Writing Visual Culture

Volume

5.0

5.0 Writing Visual Culture

Table of Contents

Vol 5 Writing Visual Culture ISSN 2049-7180

Series Editor
Dr Grace Lees-Maffei, University of Hertfordshire

Guest Editor for Vol. 5
Dr Pat Simpson, University of Hertfordshire

Click here for the table of contents

Abstracts

5.3 'Occult Arithmetic: Music, Mathematics and Mysticism'

The ancient Pythagorean sect bequeathed an abstract concept of music – later known as musica universalis – music as pattern, flow, a direct embodiment of the fundamental processes and forms underlying reality, all beginning with the connection between harmonious musical intervals and simple ratios. Through the centuries, this beguiling notion continued to re-emerge; amplified, elaborated and reinterpreted in the work of the most prominent philosophers and physicists. To what extent could it still be said to hold? In what way can it stand as an archetype for the interaction between art and science? This paper seeks to answer these questions. Circling around the statement of Liebniz that music is an exercise of "occult arithmetic", it considers – through a historically-driven speculation from Pythagoras to Schopenhauer – music's capacity to enlighten us, and how it can correspond to concepts of order and chaos, intuition, creativity and metaphysical transcendence. Further questions are ultimately raised: what does art represent as opposed to scientific enquiry? How can science and art complement one another?

[click here for the full paper]

5.4 'Natural Calligraphy'

The term 'natural calligraphy' is introduced to describe a class of dynamic lines found in nature. These lines are well-defined although sometimes short-lived. They occur in different natural processes and on different scales. A selection is presented in this paper so as to better understand the class. They possess, for instance, cusps in density, involved topology and sweeping curves. Their occurrence is sometimes surprising because diffusive processes lead to smoothening of densities, the weakening of strong gradients, and the erasure of edges and sharp boundaries. As they change over time, forms of the line - 'characters' - emerge that seem particularly striking but these can disappear as quickly as they appear. As these characters evolve from and to less remarkable forms, we have a better chance of understanding the characteristics that make them appear compelling or beautiful. The lines exist in higher-dimensional spaces and we present two-dimensional projections of these spaces (photographs and images from simulations) as illustrations in this paper. Features that we describe as striking are often a result of this projection so that the natural form and the viewer both play a part in creating a 'work of art'. We distinguish two types of experiment that we can conduct simultaneously in natural calligraphy. First, there is the scientific study of the natural

Click here for the table of contents

processes creating the line. These processes possess both predictable and random (chaotic) elements. They are therefore not strictly repeatable although some features of the process are robust. Second, there is our placement in, and subjective selection from, the process as artists. We discuss these two types of experiment in more detail in relation to our examples. The exciting possibility suggested by these natural processes is a dynamic evolving calligraphy with a continuum of forms and symbols. Modern developments in the concept of trajectory in science have enriched the simple idea of a line and the extremal principles at the heart of these developments underlie the aesthetic of natural calligraphy. This paper aims to give an introduction to these ideas that might be of interest to both to scientists and practitioners in the arts.

[click here for the full paper]

5.5 'On what we may infer from scientific and artistic representations of time'

We consider the extent to which artistic and scientific representations can give us knowledge of how things are or could be. Focusing on representations of time, we take two case studies: simultaneity and temporal order; time-travel to the past. We analyse relevant scientific representations – from Special Theory of Relativity and General Theory of Relativity – alongside relevant artistic representations – fictions which are non-committal about temporal order, and time-travel stories. In all the cases, we argue, drawing reliable conclusions from the representations requires an understanding of the metaphysics of their subject matter and of the nature of representation itself. If we attempt to work out what is represented from the representation alone, then, far from acquiring knowledge, we risk obscuring the representation's subject matter.

During the conference at which papers in this volume were given, there was much discussion over how, if at all, scientists and artists could collaborate to provide new knowledge of how the world is. We propose that scientists and artists should work not just alone or with each other, but also with (informed) philosophers. Scientific and artistic representations can be ways of knowing about the world only when supplemented by a philosophical framework in which to interpret them.

[click here for the full paper]

Click here for the table of contents

This paper queries the contrasting epistemological frameworks that operate in the sciences and creative arts. An epistemological matrix is proposed that maps knowledge as a Boolean array, primarily referencing the work and ideas of Charles Saunders Peirce and the infamous statement of Donald Rumsfeld concerning “known unknowns”. The work of Pye and Ingold is referenced so as to articulate how creative practice can be considered “a way of knowing” within a spectrum of innovation that can lead to the production of knowledge whilst Scrivener’s observations are used to offer an alternate view of how creative practice can lead to novel apprehension. Finally Zadeh’s work on fuzzy logic is employed in order to query assumptions that science is accorded special consideration as the dominant epistemology of our age. The essay concludes that knowledge, scientific or otherwise, is no guarantee that we will learn from our mistakes.

[click here for the full paper]

Vol 5 Writing Visual Culture ISSN 2049-7180

5.1 Ways of Knowing: Art and Science's Shared Imagination - Perspectives from the Sciences, Humanities and Creative Arts

Click here for the table of contents

Simeon Nelson, University of Hertfordshire

Preface

This volume of Writing Visual Culture presents selected papers from an interdisciplinary symposium at the University of Hertfordshire hosted by the Fine Art Practices Research Group, in the School of Creative Arts. The conference was convened by myself, and held on October 1-2, 2010. It was an exciting and well-attended event, drawing in members of University of Hertfordshire staff from a variety of disciplines in the arts, humanities and sciences, and also invited external keynote speakers: Tony Longson, Professor of Art, California State University, Los Angeles; Rob Kesseler, Professor of Ceramic Art & Design, Central Saint Martins College, University of the Arts, London; Anna Dumitriu, visual and performance artist; and Professor Simon Biggs, research professor at the Edinburgh School of Art.

The conference was initially convened to celebrate the first year of a new set of potential relationships between the arts and sciences, signified by the creation in 2009 of the Faculty of Science, Technology and Creative Arts at UH. While a source of interesting and valuable collaborations and interchanges, the Faculty will now be disarticulated in 2012, as a result of a restructuring plan for the University, based on Schools rather than Faculties. The relationships previously forged will, however, live on. This volume is a testament to the advances in relationships between the disciplines that had been made in that first year.

Most importantly, it is also a memorial to Dr Robert Priddey, a young and eminent astrophysicist particularly keen on bridging the 'gap' between the arts and the sciences, who was instrumental in setting up this conference. Tragically, he died suddenly in 2010 of a brain haemorrhage, before the conference took place. His colleagues and his students – both in the arts and the sciences – have a great sense of loss. This first edition of Writing Visual Culture has been designed as a tribute to his enthusiasm and interdisciplinary interests.

The call for papers, reproduced below, was illustrated with a reproduction of a drawing of diatoms by the evolutionary scientist Ernst Haeckel, from his book Kunstformen der Natur, (1899), as a way of stressing the historical relationships between artistic and scientific vision. The call itself gives a sense of the deliberately broad-based intention of the conference, to bring together professionals in the arts, humanities and sciences for a pooling of knowledge, understanding and ideas.

5.1 Ways of Knowing: Art and Science's Shared Imagination - Perspectives from the Sciences, Humanities and Creative Arts

Click here for the table of contents

Ways of Knowing: Call for Papers

> "Imagination will carry us to worlds that never were. But without it we go nowhere." (Sagan1980, 4)

> "Scientists animated by the purpose of proving that they are purposeless constitute an interesting subject for study." (Whitehead 1929, 16)

> "A universe simple enough to be understood is too simple to produce a mind capable of understanding it." (Barrow 1990, 342–343)

> "It is my supposition that the Universe in not only queerer than we imagine, is queerer than we can imagine." (Haldane 1927, 286)

This symposium is motivated by the sense of wonder shared by artists and scientists at the complex cosmos we inhabit. It forms part of the celebration of the first anniversary of the Faculty of Science, Technology and Creative Arts and is a step toward what will hopefully be a longer-term interdisciplinary research effort in science and art within the new Faculty. This first meeting is deliberately broad in scope hoping to uncover as much work in science-art within the University as possible.

In 1975 a young artist named Tony Longson worked with the computers in the engineering department at Hatfield Polytechnic to produce what are considered to be important works in the then nascent discipline of computer aided art. In 2010 Tony will return to Hatfield to give a keynote address at this symposium reflecting on thirty-five years of engagement between art and science.

Art and science, at a fundamental level, are creative acts of imagination, invention and discovery. Until the modern period they were construed as complementary aspects of a continuum of enquiry. In China, the Islamic world and India especially, art, philosophy and science flourished in this syncretic way (Morgan 2008) Despite the splitting of art and science into separate realms in the European enlightenment, cross-fertilisation and mutual fascination has continued to the present day. Examples of this would be the two way relationship of Cubism and relativity: artists had their world view radically altered by the mathematical discoveries of Poincaré, and Einstein's theories of relativity (Miller 2001). Another intertwining is found in the development of perspective in western painting as a way of seeing the world, locating an observer as separate from the observed, which was paralleled in the rise of empirical science (Kemp 2000). In the second half of the twentieth century artists rapidly colonized the

Click here for the table of contents

new computational sciences, robotics and biotechnologies (see for example Leonardo/ISAST). Today a rich field of art-science work exists globally with numerous interdisciplinary courses being created in universities and much effort being put into interpretation and dissemination of scientific knowledge through the arts.

How do art-historical and contemporary artistic perspectives inform our understandings of science? How have the sciences informed, and been informed by music, performance, the visual and media arts? Aesthetic qualities such as symmetry and beauty are sought after in both art and science. What are the interplays between scientific visualisations and the arts? How can the abstract be made concrete? How do the aesthetics of scientific illustration and visualisation affect the public reception and understanding of science? How do political and social understandings affect the direction of science?

There has been much discussion of what theorist and curator Peter Weibel calls a "third culture" (2005) within the art-science community. This third culture is syncretic, in it science recognizes the broader culture and society within which it is embedded and is more connected to the public; there is a much greater understanding between artists and scientists of each others' fields. If art and science are understood as equally necessary and complementary ways of knowing the world, how does this understanding enrich them? What type of knowledge is produced by the numerous art-science collaborations and interdisciplinary art-science courses that have grown up internationally in the last few decades? What has been the main purpose and impact of these, to interpret and disseminate scientific knowledge or something more fundamental?

Further questions would be: do artists engaging with scientists affect the outcome of any science being done? Can art be a contribution to knowledge? Can science contribute to meaning in a way similar to the arts and humanities? What is the nature of discovery and creativity in art and science? Philosophical questions might look at how the value judgments of the creative arts and the falsifiable statements of science interact when they come together.

5.1 Ways of Knowing: Art and Science's Shared Imagination - Perspectives from the Sciences, Humanities and Creative Arts

Click here for the table of contents

References

- Barrow, J.D. 1990. The World Within the World. Oxford: Oxford University Press.
- Haldane, J.B.S. 1927. Possible Worlds and Other Papers. London: Chatto & Windus.
- Haeckel, E. 1899. Diatoms. Kunstformen der Natur, http://www.classicnatureprints.com/pr.Haeckel.Kunstformen/haeckel.diatoms.html . . [Accessed 29/06/10]
- Kemp, M. 2000. Visualizations: The Nature Book of Art and Science. Oxford: Oxford University Press. Leonardo/ISAST, http://www.leonardo.info. [Accessed 29/06/10]
- Miller, A. 2001. Einstein, Picasso: Space, Time and the Beauty That Causes Havoc. New York: Basic
- Morgan, M. 2008. Lost History: The Enduring Legacy of Muslim Scientists, Thinkers and Artists, London: National Geographic Society.
- Sagan, K. 1980. Cosmos. New York: Random House.
- Weibel, P. 2005. Beyond Art: A Third Culture: A Comparative Study in Cultures, Art and Science in 20th Century Austria and Hungary. New York/Vienna: Springer.
- Whitehead, A.N. 1929. The Function of Reason. Princeton: Princeton University Press.

