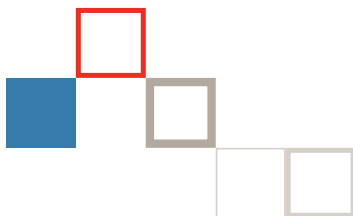
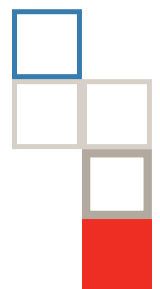


MUSIC AND NUMBERS

FRIDAY 14 MAY - SATURDAY 15 MAY 2010

1 Conference Programme 2010

Department of Music
Canterbury Christ Church University



We would like to express our sincere thanks to the following organisations for their support of this conference: Canterbury Christ Church University, the Sounds New Music Festival, the Institute of Musical Research (IMR) and the Society for Music Analysis.



Welcome

On behalf of the Department of Music, I would like to offer delegates a warm welcome to Canterbury Christ Church University and the Music and Numbers Conference 2010. I am sure this will be an exciting academic and artistic event, which will provide us all with a stimulating exchange of ideas, supplemented by some outstanding music performances. It has been a great pleasure to organise this conference and to have it coincide with, and augment, the long-established Sounds New Music Festival in Canterbury. We are delighted that the Department of Music is once again able to demonstrate its significant position on the international academic stage through hosting this conference, and we are honoured that so many distinguished scholars, composers and musicians will be joining us from all over the world. I hope you will have a rewarding and enjoyable time with us, and that you will also be able to explore the delights of one of England's most historic cities while you are here.

Dr Eva Mantzourani
Conference organiser

Conference Programme

Friday 14th May

8:30 – 12:00 2:15 – 4:00	Registration (Lg21 – Laud Building)		
10:15	Welcome Powell Building – Room: Pg09		
10:30 – 12:00	Room: Lg16	Room: Lg27	Room: Lg26
	Session 1 Chair: Ivor Grattan-Guinness	Session 2 Chair: Anton Vishio	Session 3 Chair: Richard Glover
10:30 – 11:00	Philip Maher 'Music and? mathematics'	Richard Dumbrill 'Mesopotamian origins of heptatonism'	Jonathan Pitkin 'Raising expectations: patterns, predictability and deferring the inevitable'
11:00 – 11:30	James Wright 'Wittgenstein's conception of mathematical "scaffolding" and the problem of formalism in post-tonal theory and composition'	Anton Luiten '7 Up: the case of the returning interval'	Dorothy Ker 'Music, number and space'
11:30 – 12:00	Nikita Braguinski 'Eduard Grell's systems of just intonation: nature vs. technology?'	Izabela Bogdan 'Fuga musicalis mathematica: this is how to solve a mathematical-musical puzzle and transform numbers into notes'	Michael Young 'Interplay: feature spaces in human-computer improvisation'
12:00	Lunch – Blue Room, SCR		
1:15 – 2:15	Lunchtime concert at St Gregory's Centre for Music UK Conservatoires composers' concert – A Day of Premières		
	Room: Lg16 Room: Lg16		
	Keynote address (Chair: Douglas Jarman)		
2:30 – 3:30	Dr Ruth Tatlow 'Between a rock and a hard place: the problems and possibilities of research into number and music'		
3:30 – 4:00	Coffee break – Room Lg21		

4:00 – 5:30	Room: Lg16	Room: Lg27	Room: Lg26
	Session 4 Chair: Stephen Cottrell	Session 5 Chair: Roy Howat	Session 6 Chair: Michael Young
4:00 – 4:30	Christopher Mark 'Calculating effect: Roger Smalley and the Fibonacci series'	Michelle Phillips 'The Golden Section: seen but not heard?'	Richard Hoadley and Tom Hall 'Towards embodied control of algorithmic music'
4:30 – 5:00	William Lake '7 and 13 (and other prime numbers): George Crumb's numerology and proportional schemes in Black Angels'	Bonny Miller 'Sounding the soul in Schoenberg's Herzgewächse'	Pete McAllister and Mark Gotham 'Towards a method for algorithmic segmentation'
5:00 – 5:30	Blair Johnston 'Magical numbers, the God-Devil polarity and harmonic-structural synthesis in George Crumb's Black Angels'	Mark Delaere 'The number 7 as representation of perfection in Karel Goeyvaerts's music'	
5:30-7:00	Drinks Reception at St Gregory's Centre for Music (co-sponsored by the CCCU Department of Music and the Institute of Musical Research)		
7:30	Evening concert in Canterbury Cathedral A Tribute to Mahler City of Birmingham Symphony Orchestra Chamber Players Mezzo soprano: Karen Cargill; Tenor: Brian Cefai Claude Debussy, Prélude à l'après-midi d'un Faune (arr. Sachs) Arnold Schoenberg, Verklärte Nacht Gustav Mahler, Das Lied von der Erde (arr. Schoenberg/Riehn)		

Saturday 15 May

8:30 – 12:00 2:15 – 3:30	Registration (Lg21 – Laud Building)		
9:00 – 10:30	Room: Lg16	Room: Lg27	Room: Lg26
	Session 7 Chair: James Wright	Session 8 Chair: Richard Hoadley	Session 9 Chair: Dorothy Ker
9:00 – 9:30	Georgia Tserpe 'The number 3 as an element of background structure and meaning in Christos Samaras's "Three Songs"'	Richard Glover 'The use of numerals in experimental notation'	Tomasz Kienik 'Teacher and composer surrounded by ideas of music and numbers'
9:30 – 10:00	Michael Rofe 'Nested proportions in the symphonies of Dmitri Shostakovich'	Anton Vishio 'The rhythm of queninas: number and order in musical dialogue'	Jeremy Richards 'The use of number in the music of Josquin and his contemporaries'
10:00 – 10:30	Alicja Jarzębska 'Proportion and numbers in Stravinsky's dodecaphonic compositions'	Henrik Ekeus 'Exploring and composing with difference tones: the creation of "One Half Step"'	Stace Constantinou 'The use of "Fibonacci" and "prime number" sequences in the creative compositional process'
10:30 – 11:00	Coffee break – Room: Lg21		
	Keynote address (Chair: Ruth Tatlow)		
11:00 – 12:00	Roy Howat 'Practical aesthetics of musical numbers and proportions'		

12:00	Lunch in the Food Hall, SCR		
1:15-2:15	Lunchtime concert at St. Gregory's Centre for Music Seven Haiku – a piano recital Piano: Eliza McCarthy		
	Room: Lg16		
	Keynote address (Chair: Roderick Watkins)		
2:30 – 3:30	Professor Douglas Jarman 'Musemathematics and the shining seven'		
3:00 – 4:00	Coffee break – Room Lg21		
3:00 – 5:30	Room: Lg16	Room: Lg27	Room: Lg26
	Session 10 Chair: William Lake	Session 11 Chair: Pete McAllister	Session 12 Chair: Christopher Mark
4:00-4:30	Regina Chłopicka 'Numerical inspirations in the music of Krzysztof Penderecki'	Bernard Gates 'Multiplicative transformational cycles in Berg's Op.2 and Op.5'	Christian Berger 'Josquin's Ave Maria in the focus of numbers'
4:30-5:00	Wai-Ling Cheong 'Playing with numbers: Messiaen's coordinates of linear and vertical sequences'	Tom Hall 'Twelve-tone time: analytical and compositional applications of Babbitt's time-point series system using custom software'	Alon Schab 'Purcell's early experimental forms: lists, cycles and numbers'
5:00-5:30	Michael Chandler '8 is the new 7: the symbolic representation of the "eighth day" in Messiaen's Quartet for the End of Time'	Brenda Ravenscroft 'Beyond the numbers: rhythmic structure and expression in Elliott Carter's vocal music'	Ivor Grattan-Guinness 'Why 18? Masonic numerology in Brother Mozart's music'
5:30-7:00	Drinks Reception in 'Touchdown' Laud Building (co-sponsored by the CCCU Department of Music and Sounds New Music Festival)		
7:30	Evening concert at St. Gregory's Centre for Music		
	The Number 7: The Creation and the Apocalypse Ossian Ensemble		
	Part 1 – CREATION		
	LIGHTPeter Maxwell Davies 7 Brightnesses		
	THE HEAVENSJonathan HarveyQuantumplation		
	THE LAND AND THE SEABent SørensenThe Deserted Churchyards		
	THE HEAVENLY BODIESPatrick NunnMusic of the Firmament		
	FISH AND BIRDSAnne BoydGoldfish through Summer Rain		
	ANIMALS AND MANDarren BloomEden (World Première)		
	DAY OF RESTBryn Harrison a leaf falls on loneliness (World Première)		
	Part 2 – APOCALYPSE		
	Olivier MessiaenDance of Fury for the 7 Trumpets (from Quartet for the End of Time)		
	Peter Maxwell DaviesAntechrist		
	Peter Maxwell DaviesMissa Super l'Homme Armé		

Abstracts

Douglas JARMAN

(Royal Northern College of Music, UK)

DOUGLAS JARMAN is Emeritus Professor of the Royal Northern College of Music and Visiting Distinguished Scholar in the Faculty of Humanities at the University of Manchester. His book *The Music of Alban Berg* was published by Faber and Faber/University of California Press in 1979. He has since published two monographs on the Berg operas (*Alban Berg: Wozzeck* (1989), *Alban Berg: Lulu* (1991)) and some thirty articles on Berg's music; a book on Kurt Weill (*Kurt Weill: An illustrated biography*, 1982), and has edited books on Henze (*Henze at the RNCM, 1998/1999*), *Expressionism (Expressionism Reassessed, 1993)* and *The Twentieth Century String Quartet* (2002). His critical editions of the Berg Violin Concerto and of the Chamber Concerto, which was awarded the Deutsche MusikPreis, appeared in 1996 and 2004 respectively as part of the *Alban Berg Gesamtausgabe* (U.E, Vienna and the Alban Berg Stiftung).

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Musemathematics and the shining seven

'Grandest number in the whole opera, Goulding said. – It is, Bloom said. Numbers it is. All music when you come to think of it'. (James Joyce, *Ulysses*).

According to Stefan Zweig, the years following the First War were years in which 'every idea that was not subject to regulation reaped a golden harvest: theosophy, occultism, spiritualism, somnambulism, anthroposophy, palm-reading, graphology, yoga and Paracelism'. In fact, however, an interest in such things was characteristic of the intellectual thought in the period spanning the whole period of the last decade of the nineteenth and the early decades of the twentieth century.

The works of Swedenborg, the teachings of people like Gurdjieff and Ouspensky and the writings of Helena Blavatsky and Rudolf Steiner, with their emphasis on the esoteric and the mystical, had a widespread influence on intellectual and artistic thought of the time. Such quasi-philosophical and religious ideas were bolstered by the quasi-scientific work of people like Paul Kammerer (whose study of coincidence in the Law of the Series Albert Einstein regarded as 'interesting and by no means absurd'), Hermann Swoboda, Freud's colleague Wilhelm Fliess and Schoenberg's friend and fellow chamber music player the astrologist Oskar Adler.

A feature of much of this thought was a belief in periodicity, of events and time itself moving in endlessly recurring cycles (Nietzsche's 'eternal return') the regularity of which were determined by significant numbers – the number seven, according to Blavatsky and Steiner, the numbers 23 and 28 according to Swoboda and Fliess.

Berg's interest in astrology and numerology, his familiarity with the work of Fliess and his belief in the personal significance of the Fliessian number 23 is well known. This keynote address will consider Berg's use of numbers as structural determinants in the wider context of intellectual thought at the time and will attempt to relate it to his fascination with palindromic structures. It will also discuss some of the compositional strategies through which he handles the perceptual problems created for the listener by such palindromes.

Ruth TATLOW

(Stockholm University, Sweden; Eastman Music School, Rochester, NY, USA)

Between a rock and a hard place: the problems and possibilities of research into number and music

Number studies have a justifiably infamous reputation among musicologists, earned by the heritage of literature riddled with factual error, insupportable methodology, and results pursued 'with more vigour than discretion'. And yet it need not be so. If the most fundamental methodological errors are eradicated, and the legacy replaced by scholarship of integrity based upon clear analytical principles, it should be possible to set the discipline onto a new and respectable footing.

Principle Number One: 'To find numbers in a score is no proof that the composer consciously devised them'. Adherence to this simple dictum could have prevented the publication of countless embarrassing claims and interpretations in the past, and in the future could set the foundation for new levels of discovery. Principle Number Two is equally simple, but more complex to solve: 'Find analytical methods appropriate to the questions being asked'. For example, if we want to find out whether a composer used numbers when he composed, how would we do it? If we want to know whether numerical patterns can be found in a composition, how would we do it? Although these two questions sound similar, they are entirely different, requiring different techniques, which give results of an entirely different nature. The former requires finding a method of retracing the composer's steps by using techniques that the composer would have recognised. If the results indicate that the composer seems to have used numbers, the analyst is then at liberty to ask why the composer used those particular numbers, and even what the numbers meant to the composer. If on the other hand the analyst wants to pursue the second line of inquiry, and limit his search to the score, regardless of the composer's compositional method, to see if there are numerical patterns in a composition, he is at liberty to use any technique for the search, uninhibited by whether or not the composer would have recognised the techniques. And in this case it is not only irrelevant but also inappropriate to ask why the composer used the numbers, or what the numbers meant to the composer, as the composer did not consciously devise the numbers in the score. The differentiation between conscious compositional action and the analytical result is paramount if research into numbers and music is to have a future.

In this paper I will a) illustrate some of the most frequently recurring problems within the discipline of numbers and music; b) correct some common myths using examples from golden numberism and cabbalism, and, elucidating principles from the new Historically-Informed Theory (HIT) movement; c) suggest some positive ways in which research into numbers and music can progress. Although the focus will be primarily on the problems concerning music composed before the twentieth century, the principles of HIT are valid for all Western art music.

RUTH TATLOW'S research into the history of musical ideas and theory, numerical processes and compositional methods, particularly in the music of J.S. Bach, is reflected in her publications, which include *Bach and the Riddle of the Number Alphabet* (Cambridge, 1991, 2006), many articles, commercial liner notes, and the web journal *Understanding Bach* (2006-), for which she is both designer and editor of the first three volumes. She has received numerous awards for her writing and research, including fellowships from the Leverhulme Trust, the Hinrichsen Foundation, the Swedish Vitterhetsakademien and Kungliga Musikaliska Akademien. From January to May 2010 she is/has been visiting professor in the Music Theory Department of Eastman Music School, Rochester, NY. As research consultant to the conductor John Eliot Gardiner (1999-2003) she wrote extensively on church cantatas for the renowned *Bach Pilgrimage*. In 2003 she co-founded *Bach Network UK*, and as lecturer and broadcaster, she has been a guest on numerous radio programmes, including the BBC's popular 'In Our Time' hosted by Melvyn Bragg. Ruth Tatlow is currently Chair of the Advisory Council of *Bach Network UK*, and serves on the editorial board of the *American Bach Society*. Her second monograph *Bach's Numbers? A Riddle Unravelled* is in preparation.

