- William Dougherty *The Aureole Effect* (2012) string quartet (<http://www.williamdougherty.org/>)

Appendix V: Practical Component - Recital

Recital Details

Time & Date	5:00-7:30pm, Friday 16 October 2015		
Location	Deptford Town Hall, New Cross Gate, London		
Performers	Ligeti Quartet	Mandhira de Saram (violin 1)	
		Patrick Dawkins (violin 2)	
		Richard Jones (viola)	
		Val Welbanks (cello)	
	Fei Ren (piano)		

Programme

Witold Lutoslawski (1913-1994)

String Quartet

Introductory Movement

Main Movement

Sacher Variation, for solo cello

Kaija Saariaho (b. 1952)

Sept Papillons, for solo cello

Im Traume, for cello & piano

INTERVAL

Sofia Gubaidulina (b. 1931)

Ten Preludes for Violoncello Solo

staccato - legato

legato - staccato

con sordino - senza sordino

ricochet

sul ponticello - ordinario - sul tasto

flagioletti

al tasto - da punta d'arco

arco - pizzicato

pizzicato - arco

senza arco, senza pizzicato

String Quartet No.3

Notes

Foundations of Modern Cello Technique

Throughout their studies, cellists use short technical exercises such as scales and études which, under the supervision of a teacher, provide the skills necessary to play the repertoire. Etudes in particular – formal, pedagogical works which developed in tandem with the rise of the 18th-century virtuoso – are designed to strengthen specific technical notions in a musical context, providing access to more demanding repertoire.

Surprisingly, however, the last significant collection of études for the cellist is Popper's *High School of Cello Playing*, written in 1905.

The rich palette of extended techniques for cello, achieved through a century of innovation and experimentation, has no equivalent representation in didactic literature. The cellist who desires, or is required, to meet this new rise in virtuosity must essentially decipher new idioms alone, unless fortunate enough to work with a specialist who will pass on the fruits of personal experience. In my thesis *Foundations of Modern Cello Technique*, I suggest that many of the problems which modern music faces today are connected to the performer's dearth of proficiency concerning certain musical and instrumental techniques. As I demonstrate through a survey of pedagogical material, few steps have been taken to enable cellists to gain the technical fluency needed for providing engaging performances of 20th- and 21st-century repertoire.

In my thesis, through interviews with contemporary music specialists, the study of existing publications, and my own performing experience, I present the cello's extended techniques as a linear progression of traditional technique. Three future projects guide the content and structure of my thesis: curriculum development, the creation of an online database, and the commissioning of concert études modelled on Paganini's *24 Caprices for Solo Violin*. The 24 sections of the thesis guide the reader through a technique's origin and development, basic acoustical information, and performance advice, creating a pedagogical framework. Only with a clear methodological approach can contemporary music be expected to become more than a specialism.

The repertoire in this concert programme has been selected to demonstrate the correlation between modern études and the effective performance of a concert work by the same composer. The solo works presented (though not called études as such) are essentially – by their format and content – études. Because each of the solo works in this programme focuses intensively on specific aspects of that composer’s music, these could be used as a pedagogical exercise to prepare a student for the performance of the concert works – chamber music and concerti – of the same composer.

Using this type of work to shape an instrumentalist’s skill dates back to the early 18th century. Various known as studies, études, or caprices, they were traditionally written by virtuoso cellists, who although not necessarily outstanding composers themselves, did often befriend and premiere the works of the great geniuses that we still revere today. The 20th century saw a partitioning of the role of performer and composer, and with the multitude of idiom and technical vocabulary which blossomed in its wake, short works such as those included today become a precious resource for performers. The presentation of these works aims to underline the main argument of my doctoral thesis, which is the creation of a pedagogical infrastructure for the study of modern music.

We begin with **Lutoslawski**’s substantial *String Quartet (1964)*. It is structured in two movements which are built of episodes or ‘mobiles’, culminating in an *appassionato* and *funebre* section. Throughout, the composer uses ‘controlled aleatorism’ which allows the performer a certain amount of freedom regarding pitch and rhythm (for example, the length of pause and the rate of *accelerando* and *ritenuto*). Much of the time the four players perform their musical material either independently of each other, or reacting to certain cues. This is all done in such a way, however, that the outcome is calculated and predictable; the composer is like a grand master who has foreseen all possible moves in a game of chess. One could think that performing with little regard as to what one’s colleagues are doing could be liberating, but this score presents much of the same issues as, say, a Mozart quartet. Articulation is meticulously notated in this music, and lines are clearly cut and characterized.