Contact

Simeon Nelson
Professor of Sculpture
School of Creative Arts
University of Hertfordshire
College Lane, Hatfield, AL10 9AB
s.d.lockhart-nelson@herts.ac.uk
http://simeon-nelson.com/home2.html

5.2 Ways of Knowing

Click here for the table of contents

Pat Simpson, University of Hertfordshire

Introduction

This first edition of Writing Visual Culture features a small but indicative selection of the papers that were presented at the Ways of Knowing conference, held at the University of Hertfordshire in September 2010. The central and intertwined themes of the volume are representation – both scientific and artistic - and epistemology. The three main questions from the call for papers that are addressed by the essays are: “What are the interplays between scientific visualisations and the arts?”, “Can art be a contribution to knowledge?” and, “If art and science are understood as equally necessary and complementary ways of knowing the world, how does this understanding enrich them?” This volume does not offer any simple answers – if these, indeed, exist – rather it raises a number of supplementary questions about how certain constructs of art and of science may be argued to link up with concepts of how knowledge might be defined.

The first and focal paper is “Occult Arithmetic: Music, Mathematics and Mysticism” by the astrophysicist Robert Priddey. The essay was at the stage of a preliminary draft when he died so suddenly. It has been lightly edited by his interdisciplinary research student, Alice Williamson from the Music Department of the School of Creative Arts, in order to retain a sense of his personality and wide-ranging cultural interests. It should not be seen as a finished academic paper, but rather as an insight into his modes of thinking about art and science.

Priddey’s paper asks whether the Pythagorean concept of musica universalis – that is to say music as “a direct embodiment of the processes underlying nature” (Priddey 2011) – could be viewed today as an “archetype” for a fruitful interaction between art and science. This is not a call for a literal espousal of the principles underlining the 6th century Greek theory of the “Music of the Spheres”. Rather it is a suggestion that today, in a “poetic” or “metaphorical” sense, the Pythagorean idea may offer us a potential basis for identifying two different but vitally interconnected “ways of knowing” about the complex world that we live in (Priddey 2011). One of these is through the operations of logic, mathematics and reasoning – now seen as the pathway of contemporary science. The other is intuitive, visceral and personal – which he identifies as the pathway of art. While this may seem to recall the arguments of Romantic philosophy – and indeed Priddey does invoke the concept of music theorised by Arthur Schopenhauer in The World as Will and Idea – there is also an underlying deep, and contemporary concern driving the argument. This concern is that, in the quotidian procedures of, and pressures on academic pursuit of science, the space for “awe and wonder” in the presence of the unfathomed – and possibly unfathomable

Click here for the table of contents

- complexity of the world is in danger of being lost to scientists. It is clear that despite these pressures Priddey never lost this sense of wonder. For him, art, and particularly music, provided a way of intuitively perceiving and understanding, at least in an analogical sense, a breadth of complexities in the world that could not be pinned down by science. Thus in Priddey's purview art can indeed be seen as a contribution to knowledge, a form of embodied philosophy that is necessary, complementary and enriching to scientific ways of knowing.

There is a sense in which the second essay, by another astrophysicist, James L. Collett, follows up Priddey's ideas to some extent, from a practical perspective that involves making art from scientific observations. Collett explores the idea of "Natural Calligraphy" disclosed in his beautiful, observational photographic images of refracted and reflected light, and partly theorised through the theoretical prism of quantum mechanics. In contradistinction to the commonplace "knowledge" that there are no lines or edges in nature, Collett suggests that his images of natural phenomena or processes may be seen to indicate "a dynamic and evolving calligraphy" (Collett 2011), that can be argued to share properties with traditional calligraphy, particularly as displayed in the Book of Kells and Chinese calligraphy. His conclusion points especially to the visual and aesthetic possibilities of the potentially constant and unpredictably shifting, fluid 'calligraphy' formed by pouring modulated streams of glycerol into water, as a semi-musical art form, with its origins in a simple domestic scientific experiment. In effect, Collett offers an example of a possible interplay between art and science, which, on the one hand, uses art to challenge broad scientific assumptions and, on the other hand, offers art something to learn from science about the infinite possibilities of what may be defined as drawing. For Collett, as for Priddey, both art and science are perceived as potential ways of knowing about, and interrogating the world. A rather different view is presented by the philosophers Craig Bourne and Emily Caddick who, unlike Priddey, make clear demarcations between art, science and philosophy, and question the basis on which either art or science may be viewed as producing contributions to knowledge. In the paper, "On what we can infer from scientific and artistic representations of time", they consider the extent to which artistic and scientific representations can give knowledge of "how things are or could be" (Bourne & Caddick 2011). Bourne and Caddick use diagrammatic visualisations of Albert Einstein's General and Special Theories of Relativity, and the film Back to the Future as case studies, in order to argue that both scientific and artistic representations need to be embedded in a philosophical framework, in order to constitute sources of knowledge.

The final paper by new media artist, Simon Biggs, "Between One and Zero: On the Unknown Knowns", also addresses issues concerning scientific and creative arts practices as sources of knowledge, but from a very different perspective and with a very different focus. Biggs' approach

Click here for the table of contents

uses Slavoij Žižek's critique of Donald Rumsfeld's construct of "known unknowns" as a jumping-off point, to question the nature and contemporary hierarchy of the epistemological frameworks of the sciences and creative arts. By reference to a variety of theoretical sources, ranging from Lofti Zadeh's theorisations of "fuzzy logic" in computation, through Charles Pierce's semiotic theory, to the arguments of Stephen Scrivener, David Pye, Elizabeth Hallam and Tim Ingold regarding the definition of research in the creative arts, (by way of Boolean Matrices and, ultimately, Michel Foucault's theorisations of the relationships between power and knowledge), Biggs argues that arts practice can be regarded as a "way of knowing". His conclusion, however, also offers a timely warning that our values are unconsciously informed by "unknown knowns", thus these should be subject to particular scrutiny and evaluation. What may be argued to be scientific and artistic 'truths' would thus seem to be an inexhaustible, but nevertheless significant subject for many future debates.

In summary, all of these papers offer some useful triggers for thought and future research regarding the relationships between the arts and the sciences. They suggest that, ultimately, there are infinite possibilities for fruitful interplay between these disciplines, which may be seen as potentially mutually enriching in a variety of ways. Art as a means of generating original contributions to knowledge, has already been well established as a route for doctoral research, and is the focus for considerable academic discourse (Biggs and Karlsson, 2011). The potential relationships of art and science have yet to be fully plumbed. This is very rich, and possibly inexhaustible seam.

Click here for the table of contents

References

- Biggs, M.B. and Karlsson, H. eds, 2011. The Routledge Companion to Research in the Arts, London: Routledge

Contact

Dr Pat Simpson
Reader in Social History of Art
School of Creative Arts
University of Hertfordshire
College Lane, Hatfield, Herts.
p.a.simpson@herts.ac.uk
http://sitem.herts.ac.uk/artdes_research/tvad/simpson1.html

5.3 Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Robert Priddey and Alice Williamson, University of Hertfordshire

Preface

The paper was written following a thought-provoking weekend at the SkyWay '09 festival of light in Torun, Poland. Robert Priddey and I were invited to present alongside other academics and artists at a seminar devoted to collaborations between science and art. Simeon Nelson's involvement in this event spawned a firm friendship and exchange of ideas. They hoped to run a symposium together celebrating and encouraging collaboration between science and art; Ways of Knowing was the culmination of this idea. Robert died in February 2010 at the age of 34; this highly personal, emotive paper was the last he wrote. His enthusiasm for, and vast abundance of knowledge on, so many subjects, and how they can be brought together, will never cease to inspire me. It is an honour to have had him as my doctoral supervisor. Examples of his artwork, musical compositions, poetry and other words can be found at http://robertpriddey.com/ - Alice Williamson.

> *"Musica Exercitium Est Arithmeticae Occultum Nescientis Se Numerare Animi"*
> *(Gottfried Leibniz)*

Music, most of all the arts, is perennially dubbed mathematical and abstract. This tradition goes back at least as far as Plato, who in the Republic chides acoustic investigators for rating ears above intellect. They torture strings, he ridicules, and beat them on the rack as they pluck them under tension; wringing confessions from just them as Athenian jurisprudence decreed for the interrogation of a slave (Plato The Republic, VII 531b: Bloom 1968, 209). It all seems like sound empirical science to us, but for Plato, the testimony of experience was worth no more than the flimsy deposition of a slave. He levels the same charge against astronomers: "There's nothing more beautiful," he admits, "than these ornaments in the sky" but, for being visible, they should be regarded inferior to pure patterns "in the realm of number" (Plato The Republic, VII 529).

In listing in the same breath the sins of acoustic experimenters and the sins of astronomers, Plato is alluding to the philosophical tradition said to have been established by Pythagoras of Samos in the 6th century BCE. Pythagoras is best remembered in the popular mind as a mathematician – he of the square on the hypotenuse. Indeed, Aristotle praised Pythagoras and his followers as "the first to take up mathematics" (Aristotle, Metaphysics A 5 985b 23: Barnes 1984, 1559), because they pursued general laws (such as $a^2 + b^2 = c^2$) rather than specific instances (such as $3^2 + 4^2 = 5^2$, $5^2 + 12^2 = 13^2$, $8^2 + 15^2 = 17^2$, etc.) [1] To the ancients, though, he was also revered as the founder of a religious sect, in whose creed mathematics, music, and astronomy were sacrosanct.

5.3

Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

“All Is Number” – The Pythagoreans

The Pythagorean brotherhood [2] flourished around the ancient Mediterranean from around the 6th century BCE. It seems to have been part secretive philosophical school and part mystery religion in the line of the Dionysian and Orphic cults. The initiate aspired to a state of rapture, ekstasis (whence “ecstasy”), in which one attains mystical union with the divine – homoisis theo. The Bacchics’ sacraments were wine and other intoxicants; the Pythagoreans’ entheogen, much more ascetically, was philosophy. According to tradition, Pythagoras is said to have invented the word philosophia, seen originally not as an exclusively intellectual, but as a ritualistic exercise. And the mystical insight into reality that it afforded was the Pythagoreans’ chief doctrine, a radical, mathematical ontology: all is number.

This revolutionary metaphysic could be said to have kick-started our modern picture of physics as inherently mathematical, but it was derived from a musical discovery, said to have been made by the founder, Pythagoras, himself: that intervals considered harmonious are governed by simple ratios of integers. Greek music, at least in Classical times, would have sounded alien to our ears; both Plato and Aristotle would have considered our diatonic music loose and immoral, preferring excruciating microtonal tunings. Nevertheless, all scales had a set of invariant intervals: the octave, the perfect fifth and the perfect fourth. It was these intervals that the Greek thought harmonious, and it was these intervals to which the Pythagoreans ascribed ratios, namely, 2:1, 3:2 and 4:3 respectively; probably initially referring to lengths of plucked strings, though now we know these numbers represent relative frequencies of acoustic vibrations.