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Roy HOWAT

(Royal Academy of Music, UK)

ROY HOWAT is internationally known as both scholar and pianist, whose piano teachers included close colleagues of composers including Fauré, Ravel and Poulenc. As a Music Scholar at King's College Cambridge, Roy started making the discoveries about Debussy's use of form that led, via his doctoral thesis, to the groundbreaking book *Debussy in Proportion* (Cambridge UP, 1983). Roy knows much of his concert repertoire from the composers' manuscripts, and has been a principal editor of equally groundbreaking critical editions of piano music by Debussy and Chabrier, and piano and chamber music by Fauré. In the last year his new book *The Art of French Piano Music* (Yale UP) has received several awards, including an 'Outstanding' citation from *International Record Review* and 'Book of the Year 2009' from *International Piano*. He regularly tours worldwide as concert pianist and lecturer, has recorded numerous CDs, and holds the post of Keyboard Research Fellow at the Royal Academy of Music.

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Practical aesthetics of musical numbers and proportions

This keynote address looks at the architectural and aesthetic implications of proportional systems that can be observed running under the surface of one piece by each of the composers Ravel, Fauré, Chabrier, Debussy and Schubert (discussed in that non-chronological order for reasons of logic). An immediate focus of interest is to spot the common properties that underlie and link these apparently very different structures and musical languages, even before the mid-twentieth century got its teeth explicitly into such matters in a big way.

Beyond that, a dominating question is: do the numbers involved appear to represent anything numerologically, or in the composers' minds, or in their ascertainable techniques; or are the numbers merely dumb components of the larger proportional systems? This question impinges on the larger-scale one of whether the proportional systems too 'represent' anything or are there purely for architectonic or aesthetically functional purposes – or indeed whether or not they were deliberately planted at all. How safely can we reach any conclusions on those matters? Indeed, how aesthetically and technically valid are the units or techniques we select for measuring such largely temporal structures, particularly when we primarily perceive the analyses in visual terms? All this links to the common-sense issues raised in Ruth Tatlow's address, including that of not accidentally confusing 'composer intentions' with 'discoveries in a score'; it also raises general issues of number representation that Douglas Jarman's address explores in more practical detail.

For the present address, the simplest conclusion is that the numeric systems in question appear to be primarily architectonically functional, rather than identifiable to any numerological or symbolic strand or tradition. Yet some degree of play with particular numbers per se and geometrical games does seem to lurk in each of them; indeed that is the issue that most closely links them.

Regardless of the hazards inherent in this entire field, and the need for constant common-sense safeguards in our analyses, what we find can provide highly useful ideas for composers, performers and listeners alike. Related to the issue of 'composer intentions' possibly versus 'discoveries in a score' – given our composers' almost complete silence on this issue – is the question, how important is it for performers or listeners to know about such structures? When might it be better for us to forget? Did composers sometimes 'forget' in that manner? In line with Ruth Tatlow's address, I'd like these questions and resulting perceptions to appeal to both our common sense and our artistic sense when we perform, compose or listen.

Christian BERGER

(Freiburg University, Germany)

Josquin's Ave Maria in the focus of numbers

In many ways music is associated with numbers: as 'scientia musica' and part of the Quadrivium music theory illustrates the calculation of proportions; as conversion of words by means of the Gematrie the numbers are able to symbolize meanings. Always a number is treated as symbolic, and so a basic possibility has been lost to sight: the structuring based on numberful criteria without any meaning, according to Boethius, 'From the beginning, all things whatever which have been created may be seen by the nature of things to be formed by reason of numbers.' (De inst. Arithm., I, 2, ed. M.Masi 1983). Both text and music go back to their basic elements: letters and tones, which are combined in specific ways with numbers. In the Hebrew and Greek alphabets letters are both letters and numbers. Therefore, a gematric equalization is obvious. This corresponds with counting the notes and breves in music. Both together stretch out a complex field of numbers, which is determined by common primes.

The attempt of Jaap van Benthem to examine Josquin's 'Marian motets' for numberful symbols was the starting point of a basic study of their numerical construction exemplified by the motet 'Ave Maria...virgo serena'. The text of this piece is structured in many different ways by the prime 17, whereas the music works with the number 90. Both together including the number of breve and semibreve are structured again by 17. With Josquin we have the lucky situation that we can use a printed version which is edited with the help of Josquin himself, as Glarean testified. So we can count the notes of the motet without the imponderability of a manuscript tradition.

CHRISTIAN BERGER (b.1951)

studied the violin and Music Education at the Musikhochschule in Freiburg and Musicology at Freiburg University with Eggebrecht. After completing the state examination at the Musikhochschule in 1975, he continued his musicological studies with Dahlhaus and Stephan in Berlin and with Reckow and Krumphmacher in Kiel, where he worked as an assistant (from 1980) and later senior assistant (until 1994). He took two postgraduate degrees at Kiel: the doctorate in 1982 with a dissertation on Berlioz's *Symphonie Fantastique*, and the Habilitation in 1989 with a study on French 14th century chanson. In 1995 he was appointed Professor and Head of the Music Department at Freiburg University and he became an editor at the *Musikforschung* in 1998-2001. His research focuses on late medieval music, especially the implications which the medieval hexachord based teaching system has for the polyphonic writing of the Middle Ages, late Baroque instrumental music (Biber), and 18th and 19th century French music, especially Hector Berlioz. Since 2006 he has been working on a new project which deals with Music and Number in late medieval music.

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Izabela **BOGDAN**

(Institute of Musicology, Adam Mickiewicz University, Poznań, Poland)

IZABELA BOGDAN studied English, specializing in cognitive linguistics, at Nicolaus Copernicus University in Toruń, and Musicology at Adam Mickiewicz University in Poznań, where she obtained her PhD in 2007. She has recently published the monograph *Wedding Ceremonies and Renaissance Nuptial Music in Königsberg in the years 1545-1641*. Her scholarly interests focus on the history of Ducal and Royal Prussia, especially on the musical output of the composers active in the city of Königsberg in the sixteenth and seventeenth centuries. She is currently working as an assistant professor at the Institute of Musicology at Adam Mickiewicz University in Poznań.

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Fuga musicalis mathematica: this is how to solve a mathematical-musical puzzle and transform numbers into notes

Throughout music history, numbers have constituted a core of the theoretical discourse about music, influencing the actual practice. Music, defined as 'Scientia Mathematica subalternata comprimis Arithmetica' was based on numbers, referred to as *numeri harmonici*, *numeri sonori* or *numeri musici* that determined proportions corresponding to intervals and tones.

Georg Quitschreiber (1569-1638) was a German theorist, composer and cantor in Jena. He was influenced by Gioseffo Zarlino (1517-1590), whom he considered the founder of the diatonic-syntonic scale. He was also acquainted with the treatises by Sethus Calvisius (1556-1615), Michael Praetorius (1571-1621), Johannes Lippius (1585-1612) and Heinrich Grimm (1592/3-1637), who in their theoretical discourse about music commented on *numeri harmonici* providing examples of 'Zählengesänge', compositions making use of numbers as a means of musical notation.

In this paper I will focus on some exceptional musical pieces by Quitschreiber. In some prints, published on the occasion of weddings, funerals, state events or university ceremonies, we come across his highly interesting 'mathematical-musical riddles'. Quitschreiber presented a certain dedicatee with rows of numbers reflecting the mathematical proportions that, in turn, referred to the exact pitch and duration of particular sounds, which followed a strictly planned harmonic structure and, usually, an elaborate musical form. Below Quitschreiber always provided the 'musical answer', showing the right way of 'translating' the language of mathematics into the language of musical sounds. It is therefore interesting to study in detail the way his mathematical formulas contribute to the creation of a musical form, a process the composer himself refers to as 'fuga musicalis mathematica'.

Furthermore, I will trace the links between Quitschreiber's understanding of music as revealed in his own theoretical treatises or practical 'course books' designed for school use (*De canendi elegantia octodecim praecepta*, 1598; *Musikbüchlein für die Jugend*, 1607) and his musical, mainly occasional output rooted strongly in the world of mathematics. I will also compare his theoretical views and musical pieces with the ones presented by Johannes Lippius in *Disputatio musica prima/second/tertia* (1609-1610) and *Synopsis musicae novae* (1612) or by Heinrich Grimm, the author of *Instrumentum instrumentorum, hoc est, Monochordum, vel potius Dodecachordum* (1634) and a composer of *Fuga Alia 4. Voc. Unisona Mathematicae adsignata*, another mathematical-musical 'recipe' for a polyphonic piece of music.

Nikita BRAGUINSKI

(National Musicological Institute, Berlin (SIMPK), Germany)

Eduard Grell's systems of just intonation: nature vs. technology?

In 2006 a handwritten musical-mathematical manuscript by Eduard Grell (1800-1886), the former director of Berlin's Singakademie, and two accompanying large sets of tuning forks have come to the attention of musicologists working at the National Musicological Institute (SIMPK) in Berlin. In 2009 the Institute invited me to analyse the manuscript and reconstruct Grell's theoretical system in an article that will be published in the Institute's Yearbook of 2011. In my paper I will present my analysis of Grell's previously unknown system of just intonation, I reconstructed from the manuscript and the tuning forks and examine it against the background of several fundamental problems inherent to the just intonation tradition in general.

Grell's development of his ideas about just intonation was, on the one hand, inspired by the existing historical context the Cecilian Movement and the a-cappella ideal and, on the other hand, a major breakthrough in musical acoustics, marked by such publications as Helmholtz's *On the Sensations of Tone* and the increased interest in building 'naturally' tuned instruments with more than 12 tones in an octave. During his last years, after his retirement as the director of the Singakademie, Grell successively developed 13-tone, 24-tone and 64-tone just intonation systems and built an impressive number of tuning forks (more than 300 were found in his personal archive). One set of his tuning forks represents Grell's 64-tone system but with an inaccuracy that seems strange regarding the high number of steps in Grell's scale: most of the tuning forks differ from their 'ideal' position by up to 20 cents.

Starting from this inadequacy of the proposed aim of pureness of intonation and the apparent failure to tune exactly by ear (which was presumably Grell's only option) I will address the tension between the mathematical pureness of proportion in a theoretical system of just intonation vs. the physiological limits of human perception of tone. How is the small number of audible harmonics in the spectrum of a tuning fork related to Grell's forks being out of tune? Would Grell dismiss his ideal of pure intonation as too mechanistic if he had a computer? How mathematically stringent can the musical application of Grell's system (or any just intonation system) be? In analysing the manuscript and the tuning forks, I make use of 2- and 3-dimensional lattices representing pitch in just intonation systems, as well of graphs showing the grouping of tones in a system and the divergence of real frequencies of tuning forks from the ideal frequencies of the system.

NIKITA BRAGUINSKI was born in Moscow in 1976. He studied Musicology, Slavic and German studies at the University of Cologne (Köln). Currently he works as a free musicologist at the National Musicological Institute, Berlin (SIMPK), examining Eduard Grell's personal archive, which is partially held by the Institute. He taught scientific work introductory courses at the Slavic Department of Cologne University in 2004-2007, worked as a free musicologist at the Haydn Institute in Cologne in 2005-2006 and as a research assistant at the National Musicological Institute in Berlin in 2007-2009. Besides the history and ideology of just intonation, his research interests include Russian and Soviet culture. He is the co-editor of a forthcoming collection of articles on Russian film.

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Michael CHANDLER

(Canterbury Christ Church University, UK)

MICHAEL CHANDLER studied music at the Royal Academy of Music, London. Later he studied sacramental theology at the Institute Catholique in Paris. He returned to music studies in the 1990s, receiving a Masters in Piano Performance at (as then) Canterbury Christ Church College. He subsequently followed a doctoral programme at Canterbury Christ Church University, and received his PhD in 2007; his doctoral dissertation is entitled: *At The Still Point of the Turning World: The Relationship between Time and Eternity in Messiaen's 'Quatuor pour la fin du Temps [1941]'*. He is currently lecturer and staff accompanist at the music department of Canterbury Christ Church University, as well as music tutor for the Workers' Educational Association (WEA). He also gives occasional piano recitals in Canterbury and beyond.

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8 is the new 7: the symbolic representation of the 'eighth day' in Messiaen's Quartet for the end of Time

In the preface to his *Quartet for the End of Time* Messiaen offers a vision of eternity that is primarily characterised by eternal Light. The Judeo-Christian symbolism that Messiaen chooses to employ (mostly ignored by commentators of this work) in order to portray this vision of a perfect, complete and unchanging eternal realm is that of the 'eighth day': 'This Quartet comprises of 8 movements. Why? Seven is the perfect number, the creation of 6 days sanctified by the divine Sabbath: the 7 of this rest prolongs itself into eternity and becomes the 8 of light without defect, of unalterable peace.' It is evident that Messiaen is not referring to any specific movement or movements as representing the six days of creation or the 'Sabbath' of God's rest on the seventh day: the work is not concerned with the Genesis of the first days of creation, but with the symbolic representation of the Apocalypse of the Last Days. Furthermore, the sixth and seventh movements of the Quartet do not correspond to the description given by Messiaen of the significance of the numbers 6 and 7. Even though a case can be made for the eighth movement as symbolising unalterable peace, the theological concept of the 'eighth day' in relation to the Quartet is not to be interpreted solely as referring to an individual movement, but as a symbol of the work's significance and meaning in its totality.

This paper will explore the underlying concept of the 'eighth day' as the 'circular' simplicity of eternity. The 'first day' of creation is that on which God reveals his inner Light of revelation, and, consequently, is not like any ordinary day on the 'linear' continuum of history, but is the unique day of the 'beginning' of God's light. It is also to be understood that the 'first day' of creation is a mirror of the last 'eighth day' of creation, the Apocalypse, when 'there will no longer be Time'. Thus the 'first' and the 'eighth (last)' days, though differentiated, together become symbols of eternity, in which the boundaries of beginning and end are conjoined. This concept of the 'eighth day' will be explored in relation to its use within Messiaen's *Quartet for the End of Time*. A particular focus will be directed towards its representation through symbolic constructs, including the non-retrogradable rhythm, exploring the intersection of music and mysticism in these musical symbols:

Amen, parole d'initiation, de médiation, de consommation –

Amen, parole de la Genèse, qui est l'apocalypse de l'ouverture.

Amen, parole de l'Apocalypse, qui est la Genèse de la consommation ...

(Amen, word of initiation, of mediation, of consummation – / Amen, word of Genesis, which is the apocalypse of the beginning. / Amen, word of the Apocalypse, which is the Genesis of consummation ...) (Messiaen, citing Hello).

Wai-Ling CHEONG

(The Chinese University of Hong Kong)

Playing with numbers: Messiaen’s coordinates of linear and vertical sequences

Existing studies of Messiaen’s permutation techniques tend to focus on symmetrical permutation (permutations symétriques or réinterversions symétriques limitées). Messiaen takes much pride in it, as testified by his delineation of the ‘nuts and bolts’ of the technique on a good number of occasions. Significantly, symmetrical permutation is grouped with Messiaen’s modes of limited transpositions and non-retrogradation to constitute a trilogy of techniques devoted to the charm of impossibilities. The crux of all three techniques lies in the setting up of specific delimitations — tied up with symmetries of one kind or another — to reduce the number of possibilities that would otherwise set in.