Lutosławski's *Sacher Variation (1975)* is presented as a conclusion of sorts. Written over a decade after the quartet, this miniature highlights much of the technique specific to Lutosławski's music, most notably quarter tones (the notes located exactly half-way between the twelve notes of the chromatic scale). This piece was commissioned by Rostropovich, along with 11 other works by the foremost composers of the day, to celebrate the 70th birthday of the conductor Paul Sacher. All the works are based on the letters of his name: S (Es), A, C, H, E, R (Ré), or in English note names Eb, A, C, B, E, D, charmingly iterated in the final bars.

Sept Papillons (2000) was commissioned by the Rudolf Steiner Foundation and composed by **Saariaho** for Anssi Karttunen, her former classmate at the Sibelius Academy. Each of the small tableaux 'seem to be studies on a different aspect of fragile and ephemeral movement that has no beginning nor end', to cite Karttunen's own description of the work. I first discovered Saariaho's music through this piece, which I performed in 2008 for my Master's recital at the Royal Academy of Music. It was while studying *Sept Papillons* that I first recognized the deficiency in pedagogical materials and the lack of structure within educational establishments concerning new music. Indeed, the initial thoughts which led to my doctoral thesis were prompted by this piece. *Sept Papillons* was my first initiation to the prolonged use of pressure techniques, rapid variations in point of contact, and this work extended my understanding of harmonics – techniques that are an integral part of Saariaho's musical idiom.

Familiarity with this language allowed me to better understand *Im Traume (1980)*, which concludes the first half of this programme. Commissioned by the Finnish Broadcasting Corporation, it is 'Saariaho's earliest work explicitly associated with dreams' (Anni Oskala's *Dreams about Music, Music about Dreams*). Saariaho's aims in this piece were 'to construct a formal whole which progresses as I think our dreams often progress: as fast transitions, seemingly irrational yet meaningful associations. Moods change unexpectedly or gradually, metamorphoses change the familiar into something new.' Oskala points out the rapid changes of tempo, texture, and dynamic (over 50 markings of *subito forte* and *piano*). Beneath this seemingly unconnected material, the harmony is anchored around the pitches C, C#, D, D#, G, G# and A. The

distinct musical textures are created by hitting the instruments and tapping the strings with the fingers; the cello bows on the other side of the bridge, and plays near the bridge (*sul ponticello*) to create a harmonic-rich sound, and the pianist drops a heavy book on the strings while depressing the pedal.

The second half of this programme features the music of Russian-Tatar composer **Sofia Gubaidulina**, who can be placed among the Soviet musical avant-garde of the pre-war generation together with Schnittke, Pärt, Silvestrov and Denisov. An ‘unofficial’ composer until Perestroika, she was largely unknown to the West and in her own country until 1986, when she was first allowed to travel abroad. Since emigrating to Germany in 1991, she has earned the reputation and the many prizes and honours worthy of a life-time of hard work and dedication.

The *Ten Preludes for Violoncello Solo (1974)* were suggested by my supervisor, the late Alexander Ivashkin, at the earliest stages of my research, and have proved central to my thesis work. They represent the potential of the étude as a means to gain access to a certain sound world, and place the learning of a new technique or musical aspect in relation to the long tradition established by the early masters of the instrument.

The *Ten Preludes* were written under the title ‘Ten Etudes’; the title was later changed on the impetus of the dedicatee, cellist Vladimir Tonkha, a title he felt better represented the work’s artistic value. In the early 1970s, Gubaidulina was approached by the cello professor at the Novosibirsk Conservatory, Grigory Pekker. Biographer Michael Kurtz narrates with tongue-in-cheek what would have been at the time a frustrating situation:

[Pekker] was planning to issue a collection of études for his students, and since few were available, he got in touch with several composers. [He] must have been considerably puzzled when he first looked at Gubaidulina’s études in 1974. She had used these ten pieces to explore different kinds of musical expression through different kinds of sound production on the cello. [...] Because Pekker had never studied contemporary music, he did not know what to do with the score he had been sent and simply ignored it.⁴⁴¹

⁴⁴¹ Kurtz (2007), p. 132.

Alexander Ivashkin explains in the liner notes to his recording of the *Ten Preludes* that Gubaidulina ‘wanted to explore and demonstrate unusual ways of dealing with well-known, traditional techniques for the instrument’. Gubaidulina’s *Preludes* are of undeniable value when learning to perform her large output of music for the cello, though they do not necessarily have any correlation to the music of her contemporaries. As a composer, Gubaidulina has been described, and describes herself, more as a filter than an innovator⁴⁴² – an observation most resonant when compared with the leading American experimental and European avant-garde composers of her generation – but her writing for the cello involves very distinctive elements which could be unfamiliar to a cellist approaching her music for the first time.