If something seemingly so subjective as musical harmony is governed by the first few integers, then why not everything else? This was indeed the Pythagorean view: all is number. Not merely “all is based on number” or “all can be described by number”, but all is, deep down, in an ontological sense, number. How could this work? Well, one primitive Pythagorean model of particle physics declares that matter (in this case the five elements) is made out of fundamental geometrical figures: the five Platonic solids. [3]

To the Greeks, nothing exhibited order and regularity as clearly as the starry heavens: the diurnal rotation of the sky, the unending annual progression of the sun. Above all, the Pythagoreans thought that the planets wheel about their orbits according to those same ratios that rule musical harmony. As they soar around the sky, they would thus choir consonantly like sirens or angels. The Pythagorean universe is one above all governed by order. They were the first to apply the Greek word for “order”, kosmos, to refer to the whole universe as a structured system. Furthermore, it is a harmonia, and, like musical harmony, can be appreciated and understood by the divine part of our own nature, and yield an explanation or logos through the exercise of reason.

5.3 Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Perhaps embarrassed by its odder superstitions, the religious element in Pythagoreanism was too often glossed over by later commentators in favour of its purely rational doctrines. But in our survey of art and science it is too delicious to overlook that, at the origin of the Western scientific world-view, the rational walked hand-in-hand with the irrational. Well – not irrational so much as non-rational or even supra-rational, in the sense of insights and convictions that, though held deeply and seriously, cannot be communicated through precepts nor justified through reason.

Instead, it draws on myths and metaphors. There is an interesting soteriological parable – almost like a Zen kōan – concerning Pythagoras himself, which I think contains the key to decrypting the cult's secret core symbolism. According to legend, the Master was said to have been able to hear the music of the spheres. We do not; well, actually we do, it is just that we do not notice that we do because we have always done so and never thought to question it. So distracted and corrupted by everyday things are we that we do not see the most profound and obvious truth though it lies forever beneath our nose: the Music of the Spheres is perhaps a metaphor for the greatest of all mysteries, that of existence itself (is this the "Silence of the Druids" that Charles Ives represented in his chamber work The Unanswered Question?) (Ives 1953).

Through philosophy one may aspire to the saintliness that permits one, like Pythagoras, to perceive the fundamental nature of reality, the cosmos, and this can be achieved in two ways. The first, intellectual, through the exercise of abstract mathematics and reasoning in search of an explanation, or logos. Plato, as we have seen, thought this sufficient: there is no need to experience the phenomenological world in order to understand the higher realm of abstract "Forms". But is a rational account enough? Pythagoras heard the music, remember! The second, non-rational: intuitive – visceral, ecstatic, even – the experience of music leading to mystical communion with the nature of reality.

This Music of the Spheres, taken as a literal model of the universe, though fanciful, proved irresistible to the greatest physicists – Ptolemy, Copernicus, Kepler and Newton, all of whom tried to preserve it in some way. [4] Their attempts all fell by the wayside. But on a metaphorical or poetic level it still stands as an archetype of science/art discourse: science, at its birth in the 6th Century Greek colonies, was made vivid and personal and piquant through art.

5.3 Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

The Dynamics of Music

A well-known line of Gottfried Leibniz provides the title for this essay. Leibniz was corresponding with his disciple Christian Wolff: [5] "musica exercitium est arithmeticae occultum nescientis se numerare animi" ("music is the hidden arithmetical exercise of a mind unconscious that it calculates") (Leibniz 1712, 199).

Music is arithmetic: Plato would have no dispute with that. But, crucially, it is hidden arithmetic. Listening to music, the conscious mind does not explicitly count and divide and compare ratios and derive intellectual pleasure thereof. Appreciation of the patterns and forms of music is only partly rational; for the most part, it is unconscious, emotional and intuitive. One knows without knowing one knows. Most listeners will recall the salient features of an entity as complex as a Beethoven symphony after only one or two hearings. Memorising the phone book or the decimal expansion of pi would be, in distinction, dishearteningly effortful. While Beethoven's notes rendered into pure number would undoubtedly prove more consistently patterned and memorable than the phone book, I for one prefer not to experience the Eroica that way. Music consists of emotionally significant content organised in an intuitively amenable form.

Although Leibniz was speaking of the static numerology of harmony – the consonant bliss of chords governed by the Pythagorean ratios [6] – his remark might just as well have encompassed the time-dependent patterns and forms of music, music as change, music as motion, music in a dynamical sense. In Leibniz' day, dynamics as a science was yet in its infancy. We are used to the post-Newtonian world in which maths can send a man to the Moon, but through the 17th Century it yet aspired to mathematical rigour. Leibniz himself had had a leading hand in its rearing, having developed Descartes' vague notion of vis viva, "living force", into the mathematically concrete concept that we now call kinetic energy. [7] Ultimately, the rise of Newtonian dynamics made clear that the motions and interactions of bodies was equally as mathematical a matter as Pythagoras' ratios.

Leibniz' intuition must have led him to suspect that the motions of bodies followed mathematical laws. It was left to his rational mind to derive such a law by contemplating idealised configurations, contrived to make clear new lines of reasoning – a "thought experiment" as such contemplation is termed. Perhaps, given that the Pythagorean ratios governed harmony, the science of musical statics, there were equally laws of musical dynamics that were yet to be discovered?

The Pythagorean basis of harmony confers at least some level of objectivity, consonance and dissonance providing fields of force directing the motion of music. And we can indeed speak of

Click here for the table of contents

"motion" in music, for music's most salient characteristic is that it takes place in time. Musical elements and structures subsist in time. It is their evolution that we find fascinating, and the degree to which this development is conditioned by the innate potential of elements and their interaction with contrasting ideas. Dynamical dissonance embraces a much wider concept than disharmony: interruption of rhythmic pattern, change of key, disruption of mode, asymmetries and broken progressions, knock the system out of equilibrium. The music, to recover its balance, wanders through even more remote regions before it winds its way back to its state of rest in order and consonance. It is dissonance that drives the music forward; perfect harmony is musically inert, incapable of further development.

I do not mean this analogy to be taken too formally. Music cannot be modelled as a literal physical theory. But on some underlying level, the same cognitive resources are harnessed when we observe complex dynamical systems as when we watch tendrils of ink curling through water, debris dancing in dust devils, or as when we hear the swirling arabesques of a Chopin Étude.

Music is like physics, but physics in a sense closer to the Aristotelian word physis – the propensities of objects to grow, change, move according to their own nature. This sense is as much organic and biological as it is mechanical, as much teleological as it is deterministic.

Above all it is intuitive, but this is not to imply intellectual inferiority. Musicologists praise the "logic" of a Haydn quartet or a Beethoven sonata. Sibelius famously told Mahler that the essence of the symphony lay in its "profound logic". [8] So – "profound logic"; "hidden arithmetic": not in the sense of simplistic algorithm or crass numerology, but a subtle, poetic rigour concealing its secrets beneath the surface. To bowdlerise Blaise Pascal, "the Art has its reasons, which Reason doth not know". [9] When the organisation becomes too explicit, too trite, art falls apart. The subtle nebulae of Rothko's blocks, the whorls of a Pollock drip painting, the sonic torrent of a Nancarrow Player Piano Study are too overwhelming for my intellect to absorb; yet my intuition delights in their rich textures, and I want to believe they are the product of an order too subtle or complex for my rational mind to fathom.

Unruly Rules; Inklings & Intimations

It is interesting that Leibniz, the champion of the "occult arithmetic" of music as an intuitive form of calculation, developed a distaste for the abstraction of science, railing against those "…incomplete and abstract concepts, which thought supports but which nature does not know…these are nothing but the incomplete thoughts of philosophers who do not sufficiently look into the natures of things" (Leibniz 1703, 252-258).

5.3 Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Leibniz, one of the foremost mathematical physicists of the Enlightenment, knew that the abstraction of physics – that remarkable intellectual triumph of his era – was not enough. How, after all, could it be otherwise? We live in a world of such complexity that classical physical models were necessarily idealised approximations determined under carefully isolated, close-to-equilibrium conditions. They seem laboured and unintuitive because in an environment teeming with complexity, they make bad cognitive templates for any efficient, fast-reacting creature. An intelligent organism that made extrapolations about its environment by solving differential equations from the bottom up would make for very bad design sense. In a desperate, tight, fight-or-flight situation, we don't have time to solve differential equations. Neither do we have the luxury of taking measurements precise enough to beat the notorious sensitive dependence on initial conditions characteristic of nonlinear systems. [10]

That is not what we do. Fortunately, the physics of non-linear systems, complex systems and – Chaos Theory in the popular parlance – offers clues as to what strategy the "blind watchmaker" of evolution might have adopted instead.

That there can be a science of complexity at all is remarkable, no less that we find the objects of that science – strange attractors and fractals – intriguing and beautiful, and that intelligent life can flourish in a world. [11] It is possible because systems that are nonlinear, far from equilibrium, or that possess many degrees of freedom, exhibit striking emergent order on high levels, patterns which exhibit universal properties independent of their method of production. The burgeoning science of pattern formation shows us that simple low-level rules can give rise to remarkably rich phenomena, preserving qualitative and quantitative similarities across a wide range of physical, chemical, biological and computational systems.

In Karl Popper's words, "all clouds are clocks, even the most cloudy of clouds" (Popper 1966). But you're not going to get very far very fast if you persist in modelling each and every water molecule in a cumulonimbus. No, but there is something irreducibly "cloudlike" about our perception of clouds that defies clocklike analysis, yet manages to follow into its own set of amorphous natural laws couched in terms of ineffable cloudessence. They seem to follow a set of unruly rules. So perhaps it is truer, from the point of view of human intuition, to say that "all clocks are clouds, even the clockiest of clocks." Clocks are ideal abstractions; clouds are the bread and butter of the complex and messy world that we inhabit. A perceptual system attuned to the high-level, universal, laws that emerge from complex systems would prove adaptable to a remarkably wide range of phenomena. world that we inhabit. A perceptual system attuned to the high-level, universal, laws that emerge from complex systems would prove adaptable to a remarkably wide range of phenomena.

5.3 Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Music (and art in general) is perhaps an echo, isolated and distilled, of such a perceptual capacity, an exercise not quite in arithmetic, but in a sort of "folk physics", based on qualitative, intuitive inklings of emergent properties which we use to navigate through a seemingly ruly-yet-unruly world. All we need to know are the unruly "cloud" rules; we neither need to know the underlying ruly "clockwork" rules, nor can we derive them, thanks to the sting-in-the-tail of universality.[12] Still, we have faith that there is an order. That faith sets the creative artistic flame alight, no less the scientific curiosity tingling. In art, we aim to transpose the high-level pattern into new media, like paint on canvas or notes on strummed strings, with rules each of their own; to transpose and to amplify and to spin into new creations. In science, we wish to isolate and reduce and ascertain the rules that give rise to the patterns, confirming our hunch that such rules exist, and that they might reveal some fundamental new law of nature. Art sets patterns free, to do as they will, without having to explain themselves; science pins them down.

When we step back from the canvas or leave the concert hall and encounter textures in the real world – the web-like veins of marble, the grain of wood – we carry over these intuitions for forms and structures, patterns and processes that have been honed through our contact with art. We start to see van Gogh's swirling skies, hear Messiaen's pungent harmonies in birdsong. The role of art is to disclose, amplify and present back to the world the latent order that we perceive within it. It makes concrete our grasp of pattern, process and form that observation of nature engenders within us. When we sense an order that we cannot quite grasp consciously, it sets our imagination tingling: "The imminence of a revelation that does not occur," Jorge Luis Borges once wrote, "is, perhaps, the aesthetic phenomenon" (Borges1964, 223). In unsatisfied curiosity lies endless creative potential.