The derivation of $n!$ permutations out of n components works well in cases that involve just a handful of components, but the permutation of say 12 components to generate 12! permutations is plainly out of the question. Messiaen’s first use of symmetrical permutation appears in *Île de feu 2* (1950). In this experimental miniature Messiaen reduces the choices opened up by the astronomical 12! permutations to a mere twelve permutations by fixing the change of positions that takes place between consecutive permutations (see Appendix). More specifically, in *Île de feu 2*, the twelve pitch-classes are reshuffled to occupy each of the twelve positions only once, and thus the vertical alignment of all the twelve symmetrical permutations creates only one vertical sequence of the twelve pitch-classes, which keeps them rotating in the same order. The symmetrical permutation schemes of *Catalogue d’oiseaux* (1956–58), *Chronochromie* (1959–60) and other later works, which generate well over thirty rather than just twelve permutations, might strike us as much more complex in setting; nevertheless, the ruling principle remains unchanged.

In this paper I shall argue that Messiaen’s penchant for the superimposition of pedals in his earlier works, such as the ‘Liturgies de crystal’ of the *Quatuor pour la fin du temps* (1940–41), may explain his subsequent move to superimpose the symmetrical permutations. While the superimposition of pedals of different lengths creates vertical alignments that vary until the initial one is regained, in the case of symmetrical permutation, regaining the initial vertical alignment is no longer an issue, for the tireless repetition of pedals is abandoned. Just as the varied lengths of the superimposed pedals (their lowest common multiple) dictate the number of times the pedals need to be repeated before the initial vertical alignment recurs, in a symmetrical permutation scheme, the lengths of the vertical sequences (created by the superimposition of symmetrical permutations) may vary, and their lowest common multiple dictates the total number of permutations. The coordinates of variance and invariance that inhabit respectively the vertical and linear dimensions of the superimposed pedals are thus, in this sense, shifted around to control the linear and vertical dimensions of the superimposed symmetrical permutations.

Appendix:	The twelve symmetrical permutations of the twelve pcs in <i>Île de feu 2</i> (p. 6) shows that the linear sequence of the twelve pcs varies, but the vertical sequence remains invariant.											
Permutation	twelve pcs (0 = C; T = B-flat; E = B)											
I	5	T	4	7	1	8	2	9	3	E	0	6
II	8	0	1	9	T	3	4	E	7	6	5	2
III	3	5	T	E	0	7	1	6	9	2	8	4
IV	7	8	0	6	5	9	T	2	E	4	3	1
V	9	3	5	2	8	E	0	4	6	1	7	T
VI	E	7	8	4	3	6	5	1	2	T	9	0
VII	6	9	3	1	7	2	8	T	4	0	E	5
VIII	2	E	7	T	9	4	3	0	1	5	6	8
IX	4	6	9	0	E	1	7	5	T	8	2	3
X	1	2	E	5	6	T	9	8	0	3	4	7
XI	T	4	6	8	2	0	E	3	5	7	1	9
XII	0	1	2	3	4	5	6	7	8	9	T	E

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REGINA CHŁOPICKA is Professor of Musicology in the Academy of Music in Kraków. Her publications, which number over 60, span four research fields: Polish contemporary music (e.g. Krzysztof Penderecki: *Musica sacra - Musica profana*. Warsaw 2003); topos of death in music; 20th-century musical theatre; methods of musical analysis and the problems of musical gesture. She has participated in numerous international conferences (e.g. Chemnitz, Leipzig, Strasbourg, Paris, London, Aarhus, Vilnius, Budapest, Bratislava, Aix-les-Bains, Theoule sur Mer, Ljubljana, Seoul) and has been Co-editor of the *Studies in Penderecki research series* (Princeton; Vol.I.1998, Vol. II 2003, Vol.III in preparation). She was for six years Dean of Faculty of Composition, Conducting and Theory of Music at AM in Kraków (Excellence in Teaching Award 2003); lecturer running seminars e.g. ENS Paris; Université F.Rabelais Tours; International Bach Academy, Eugene; Seul National University. She is a member among others of the Polish Composers Association (qualifying commission), S.F.A.M (France), Société Internationale d'Histoire Comparée du Théâtre, de l'Opéra et du Ballet.

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Numerical inspirations in the music of Krzysztof Penderecki

In the oeuvre of Krzysztof Penderecki, numerical inspirations appear at various times, in various ways and on various levels of work organization. This paper demonstrates various numerical orderings in Penderecki's music, using selected examples of scores and recordings, as well as specifying the functions they perform in the works.

In his early output, in which the composer searches for ways of organizing new sound material, numerical series function mainly as factors ordering elements at the level of musical language (e.g. in *String Quartet*). A different function is performed by the inspiration with the magic square, which is manifested in two areas: building basic sound structures (e.g. twelve-tone series) and constructing form (e.g. *Dimensions of Time and Silence*). In his later works, the composer's attention is transferred to constructing specific proportions of movements or phases of large form (e.g. symphonies). In the 1980s and 1990s, the inspiration with numerical symbolism comes to the fore. The inspiration with the mysterious and magical number seven is a good example as it is particularly significant in many traditions and cultures (*Seven Gates of Jerusalem*).

Thus numerical inspirations in Krzysztof Penderecki's music on the one hand constitute the continuation of European tradition by making use of proportions or numerical orderings in composition as methods of constructing a special artistic order. On the other hand, due to the search for symbolic or mystical meanings of particular numbers, the inspirations form part of the intercultural space in which man tends to reveal the universal order and sense of existence of the universe.

Stace **CONSTANTINOU**

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The use of 'Fibonacci' and 'Prime number' sequences in the creative compositional process

The 'Prime number' and the 'Fibonacci' sequences provide a mathematically coherent logic that can be applied to the composition of musical works. The sequences can be applied to different parameters of music: pitch, rhythm and instrumentation are examples and can also be applied in various different ways, depending on the desired result or type and degree of experimentation. The sequences can be treated in a simple mathematical way to realise a wide range of musical results, from straightforward objects to complex textures. Patterns of self-similarity, symmetry and asymmetry as well as variation are also explored. In this paper, musical examples are given from four of my pieces, all realised using the techniques and method briefly described above. The most simple or transparent method has been realised in the piece Fibonacci no.1. Focussing on the unfolding of the Fibonacci sequence the music is realised using an initial opening that accurately describes the sequence. It does so by assigning the numbers a simple sinusoid each, both in terms of its frequency and temporal placement. String Quartet no.1 makes use of the same sequence throughout its eight movements; there is also a golden section hidden in the form. The opening of the quartet realises the early digits of the Fibonacci in its most obvious form, as the sequence is applied to the selection of notes in time. Song-Cycle uses the prime number sequence firstly by means of generating the harmonic content and thus a highly nuanced tempered pitch system. The prime numbers form different and unique ratios which can be applied to realise various scales which appear throughout the piece. The final song in the cycle applies the sequence to form a complex harmonic contexture realised using primes: 1 (included as a fundamental reference) 2,...51. String quartet no.2 develops both the degree to which the prime number is used and the variety of different uses within the construction of the music. The results are at times highly complex in musical terms.

STACE CONSTANTINOU is a composer who explores the relationship between idealisms and composition – in particular, the relationship between mathematical systems and the impact on temperament, tuning and musical form; and Zen and the emancipation of spontaneity within the technical framework of compositional logic. Winner of the Ricordi and Schillinger Composition Prizes Constantinou's pieces have been broadcast on National BBC Radio 3 & 4 and have been performed in concerts in the UK and on the Continent, including at the International Computer Music Conference and the Huddersfield Contemporary Music Festival Electric Spring. His piece Song-Cycle for 7 tapes, virtual pianos and soprano has been performed by Jane Manning OBE in Soho, London and at Kingston University, and his String Quartet No.1 and most recently String Quartet No.2 have been played by the Arditti Quartet. He lives in London with his wife, and works as a composer and teacher as well as studying for a PhD in composition at Kingston University, under the supervision of Dr Paul Archbold.

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The number 7 as representation of perfection in Karel Goeyvaerts's music

The Belgian composer Karel Goeyvaerts (1923–93) owes his reputation to the fact that he was one of the founders of European serial and electronic music at the beginning of the 1950s. With the serialization of all parameters, the use of number as an operational tool became inevitable. In electronically generated serial music the realization score even contains listings of parametrical values expressed in numbers only. For Goeyvaerts numerical order is not only a necessary compositional tool, it also functions as the symbolic representation of absolute perfection. As will be demonstrated in this paper, Goeyvaerts continues the Pythagorean tradition of music theory in general and its medieval theological interpretation in particular. From the Nr. 1 (*Sonata for two pianos*, 1950–51) onwards until the very last works, the number 7 functions as the abstract representation of perfection, of metaphysical and divine order.

The middle movements of Goeyvaerts's pioneering Nr. 1 are based on the strict application of a so-called 'synthetic number'. After having assigned numerical values to the different degrees of pitch, duration, loudness and attack, Goeyvaerts makes sure that each and every tone in these movements yields the number 7 as sum of the four parameters.

The cultivation of the number 7 (and 14) as a symbol of absolute perfection is obvious not only in Goeyvaerts's strictly serial works from the early 1950s (Nr. 1 to Nr. 7) and in titles of later compositions such as *Fourteen holy fifths with aureole* or *The Seven Seals* (both from 1986). It is somewhat unexpectedly to be found in Goeyvaerts's most playful, experimental and aleatoric works as well. Eloquent examples will be offered by *Parcours* (1967), the graphic score of which is in itself a visual representation of symmetry and circularity, and by *Mon doux pilote s'endort aussi* (1976), the sensuous beauty of which seems to contradict its underlying numerical constructivism.

Although this paper is based on score analysis including study of the sketches, it will also offer a historical and an aesthetical explanation for Goeyvaerts's life-long obsession with the number 7.

Richard DUMBRILL

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Mesopotamian origins of heptatonism

There is no textual evidence that the earliest Mesopotamian system was pentatonic, although the iconography reveals that this might have been the case. During the Old Babylonian period, a cuneiform clay tablet gives clear indications that the musical system at that time spanned an enneachord. Many have argued that this was evidence of heptatonism. However, the only evidence is that the system was enneatonic and was made up of two conjunct pentachords stemming from a central point and from which, therefore, one ascended and the other descended. The other intervals were made up of fourths rising and falling from the boundaries of the enneachord until, firstly a pentatonic system was reached, and then continuing the process, a tritone symmetrically placed finished the procedure of the enneachord. The scale that resulted would have been either ascending: g-a-b-c-d-e-f-g-a or descending: a-g-f-e-d-c-b-a-g. As a result of this system of tuning, the intervals would all have been 'just' rather than 'Pythagorean' and suited, therefore, to sexagesimal mathematics which were devised and used, as long ago as 5000 years, by the inhabitants of Mesopotamia.

Only recently, in 2008, new evidence re-discovered by the author, showed, in support of the just qualities of the fifths, fourths and thirds, four cuneiform tablets dating from around 2200BC. These revealed tables expressing musical quantification of intervals, since the numbers ranged from 1 to 81, exclusively, and omitted only numbers which did not belong to the enneatonic sexagesimal quantification. This constituted proof not only that Pythagoras had been preceded by scholars from Nippur in ancient Iraq, by almost 2000 years, but that Plato simply plagiarised his cosmology from the much older Babylonian model.

It was also in 2008 that another cuneiform clay tablet (which had been wrongly identified as an astrological document because of a heptagram drawn on it), was re-discovered by two young Dutch scholars. Richard Dumbrill proved that this text, probably dating from the first millennium B.C., constituted the first evidence of a heptatonic system where each of the points of the heptagram represented a note of the scale. The tablet was further illustrated by columns under the heptagram with numbers which unequivocally produced a pattern well known to musicians: an alternation of fifths and fourths leading to a descending heptatonic system: b-a-g-f-e-c-d or ascending: f-g-a-b-c-d-e. The heptagram is inscribed within a circle on which each point of the star is also labelled with a number. These range from 1 to 7. It is contended that the heptagram with its surrounding circle represented a device, probably made of copper, to show, by rotating the outer circle against the heptagram, the nature of each of the seven 'modes' arising from the initial tuning. So not only does the text offer proof of the earliest evidence for heptatonism, but also evidence of seven modes arising from it.

It follows that the tuning of an instrument with this method means that the intervals, exception made for the fourth and the fifth, are no longer 'just' but 'Pythagorean'. Thus, the Pythagorean system was 'invented' about 500 years before his birth, interestingly. This presentation will be illustrated by photographs of the textual evidence as well as will the relevant iconography.

RICHARD DUMBRILL was born in France in 1947 and learnt music in Reims (piano, harpsichord, organ, harmony, composition, fugue, counterpoint, improvisation). He became interested in early music, especially with the Moors of Spain pre Reconquista. This led him to Fez in Morocco where he spent many years researching the repertoire and the organology when he was director of Dar Hadara. He moved to the Middle-East, especially Iraq, Syria, etc. where he researched from much older sources. He has been working for the past 20 years at the British Museum on the Sumerian and Akkadian materials, on both cuneiform texts and the instrumentarium of ancient Mesopotamia. Richard Dumbrill is the founder of ICONEA (www.iconea.org), the International Conference of Near Eastern Archaeomusicology, with a first conference held at the British Museum in 2008; ICONEA 2009 took place at the Sorbonne University, Paris, and ICONEA will be held at the British Museum in December 2010 on the theme of the musical exchanges between Mesopotamia and Egypt during the Hyksos period. Additionally, Dumbrill sits on international PhD juries and also conducts research theses, and post doctoral research projects at the Sorbonne. He has written many works including his *The Archaeomusicology of the Ancient Near East*.

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HENRIK EKEUS is a musician, artist and software engineer. With a background in computer science, in 2003 he went on to study Sound Design and has since been working in sound and cross-media art. In 2007 he completed a Masters in Composition under Nigel Osborne at Edinburgh University, where he focused on generative and algorithmic music. His work has featured in numerous festivals and events and includes acoustic and electronic compositions, installations, sound walks and film soundtracks. He is currently a PhD candidate on the Media and Arts Technology program at Queen Mary, University of London. His research seeks to elucidate the use of generative processes and systems in the arts, and their role as creative driver and intermediary between artistic form and artist.
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Exploring and composing with difference tones: the creation of 'One Half Step'

'One Half Step' (2007) for amplified piano and sine wave generator is a composition that grew out of a systematic study and exploration of difference tones. Difference tones, also known as combination tones, are a well documented psycho-acoustic phenomenon; when two tones are played simultaneously a third tone whose frequency is the difference of the two can sometimes be perceived. In this paper the composer will outline the systems developed in this exploration of difference tones and then show how these studies lead to the composition of 'One Half Step'.