One can of course only speculate as to how much consideration was given during composition to the students prospectively studying her works. Though they were never published or used explicitly as études, their value as formative pieces is indisputable.

Given that the étude is a workspace in which a particular technical aspect is isolated and explored, Gubaidulina understood and exploited a tool which few composers have in the 20th and 21st centuries. Some of the études explore extreme versions of traditional techniques; others explore extended techniques, and others still only traditional techniques but always through the idiom of the composer. Graphic notation that is often seen in Gubaidulina’s works is also occasionally used. These pieces are thoroughly individual and idiomatic of Gubaidulina’s own compositional style, but first and foremost, this work’s true value lies in its format – Gubaidulina is one of the few composers in the 20th century to generate a digest of her individual style and techniques as a legacy.

The programme concludes with Gubaidulina’s *String Quartet No. 3 (1987)*, premiered on August 22, 1987 at the Edinburgh Festival by the Arditti Quartet. This single movement work found inspiration in lines from T.S. Eliot’s *The Waste Land*. Thanks to Prof Ivashkin’s encouragement, the Ligeti Quartet has extensively performed both the third and fourth string quartets, including to the composer herself, and I have performed

⁴⁴² This description has been made by both Stockhausen and Gubaidulina herself. Kurtz (2007), p. 69.

Appendix V: Practical Component - Recital

Sonnengesang for soloist, chamber choir and percussion with Ivashkin conducting.

Throughout this extensive exploration of Gubaidulina's music, I found myself returning to the *Ten Preludes* as a reference, my understanding of the phrasing, musical structure and techniques stemming from these. Following the prolonged opening passage of pizzicato harmonics and pizzicato-glissandi, two of the most distinctive techniques used in the third quartet can be heard initially in the tenth *Prelude*: hitting the string with the left-hand finger (*con le dita* or finger percussion), and pizzicato-tremolo.

It is with affection, profound respect, admiration, and gratitude that I dedicate this recital and my thesis to the memory of Alexander Ivashkin, and to his wife and my mentor, Natalia Pavlutskaya.

Val Welbanks

The image displays two staves of musical notation for piano. The top staff features a complex rhythmic pattern with various time signatures (2/4, 3/4, 4/4) and dynamic markings such as *f*, *p*, *subitopp*, and *ppp*. It includes technical instructions like "MARTINO" and "8 va." (8va). The bottom staff continues the piece with similar rhythmic complexity, including markings for *fff* and *p*, and a tempo marking of $\text{♩} = 60$. The notation is dense and intricate, characteristic of Ligeti's style.

Excerpt from Saariaho's *Im Traume*

Val Welbanks leads a busy chamber music career as the cellist of both the Ligeti Quartet and the Marsyas Trio. The **Ligeti Quartet** is dedicated to bringing modern and

contemporary music to all those who will listen, packing concert halls, art galleries, theatres, nightclubs, and last August even a fishing boat. The quartet has performed at the Wigmore Hall, Purcell Room, LSO St Luke's and international festivals including the Pablo Casals Festival (France), Musik 21 Nachwuchsfestival (Germany) and 'HellHot!' New Music Festival (Hong Kong). The quartet's first CD (Signum Classics, 2016) includes Peter Maxwell Davies's trumpet quintet. The **Marsyas Trio** presents music from all eras written for flute, cello, and piano, and is also active in commissioning new works. It is supported by the Arts Council England, RVW Trust, Ambache Charitable Trust, Hinrichsen Foundation and Britten-Pears Foundation for their work with composers and in 2011 received a Women Make Music award from the PRS for Music Foundation. The trio released *A Triple Portrait; Chamber Music of Elena Firsova* in May with Meridian Records.

Val is currently completing her PhD at Goldsmiths College (University of London) on the pedagogy of contemporary music. She is researching under the supervision of composer Roger Redgate, and previously the late cellist Alexander Ivashkin. In 2008, she obtained a Masters in Music Performance at the Royal Academy of Music in London, graduating with distinction from Philip Sheppard's class. Her passion for cross-disciplinary arts sees her often performing in plays, operas, dance productions, sound installations, and recently, a shadow puppet project initiated by the Marsyas Trio. She has performed both Lutosławski's and Dvořák's Cello Concertos with the Torbay Symphony Orchestra.

ligetiquartet.com

marsyastrio.com