Music as Metaphysical Abstraction

But there are those that would consider this speculative union between music and physics too easy and banal and incapable of doing justice to the greatest art. Have we not neglected the mystical, metaphysical element of Pythagoreanism? Physical theories come and go – yesterday it was Newton, the day before Pythagoras, now it is chaos theory; but tomorrow? A great work of art is eternal, and must transcend the theory of the age if it is to survive. It is not physical, but metaphysical.

The philosopher who, after Pythagoras, is renowned for elevating music to the level of metaphysics is Schopenhauer. Paraphrasing Leibniz, he remarked that: "music is the hidden metaphysical exercise of a mind unconscious that it philosophises" (Schopenhauer (1819) 1910, 333). The pleasure of music is not merely the intellectual satisfaction of arithmetic, of "making a sum come out right", as he says, but:

> *We must attribute to music a far more serious and deep significance, connected with the*

Click here for the table of contents

> *inmost nature of the world, and our own self. Music is as direct an objectification of the whole Will as the world itself. That is why the effect of music is so much more powerful and penetrating than that of the other arts; for they speak only of shadows, but music speaks of reality itself.*

In other respects, his was a most un-Pythagorean system, in which the ultimate nature of reality, which he called the Will, was a chaos, not a cosmos. Like Kant's Things-in-Themselves, the Will remains hidden and all we see are distorted appearances, refracted through the flawed prism of consciousness. But unlike Kant, Schopenhauer granted that, through art, and through music in particular, the "inmost nature of the world" was ultimately accessible to us. Music speaks directly in terms of metaphysical fundamentals.

The 6th century philosopher Boethius distinguished between ordinary audible music, musica instrumentalis, and the abstract music of the cosmos, musica universalis. Music is here considered, not so much a representation of the world in the medium of sound, but in a metaphysically prior position: the transcendent order and process from which both audible music and the physical universe arise.

Paradoxically, it is only through the experience of musica instrumentalis that we approach musica universalis. Art affords a glimpse of eternal, universal truths, but it does so through being embodied in finite particulars, experienced by corrupt and imperfect beings. When Shakespeare, in The Merchant of Venice, says of the Music of the Spheres that "Such harmony is in immortal souls, / But whilst this muddy vesture of decay / Doth grossly close it in, we cannot hear it" (Shakespeare The Merchant of Venice V.i.63). He is wrong; art ennobles "this muddy vesture of decay".

Science is concerned with the general properties of things; but it is their particular essences that we experience most vividly. The wonder of art is that it makes intuitively explicit the universal laws and underlying forms immanent within these particular, contingent essences. Oilpaint, hogbristle brush, canvas; gut string, hair bow, spruce soundboard: these are not merely the means of representing; their homespun, down-to-earth characteristics inform the very essence of their purpose. Art aspires to spirit by revelling in its embodiment in flesh.

It's not so much that art represents any particular philosophy; art is philosophy. Art-philosophy is mythology in the widest and the best sense – an exercise in fantasy that takes one's entire belief system into its purview. By manipulating, arranging, editing objects in the world, the artist selects the configuration that articulates most clearly to the viewer his or her belief; a belief that does not suffer the theory-ladenness of scientific models because – like the best scientific experiments [13] – it states its case directly in terms of real objects rather than derived concepts.

Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Anarchist historian and art writer Herbert Read summed things up concisely: “Art becomes an intuitive means, as exact as mathematics, for representing the fundamental characteristics of the cosmos” (Read 1959). Maybe not so much as representing – ultimate truths are too vast and too subtle for that – but conditioning us to glimpse the deep underlying principles that bind all things.

Summary

The greatest gift science has to give is a sense of awe and wonder. When I observe the planet Jupiter through a telescope or watch birds flocking I still, after so many years, feel an overwhelming rush of emotion that is almost religious, an inexplicable sense of coming into contact with the mystery of Being. This must be close to the Orphic experience of ecstasy – a feeling so intense, so shocking in its profundity that one loses oneself.

It must, too, lie behind the Pythagoreans’ reverence for number and for the Music of the Spheres. It is life-changing; surely as much for the ancient Greeks as for us. Unfortunately it has little to do with modern academic science, procedural, humdrum, metric-obsessed, grant-starved and backbiting. I know how Whitman felt when he evacuated an astronomy lecture “soon unaccountable… tired and sick” (Whitman 1900) and went to gaze dumbstruck at the stars (I dare say, I’ve given lectures myself like that). It needn’t be like this: we must simply never forget what is at stake, the profoundest of human emotions, more important than mere cleverness. Art can do this too – to name a couple of personal choices, the conclusion of Sibelius’ Seventh Symphony, or Cézanne’s Grandes Baigneuses.

This subjective, Orphic art, in dialogue with science, can satisfy our craving for meaning; amplify the numinous and sublime in nature; intimate the infinite; and hint, through our particular, subjective, finite interaction with the world, at nature’s universal law. “Science, unadulterated,” wrote Bertrand Russell, “is not satisfying; men need also passion and art and religion” (Russell 1945, 26). After all the numbers have been crunched, lines plotted, hypotheses confirmed and papers published, there is still room for explication, chomping over and celebrating the significance of ideas and the relevance they hold to us as finite individuals. The artistic instinct brings out and makes personal – makes gratifying and candid and spontaneous – these deeper layers of reality peeled back through scientific exploration.

Footnotes

[1] Though the oldest known proof of Pythagoras’ theorem was that given three centuries later by Euclid; please also note that the algebraic forms stated here were not used until Descartes applied algebra to geometry in the 17th century.

Robert Priddey, ed. Alice Williamson ‘Occult Arithmetic’ Writing Visual Culture 5 (2012)

Occult Arithmetic: Music, Mathematics & Mysticism

Click here
for the table
of contents

Footnotes

[2] …and "sisterhood": women, who otherwise got a raw deal in the Ancient Greek world, were admitted as equals by the Pythagoreans.

[3] Interesting to note that Pythagoras' father Mnesarchus was supposedly a jewel engraver: perhaps the regularity of crystal forms inspired this geometric ontology.

[4] See Godwin 1993 for a detailed history of the discourse surrounding the "Music of the Spheres", covering astronomy, philosophy, mysticism.

[5] Himself incidentally the teacher of Lorenz Mizler, who founded the Sozietät der Musicalischen Wissenschaften to promote the development of a musical science based on mathematics, and whose most renowned member was none other than Johann Sebastian Bach.

[6] It is far-fetched to think that appreciation of harmony involves any sort of calculation in a literal sense, whether conscious or not.

[7] Leibniz developed this concept between 1676 and 1689. For more on the debate surrounding the vis viva see Smith 2006.

[8] The original wording of their German conversation was never recorded, Sibelius reporting the phrase "djupa logik" in Swedish to his biographer Karl Ekman. I'm grateful to the Sibelius scholar Andrew Barnett for clarifying this matter (Barnett 2007, 185).

[9] "Le coeur a ses raisons, que la raison ne connaît point" (Pascal 1669, IV.277)

[10] i.e. what is now commonly known as the 'butterfly effect' in chaos theory: in nonlinear systems, a small change in initial conditions can cause very large differences at later states.

[11] Perhaps this Goldilocks-like balance between sterile order on the one hand, and chaotic complexity on the other, is necessary for the evolution of intelligence? The world cannot be too predictable, otherwise higher intelligence has no need to evolve beyond simple algorithm; too random and no mind can second-guess it. "Just right", on the infamous Edge of Chaos, and brains will flourish, coaxed by biological success to evolve ever greater and more subtle architectures. If a similar balance between cosmos and chaos – between Apollonian and Dionysian – regulates aesthetic fascination, then it is no surprise that we find the natural world beautiful. Beauty is a precondition for the existence of intelligent minds.

[12] Any number of clockwork mechanisms can be fabricated into a qualitatively similar set of clouds…'universality' here refers to the phenomenon of large scale systems displaying properties that are independent of the properties of the interacting parts.

[13] e.g. Newton's demonstration of the spectral dispersion and recombination of white light with prisms. The experiment unveils hidden truths about physical reality even though Newton's own corpuscular model of light, which he thought his experiments supported, was wrong.

Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

References

- Barnes, J. 1984. The Complete Works of Aristotle, Volume 2: The Revised Oxford Translation. Princeton: Princeton University Press
- Barnett, A. 2007. Sibelius. New Haven, CT: Yale University Press.
- Bloom, A. 1968. The Republic of Plato. New York: Basic Books
- Borges, J.L. 1964. "The Wall and the Books." Labyrinths. London: Penguin, 221-223.
- Godwin, J. 1993. The Harmony of the Spheres: A Sourcebook of the Pythagorean Tradition in Music. Rochester, VT: Inner Traditions International.
- Ives, C. 1953. The Unanswered Question. New York: Southern Music Publishing Co.
- Leibniz, G.W.1703. "Letter to Burchard de Volder". In Die Philosophischen Schriften von Gottfried Wilhelm Leibniz, ed. Cl. Gerhardt. 1875. 7 vols, vol.3. *This is not necessarily the source used by Priddey but an indicator of where the material may be found.*
- Leibniz, G.W.1712. "Letter to Christian Goldbach". In Schutz, A. 1964. "Mozart and the Philosophers", The Collected Papers, vol.2, ed. A. Brodersen, Studies in Social Theory. The Hague: Phenomenologica, Martinus Nijhoff. *This is not necessarily the source used by Priddey but an indicator of where the material may be found.*
- Pascal, B. 1669. Pensées de M. Pascal sur la religion, et sur quelques autres sujets, qui ont esté trouvées après sa mort parmy ses papiers. Paris: Port-Royal
- Popper, K. R. 1966. Of Clouds and Clocks: An Approach to the Problem of Rationality and the Freedom of Man. St Louis, MO: Washington University Press.
- Read, H. 1959. A Concise History of Modern Painting. London: Thames & Hudson.
- Russell, B.1945. A History of Western Philosophy and Its Connection with Political and Social Circumstances from the Earliest Times to the Present Day. New York: Simon and Schuster.
- Schopenhauer, A. (1819. Die Welt als Wille und Vorstellung. Leipzig: F.A. Brockhaus) 1910. The World as Will and Idea. 7th edition, trans. R.B. Haldane, and J. Kemp. London: Kegan Paul, Trench, Trubner, 3 vols, vol.1. Shakespeare, W. The Merchant of Venice.
- Smith, G.E. 2006. "The Vis Viva Dispute: A Controversy at the Dawn of Dynamics", Physics Today 59 (10):31-36.
- Whitman, W. 1900. "When I heard the Learn'd Astronomer." Leaves of Grass. Philadelphia: David McKay.

Robert Priddey, ed. Alice Williamson 'Occult Arithmetic' Writing Visual Culture 5 (2012)

5.3

Occult Arithmetic: Music, Mathematics & Mysticism

Click here for the table of contents

Robert Priddey, ed. Alice Williamson 'Occult Arithmetic' Writing Visual Culture 5 (2012)

Contact

Alice Williamson

Music Department

School of Creative Arts

University of Hertfordshire

College Lane, Hatfield, Herts.

lacie@cantab.net

5.4 Natural Calligraphy

Click here for the table of contents

James Leonard Collett, University of Hertfordshire

Calligraphy can be a synthesizing activity to bring into dynamic equilibrium the forces of the intellect and the pleasures of the senses. Lee Hall (adapted by Sheila Waters and forming the frontispiece to Child (1985)

How are lines drawn in the world? What shapes the paths taken by light and by matter? And what do the answers to these questions have to do with calligraphy concerned as it is with the shape and quality of a line?