Beginning with pen and paper, a survey of difference tones attainable from within equal temperament was undertaken. The initial goal was to get a sense for their pitch values and to see if they would manifest themselves in identifiable patterns. Due to the number of calculations needed this soon became untenable and led to the development of custom software to carry out the calculations faster and with greater accuracy. As it became possible to work out all the difference tones that could be generated from within equal-temperament instantly, it was also possible to go 'backwards'; make software that given any target frequency would return pairs of equal-tempered notes whose resultant difference tone is close to the target frequency. This system thus provided the composer with a method for 'alluding to' frequencies outside equal-temperament from within it. The output of this system led directly to composition of 'One Half Step', its pitch and temporal material effectively a survey of all the difference tones between two keys on the piano.

In 'One Half Step', a sine wave slowly, linearly and almost imperceptibly travels from middle C to the C# above it. Whenever the sine wave approaches a frequency which can be 'emulated' in the difference tone of any pair of notes on the piano, these are played and left to resonate as the sine wave 'cuts' through the difference tone. To stay in synch with the sine wave, the pianist plays along to a click track. Due to idiosyncrasies of equal tempered tuning, the timing of notes as defined by the output of the software would not neatly fall on beats or divisions thereof. Therefore, to be able to notate and then to make the piece not too difficult to play, quantization of the output had to be carried out; only a machine would be able to play it 'perfectly'. Although the timing and choices of notes were determined by the algorithm, there remained dynamics and articulation to be defined by the composer. These were intuitively formed in an 'interpretation' of the output of the system, in much the same way that a performer would interpret a score.

'One Half Step' is just as much a mathematical study as a musical work; an experiment designed to explore an acoustic phenomenon and characteristics of equal-temperament turned into the framework for an algorithmic composition.

Bernard GATES

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Multiplicative transformational cycles in Berg's Op. 2 and Op. 5

Many compositional techniques and theoretical constructs have fortuitously evolved, almost by chance, simply as a result of the number of semitones in the octave. Scales and chords have emerged from this quality of twelveness through the equal division of the octave into semitones, whole tones, minor thirds, major thirds and tritones, giving rise to various types of cyclic formation, and to elaborate schemes of pitch-class set classification. Twelve-note serialism has developed through the discovery that self-complementary or Z-related six-note pitch-class sets can be combined as T_n or T_{nI} equivalences. The numbers five and seven have had a special place, again by chance, as viewed both from practical and theoretical perspectives. Since five and seven are coprime with twelve, a permutation taking every fifth or seventh note of a twelve-note series will produce a new series without repetition of a pitch class, a phenomenon which Berg exploited in the construction of Alwa's series in his opera *Lulu*, composed between 1928-1935. For the same reason, an expansion of the chromatic scale by a factor of five or seven creates a cycle of fourths or fifths, while a further expansion restores the chromatic order.

Although this cycle of fourths/fifths transformation (multiplication by five or seven) has traditionally been used as a compositional strategy for transforming sets, often in conjunction with transposition, the resultant relationships might also be used as analytical tools. It is this latter aspect that will be explored further in this paper, and will be shown to apply even in works from the free-atonal, pre-serial period represented here by Berg's Op. 2 and Op. 5. Under these operations, prime form elements of a set class are transposed by these multipliers to create either the same prime-form set class (M -invariant) or an equivalent set class (M -related), such that the fourths/fifths-cycle (interval-class 5) aspect of a set class is 'swapped' for or mapped into the semitone-cycle (interval-class 1) aspect, while the other four interval-cycle aspects (interval-classes 2, 3, 4 and 6) are retained intact. When either operation is re-applied to the equivalent set class, the original set class is restored, at a transposition level of T_0 , T_4 or T_8 . Where T_4 or T_8 transpositions of the original are involved, six-fold cycles of transformationally-interrelated M -related pairs can be set up. The cycle of fourths/fifths transform also allows all Z hexachords to be correlated transformationally, some interchangeably in groups of four, and all in alternating Z -paired and M -paired cyclic patterns. Six privileged Z -related pairs are cross-relational, displaying both the 'equal interval classes (ics) 1 and 5' property of the M -invariant class of set classes and the 'sharing ics 2, 3, 4 and 6 with an M -partner' property of the M -related class. The six privileged Z -pairs point the way towards other considerations, such as diatonic vs. chromatic symmetries in pentachords and tetrachords, and transformations between M -paired chromatically-biased and diatonically-biased set classes.

BERNARD GATES studied composition and clarinet at the Royal College of Music from 1964 to 1967. He has an interest in the music of Alban Berg and in theoretical issues surrounding music from the free atonal period of the Second Viennese School, and has pursued his undergraduate and research studies part-time while working as a clarinet and saxophone teacher. His PhD thesis, *The Codification of Pitch Organisation in the Early Atonal Works of Alban Berg*, completed between 1990 and 1999, includes the presentation of a genera system which has formed the basis of his recent research and an article currently under submission to *Music Analysis*. He has given papers at three music analysis conferences, CUMAC 1997, HUMAC 2003 and CarMAC 2008.

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RICHARD GLOVER is currently completing a PhD with Bryn Harrison at Huddersfield, investigating perception and cognition within music of sustained textures. His music will be featured at the Huddersfield Contemporary Music Festival 2010, and he has recently had music performed in the Ergodos Festival (Dublin), Seoul Computer Music Festival, MicroFest (Surrey) and Projektatelier Staab, Cologne. He was apprentice Composer-in-Residence with the BCMG 2007-8, which included a premiere of a new work in September 2008. His music has been performed by Rolf Hind and David Alberman, Quator Bozzini, Psappa, Smith Quartet, Scottish Ensemble, Jack Quartet, Goldberg Ensemble, Gemini, Apollo Saxophone Quartet and many others, and has received numerous broadcasts of his work on Radio 3. He has given a number of papers at international conferences on perception, drone music, and issues with microtonality and tuning in his own and other composers' music. He lectures at the University of Huddersfield in composition and popular music.

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The use of numerals in experimental notation

This paper will discuss the use of numerals in experimental music notation, investigating how they signify more than just a mathematical object but help to convey particular attitudes towards performance to the interpreter. One facet of certain strands in experimental composition is that of the music existing 'in and of itself' (Manfred Werder): no external agent is represented through the compositional process, and much care is taken to convey this phenomenological approach to sound production within the musical score. Many of these pieces rely on simple counting processes, following number patterns and the use of repetition to generate material; what becomes apparent about the way these pieces are notated, is that all text instructions are stated initially, thereby leaving the main body of the score as numerical schemata only. How does this 'numeral-only' approach affect the strategy of the performer? Does the abstract nature of individual numbers communicate something extra-mathematical to the reader, something that would bring about a particular approach to performance?

The varied use of numerals in scores will be discussed; Christian Wolff's score for Edges places a '3' amongst many contrasting other symbols, in a seemingly provocative act for the 3 to be interpreted in a range of ways. A list of numbers (something I have explored in some of my own compositions) indicates a single continuum through which to carefully proceed, and the grid of numbers, such as that found in Phill Niblock's Five More String Quartets and Michael Pisaro's pi, ensures the performer immediately perceives each single numeral's position amongst the others, removing any unique individual characteristics.

Pisaro has described the 'necessary complement' between precision of number and indeterminacy of language in notation (Pisaro, 2009: 36). The paper will investigate this notion further, examining the relationship between text instructions with varying levels of indeterminacy and ambiguity, supporting a numeral-only score.

The role of the performer is discussed, building upon pianist Philip Thomas's 'non-interventionist' model for performance. This approach exists 'without reference to any external stylistic code' so as to 'focus upon the production of sound within the parameters of the score' (Thomas, 2009: 91). This model is applied to various numerical-based scores, and along with a study of relevant recordings, the non-interventionist ideal is propounded with regard to the use of numerals as communication of intention.

The younger generation are represented by Taylan Susam, Joseph Kudirka and John Lely, and the paper explores whether there is any notable progressive lineage in the manner in which numerals as carriers of content in-and-of-themselves are employed by younger composers. The relationship between indeterminacy of language and the heightened accuracy offered by numerals is explored further within their music, and the friction between the two concepts emerging from these scores provides an avenue for both performative and compositional research, opening up various creative possibilities for the future.

Ivor **GRATTAN-GUINNESS**

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Why 18? Masonic numerology in Brother Mozart's music

Although Mozart's status as a Mason is well known, little effort has been made to understanding its place and significance in his life and work, especially the ideals and principles which it involves. Here attention is paid to one example of the numerology, a central features of Masonic lore, which plays important roles in his music in ways which have hardly ever been noted. The history and significance of 18 is traced back to a problem posed and solved by ancient Egyptian mathematicians. The relevance of alchemy and especially of Rosicrucianism is also noted. The focus falls mainly on Die Zauberflöte, but a reason will be proposed as to why he wrote the three symphonies in 1788.

IVOR GRATTAN-GUINNESS is Emeritus Professor of the History of Mathematics and Logic at Middlesex University, England. He was editor of the history of science journal *Annals of Science* from 1974 to 1981. In 1979 he founded the journal *History and Philosophy of Logic*, and edited it until 1992. He edited a substantial *Companion Encyclopedia of the history and philosophy of the mathematical sciences* (two volumes, 1994, London, Routledge), and published *The Fontana History of the mathematical sciences; The rainbow of mathematics* (1997, London, Fontana); and *The search for mathematical roots, 1870-1940: Logics, set theories and the foundations of mathematics from Cantor through Russell to Gödel* (2000, Princeton, Princeton University Press). He edited a large collection of essays on *Landmark writings in Western mathematics, 1640-1940* (2005, Amsterdam, Elsevier), and a smaller collection of his own articles as the book *Routes of learning: Highways, pathways and byways in the history of mathematics* (2009, Baltimore, The Johns Hopkins University Press). He was the Associate Editor for mathematicians and statisticians for the *Oxford Dictionary of National Biography* (2004). In July 2009 the International Commission for the History of Mathematics awarded him the Kenneth O. May Medal in the History of Mathematics for his contributions to the field.

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Twelve-tone time: analytical and compositional applications of Babbitt's time-point series system using custom software

Rhythm and rhythmic systems within twelve-tone music remains an under-explored aspect of a musical system that has tended to focus on number-based associations between pitches. Whilst the notion of the twelve-tone (pitch) row is almost one of Modernism's musical clichés, a number of composers in the twentieth century explored a systemisation of musical rhythm, including Milton Babbitt, Pierre Boulez, John Cage and Karlheinz Stockhausen among others. The majority of such experiments, however, interpret numbers as durational units, for example through the association of a fixed duration with each note of the chromatic spectrum. It was Milton Babbitt, however, in his 1962 article 'Twelve-Tone Rhythmic Structure and the Electronic Medium' who proposed the so-called 'time-point' system, one which in a variety of ways he has compositionally explored over many decades.

The time-point system associates pitches not with fixed durations, but with positions in a rhythmic grid (the 'modulus'). Duration thus becomes the distance between two time-points within or across moduli. Moduli themselves can vary from a single beat to a single bar (or more). The advantage to a composer employing the twelve-tone system is that, unlike durationally-based schemes, the time-point series maintains interesting and meaningful relationships under the usual twelve-tone transformations associated with pitch, such as transposition and inversion. On the other hand, criticism of the time-point system centres around claims of perceptual opacity that result from Babbitt's rhythmic practices, yet its supporters evidence ways in which they claim Babbitt reinforces the sonic comprehensibility of his music.

Within the context of the notional regular Western tuning system (12-TET), it is intuitive to form a time-point series comprised of twelve positional 'points', each associated with, for example, a pitch in a twelve-tone row, as in Babbitt's practice. However, even within the 12-TET context there is no numerical constraint to the number of points employed in a series. Outside of 12-TET, time-point series can be meaningfully employed in music employing alternate and expanded tunings (for example 19-TET), or indeed in music that bears no relation to pitch-based twelve-tone music.

The musical rhythmic patterning that results from employing time-point series can vary from the intricacies of Babbitt's 1986 composition for solo snare drum, 'Homily', to experimental pulse-based electronica dance music, and this paper demonstrates the system at work in a number of such contexts. Custom-made software designed to facilitate musicological analysis and strategies for composition employing time-point series has been created, and implemented in the SuperCollider music programming environment. Such software can not only assist the user explore the musical opportunities and constraints that the time-point system presents, it also provides real-time musical representations of this both inherently mathematical and musical material. This paper will present an overview of the time-point series system with examples from different musical contexts, and demonstrate the software environment designed for exploration of the time-point system.

Richard **HOADLEY** and Tom **HALL**

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Towards embodied control of algorithmic music

Algorithms are step-by-step procedures which provide solutions to specific problems. In music made with the assistance of computers algorithms are typically used to generate stylistic or more freely structured pattern and number-based compositions. The use of algorithms affords both understanding of and experimentation with these vital aspects of music-making. Such use is often tightly controlled in order to isolate these analytical aspects; any live performance happens alongside automatic processes. Other systems specialise in the exchange of information between live and automated performances.

Generic and performance-based systems of algorithmic control have become more commonplace as commercially available technology has developed. This is particularly the case with technology surrounding games and other consumer IT products (for instance the Nintendo Wii, Microsoft Natal and the Apple iPad), where the visceral component is increasingly seen as particularly important. These systems now commonly allow significantly more physical control of some algorithmic processes, although the latter are frequently themselves highly limited and controlled, a situation often unfortunately reflected in the quality and scope of the resulting music.

Of central concern in uniting the physical with the algorithmic is the nature, quality and validity of the metaphor existing between physical action and software-driven reaction. Current technology allows, even with relatively low levels of expenditure and specialisation, increasingly convincing metaphorical links between embodied action and reaction. In gaming, the preference lies in developing the faithfulness of these metaphors and their similarities to the 'real' action. In music, this would apply to areas such as physical modeling where the goal is to make the computer metaphor as precise as possible. In more creative areas this is not necessarily the case; it may well be that goals are more elusive – literally intangible in systems which don't use direct physical contact. Any number of questions and possibilities follow. For example, if a physical action involves, say, the touching of a random few of a large group of wire tendrils which form part of a sculpture, what sonic and/or musical reaction might this produce? Criteria for decisions regarding the role of expectation and predictability are also required in terms of how closely function should follow form. Should metaphors for control be constantly invented, developed, rehearsed and redeveloped and if so, what will this do for the resulting music?

It is now possible easily to prototype custom-designed physical interfaces for the control of custom-designed algorithmic software. If carefully planned, the use of groups of different musical parameters can lead to particularly expressive and musical generative results. This paper describes and demonstrates such a system designed, built and implemented by the authors. The results of its practical use in a collaboration with a dance troupe are analysed, and current and future development is outlined.

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Proportion and numbers in Stravinsky's dodecaphonic compositions

The analysis of Stravinsky's dodecaphonic compositions has tended to concentrate upon the intervallic relationships either within the framework of an abstract series or between the series used in different works in a search for analogies between the musical whole and the permutational-transpositional modifications of the series. In contrast, this paper proposes a cognitive approach to music analysis by using a new category, the parton, a concept described in my book *Strawiński: Myśli i muzyka* [Stravinsky, his Thoughts and Music] (Kraków 2002).

In the cognitive approach to the theory of the musical work the concepts of sound-gestalt, perceptual invariance and auditory scene as a montage of sound-gestalts are of special interest. I proposed a new term 'parton', to designate a sound-unit, conceived and perceived as a repeated sound-gestalt (sometimes with modifications). Based on the research by cognitive psychologists, which suggests that in the aural experience of sound-gestalt similarity one can distinguish three types of invariance – of pitch, of rhythm and timbre – I distinguished three types of sound-gestalts (partons): (1) those with pitch invariance (in nineteenth-century music theory this kind of formal unit was called a motif, a theme, Satz, etc); (2) partons with rhythmic invariance (such formal units were called talea by early music theorists, and later this kind of similarity was understood as a rhythmic theme or dance rhythm); (3) partons with sonoristic invariance (such amelodic sound-units can be found in the work of many twentieth-century composers). In the repeated partons with sonoristic invariance the specific sound-colour (associated with a sound source, articulation, as well as the register and general motion of pitches) remains stable. These kinds of sound-units are usually modified by means of different successions of pitches, different durations assigned to individual sound-units or different types of their montage (one sound-layer or as simultaneous sound-layers).

In my paper I will focus on Stravinsky's dodecaphonic works such as *Canticum sacrum* and *The Flood* and demonstrate how one of Stravinsky's most influential innovations – the effect of discontinuity and the opposition of contrasted formal unit (the parton) – is connected with proportion and series of numbers. For example in an instrumental movement entitled *The Flood*, based on the repetition of four sound-units (the partons with sonoristic invariance) whose overall montage forms a palindrome. The pitch succession in the second part is a retrograde of the first one. The palindrome symbolizes the flood: its beginning, peak, and end. The composer repeats these four partons a number of times while at the same time changing their duration, metrical organization and pitch successions. But the notation of pitch classes is subordinated to a pre-compositional twelve-tone series of pitch classes.

Blair JOHNSTON

(Indiana University, USA)

Magical numbers, the God-Devil polarity, and harmonic-structural synthesis in George Crumb's Black Angels

George Crumb's published remarks about his electric string quartet *Black Angels* (1970) explain how 'magical' numbers 7 and 13 pervade the work in a variety of ways. 7 and 13 are associated with rhythmic groupings, segments of measured time, a certain motivic pitch structure, ritualistic counting in different languages, the internal proportions of individual movements, and the arch-like, palindromic design of the work as a whole: thirteen movements in symmetrical pairs, the seventh movement a centerpiece. However, it remains to incorporate these numerical (or, as Crumb describes them, numerological) considerations into a more comprehensive interpretation that takes into account the work's intricate pitch organization and its decidedly non-palindromic expressive trajectory.

Existing scholarship (Richard Bass, Edward Pearsall) has suggested the eclectic, even dialectical nature of Crumb's pitch language, and the usefulness of pitch-class set and pitch interval analysis for revealing his works' underlying structural features. Crumb's harmonic vocabulary features an interplay of symmetrical and asymmetrical materials (derived from early twentieth-century models, as Bass has shown), a mix of tonal and non-tonal elements, and an 'oppositional relation between equilibrium and disequilibrium' and between 'stasis and motion' (Pearsall). My interpretation of *Black Angels* suggests a similar interplay of distinct, even incompatible structural principles on multiple levels of organization—a static proportional scheme and a goal-oriented 'voyage of the soul' (Crumb), or, to put it another way, music painted by the magic numbers and music painted against the numbers.

Drawing on Bass's and Pearsall's work, and on research in music cognition and semiotics, this paper presents an analysis focused on two movements: Devil-Music (No. 4) and God-Music (No. 10). The two movements are partners in the palindromic design, but dramatic foils of one another. I argue that the structural palindrome in *Black Angels* is imbalanced around these two movements in significant ways. Crumb's plotting of the work as a narrative in three stages—Departure ('fall from grace'; five movements), Absence ('spiritual annihilation'; four movements), and Return ('redemption'; four movements)—is conceptually and literally asymmetrical, and does not correspond to the movement pairs defined by the seven-thirteen palindrome. And while the midpoint of the work (No. 7) is clearly a dramatic highpoint, the expressive crux of the work (No. 10) occurs well after this midpoint, and not at a point clearly associated with either 7 or 13.

In *Black Angels*, then, a teleological/goal-oriented process and a numerological/palindromic structure are superimposed. God-Music represents a point of culmination—an expressive crux—in the teleological process. In God-Music, contrasting pitch materials from earlier in the work are synthesized in a quasi-tonal, octatonic, timbrally refined context. Materials involved include the 'devil' chord (016), which is a direct manifestation of 7 and 13; a motive (014) associated with two distorted tonal allusions, Schubert's 'Death and the Maiden' (No. 6) and the Sarabanda de la Muerte Oscura (No. 8); and a whole-tone motive (026) from *Lost Bells* (No. 3). At the very end of the work, a superset (0146) that contains all these materials is presented in summary—and as a palindrome with seven attacks, suggesting a synthesis of the teleological and the numerological.

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DOROTHY KER studied composition with Nicola Lefanu and Harrison Birtwistle at King's College, London and the University of York. Her music is performed and broadcast in both hemispheres and has been heard at international festivals in Auckland, Belfast, Huddersfield, Perth, Taipei, Seoul, at the ISCM, in London and on BBC Radio 3. In 2007 Lontano Records released the CD 'diffracted terrains: Chamber Music of Dorothy Ker' to critical acclaim. In 2008 a collaborative project with artist Kate Allen, choreographer Carol Brown and mathematician Marcus du Sautoy led to the theatre piece 'the 19th step'. In 2008 pianist Nicolas Hodges gave the premiere of 'The history of rock' at Darmstadt Internationalen Ferienkurse für Neue Musik. Current projects include a collaboration with the oboist Christopher Redgate. She held an AHRC Research Fellowship at Reading University 2001-2004 and 2005-2010 was RCUK Fellow at Sheffield University, where she is now a Lecturer in Composition.

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Music, number and space

Number is an essential and powerful tool of composition. Composing, we engage with number both on the level of controlling and defining immediate musical materials and on the level of structural and poetic invention. The relationship we have to number through music is commonplace and instinctual, while at the same time we use numbers to generate the new, or to endow our music with primal, cosmic or spiritual properties. Number links to the deeper structures of nature that transcend disciplinary boundaries. Crucially, number is a potent means of engaging with spatial concepts—of imagining spatially, on both architectonic and organic levels (Harrison J. (1999) *Diffusion: theories and practices*, with particular reference to the BEAST system. eContact 2.4 ix. <http://cec.concordia.ca/econtact/diffusion/beast.htm>). Conversing with a mathematician, we discover a shared sense of the qualities of space rendered by particular categories of number (prime, irrational, transfinite, etc.), gained through a common desire to explore possibilities—and impossibilities—of space: symmetrical-asymmetrical, finite-infinite, whole-irrational, hyperdimensional-liminal.

Jorge Luis Borges's short story *The Library of Babel* exploits at least four different 'kinds' of maths in describing the library which is the universe: the maths of concepts embodied in words, the maths we understand through number and calculation, the maths we calculate against our bodily experience, and symbolic concepts derived from maths. The mathematical concepts Borges deploys have qualities that are conveyed through his text, which aid our apprehension of the library in its exhilarating infinity. The musical imagination similarly engages with space on these specific, experiential and symbolic levels. Mathematics is a means to engage with and develop these qualities, while there must also be a certain understanding of how qualities translate—or may be lost in translation—between mathematics and music, while fabrications or 'corruptions' of data that nevertheless capture certain qualities may be more aesthetically pleasing than straightforward mappings or derivations. Our engagement with number in the process of composition is transitional and conditional: to compose is ultimately to transcend number. The critical link is the body and our success in translating any data or concept into a form that can be apprehended and articulated sonically. At the same time, many of the qualities we appreciate in number are at the edge of our apprehension—indivisibility, infinity, irrationality, liminality, dimensionality. How does number underpin and progress the pursuit of these qualities in music?

Tomasz KIENIK

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Teacher and composer surrounded by ideas of music and numbers

It is an obvious fact that the concept of numbers and music has been strictly connected ever since Pythagoras's monochord experiments. It was also revealed in Boetius and St. Augustine's speculative philosophy and manifested in mediaeval symbolism of the Holy Trinity. The concept has also passed through the Renaissance counterpoint inventions, proportions and symmetry in the classicism, Leibniz's 'the soul that counts', golden ratio (sectio aurea) in Bartók's works, Xenakis' stochastic procedures, prime numbers in several composers' works, up to algorithmic composition and fractal inspirations in music. Some of these phenomena can be successfully implemented into widely understood didactic practice, because the latest methodologies of education assume the widest possible (and 'network') vision of connections between subjects being taught simultaneously. Interdisciplinary, computer-assisted classes with sound-to-numbers and vice versa procedures applied, are worth considering, in a sense of mutisensorial teaching and multi-subject correlation at schools and universities.

The first didactic example is the transformation of graphics into sound through numbers. Owing to Coagula software, it is possible to demonstrate a process of transforming paintings into musical samples, including mathematical coefficient variability. This can be used in context of fine art teaching, when it is possible to introduce different kinds of paintings, (from childrens' scrawls to great masters' works) and to transform them into wave files. Moreover, the extraordinary files can be used as samples in the process of musical composing, instead of synthesizer timbres.

Another author's idea is an exemplification of transforming planets' motion (and their different mathematic data) into waves or even musical chords. It is a speculative approach, being the 'musical astronomy' or 'astronomical musicology' derived from the Musica Mundana philosophy. Boetius claimed that the motion of planets may generate music (inperceptible by hearing), composed by God's hand. The computer procedures make this 'music' audible, and lead the student from his physics lessons or lectures to a musical experiment. A specific idea of the mathematics subject, a 'lesson between music and algebra', is also likely to be considered using fractals, the equations of which can be transformed into musical pitches using FractMusic 2000 software. The program can demonstrate to students an example of both realities: algorithmic composition (musical subject) and fractal matter (a maths domain).

The final didactic view I would like to propose for discussion is a set of remarks on the technology of creating my two musical pieces. The first is the Violin concerto based on mathematical 'scale element step selection' technique. It is a process of picking every second, third, fourth and consecutive elements of the transposed diminished scale, applied to musical motives and chords. The second issue is the technical aspect of my 7 per organo solo, related to the seventh interval and to the symbolism of number seven, and implemented into this composition.

TOMASZ MARCIN KIENIK is a music theorist and composer, living in Wrocław. He was born in 1976 in Zielona Góra and studied at the Academy of Music in Wrocław, gaining a diploma in music theory (1999) and in composition (2000), awarded with summa cum laude. He also gained his PhD in musicology (2008) at the University of Wrocław. Presently he works at the Institute of Musical Culture and Art at the University of Zielona Góra and in the Secondary Music School in Wrocław, giving lectures and classes on the theory of music. He has taken part in several conferences and has written research articles about twentieth-century Polish music, especially the works of Kazimierz Serocki. He also composed orchestral and chamber music and realized commissioned popular music arrangements e.g. for Radio Klassik in Hamburg. He has been a prize winner at both the Tadeusz Baird Composers' Competition (Warsaw) and the Andrzej Panufnik Composers' Competition (Kraków). He connects the activities of being: the lecturer, the teacher, the research worker and the composer (www.kienik.pl)

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7 and 13 (and other prime numbers): George Crumb's numerology and proportional schemes in *Black Angels*

Prime numbers must hold a special fascination for George Crumb. In the first ten years of his mature style (1962-71), his seven compositions with more than four movements all have prime numbers of movements (5, 7, 11, or 13). Moreover, numerological patterning within his movements often favors prime numbers, for example, the refrains in *Lux aeterna* are all multiples of eleven sixteenth notes in length. In addition, about half of his works from this decade have programmatic allusions.

Crumb's *Black Angels: Thirteen Images from the Dark Land* (for electric string quartet, 1970) exhibits all of these preferences. It has thirteen movements, a cryptic numerology for each movement based on seven and thirteen, and a program representing a journey of the soul to hell and back. It also engages in a dialectic between God, represented by 7, and the devil, represented by 13, which Blair Johnston's paper explains. Numerological patterning applies variously to meter signatures, numbers of notes within gestures, numbers of gestures, and the like. Crumb's sketches for the piece show the evolution of this numerology.

Crumb has acknowledged his preoccupation with time (Lake, 2005). Had he not, one might still infer it from the frequency with which his titles mention time specifically or employ words that invoke time in some manner, such as night, autumn, and ancient. Another manifestation of this preoccupation is his 'remarkable instinct for the manipulation of time' (Wernick (1986), *George Crumb: Profile of a Composer*). Like Bartók and Debussy, the influences of whom he readily avows, Crumb possesses a highly developed sense of proportion. (See Lendvai (1979) *Béla Bartók: An Analysis of His Music*, and Howat (1983), *Debussy in Proportion: A Musical Analysis on proportions within the works of these two seminal composers*).

Black Angels is a tour de force of prime-number proportions. The formal proportions of every movement the duration of which is fully specified by the score (seven of the thirteen!) correspond exactly (to three decimal places!) to fractions with the prime numbers 7, 11, 13, and 17 as denominators. Few of the prime-number-fraction proportions are by-products of a simplistic measuring-out of the music in prime-number groups of some consistent unit. Most arise from multiple musical subsections of varying lengths, some involving different tempi. One of the movements features faux-antique music in four-measure phrases, which nonetheless participates in the prime-number-fraction proportional scheme. Incredibly, Crumb's sketches contain no calculations of any of these proportions. It appears this prime-number consistency came about through Crumb's profound intuition for proportions.

Anton D. LUITEN

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7 Up: the case of the returning interval

Discounting the abundant use of the octave, the interval of seven semitones is the most commonly employed interval in the history of music. According to the natural laws of physics, it is the first interval to be produced after the octave as an overtone, and therefore sustains a tonal affiliation with fundamental pitch. Composers of the late nineteenth and early twentieth centuries began to experiment with these natural intervallic properties and by extension with the major-minor tonal system. Some composers turned to the music of their own lands, amalgamating folk-derived material with the pre-established tonal practice.

Bartók reached a perfect synthesis of the modal and the tonal forms in the late 1920s and 1930s and he himself has described the melodic aspect of his music as the incorporation of processes involving the compression of a diatonic theme to reveal a chromatic equivalent, and the extension of chromatic degrees to formulate a diatonic equivalent. In due respect to the numeric theme of the conference, the second movement of Bartók's Sixth String Quartet (1939) has been chosen as it is melodically bound together with the interval of 7 semitones. It is used as a point of departure and return, positioned in inverted form to produce a passage based almost exclusively on five semitones, and forms the background interval from which smaller cells of symmetrical and chromatic attributes can be derived.

The movement begins with a rare occurrence of traditional harmonic function: an anacrusis containing a clearly outlined chord V followed by a first beat example of chord I, which includes the major 7th. However, perhaps somewhat subtly, the chords contain triads that are symmetrically inverted. The first is simply an example of the major triadic form (in semitones: 4+3) and the second, although in the context of a major chord, is an example of the minor form (3+4). This symmetrical relationship is made explicit later in the movement, where these major and minor forms of the triad unfold melodically and also imitatively in all four voices. As is typical with Bartók's melodic practice, ideas that appear subtly or even in a latent capacity early are often brought to the fore later in the music.