Let's start simply, ignore the quality of line and just think about its progress - of getting from A to B. One of the ways of transferring a drawing to a support for painting is pouncing. A series of holes is made along the lines of the drawn design. The drawing is laid on the canvas or panel, and fine charcoal or chalk dust in a small muslin bag pounced or rubbed over the holes leaving a faint network of dots on the support. Now completing the transfer of the design is not the simple exercise of pair-wise joining the dots because the intent is to use the dots as a guide to recreate the curves of the original drawing. If the dots are close together, simple line elements are reasonable, if inelegant, approximations to the curve. But where the dots are sparse, the copyist must make judgements: in getting from A to B, the path is a curve, weighted by the knowledge of points that precede A and those we will join beyond B. The points constrain the curve but without further prescription its path is not unique. One such prescription might be to minimise extremes of curvature, or more specifically (some function of) the curvature averaged along the path. A convenient way to compute this path is to use a mechanical spline - a thin piece of flexible wood pressing against pins placed at the pounced points. The anchored spline relaxes to follow the curve in which it has the smallest possible elastic bending energy given the constraint of the pins. The local bending energy within the spline is related to its local curvature; so the relaxed state, minimizing the sum of all these local energies, also minimizes (the square of) the local curvature summed along the spline. The resulting smooth curve manifests a natural law and indeed, more generally a natural principle – that equilibria (relaxed stationary states) are associated with constrained configurations of least energy. This does raise an interesting question – are these relaxed states aesthetically appealing because we recognise them as equilibria – stationary and therefore unthreatening?

A bent wooden strip generates pleasing interpolated curves – can we learn more from other naturally created paths? You are walking along a beach and see a swimmer in difficulties. The line between the two of you is oblique to the shoreline [Fig. 1]. You want to reach the swimmer as quickly as you can.

Natural Calligraphy

Click here for the table of contents

But you can run faster than you can swim and so you realise that it may be better to follow a path that allows you to exploit this, not simply the straight line path from A to B. The bent path is longer (and its initial direction quite alarming to the swimmer who might think you are racing to someone else). However, the total time can be made shorter than the simple straight line path as you have less distance to travel in the water where your speed is lower. The exact offset in your bearing (and the bending of the line) depends on the ratio of your running and swimming speeds. The path from A to B now consists of two line elements: but if we imagine the sand getting wetter as we approach the water (making running more difficult) and swimming getting easier as we head further from the shore, the trajectory will become a curve, still with the property of being the path from A to B that takes the shortest time. If we replace the rescuer by a light ray and sand and water by air and glass (or any material in which light travels slower than air), we have refraction of light at the interface.

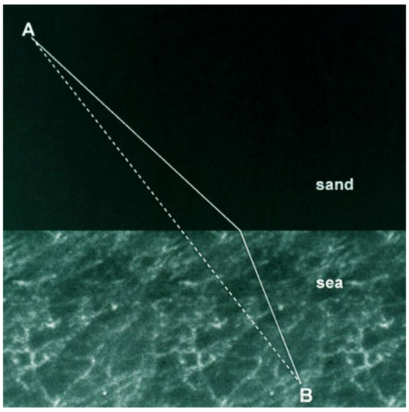

Fig. 1: The minimal time path between A and B is not the simple straight line trajectory (dotted line) but the refracted path that involves less distance in the sea where the rescuer's speed is lower. Diagram © the author.

Another natural path is therefore described by an extremal principle – in this case Fermat's principle of minimal time. It turns out that this is actually a special case of a more general principle that can be used to describe not just light but objects as diverse in size as atoms and stars – the principle of least action. So dynamic processes in nature and the calligraphic properties they possess are, just like the spline, described by an extremal quantity. The principle of least action underlies an approach to the study of quantum paths pioneered by Richard Feynman (Feynman 1942). In quantum mechanics we cannot identify one true trajectory that a particle will follow. But to each possible path we can attach a weight and this weight is determined by the action evaluated along that path. It would seem like quite a task to enumerate all possible paths (and indeed it is) but fortunately cancellation of contributions from neighbouring paths occurs so that the focus of attention remains, in typical cases, close to the classical trajectory. Nevertheless this

5.4 Natural Calligraphy

Click here for the table of contents

is now diffuse: the consideration of non-classical paths close to the unique classical trajectory is now required in determining where our particle might be found. There is something of an analogy here with exploratory drawings, for instance Leonardo's Rearing Horse in the Royal Collection at Windsor Castle (Zöllner and Nathan 2011, 317). In this pen and ink and red chalk study, we see the limbs and head of the horse depicted in several overlapping dynamic states with the fixed curves of the torso qualified by stronger lines.

But we should not think of these microscopic paths as determinate and visible like Leonardo's construction lines or aircraft contrails, they are potential paths useful in calculation but forever inaccessible as visible histories. When quantum mechanics was developed, real paths visible in the laboratory, such as the contrails of α-ray tracks in a Wilson cloud chamber, seemed at odds with the weakened idea of the classical trajectory. But even these paths really only consist of many pinned points - locations where atoms have been ionised and condensation has occurred; we complete the full path in our minds. The cloud chamber does raise another interesting question: how to reconcile the spherical wave that theory predicts to accompany the α-particle's emergence from a radioactive nucleus, with the linear trail we observe, without abandoning the wave description of the particle. As Neville Mott nicely put it, the difficulty of imagining how: "a spherical wave can produce a straight track arises from our tendency to picture the wave as existing in ordinary three-dimensional space, whereas we are really dealing with wave functions in the multispace formed by the coordinates both of the α-particle and of every other atom in the Wilson chamber" (Mott 1929, 79). This mutual dependence is also a feature of intermediate pinning points along Feynman's ghostly trajectories. A higher dimensionality underlying a path will be a recurrent theme in this paper.

Quantum mechanics has led us then to weaken the line strength of classical paths and dispense with the idea that they have no thickness. We can think of the quality or breadth of each path varying along its length, dependent on the degree to which nearby trajectories contribute at each point. A character in traditional calligraphy has a line changing in definition and breadth along its length. There is a simplistic analogy here. The tip of the drawing instrument (be it pen or brush) has a width; so that different parts of the tip describe different paths. The breadth of the character is changed by varying the angle between the tip and the line of the figure, with the narrowest line created by having the two parallel. More interestingly perhaps, some calligraphic characters can be imagined as three-dimensional ribbons, twisted and viewed in two-dimensional projection. What we perceive as the energy of these characters may unconsciously be related to the dynamic of this twist.

5.4 Natural Calligraphy

Click here
for the table
of contents

Varying line strength is also familiar in the evolving calligraphy of the caustics formed at the base of a swimming pool by intersecting light rays refracted to different degrees by the gentle disturbance of its surface. A static example created by reflections rather than refraction is depicted in Figure 2. The caustics in this figure nicely introduce the idea of line strength in natural calligraphy but there is a feature of the quantum paths that eludes them. In the caustics, line strength is related to reinforcement – intensities from many overlapping rays, arriving from slightly different directions, are purely additive and cannot lead to cancellation. The sources of light are incoherent and so there are no interference effects in determining the strength of line. But it is just these phase effects that lead to the addition and subtraction of neighbouring paths in quantum mechanics and the resulting 'smeared' classical trajectory.

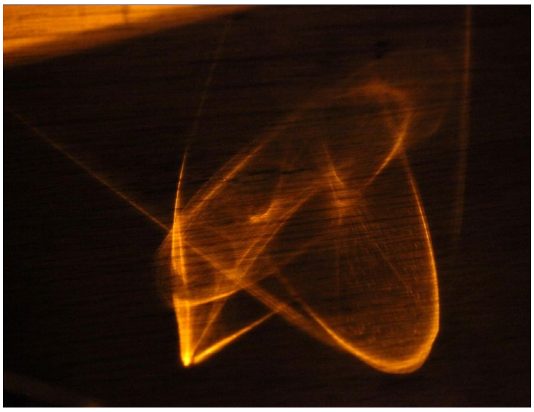

Fig. 2: The sweeping curves and varying strength of caustics formed on a wooden bathroom shelf by light reflected from two extravagantly curved plastic bottle lids. (Photo © the author)

We can make one more observation here. The light rays from the bottle lids in Figure 2 are streaming through a three-dimensional space. But they are made visible to us when they strike a two-dimensional shelf (and are captured in a two-dimensional image). The pattern of scattered light will change if we change the position of the scattering surface. We can select from the continuum of positions of the surface, those that give rise to illuminated 'characters' with a special appeal to us. Experimentation suggests that the most interesting 'characters' have localised well-defined intense arcs and cusps embedded in a veil of ghostlier curves – a high dynamic range of brightness and of spatial frequency. Small movements of the surface or of the light sources change these two distributions and with it the 'character'. We can, to some extent, quantify the appeal of a particular figure in the numbers that represent these distributions, in the same way that we can investigate how we respond to computer-generated landscapes by varying their fractal dimensions. Talk of numbers and beauty is fraught with danger and cultural references and tradition will colour any aesthetic of the characters. However traditional strokes across cultures are all limited by the articulation of the hand and there is a universal appreciation

Click here for the table of contents

of fluidity and instinctive mark-making. Their very simplicity does make it meaningful to ask about the sensual impact of varying geometrical qualities such as curvature and balance.

will change if we change the position of the scattering surface. We can select from the continuum of positions of the surface, those that give rise to illuminated ‘characters’ with a special appeal to us. Experimentation suggests that the most interesting ‘characters’ have localised well-defined intense arcs and cusps embedded in a veil of ghostlier curves – a high dynamic range of brightness and of spatial frequency. Small movements of the surface or of the light sources change these two distributions and with it the ‘character’. We can, to some extent, quantify the appeal of a particular figure in the numbers that represent these distributions, in the same way that we can investigate how we respond to computer-generated landscapes by varying their fractal dimensions. Talk of numbers and beauty is fraught with danger and cultural references and tradition will colour any aesthetic of the characters. However traditional strokes across cultures are all limited by the articulation of the hand and there is a universal appreciation of fluidity and instinctive mark-making. Their very simplicity does make it meaningful to ask about the sensual impact of varying geometrical qualities such as curvature and balance.

In the case of the light caustics we have just described, the two-dimensional surface can, in principle, be moved so as to meet the envelope of light rays in differing ways and give rise to different characters. There is another example of natural calligraphy, where the two-dimensional surface is now fixed but the characters still evolve, and that is the vertical soap film [Figs. 3, 4, 5]. In fact the soap film is truly three-dimensional because, although its thickness is tiny, it is variations in this dimension that give rise to the different colours in the film. These are interference colours so, unlike the case of overlaid intensities in the caustics, we are seeing phase effects and cancellation of waves.These are effects of just the type we described earlier that give a breadth and varying quality of line to the classical path of a particle just the type we described earlier that give a breadth and varying quality of line to the classical path of a particle.

The colour in a particular region of Figures 3 to 5 indicates that the thickness of film there can accommodate a whole number of that colour’s waves (reinforcement through interference); so the picture can be thought of as a natural contour map, albeit of a very shallow topography. The colours are ephemeral, changing as the film thins under drainage or evaporation. When the soap film is drained vertically, there is initially horizontal striping reflecting the gradually increasing thickness toward the base of the film; but instabilities set in at the edges of the supported film [Fig. 4], and can be further stimulated to create a turbulent structure that resolves itself into relatively stable islands.