In line with Bartók's own description of his melodic practice, these triads are melodically compressed within this section. However the binding factor is the boundary interval of seven semitones, which is maintained for most of these presentations. The material is immediately compressed to a version of the octatonic scale (1+2+1+2+1), which later expands to a boundary interval spanning a complete octave. The section ends with the ultimate compression of pure chromaticism with the return of the boundary interval of seven semitones.

This paper shows how Bartók has used the well-known interval of 7 semitones in his stated premise of expansion and contraction, and how it manages to unify the movement with its insistence on return.

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Music and? mathematics

There is the widely held view that mathematics (in which so few are confident) and music (which moves so many) are somehow, mysteriously, alike. In my talk I hope to illuminate – and interrogate – this mystery by articulating the affinities and differences between mathematics and music. That this talk is an interrogation explains the '?' in the title.

Acoustics, which involves mathematics, does not provide the intrinsic, experiential link I am seeking. Nor does the fact that music can often be described conceptually in – to coin a neologism – a mathematicalish way. The well-documented presence of numerology (numbers having extra-musical significance) in, for instance, Bach, Mozart and Beethoven does not provide the link I am searching for since it is often unclear what aesthetic significance numerology has. More significantly, perhaps, for the listener is the fact that many composers have used mathematical concepts to structure their music: for instance, Schoenberg and Webern (symmetries) and Debussy and Bartók (the golden section and Fibonacci sequences). Yet these do not constitute the intrinsic, experiential affinities I am after.

An intrinsic concept embedded in our experience is to do with time: to do with the fact that, on the one hand, a piece of music unfolds in time; and on the other, one's experience of mathematics (whether by studying or discovering) takes place in time. Moreover, our musical and mathematical experiences are often dialectical: prospectively astonishing, retrospectively inevitable. What is more, music and mathematics are both non-representational in that: a piece of music does not picture, in an identifiable way, part of physical reality; whilst a mathematical statement is independent of physical reality (although it may have applications to our understanding of physical reality).

Yet, as I argue, there are profound differences between mathematics and music. Mathematics involves and embodies the laws of conceptual logic (of identity, of contradiction and of the excluded middle). Music diametrically contradicts these three laws; and in so doing embodies the primary processes of the subconscious.

Christopher MARK

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Calculating effect: Roger Smalley and the Fibonacci series

From the beginning of his career Roger Smalley (b.1943) has had a constructivist bent. Indeed, he stated in the late nineties that he has always found it impossible to write music without some kind of pre-determined scheme to control form, pitch-content, or duration (or all of these). His earliest music, influenced by Peter Maxwell Davies, employed serial methods, or methods derived from serialism, to generate and organize both pitch and duration. In the mid-sixties he attended Stockhausen's classes in Cologne, in which the latter talked about *Momente* (the first version of which was completed in 1961) 'at great length' (to quote Smalley). Not only *Momente* but also *Klavierstück IX* (also 1961), and *Plus-Minus* (1963) employ the Fibonacci series, and it is likely that contact with these works encouraged Smalley to use the Fibonacci series himself to integrate local duration and formal proportions. In contrast with Stockhausen's usage, however, and in contrast with the number-working of many of the Darmstadtian and post-Darmstadtian avant-garde, Smalley's approach is remarkably straightforward. The interaction of parameters that this simplicity enables is, though, of considerable richness.

In this paper I shall, with the aid of Smalley's sketches, outline the role of the Fibonacci series in contexts drawn from three of his works – *Monody* for piano and ring modulation (1971-2), *Konzertstück* for violin and orchestra (1979-80), and *The Southland* (1986-8) for chorus, gamelan, folk group, and orchestra.

In *Monody*, which has the air of a study about it, the Fibonacci series is linked with another 'natural' construct, the harmonic series: in the first section of the work the 13 notes of the chromatic scale (including the upper octave in the count) are divided into the five notes of the harmonic series decorated by the remaining eight notes, which are grouped into a pattern ($3+2=5$, $2+1=3$) that is itself part of the Fibonacci sequence. In fact all durational relationships in the work are derived from the Fibonacci sequence. In the *Konzertstück* the Fibonacci sequence is again all-pervading, linked this time to an all-interval (though not twelve-note) series which, on a broader structural level, gives rise to quasi-tonal relationships reminiscent of Lendvai's 'axis system'. The *Southland* begins in the *Dreamtime*, with the harmonic series and Fibonacci sequence employed as symbols of birth, or genesis. The Fibonacci series controls the pacing of events, underpinning an accelerating process in which the text, from Jack Davis's 'The Drifters' gradually becomes intelligible.

Whilst the sketches indicate (though not, as I shall discuss, unproblematically) something of the way in which the music was composed, my main concern is with effects perceived by the listener and, bearing in mind the performance strand of the conference, the usefulness (or irrelevance) for performers of the knowledge of the Fibonacci workings in Smalley's music.

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PETE MCALLISTER is currently studying with Margaret Bent as a DPhil student at St Catherine's College, Oxford, and is co-convenor of the Oxford Graduate Colloquium series. His doctoral research is concerned with thirteenth-century notational history, but he is also pursuing topics in post-tonal analysis, Schenkerian theory and the relationship between aesthetics and the philosophy of mathematics. Previous projects include a thesis on the Montpellier Codex supervised by Suzannah Clark, an edition from the St Emmeram Codex with Peter Wright, and an analysis of Dallapiccola's 'Goethe-Lieder' with Dan Grimley.

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MARK GOTHAM graduated from the University of Oxford in 2008 with the Gibbs Prize for the highest-ranking first class degree awarded in music. Since then, he has gained a Masters degree in composition from the RNCM with the support of a full scholarship from the Arts and Humanities Research Council, and pursued a richly varied freelance career as a composer, conductor and performer. Performances of his compositions and arrangements have been given across the UK – including at Blenheim Palace and the Aldeburgh Festival – and at major festivals abroad. He is currently fulfilling various commissions for large-scale orchestral, choral and operatic works to be performed later this year. Mark also works regularly for The Royal Opera House, Covent Garden most often writing piano-reductions for the new works they commission. Mark has provisionally been awarded the Fulbright Scholarship to commence a PhD in music theory in the USA next academic year and is currently awaiting university admission decisions.

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Towards a method for algorithmic segmentation

Since it is impractical and undesirable to systematically examine every set of musical events, pitch-class set and other methods of analysis must rely on a pre-analytical segmentation process, to determine which sets of notes it is analytically relevant to treat as a unit. According to Forte's criteria: 'The determination of a significant set, as distinct from a nonset, is not always easy. Some informal guides are: (1) the set occurs consistently throughout — it is not merely "local"; (2) the complement of the set occurs consistently throughout; (3) if the set is a member of a Z-pair, the other member also occurs; (4) the set is an "atonal" set, not a set that would occur in a tonal work.' (Forte, 1972). However, Forte's criteria embody three problems of segmentation methodology: firstly, the fourth criterion begs the question for all but a strictly limited set of repertoire; secondly, they are not possible to follow rigorously and systematically, and therefore do not produce replicable results; and thirdly, their criteria of consistency are often statistically insignificant — that is, due to the multiplicity of possible sets in a piece of any appreciable size, they are conditions that would equally be satisfied by 'pieces' comprising pitches selected at random. Other segmentation methodologies are often less useful, even less explicit, or both.

The first paper of the panel (delivered by Pete McAllister) sets out the above problem in detail (in particular, demonstrating statistical insignificance in some published findings), and proposes a 'criterion of correctness' (Dunsby) for the segmentation process by means of metric space theory: a metric space is constructed such that there is a well-defined coherence function on any set of musical events within a piece, taking into account the parameters of pitch, duration, register, dynamic, and instrumentation. The metric space approach itself as well as the specific calculations chosen are explained, examined and its applicability to the task assessed. In particular, such a function would be a well-defined mathematical object, its assumptions made explicit and capable of variance to suit the repertoire, and would be algorithmic, and therefore capable of being automated. Finally, the relationship between algorithm and analyst is discussed.

The second paper of the panel (delivered by Mark Gotham) develops certain of McAllister's themes. It seeks primarily to contribute a similarity measurement for timbre that could be adopted by the segmentation system proposed. Timbre is a notoriously difficult variable to quantify in a meaningful way and therefore demands this special treatment, separated from the flow of McAllister's proposition. As an aside, the relative paucity of existing timbral analysis is discussed. It is a surprising fact that timbre – a compositional parameter that is so basic to an appreciation of music at any level – has received so little scholarly attention. This is partly due to the difficulty in developing a taxonomy by which to describe sound that relies neither on ornate poeticism, nor impenetrable acoustics. It may also be symptomatic of the subordinate role that composers have traditionally assigned to timbre, although this subordination may, in turn, reflect the under-theorisation.

Finally, an application of the complete segmentation model to a general quantification of change patterns in music is proposed. The rational segmentation of music affords the opportunity for comparison between those separated sets. An holistic value of the change that takes place from one set to the next would allow the development of an analysis according to the quantity and quality of change types through a piece. I expect this research to reveal normative patterns of variation that obtain across ostensibly diverse musical styles within and between the musical parameters employed. Perhaps most interestingly of all, will be the analysis of significant deviations from those patterns. If successful, this study would be of considerable interest not only to theorists and analysts but also to composers. I expect that the observation of generic patterns will be provocative to the many composers who deliberately resist them and hope that this will further promote original thought.

Bonny H. MILLER

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Sounding the soul in Schoenberg's *Herzgewächse*

Composed in a burst of creativity that provided Arnold Schoenberg a much-needed artistic lift, *Herzgewächse*, Op. 20, has grown in estimation from a 'bizarre and unhealthy' aphorism (Nathan, 1936) to 'a work of brilliant originality in sound and texture' (Simms, 2000). This unique setting for harp, harmonium, celesta, and soprano supports varied analytical approaches based on parameters of pitch, motive, texture, and the exceptional circumstances of its publication in the 1912 *Blaue Reiter* alongside Schoenberg's essay 'Das Verhältnis zum Text'. Composed specifically for the art publication, *Herzgewächse* is a work uniquely tied to the spirit and content of the *Blaue Reiter*. The text of *Herzgewächse* depicts the process of spiritual growth and enlightenment, expressed in the metaphor of a lily reaching upward in prayer above sorrows and malaise. In *Herzgewächse*, the form of the work is a graphic representation of the content of the poem, and the parameters of vocal style, rhythm, metre, texture, and gesture undergo major changes in the course of the piece as an expression of the idea of transformation, not only as depicted in the poem, but also in the larger sense of the *Blaue Reiter* almanac and its mission. The *Blaue Reiter* artists believed that mankind was beginning a great step to the age of the spiritual, and that art would serve as a catalyst in this next step of human evolution. Schoenberg's setting for the almanac is a musical articulation of that spiritual aspiration.

Among the formal analyses of its thirty bars—all based on clearly articulated changes in meter, vocal style, and instrumental texture—are descriptions of 2 sections (Hough, 1982, 1983), 3 sections (Ruf, 1984, 2002), and 4 sections (Simms, 2000). The most obvious division occurs at the exact midpoint between bars 1-15 and 16-30, coinciding with the first active verb in the text and abrupt changes of musical texture. This symmetry of bars reveals an underlying asymmetry with the proportion 7×13 to 7×16 quaver notes (the initial upbeat necessitates computation based on quaver notes). The common denominator, 7, plays a structural role in Schoenberg's *Pierrot Lunaire* and *Jakobsleiter*. The progression in the intriguing ratio from unlucky prime (13) to perfect (16) mirrors the process of spiritual evolution in *Herzgewächse*.

Schoenberg's additional changes of texture parse the work into Golden sections that approximate a chambered nautilus. *Herzgewächse* demonstrates two Golden sections: a total of 203 quaver notes equals $125/126 + 77/78$, and 78 equals $48 + 30$. The Golden section at 126 coincides with the beginning of the third division cited by Ruf and Simms. The spectacular climax of the vocal line on *f* occurs at the Golden section of the second segment, 48/49, at the beginning of Simm's fourth section. While such numerical calculations were probably the furthest concerns of the composer at the time of composition, Schoenberg would have been delighted that his unconscious called forth such elegant and symbolic proportions in *Herzgewächse*.

BONNY HOUGH MILLER holds masters and doctoral degrees in piano performance. She has performed widely as a recitalist and accompanist, as well as teaching piano and music history at universities in Missouri, Georgia, Florida, Virginia, and Louisiana. Her research papers and lecture-recitals at national and international meetings address topics from Mozart to American popular music. Miller's publications have appeared in the *Journal of the Arnold Schoenberg Institute*, *Notes of the Music Library Association*, *Fontes artes musicae*, *Bulletin of the Society for American Music*, *Piano Quarterly*, and *Cecilia Reclaimed: Feminist Perspectives on Gender and Music*. The focus of her research for twenty-five years has been the publication of music scores in popular press periodicals, such as literary journals and household magazines. She is based in the Washington DC area as an independent scholar.

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NICHOLAS PETERS (b.1984), is a SAM shortlisted composer currently based in Somerset. He studied composition with Nick Atkinson and music analysis with Roger Heaton at Bath Spa University College, where he graduated in 2005 with a First Class Honours Degree in Music. Since late 2005 he has been studying composition with Christopher Fox; first at Huddersfield University on the Masters programme in composition (passed with distinction), and then from late 2006 at Brunel University on the PhD composition programme. Performances of his music have been given across the UK by performers such as The Arditti Quartet, Anton Lukoszevieze, Rhodri Davies, Charlotte Pugh, Philip Thomas, Lorna Osbon, The Galliard Wind Ensemble, and the John Armitage Memorial Concert Series. Peters has just completed a recorder and piano piece for Charlotte Pugh and Charles Wiffen, which will be premiered later this year. He is currently writing a solo cello piece for Anton Lukoszevieze.

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Block durations in my recent music: questions of proportion

This paper examines the role of numbers, particularly in the form of block durations, within two of my recent compositions, Northfield Road for 9 instrumentalists (2009) and Balaclava for cello, harp and speaking voice (2009). These two pieces employ a block structure in contrasting ways, with Balaclava using independent parts where Northfield Road does not; thus, the role of numbers and therefore the questions of proportion are slightly different in each one.

A number of different considerations relevant to both pieces will be addressed first. These will include: i) explaining why and how I consider small collections of numbers to be an integral part of the development of other material throughout the composition process in each piece; ii) discussing how the sets of numbers are derived; and iii) illustrating how the numbers are used within processes to develop other material, for example through the use of chance operations to decide the order of blocks. The central ideas of this paper will then be addressed by discussing the contrasting exploration of block durations in each piece. In particular, this will involve considering the effects upon proportion when the same block structure is used for all parts, as in Northfield Road, or when three independent block structures are employed, as in Balaclava. Additional to the questions of proportion in these pieces is also the consideration of whether the listener is presented with a sonic environment where they have the freedom to perceive, for themselves, relationships within the block structure that the number patterns form an integral part of.