Natural Calligraphy

Click here
for the table
of contents

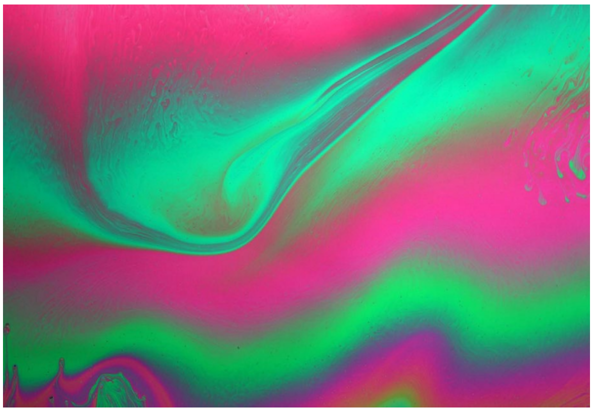

Fig. 3: Interference colours in the early evolution of a draining soap film. Note the varying crispness of line in different parts of the film and the broad range of intensity. (Photo © the author)

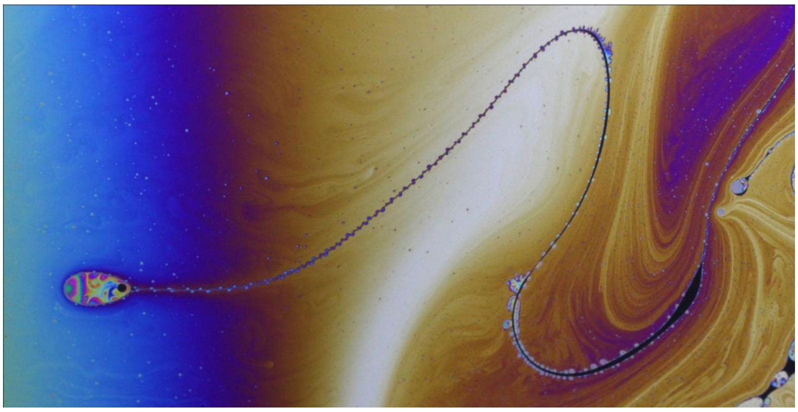

Fig. 4: The sinuous trail of a heavy droplet falling within the film. Note the interlacing on the tail and the broad banding present before the film becomes strongly turbulent. (Photo © the author)

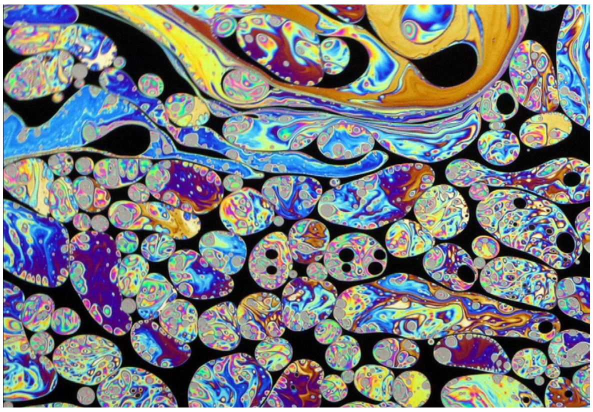

Fig. 5: Interference colours in the late evolution of a thin vertical soap film. The dark regions ('the page') are the thinnest regions of the film. (Photo © the author)

5.4

Natural Calligraphy

Click here for the table of contents

This late stage in the evolution of the film [Fig. 5] leads to a calligraphic ornamentation that has strong resonance with the intricate abstract whorls in early illuminated books such as The Book of Kells. A nice example is provided by the historiated initials on Folio 34r, the Chi-Rho page, in which spiral mandalas float like islands within island lakes in a geometric archipelago (Meehan 1994, 27).

Let's examine our idea of the two experiments – the scientific and the artistic - in the context of the soap films. The scientific study focuses on the instabilities that occur; when thicker portions of the film are displaced from their equilibrium positions (for example by gently blowing on the film) or when fast-flowing streams develop close to the edge of the film. But not every flow in the film leads to a calligraphic character that works artistically. The success of Figure 3 again seems to be related to the co-existence of intense well-defined curves in a smoother background, enhanced in this case by a striking juxtaposition of colours. What do we understand by meaning in an abstract image like Figure 3? Calligraphic characters can carry literal meaning when they represent words; but they can, simultaneously or independently, convey meaning through their shape (for instance, Klee, 1961). Nicolette Gray (1970, 28) gives some specific examples from branches of early Western calligraphy: 'dynamic energy in a Gothic flourish, insecurity in a cramped Merovingian irregularity, balanced self-sufficiency in the litterae caelestiae'. The well-defined intense regions of Figure 3 are first to draw our attention when we try to read the image. But we pick them out because they sit in a background which has gentler coloration and smoother transitions. On the other hand, a world too dense with potential meaning becomes overwhelming. So whilst we admire the order on many different scales and in differing colours that seems to underlie Figure 5, we don't progress much beyond that. We are perhaps not trying to understand this world when we look at it, but the richness of the pattern suggests its exploration may go very deep. The selection process in our artistic experiment seems then to be directed toward those images in which we can visually select features within them strong enough to bear distinct meanings; and selection implies that there are also features within the same image that that don't immediately have this property.

We now turn our attention to the components of natural calligraphy to see if we can draw useful comparisons with the physical elements of traditional calligraphy. Ching Hao separated brush and ink in the six essentials of painting described in his Pi Fa Chi (Notes on Brushwork) and repeated in the compendium, The Spirit of the Brush, compiled and translated by Sakanishi (1939). A Chinese calligraphic character has a life in the movement of the brush and the laying down of the ink, modulated by the resistance and absorbency of the paper to that viscous fluid. A natural calligraphy with a similar angular elegance and dependence on process and material is that of the spark. The character so created, in the photographic documentation of the event, is partly the result of chance

Natural Calligraphy

Click here for the table of contents

(the shape and size of the incandescent fragment of steel) but is also strongly dependent on the carbon content of the steel - indeed spark testing exploits the character of the spark to deduce the carbon content. The hot carbon is rapidly oxidised to carbon dioxide and the expanding hot gas blows the fragile steel scrap apart - individual fragments are smeared into jets of light even in a brief exposure [Fig. 6]. The balance of the character is preserved naturally by the requirement that momentum be conserved – a small fast moving offshoot from the main line causes that line to veer in the opposite direction. Balance is achieved in the pictogram of the spark by a conservation law of nature. This conservation law is known to arise from a particular symmetry of the equations describing the motion (Arnold, 1978, for example) – an invariance to spatial translation. Since the momentum is a product of mass and velocity, a small particle of low mass ejected in one direction may need only a small compensating velocity shift in the more massive parent fragment. When we judge the balance of a calligraphic character, we will naturally weight the thickness of the line in much the same way, so that the centre of mass of the character remains stably and, from our perspective, comfortably positioned deep within the character. This is a well known characteristic of standard Chinese characters and geometrical guidelines ('hua ko') are often used in the preparation of texts for printing (Gaur 1994, 111). The Feynman diagrams that are widely used in quantum mechanics, designed to simplify involved calculations and manifest momentum conservation, look not dissimilar to the spark. Clearly the character we have created here is very dependent on the exposure time within our camera. But the balance will exist in any image by virtue of the physical law, at least as long as the brightness of a fragment is proportional to its mass (something however that is far from guaranteed). The artistic experiment in the case of the spark involves the selection of a spark image with sufficient detail (the varied strengths and angular dispersal of lines) to hold the attention without losing its luminous simplicity.

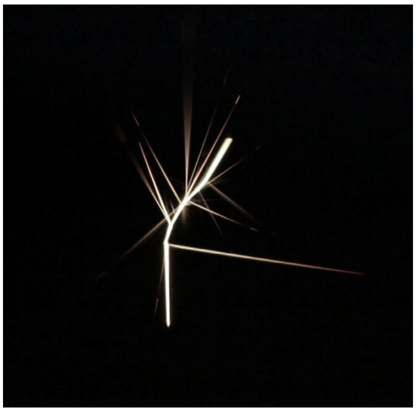

Fig. 6: This image of a single spark shows the sequential break-up of the main fragment (the strongest line). Note the branching of the smaller ejected parts and the compensatory movement of the fragment to balance momentum. (Photo © the author)

5.4 Natural Calligraphy

Click here for the table of contents

If sparks can be compared to a cursive Chinese script, the fluid and rolling line of semi-cursive script requires a different natural hand. We might also have in mind here, styles of cursive writing within Islamic calligraphy, in particular Thuluth or the closely-related Tawqi (Safadi 1978). These share long gently curved horizontal wave-like strokes that are punctuated by loops or cusps. Episodes of slow change in the line's journey begin and end in sudden but graceful changes in curvature. So where can we look to find a similar intermittence in nature?

A nice example is provided by a thin stream of glycerol released into water [Fig. 7]. The interface between two distinct fluids in relative motion is a fertile source of instability though we can exert some control over the evolution of the character by modulating the supply rate of glycerol. There is again an important lesson to take from this example – the stream with its sinuous line is three-dimensional and viewed from different angles offers distinct projections and hence quite distinct characters. Meaning could, quite literally, be changed by our perspective. The head of one stream [Fig. 8] provides a beautiful natural counterpart to knotted decorated animal letters represented in The Book of Kells.

Fig. 7: A jet of glycerol released into water. Some idea of the three-dimensionality of the line can be got from the 'hotspots' along the stream which indicate that a significant component of the movement of the glycerol tube is along the line of sight. (Photo © the author)

5.4 Natural Calligraphy

Click here for the table of contents

Fig. 8: The intricate topology of the head of a glycerol stream. The classification of knots can be based on a study of properties of their projected intersections, properties that are invariant under moves that leave the topology of the knot unchanged. As a result, knots as symbols can be robust carriers of meaning. (Photo © the author)

There are reminders too of an intriguing scientific sculpture in the Whipple Museum in Cambridge, an interesting example of how real models can help in the visualization of natural phenomena. Three tangled wire loops represent the motion of an earth particle during the earthquake of January 15, 1887 constructed by Professor S. Sekiya of the Imperial University Japan. The motion in the model is magnified by a factor of 50 in all three space dimensions, doubtless for clarity but also constrained by the use of relatively thick gauge wire. A sequence of numbered tags along the wires represents second markers, so that in all 72 seconds of motion are represented in the wire loops. This is truly a line that resides, and is fully appreciated, in three-dimensions. However, the passage along the line can be seen in different terms in our two experiments. In the scientific one, we follow the pace of the time markers, but in the artistic one, we follow the natural pace of the curve – a curve that, like the spline described earlier, is an interpolation (and therefore an invention) from sparse data.

Calligraphic characters are of course often carriers of meaning and this requires a lack of ambiguity in deciphering them, although this may be overcome statistically by context (the principle behind some methods of code breaking). However in this last example, we have seen that a calligraphic reading may be changed by altering our viewing position. Whilst geometric properties of characters are not invariant under plastic deformation (or an altered viewpoint), topological properties are. So knots - already the seeds of a rich symbolism that exploits their strength (Eliade 1952) – are also robust carriers of potential meaning.

5.4 Natural Calligraphy

Click here
for the table
of contents

One of the themes developed here is that natural calligraphy often involves the projection of a structure from a higher-dimensional space. Up to this point, however, the examples selected can be interpreted as projections from three to two-dimensional space. The majuscules of natural calligraphy are drawn on cosmic scales and they also require us to think in terms of higher dimensional spaces to appreciate how they form. Galaxies are sometimes surrounded by sweeping streams and veils of stars [Fig. 9]. The delicacy of these structures belies the destruction to which they owe their origin. A small galaxy orbiting in close proximity to a massive host galaxy will be tidally stressed - the parts of the small companion closer to the host experience a greater gravitational pull than those parts further away. If this differential pull is large enough, it can overcome the binding of the small galaxy and tear it apart.

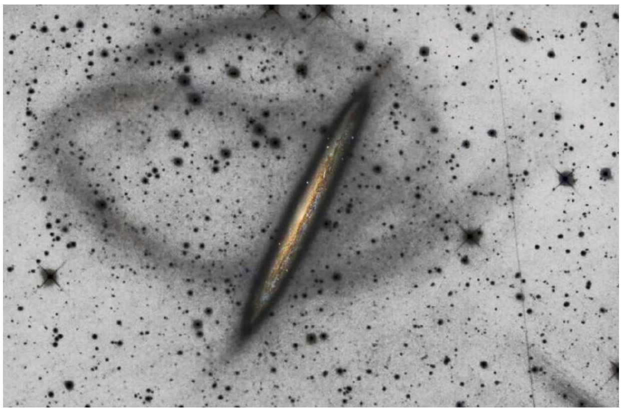

Fig. 9: The spiral galaxy NGC 5907 and its associated ghostly stream of stars - the unresolved grey band in the negative image external to the main galaxy. The main galaxy is represented in the central oval positive image. The main galaxy disc is seen edge-on so that the stream lies well outside the plane of the disc. The calligraphic character of the stream depends on many factors including the internal strength of the progenitor dwarf galaxy and its associated survival time. Whilst the dwarf survives, frictional forces from the diffuse star cloud through which it moves can modify the orbit and accordingly divert the arc of dispersed stars. (Image ©: R. Jay Gabany (Black Bird Observatory) taken from Martinez-Delgado et al. (2008, 463) and reproduced with kind permission of the authors and the Astronomical Society of the Pacific)

Stars leak out of the small galaxy and their differing speeds around the larger galaxy translate over time into a difference in position. A nice analogy is the slowly increasing length of a field of marathon runners. However, unlike a marathon field, the dispersal results from the combined effect of the runners (stars) starting with different speeds and the fact these speeds lead them to locations within the galaxy (orbits) where they are carried at different speeds. It is as if the marathon was run along a series of neighbouring moving walkways, driven at slightly different rates. There is another complication – the image of the stream we see is a two-dimensional projection of a three-dimensional structure (like the glycerol stream) and can show density enhancements that are simply the result of projection effects.

5.4

Natural Calligraphy

Click here for the table of contents

The stream can display caustics and self-intersections which evolve over time in a truly dynamic calligraphy. What dictates the sharpness of the characters created? The crucial quantity is the distribution of the stars in something called phase space – the six-dimensional space of position and velocity components. If the dispersion of the stars in phase space is small - the system is described as being cold - then the calligraphic character can be well-defined and caustics appear, reminiscent of perspectives through Naum Gabo's wire and Perspex sculptures (Nash and Merkert 1985, 122). A hot system on the other hand has a broad dispersion (like a diffuse ink spot), so that the character lacks sharp edges and caustics are weak. Figure 10 shows a simple simulation of the dispersion of stars in the gravitational (tidal) field of a massive galaxy. The character evolves over time with a shape dependent on the shear in trajectories caused by the galaxy's force field (the process), the initial dispersion of released stars, both in position and velocity, and the ease with which they unbind (the material). In this example, the force field was assumed not to change with time. It is clear that this assumption is only true where the stream is so dilute that it has little self-interaction and feels only the effect of the massive galaxy. Strictly, the massive galaxy will react to the unwinding stream but with the gentle reflex of a dancer casting off a thin veil. There are cases however where the galaxies are closer in size and this reflex leads to a significant evolution of the massive galaxy and its force field. There is something of an analogue in contemporary practice: Zhang Qiang, the creator of 'traceology', has the surface on which he is writing moved by an assistant in an unrehearsed and unpredictable way (Barrass 2002).

We can now summarize what we mean by natural calligraphy. Our common expectation is that natural processes lead to a universal softening of lines through diffusion, the gradual disappearance of linkages, and the merging and blending of colours. Natural calligraphy however describes the means by which nature creates beautiful well-defined lines, intricate knots and sharply delineated areas of colour. We see that traditional calligraphy shares these physical characteristics although its forms depend on the interplay of technical virtuosity and cultural reference. Our concern in this paper is not with the latter, or with the interesting question (which we will address elsewhere) of the aesthetic properties of particular curves and knots. We have however attempted to show that the principles that underlie the shaping and evolution of natural trajectories – extremal curves and conservation laws derived from symmetries – are reflected in the natural (and satisfying) way the hand can form a curve and stroke, and in the resulting balance of a character. The compelling beauty of some calligraphy is interesting and it is useful to understand why this is the case and how this aesthetic evolves within a tradition and a culture. This is too large a question for this paper but it is relevant to our theme.

5.4

Natural Calligraphy

Click here
for the table
of contents

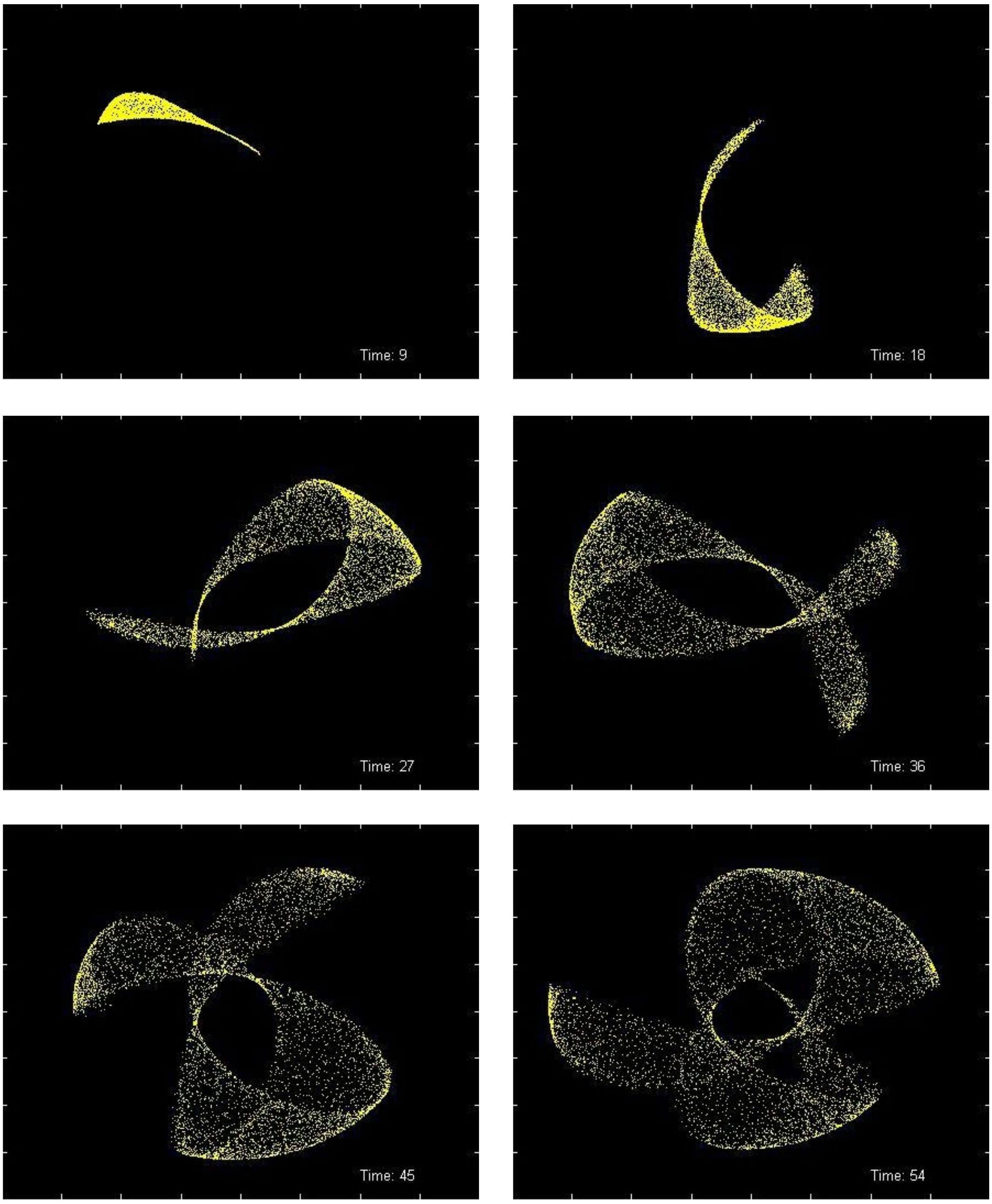

Fig. 10: A time sequence showing the calligraphy of an evolving stream of stars. The stars move under the gravitational force exerted by a massive galaxy. The cusps in density near the outer envelope of the stream are caused by the slowing-down of the stars as they reach this outermost limit, like a pendulum bob at the extremity of its swing. (Photos © the author)

5.4 Natural Calligraphy

Click here for the table of contents

Modern theoretical physics represents a way of understanding the world that is often practised without an acknowledgement of the tradition in which it is nestled. Current theory development in microphysics is based on aesthetic prejudices, not suggested by experience or experiment, a recipe in the past for generations of misdirection. We are vulnerable to aesthetic archetypes and we need to be aware of how and why we involuntarily succumb to some symbols and schemes. In the case of knots for instance, they can carry information (or meaning) in a robust way – we see them as persistent and having strength, but they also have an attractive plasticity (and corresponding independence from particular coordinate systems). Those areas of physics that we have drawn on in this paper lie within the realm of experimental and observational testing. Quantum mechanics was introduced to the argument to show how the path of an object really comes about from the interplay of many potential paths and we noted that an extremal principle (and symmetry) underpins this picture. The dynamics of a small galaxy was used to illustrate a high-dimensional space from which calligraphic characters emerged through projection. These projections might be images such as Figure 9 that we can photograph in the sky. However, we could also project into a two-dimensional space with components of position and velocity. We cannot observe this space but we can create the projection in a computer and evolve characters within this space. This was a recurrent theme of our discussion; that natural calligraphy is a process, but a process in which, as observers, we have to play a part.

Natural calligraphy suggests new departures for something we could call, in the broadest sense, artistic letter-forming. Contemporary calligraphic art is rapidly evolving and we will summarise how it may draw on lessons from nature as presented in this paper. First, a recurring theme of our natural examples was that the stroke-making processes were occurring in higher dimensional spaces and the characters were projections of the strokes in lower-dimensional spaces. We find two-dimensional characters which have broad and narrow elements attractive (for example, half-uncial script). It would be interesting to investigate if one reason for this is an unconscious reading of them as dynamic twisted ribbons viewed in projection. We can embrace this further - calligraphy could be made more sculptural. A work could be made in which we would have to assimilate different physical viewpoints to uncover the piece's sense, and in the case of calligraphy, we can imagine viewpoints carrying very particular meanings as 'letterforms' appear and disappear as we move around their higher-dimensional sculptural parent. This picture envisages a static parent, so that our movement alone creates change. But we have also given examples where there is instead time-dependence in the parent itself (like the disturbed galaxy), so that even a stationary observer will see an evolution of curve and hence, in principle, meaning. We can imagine a (probably hypnotic) calligraphic 'space' in which multiple letterforms

Click here for the table of contents

evolve over time giving rise, from time to time, to tiny islands of ephemeral meaning [Fig. 11]. We also made the point that there are properties of the parent, such as its knottedness, that do persist under different projections and in many cases under dynamic evolution. These are robust characteristics that could carry a persistent set of references for the parent, such as a vocabulary or grammar. There can be a random character to this process that runs a little counter to the discipline that calligraphy is traditionally associated with, but mutation can be simultaneously encouraged and monitored. Most of the natural processes described here, although deterministic, were unpredictable. They manifested laws of nature but in an irreproducible way – no two sparks are likely to show the same pattern of tendrils of light, but they all show the balance that momentum conservation forces on them.