I will also explore the approaches of John Cage, Morton Feldman and James Saunders towards block durations and proportion to complement and contextualise the discussion of my own music. I will do so with examples from Cage's late number pieces that use time brackets to create an anarchic society of sounds; Feldman's late pieces of the 1980s that explore deploying material over extended time scales; and finally Saunders's #[unassigned] pieces that explore sounds that are nearly inaudible, which result in unpredictable block durations. Overall, this paper will aim to demonstrate how working with small collections of numbers underpins my current aesthetic, which is centred upon creating pieces with multi-layered textures where all the material and subtle variations thereof are audible.

Michelle PHILLIPS

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The Golden Section: seen but not heard?

The golden section, a division made such that the ratio of the larger portion to the whole is equal to that of the smaller to the larger, is a cultural phenomenon. From fields such as web design, to engineering, phyllotaxis and dentistry, the golden section is ubiquitous, featuring in the last few years alone in journals such as *Science*, *Aesthetic Plastic Surgery*, *Magnetic Resonance in Medicine*, and the *Journal of the Society of Architectural Historians*. The proportion receives mention on micro-blogging website Twitter at least daily, and is the subject of over 40 Facebook groups, with a total of more than 7,000 members around the world. The golden section (and/or Fibonacci series) is adduced in over 120 instances in music journals and books, 90% of which appear after the popularisation of the concept by Lendvai's work on Bartók's music, and 62% of which follow Howat's work on Debussy. Detailed examination of the golden section's manifestation in music analysis reveals remarkable trends, and it has featured ever more frequently in music analysis since the 1970s.

One of the most remarkable trends is the lack of attention devoted to whether the golden section can be heard. Fewer than a quarter of studies consider this, even though many claim that such proportional construction adds to a work's aesthetic effect. Despite Lendvai's (1984) assertion that the golden section 'fulfils its task only if it can be perceived', and the wealth of empirical study of the visual salience of the proportion, there has been no investigation into whether the golden section can be heard. On the contrary, empirical work in the field music perception has suggested that musical form may not be perceived globally at all, but rather only on the local (e.g. metrical) level. Furthermore, studies of musical time are now beginning to suggest that musical bars, or sections, may not in fact be perceived in absolute relation to one another. Rather, the experience of elapsed duration during music listening is influenced by multiple factors, including the volume, tempo, modality and harmonic variation of the music.

In this paper I will refer to recent findings in the field of music perception and outline my own experimental work so far. I will propose that, whilst the purported manifestations of the golden section may be informative about the composer's own musical conceptions, this proportional relationship is not necessarily perceived by the listener. Moreover (and with reference to Benjafeld, 2010) I will briefly outline possible theories as to why the golden section may have penetrated the field of music analysis so starkly. Its inherent irrationality and relationship with other numbers lend ease of application, and its mathematical intricacies and fascinating history grant a mysterious allure. However, the music analyst's search for the golden section, a mathematical phenomenon which it seems may (at best) be seen but not heard, appears often to be 'a symptom of analytical desperation' (Cook, 1998).

MICHELLE PHILLIPS is a postgraduate researcher specialising in the golden section's various manifestations in music and music analysis. Her work in the Centre for Music and Science (within the Faculty of Music) at the University of Cambridge has also led to an interest in the perception of large scale musical form, and the notion of musical time (experience of elapsed duration during music listening). Michelle completed her undergraduate and masters degrees at the University of Nottingham; the former in music and German, and the latter exploring the notions of music, musical culture, and musical form in contemporary Austrian literature, supported by the AHRC. She plays the saxophone in the Equinox saxophone ensemble and Quadrangle quartet, and is a qualified chartered accountant.

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Raising expectations: patterns, predictability and deferring the inevitable

This paper explains how and why numbers underpin the developmental techniques employed in a number of my recent compositions. With particular reference to a representative excerpt from a recent orchestral piece, *Mesh*, I shall explain how my thematic ideas are very often subjected to gradual changes in parameters such as pitch, duration and density of scoring (or a combination of these) over the course of several consecutive near-repetitions. Although originally conceived as a way of giving developmental passages a 'rightness' of pacing and a strong sense of forward momentum, I have more recently come to hold the opinion that such processes allow the creation in the listener's mind of a succession of different expectations as to how the music is likely to continue, each of which comes to compete with and eventually supersede the one before.

This paper shows how the music of my chosen excerpt makes it possible for the listener to become aware of numerical patterns which give rise to a gradual overall increase in pitch, and decrease in duration, of successive iterations of a contrapuntal exchange, and to form the expectation that these will continue. It is claimed, however, that the longer the passage conforms to this expectation, the more likely the listener is to become aware of limits beyond which the patterns will be unable to pass: the highest possible pitch and speed, for instance, at which the performers will be able to play. This leads him/her increasingly to expect that rather than continuing along the same lines, the passage will have to come to an end and give way to something else.

The listener is given several reasons to think this. Not only is each contrapuntal exchange shorter than the last, but the duration of the exchanges is itself reduced by a progressively smaller amount each time. Similarly, the pitch at which the exchanges take place increases by ever-smaller degrees. As this happens, the listener may begin to sense that it cannot be long before not only the passage's maximum pitch and speed, but also the minimum degree of difference in pitch and speed between one exchange and the next, will be reached.

I will show how this passage nevertheless finds ways of continuing beyond the apparent limits of the processes of ascent and acceleration which underlie it: for example by increasing the number of exchanges that take place between each reduction in duration, or by the gradual flattening-out of contrapuntal detail within each exchange, in accordance with the ever-shorter timescale available to it in which to take place. The intention is that with each limit the passage appears to transcend, and the longer it manages to go on thereafter, the more likely the listener is to begin to doubt his expectation that it is about to come to an end, thus creating a further sense of confounded expectation when, eventually, it does.

Brenda RAVENSCROFT

(Queen's University in Kingston, Ontario, Canada)

Beyond the numbers: rhythmic structure and expression in Elliott Carter's vocal music

The complexity and sophistication of Elliott Carter's polyphonic rhythmic language is well known, particularly to performers of his music. Large-scale rhythmic control is frequently achieved through long-range polyrhythms, while short-term pulses and steady speeds organize rhythm more locally in individual lines. The role played by rhythm in Carter's compositional method is central, his sketches showing that calculating a structural polyrhythm is often his first step in the creative process.

Although Carter's music is written with meter signatures, pulses usually have complicated relationships with the notated meters, polyrhythms are expressed by complex ratios, and pulse tempi vary considerably from the overall tempo markings of the piece. In the song 'Anaphora' from *A Mirror on Which to Dwell*, for example, two pulses in the ratio 65:69 proceed at speeds of MM 15.65 (an attack every 23rd quintuplet semiquaver) and MM 16.62 (an attack every 13th triplet quaver) in relation to the overall tempo of crotchet = 72. As is Carter's practice, the polyrhythm guides the deep structure of the piece, and points at which the two pulses converge and diverge are used to indicate structurally significant moments.

While pulses, speeds and polyrhythms serve important musical functions by creating rhythmic continuity and large-scale structural coherence, it is intriguing to consider the expressive role they might play in Carter's vocal music, where his primary compositional goal is to convey his interpretation of the words. Since the composition of *A Mirror on Which to Dwell* in 1975, Carter has focused much of his compositional attention on music for the voice, particularly on song cycles, and he is widely considered to be one of the leading musical interpreters of American poetry.

My paper explores the expressive role played by rhythm in Carter's recent vocal music. I open by defining and distinguishing the rhythmic terms used in the analysis, and by placing my work in the context of other published work on rhythm in Carter's music.* Using musical examples from four song cycles—*A Mirror on Which to Dwell*, *In Sleep*, *In Thunder* (1981), *Of Challenge and of Love* (1994), *In the Distances of Sleep* (2006) – I show that the carefully calculated rhythmic schemes also serve expressive roles by representing literal aspects of the texts, by signifying personae in the poems, and by metaphorically expressing Carter's understanding of the words.

*See for example: J. Bernard, 'The Evolution of Carter's Rhythmic Practice', *Perspectives of New Music* 26/2 (1988), 164-203; J. Link, 'Long-range Polyrhythms in Elliott Carter's Recent Music', unpublished Ph.D. dissertation, City University of New York, 1994; Y. Uno, 'The Tempo-Span GIS as a Measure of Continuity in Elliott Carter's Eight Pieces for Four Timpani', *Intégral* 10 (1996), 53-91; B. Ravenscroft, 'Finding the Time for Words: Elliott Carter's Solutions to the Challenges of Text-Setting', *Indiana Theory Review* 22/1 (2001), 83-102; B. Ravenscroft, 'Setting the Pace: the Role of Speeds in Elliott Carter's *A Mirror on Which to Dwell*', *Music Analysis* 22/3 (October 2003), 253-282; M. Sallmen, 'Listening to the Music Itself: Breaking Through the Shell of Elliott Carter's "In Genesis"', *Music Theory Online* 13/1 (Sep. 2007); and E. Poudrier, 'Local Polymetric Structures in Elliott Carter's 90+ for Piano (1994)', in B. Heile (ed.), *The Modernist Legacy: Essays on New Music* (Farnham: Ashgate, 2009), 205-233.

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Jeremy RICHARDS

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JEREMY RICHARDS is currently studying a PhD at the University of Melbourne, Australia, specialising in the use of mathematical forms in the music of Josquin and his contemporaries. He received his Masters in Music from Monash University in 2004. He is currently working as a lecturer at the Australian Guild of Music Education. He has composed, amongst other works, two symphonies and a two-hour orchestral concerto, and has made a number of popular and jazz recordings that have been broadcast on Australian radio. He has worked as a conductor, performer, recording artist and music educator for the last 20 years. In 1990 his *Missa Brevis* won the Australian Young Composer of the year award and was subsequently performed throughout Australia and Europe. He currently resides with his two wives and five children in Traralgon, Eastern Victoria.

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The use of number in the music of Josquin and his contemporaries

The works of the early part of the fifteenth century present some interesting challenges for the modern scholar. One area that has not been analysed in great detail is the extensive use of formal structures in the music of the Renaissance. There are a few examples, like the explanation of metrical considerations in the Dufay motet, *Nuper Rosarum Flores*, by Warren and Wright, however the current research I am undertaking casts new light on whether or not Renaissance composers were always aware of form and numerical ratios when creating their works. By counting the number of breves and/or semibreves in random selections of works from this period, I have been able to deduce that, in a high percentage of cases, these works show clear evidence of metrical divisions and perfect ratios. We are looking at a period when the classical formalism of antiquity was highly prized and being rediscovered, and was reflected in art, architecture and indeed music – Leonardo's Vitruvian man perhaps being an indicative vision representative of the ethos of Renaissance symmetry with man at the centre. Josquin was definitely the leader in this field of structuring musical works numerically. Even his lesser works have this numerical structure, ratio and formalism firmly implanted in their substructure. However, as my research is beginning to make clear, this use of metrical structure is not limited to Josquin. The work of Isaac consistently makes use of mathematical ratios, so too, La Rue, Agricola, Mouton, Brumel and Compere; and indeed as we go down the list, we find that this is not just apparent as a passing fancy, but an inherent part of the music of all of the leading composers working in Western Europe at the turn of the sixteenth century.

As the canon from 1490 – 1520 is relatively extensive, my study focuses only on Masses at this stage, and in particular the Gloria and Credo sections with scope for motets in the future. The reason I have chosen these sections is that the text therein is not metered or rhyming, and therefore one might plausibly assume that if the composer has created the work in a perfect, numerically deductible form, it is not due in any part to the structure of the text – as may be the case in a 3 x 3 Kyrie Eleison structure or a 2 or 3 sectioned Agnus Dei. The results thus far have been both fascinating and astounding and I believe they will cast new light on current interpretations of both musical and mathematical scholarship of the Renaissance.

Michael ROFE

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Nested proportions in the symphonies of Dmitri Shostakovich

For such a widely performed – and widely discussed – composer, surprisingly little apolitical, analytical research has been undertaken on the music of Dmitri Shostakovich. Fortunately, this trend is beginning to reverse, and with the recent publication of the New Collected Works has come a range of draft materials that point to a carefully considered musical language. In particular, several manuscripts have emerged that contain extensive mathematical markings, as well as large-scale formal sketches and diagrams.

Forming part of a wider research project due for publication in 2011, the present paper offers an introduction to the widespread presence of symmetrical and golden-section proportions in Shostakovich's symphonies. A range of examples will be considered in order to reveal the varied roles that these proportions play. In particular, the paper will demonstrate that multiple phrase-level proportions often build into longer-range proportional patterns. This idea of nested symmetries and golden sections – proportions within proportions – is a consistent part of Shostakovich's musical language. A range of nesting patterns will be exemplified and discussed, and in each case, a close relationship will be seen between particular patterns and the pervading (and changing) sense of dynamism or stasis – growth or emptiness – that the music projects.

This link between proportional structure and perceptual effect is vital, and little-explored. Shostakovich's music is frequently described as manipulating curves of energy: music that is rhythmically driven and insatiably repetitive is directed towards monumental points of crisis and eventual points of release (the first movements of the Fifth and Eighth symphonies, and the finale of the Eleventh, exemplify this 'energetic' style). Yet, at other times, his music feels empty, barren, and motionless (as in the fourth movement of the Eighth, or the opening of the Fourteenth). The extent of directional energy frequently relates to the ways in which proportional nesting takes place: proportions that align at crucial turning points or points of arrival give rise to a sense of structural (or hypermetric) focus; where proportions do not align, or where points of alignment are more widely spaced, a greater sense of free-floating stasis prevails.

The notion of proportional nesting therefore has a wider significance: individual proportions do not work in isolation in Shostakovich's music; they do not simply control what is at a single point of symmetry or golden section in a given time-span. Rather, they function together, helping to anticipate, establish or undermine musical patterns and perceptual effects as a work unfolds. We are thus led to a reformulation of the significance and effects of proportional structure in general: it offers a spatial architecture, but can also function as a temporal process, helping to shape the way in which time is felt to pass, and energy is felt to accumulate and dissipate.

MICHAEL ROFE completed his PhD, *Shostakovich and the Russian Doll: Dimensions of Energy in the Symphonies*, in 2008, and is currently expanding this work into a book (Ashgate, 2011). His analytical approach centres on issues of proportional structure and their effect upon listener perceptions. Other current research projects include a forthcoming book on the music of Kaija Saariaho, and an article on the neglected Russian music theorist, Boleslav Yavorsky. Based in York, he works freelance, teaching for the Universities of York and York St John, where he specializes in analytical approaches to twentieth-century music.

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ALON SCHAB is a graduate of the Jerusalem Academy of Music and Dance (recorder and composition). He is currently an Ussher Fellow at Trinity College Dublin, where he is studying for a PhD (under the supervision of Martin Adams), focusing on Henry Purcell's compositional technique. Other fields of interest are keyboard music 1550–1700, English consort music, Israeli music, and progressive rock. He also sings and plays bass guitar with folk-rock group Bentaim (Tel-Aviv).

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Purcell's early experimental forms: lists, cycles and numbers

Ever since their 'rediscovery' in the early twentieth century, Henry Purcell's fifteen Fantazias (c. 1680) have fascinated performers, listeners, composers and scholars: they were written at remarkable speed; nothing is known of the context in which they would have been performed (and if they were intended for performance at all); the models on which some of them are based are outmoded (In Nomine), especially when compared to the bold and modern, almost prophetic, harmonic language they exhibit; at least in one case, it may even seem that Purcell was trying to play a musical trick, perhaps to impress his colleagues (Fantazia upon one note).

My paper attempts to explain some of the peculiarities of Purcell's Fantazias through investigation of what I identify as their infra-structure and through study of the mathematical principles that dictate it: Purcell's concept of form, as reflected in some these early works, was grounded in a cyclic treatment of seven- and eight-note scales that has not been recorded in contemporary treatises. While some of the imitational sections in the Fantazias are based on presenting the principal subject starting on the primary degrees of the mode (the final, a fifth above it, a fifth below it etc.), some sections betray a conscious attempt to incorporate entries on all degrees. This attempt, joined with the limited spaced the composer allocates to it (sometimes a section of eight bars) results in great density and harmonic progressions which may sound arbitrary but in fact are meticulously planned.

Using lists of pitches, which he exhausted in turns, Purcell on the one hand, sought and achieved control over musical form and, on the other hand, created a framework for bold vertical sonorities, which, at least in part, gave these works their reputation as experimental, personal and rare masterworks. Focusing on the four-part fantazias, the study will demonstrate how during the process described by J.A. Westrup as Purcell's 'progress from freedom to a regularity no less free', the composer used numbers, lists, and considerations which lie outside the borders of the emerging tonal system, and experimented with other fascinating shaping forces in music.

Georgia TSERPE

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The number 3 as an element of background structure and meaning in Christos Samaras's 'Three Songs'

The Greek composer Christos Samaras set to music in 2004 three poems by Konstantinos Kavafis, 'As much as you can', 'Che fece... il gran rifiuto' and 'Days of 1903'. The songs are written for voice and piano and are based on the date 23.4.1972, which had personal significance for the composer and for the inspiration behind his composition.

This paper attempts to decipher the melodic, harmonic and formal structure of the songs in the light of numerical and other extra-musical considerations. The conclusions arise from the examination of the relationships that govern both the linear and vertical-harmonic texture, in the small- and large-scale formal structure. Samaras uses traditional but non-functional harmonic elements in the middleground and background structure, whereas the musical surface comprises random melodic patterns and consonant triadic elements, as superimposed thirds prevail. This paper investigates the effects of particular note combinations and the importance of tonal centres, arrived at by numerical considerations; these create the songs' distinct harmonic environment which includes both tonal and harmonically diffuse material. The paper also considers the structural significance that note-numbers have for the large-scale form, particularly the way the important number '3' is emphasized as a basic element of the deeper-background structure.

The style of the songs follows the aesthetics and meaning of the poems. In relation to this, the study examines not only the structural function of the note-numbers but also their semantic function, which arises through connections with points of the poetic text. Specifically, the date's numbers appear as notes; for example, 1=c, 2=c#, 3=d, 4=eb, 7=f#, 9=ab. Consequently, the main note material of the song is c#-d-eb-c-ab-f#-(c#). Analytically, the number 3 exists both as a harmonic interval arising from superimposed thirds, and in the metre of the second and third songs. The number 4 is presented melodically as fourths and as rhythm (four semiquavers) in the left hand in the second song; in the same song the number 9 (ab) functions semantically. In the musical surface, also, couples of numbers and number sums arise: the number-couple 2-7 (c#-f#) corresponds to a melodic fourth, 2-3 (c#-d) to melodic second (which exists everywhere in the songs) and the sum 3+2 appears as metre 5/8 in the first song and rhythmically in the third song. In the background structure the number 3 (d) emerges, which carries in correlation with the poetic text the meaning of the 'will' of the lyric 'I', the 'yes'. This number is juxtaposed with the number 10 (the sum of all numbers $2+3+4+1+9+7+2=28=2+8=10$), which transports the meaning of stability, the rightness, the 'no' of the lyric 'I'. All these elements, which constitute a clear structure, are identified with the composer's ideology, as formulated in his writings.

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ANTON VISHIO teaches music theory at the Steinhardt School at New York University, where he is also a member of the Music and Audio Research Laboratory (MARL). He received his PhD in theory from Harvard University, where he studied theory with David Lewin and composition with Donald Martino. He has taught at a number of schools, including the University of Buffalo, McGill University, and Vassar College. Recent areas of focus have included the theory and performance of polyrhythm, structures of time in the organ works of Messiaen, and Oulipian poetics. He is active as a composer, interested in problems of miniature forms and of text-setting; as a pianist, he was awarded with Christoph Neidhöfer a Kranichsteiner Musikpreis at the 1994 Darmstadt Ferienkurse.

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The rhythm of queninas: number and order in musical dialogue

This paper explores the animation of number in music through techniques derived from the researches of the Oulipo, the (mostly) French group of writers and mathematicians founded by François Le Lionnais and Raymond Queneau in 1960. I shall describe a family of strategies for using number constructs in the creation of musical works. In particular, I focus on the extension of the poetic form of the sestina, a series of six stanzas of six lines each in which the ends of the lines are rearranged from stanza to stanza in a specific spiral pattern: 123456 becomes 615243 becomes 364125, etc., cycling back to the original configuration after six iterations. The basic structure, devised by the troubadour Arnaut Daniel, had already been reappropriated for musical purposes by Ernst Krenek in his Sestina of 1957.

However, the generalizations of the pattern to other stanza lengths, pioneered by Queneau (hence the later term quenina) and formalized by Jacques Roubaud among others, are no less suggestive of musical application. In fact, the apparently 'jumbled' number series that result from this reordering share particular properties that seem more indigenous to musical contexts than to poetic ones; to highlight these, I use an adjacency matrix to track particular patterns through the quenine spiral. In the process, I revisit ideas about permutational serialism, in particular the technique of 'proliferating series' developed by Jean Barraqué and the durational schemes utilized by Olivier Messiaen in *Chronochromie* and other works.

A quenina of 12 objects does not exist – instead of a single cycle of length 12, there is one cycle of length 10 and another of length 2. By contrast, there is an 11-quenina – that is, the spiral permutation applied to 11 objects yields a single cycle of length 11 – and I study its effects on a well-known construct, the all-interval row. The characteristic quenine rearrangement of the intervals of the row does not in fact lead to other row forms, but produces instead a family of all-interval orders – collections of 12 pitch classes which contain duplications – and such a family forms a kind of signature for a given row; more strikingly, and generally characteristic of quenine patterning, one might say that every moment in the design bears the memory of some other moment, since every order intersects with every other order in exactly one succession – and that memory might be projected or suppressed, depending on the musical task at hand. This cross-reference suggests another way to look at permutation operations more generally, a subject for further research. I conclude with some examples of quenine designs and realizations drawn from compositional work in progress.

James WRIGHT

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Wittgenstein's conception of mathematical 'scaffolding' and the problem of formalism in post-tonal theory and composition

Though his critique of language is well known, Ludwig Wittgenstein's extensive writings on mathematical topics – the foundations of mathematics, the nature of numbers, their cognitive and empirical origins, and their proper manipulation and application – remain to be fully explored. Adopting Wittgenstein's conception of mathematical modelling in this paper, I will undertake a critique of the axioms and methods of post-tonal music theory and analysis, and the compositional precepts that are rooted in them.

Wittgenstein was unrelenting in his attempt to 'civilize mathematics' by seeking clarity concerning its epistemological status. In particular, he stood adamantly opposed to any brand of radical formalism that reduces mathematics to the manipulation of meaningless symbols and ignores actual human experience and use. The core insight underlying much of his thought is the notion that logical and mathematical propositions are tautological; i.e., that they do not, in themselves, say anything about the world. For Wittgenstein, the truths of mathematics are irrefutable precisely because they are devoid of factual and empirical content. They are known a priori in the sense that they can be established by means of the formal machinery of mathematical axioms alone, without reference to empirical data. On this view, it is a pernicious error to think of any form of pure mathematics (i.e., taken independently from its applications), as something that is descriptive of an objective domain beyond mathematics itself. Wittgenstein saw this as a lazy habit of thought that erodes our thinking about mathematics and leads us to give an erroneous form of expression to its results. He argues that set theory (of Cantor and Hilbert), for example, makes the mistake of being 'about numbers', and of purporting to describe some imagined and abstract mathematical reality thereby. To understand the true essence of mathematics, according to Wittgenstein, is to understand its epistemological status and its proper application.

This points toward a central problem of music-theoretical formalism and 'theorism' (to borrow Nicholas Cook's term). The post-tonal theoretical work of Forte, Babbitt, Perle, Straus, et al, purports to describe musical logic by subjecting compositional structures to analytic tools derived from modulo-12 set theory. However, as critics such as Benjamin, Davis, Regener, Rowell, and Taruskin (for example) have shown, many of the analytical findings obtained thereby can be traced to the axioms of modulo-12 mathematics itself, rather than to perceivable properties of the piece (or body) of music in question. As objects of knowledge and perception, the status of many set-theoretical postulates therefore remains undetermined. Abstract inclusion-relations (set complexes, super sets, nexus sets, Z-related sets, K- and Kh-related sets, for example) and equivalence-relations (inversional equivalence, for example), exclusion-relations, similarity-relations, and complex set transformations (Riemannian operations, Klumpenhouwer networks, for example) have proven resistant to empirical study.

Wittgenstein's insights provide us with a powerful epistemological lens through which to view such tools of post-tonal theory. Notwithstanding his critique of mathematics, Wittgenstein did not consider logical and mathematical propositions to be worthless by virtue of their formalism. He describes how mathematics can provide a powerful form of 'scaffolding' upon which empirical descriptions of the world can be constructed, even if it cannot, in itself, describe anything in the world. With the aid of Wittgenstein's conception of mathematical scaffolding, we can better understand the ways in which post-tonal theory can (and cannot) be gainfully applied to some of the central problems facing the composer and analyst.

JAMES WRIGHT has pursued a broad-ranging career as a composer, pianist, musicologist, and teacher. In 2002, he received a PhD in music theory from McGill University, where his dissertation on Schoenberg and Wittgenstein was awarded a Governor-General's Gold Medal, the first time in McGill's history that this distinction had been conferred upon a musicologist. His primary scholarly contributions include two books on the life and work of Arnold Schoenberg: *Schoenberg, Wittgenstein, and the Vienna Circle* (Bern: Verlag Peter Lang, 2nd edition 2007) and *Schoenberg's Chamber Music, Schoenberg's World* (Hillsdale, N.Y.: Pendragon Press, 2009). He serves on the Board of Directors of the Ottawa International Chamber Music Festival, and he is Vice-President of Ottawa New Music Creators, an Ottawa composers collective. An Associate Composer of the Canadian Music Centre, James Wright is widely known as a composer of choral music whose works have been commissioned, performed, and recorded by choirs throughout North America. Dr. Wright is an Associate Professor of music theory and composition, and Supervisor of Performance Studies, in the School for Studies in Art & Culture (Music), at Carleton University, Ottawa, Canada.

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MICHAEL YOUNG is a composer and Senior Lecturer at Goldsmiths, University of London. He is co-founder of the Live Algorithms for Music network www.livealgorithms.org. His recent work has focussed on interaction/generative systems, including a series of pieces for solo instrument/computer ‘_prosthesis’ (oboe, flute, piano, cello). Audio examples and other information www.michaelyoung.info. He has also collaborated in a number of joint science/visual arts projects, the most recent, Exposure, is a real-time generative installation and exhibition exploring sonification, human habitation and environmental change in Greenland which has recently been shown in Scotland (www.ground-breaking.net).

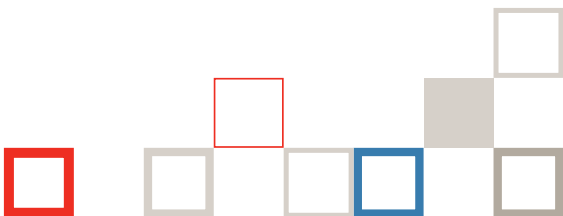
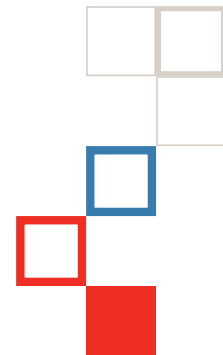
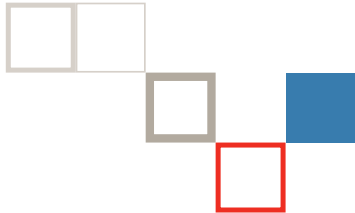
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Interplay: feature spaces in human-computer improvisation

Artificial intelligence applied in real-time offers novel opportunities for live interplay between musicians and computers. Quasi-autonomous systems (live algorithms) differ to the norms of computer-as-instrument, with reliance on human agency, and computer-as-proxy, in which the designer’s intentions are encoded as a score, rules or other symbolic representation. Live algorithms should be able to act responsively, proactively and appropriately without such direct intervention. Free improvisation provides an appropriate context for interplay because it avoids explicit knowledge representation in the form of contextual or stylistic constraints. Musical structures can only emerge as a consequence of mutual listening and adaptation occurring in the performance. Listening may attend to any range of apposite features, but without reference to an established grammar. Adaptation occurs as participants modify and respond to the shared audio environment, and their internal representation of it. Gärdenfors’ theory of conceptual spaces (a model of semantics and an intermediate, bridging theory between symbolic and sub-symbolic AI) offers a way to understand interplay between participants of equivalent status, whether of human or machine origin. Human listening, musical reflection/planning and playing might be modelled as feature analysis, algorithmic exploration a feature space, mapped to synthesis.

This paper presents an overview of two human-computer performance systems designed by the author that explore interplay in a limited creative context. In the first (the _prosthesis series) the system models a player’s improvisation by extracting n features and applying a statistical analysis. The features comprise integral domains such as pitch-loudness and duration-interonset interval calculated as the normalised mean and variance over a rolling time period t . So each axis in the resultant n -dimensional feature space describes these relational properties. A specific point in the space represents music material determined by a unique combination of properties. As the player continues, the feature space is continually traversed. The system marks a new point when a region is encountered that is sufficiently distant from any other previous marked point, and can also continuously measure the distance between the current point and any other marked points. Gärdenfors describes the functional relationship between conceptual similarity (comparing musical materials in this case) and quantifiable distance. This system, metaphorically speaking, demonstrates its new awareness of similarities by mapping distance values to parameters governing its own sound synthesis. The player is invited to evaluate in performance how the system is associating its musical ‘behaviour’ with his/hers, and learn to adapt accordingly.

In the second, (prototype) system developed with Oliver Bown, (Clap-along) a random target point is assigned in a feature space representing the summation of simultaneous computer-generated and human rhythmic loops (features such as homophony and clumping). The challenge for each participant is to adjust their contribution so that the collective rhythm, as represented in this feature space, approaches the unknown target. The machine employs a simple GA or generate-and-test algorithm, and the human a degree of invention, guesswork or careful adaptation. As the target is approached, it randomly shifts position: this ensures an unending negotiation in the shared feature space, on an equal footing.



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