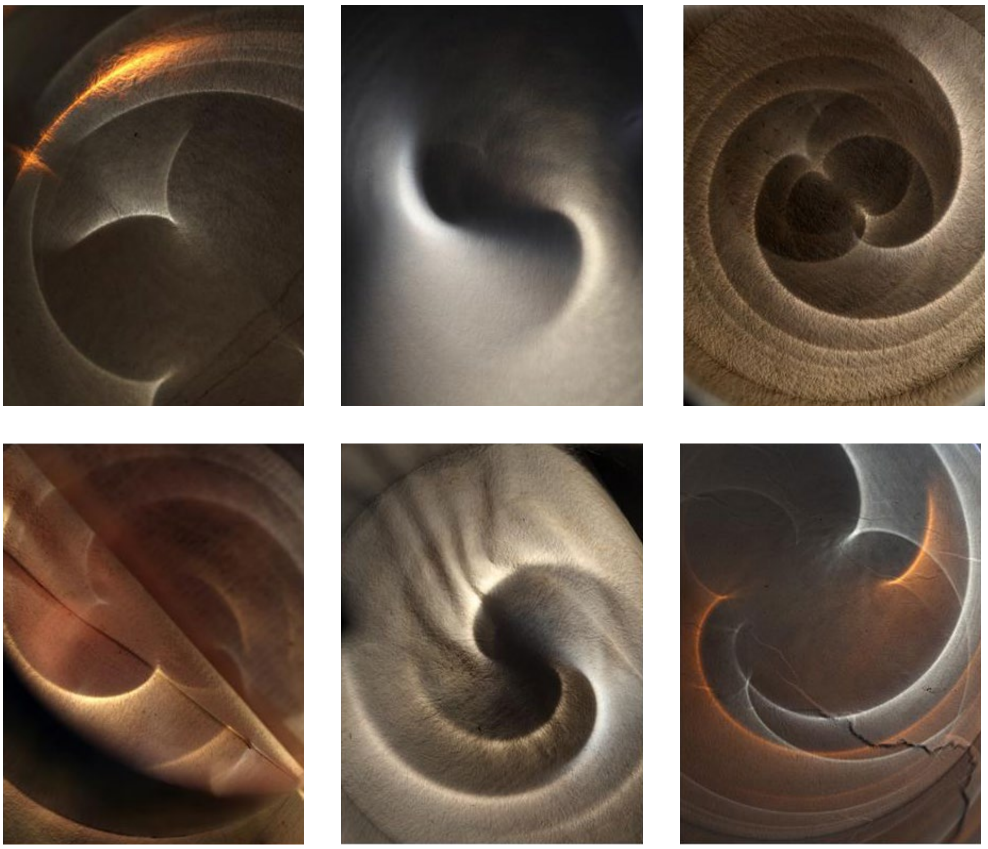

Fig. 11: Six Letters from a Utopian Alphabet, 2011. These letterforms made from light are made one from the other by small changes in the position of the light sources and small displacements of the scattering surface. (Photos © the author)

5.4 Natural Calligraphy

Click here for the table of contents

Another beautiful lesson of natural calligraphy is the pleasure to be had in seeing the process. A calligraphic mark often reflects the verve or grace with which it was formed but we see it at one time and as a finished object. But we lose something, like watching a ballet in fast forward or frame-by-frame; the meaning that is carried in the pacing. Clearly a technician is limited by transference of ink to paper, by articulation of the hand, and by the need to breathe and pause. But a glycerol train could run virtually endlessly and be modulated mechanically by a pre-written programme like a player-piano, allowing the artist (or indeed artists) to orchestrate multiple parallel lines of composition – a new calligraphy sharing many of the possibilities of music performance. The modulation controls the rate of supply of glycerol to the stream; it might thicken, thin or even stop. We control the presence and position of changes in the stream but we cannot make the changes with wholly predictable outcomes. We are removed further from the art work than we are in other practices that have a random element such as drip painting. But the randomness leads to something graceful and striking, even as it is unexpected - qualities we surely welcome in making a work of art.

Acknowledgements

I am honoured to present this paper in Robert Priddey's memory, but sadly realize how much his incisive commentary and depth of learning could have improved it. I am very grateful to: Simeon Nelson for encouraging the exchange of scientific and artistic ideas and asking me to speak at this meeting; Professor Elias Brinks, R. Jay Gabany and Dr David Martinez-Delgado for suggesting and providing Figure 8 as a beautiful example of a stellar stream; and the referees and editor Pat Simpson for encouragement to expand the conclusions of the paper.

Natural Calligraphy

Click here for the table of contents

References

- Arnold, V.I. 1978. Mathematical Methods of Classical Mechanics. New York, Heidelberg, Berlin: Springer-Verlag.
- Barrass, G.S. 2002. The Art of Calligraphy in Modern China. London: British Museum Press.
- Child, H., editor. 1985. The Calligrapher's Handbook London: A & C Black.
- Eliade, M. 1952. Images et Symbole. Paris: Gallimard.
- Feynman, R. 1942. "The Principle of Least Action in Quantum Mechanics." PhD Thesis Princeton University.
- Gaur, A. 1994. A History of Calligraphy. London: The British Library.
- Gray, N. 1970. Lettering as Drawing. London: Oxford University Press.
- Klee, P. 1961 The Thinking Eye. London: Lund Humphries.
- Martinez-Delgado, D. et al. 2008. "An External Perspective of a Stellar Tidal Stream: Fossils of the Hierarchical Formation of the Nearby Spiral Galaxy NGC 5907." Astronomical Society of the Pacific Conference Proceedings 399: Panoramic Views of Galaxy Formation and Evolution: 461-464.
- Meehan, B. 1994. The Book of Kells. London: Thames & Hudson.
- Mott, N.F. 1929. "The Wave Mechanics of a-Ray Tracks." Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 126:79-84.
- Nash, S.A., and J. Merkert, editors. 1985. Naum Gabo – Sixty Years of Constructivism. Munich: Prestel-Verlag.
- Safadi, H. 1978. Islamic Calligraphy. London: Thames & Hudson.
- Sakanishi, S. 1939. The Spirit of the Brush. London: John Murray.
- Zöllner, F and J. Nathan. 2011. Leonardo da Vinci (Vol. II: The Graphic Work) Cologne: Taschen.

Contact

Dr James L. Collett
The Centre for Astrophysics Research
Science & Technology Research Institute
University of Hertfordshire
College Lane, Hatfield, Herts.
j.l.collett@herts.ac.uk

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

Dr Craig Bourne, University of Hertfordshire. Emily Caddick, Institute of Continuing Education, University of Cambridge, and Research Fellow, Institute of Philosophy, University of London.

Both science and art use a variety of forms of representation. In this paper we focus on scientific and artistic representations of time. Both art and science use pictorial representations. Artistic pictorial representation of time might take the form of a photograph or a painting, whereas in the scientific case it can take the form of a diagram, such as a Minkowski space-time diagram used in the special theory of relativity (and explained in more detail below). Both art and science also use linguistic representations to represent time. Artistic linguistic representations of time might take the form of sentences of a natural language, such as those found in novels, typically using tensed verbs to express claims about the temporal order of events, for instance. Scientific linguistic representations of time might be expressed in a formal language, such as in the form of mathematical equations. Whilst these are familiar ways of representing time, the moral of this paper will be that drawing valid conclusions about the nature of time from either artistic or scientific representations such as these requires an understanding of the metaphysics of time, which cannot be gained from these representations alone, and an understanding of the nature of representation itself.

How representations can help and hinder our understanding of time

Representations of time need careful handling. Inferences drawn about time solely on the basis of the representation are liable to lead to false conclusions concerning the nature of time. To illustrate this, we shall consider two major scientific theories of the twentieth century: (1) Special Theory of Relativity (STR) and (2) General Theory of Relativity (GTR). We shall discuss each together with closely analogous artistic representations. We shall use these cases to illustrate philosophically interesting issues surrounding: (1) the representation of temporal order and simultaneity and (2) the representation of possibilities (using time travel as an example).

Case-study 1: Simultaneity and Temporal Order

a) Special Theory of Relativity

What can we learn about temporal order and simultaneity from considering time's representation in the Special Theory of Relativity (STR)? First, consider the two principles which characterise STR:

[1] **The Law of the Propagation of Light:** it is a law of nature that light (in a vacuum) is propagated in straight lines with a constant speed c (approx 300,000,000ms-1)

Click here for the table of contents

[2] **The Principle of Relativity:** all inertial (i.e. non-accelerating) frames of reference (i.e. co-ordinate systems) are equivalent for the description of all physical phenomena: the same laws hold in all inertial frames. More crisply: whatever is a law of nature for one person is a law of nature for another.

So, light always travels at c within each inertial frame of reference, no matter what is the speed of that inertial frame of reference relative to any other inertial frame. In other words, principles (1) and (2) above entail:

[3] **The Limit Principle:** regardless of the speed of an observer, they can never overtake a ray of light: however near their speed approaches that of light (as judged from another inertial frame of reference), light still travels within their frame at c.

To see the implications this has for simultaneity and temporal order, we can represent (1), (2) and (3) in a Minkowski Space-Time Diagram (Figure 1). Since STR says that light travels at a constant speed in all directions, we can represent the path of a light-ray from the origin as a straight line (indicating constant speed) along both the positive and negative x-axis (which is the only spatial dimension represented).

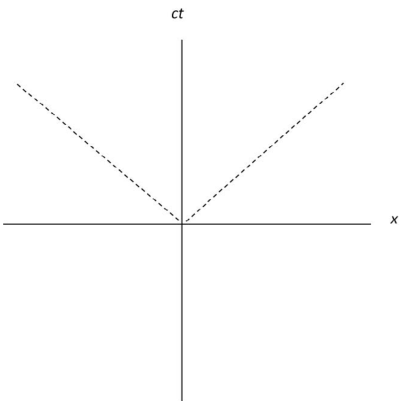

Fig. 1: Light travels at a constant speed in all directions

When we include a second spatial dimension, we can see that light travelling from the origin generates a so-called 'light cone', as in Figure 2.

As noted in the Limit Principle above, no massive object can travel faster than the speed of light. So the possible paths of massive objects (such as a and b) through space-time must fall within the light cone. So we can view the light cone associated with each space-time point as a theoretical boundary that marks out where objects are able to travel [Fig. 2].

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

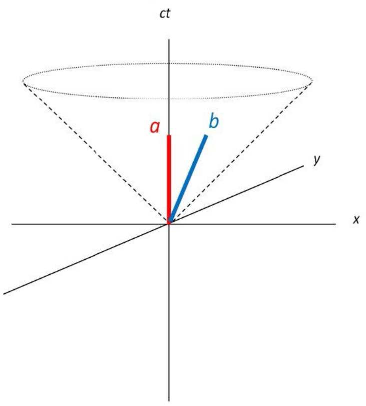

Fig. 2: a is taken to be at rest with b moving with respect to a; all possible trajectories of objects from the origin fall within the light cone.

But for ease, let's focus on two dimensions of the upper right-hand quadrant of this diagram. The horizontal axis represents the plane of simultaneity for a, who is at rest. But what about b? The interesting thing about STR is that light travels at a constant speed for both a and b. But how can light travel at the same speed for a and b, when b is moving with respect to a? It must be that b's measurement of time and space is different from a's. We can represent b's coordinate system with respect to a's in [Fig.3].

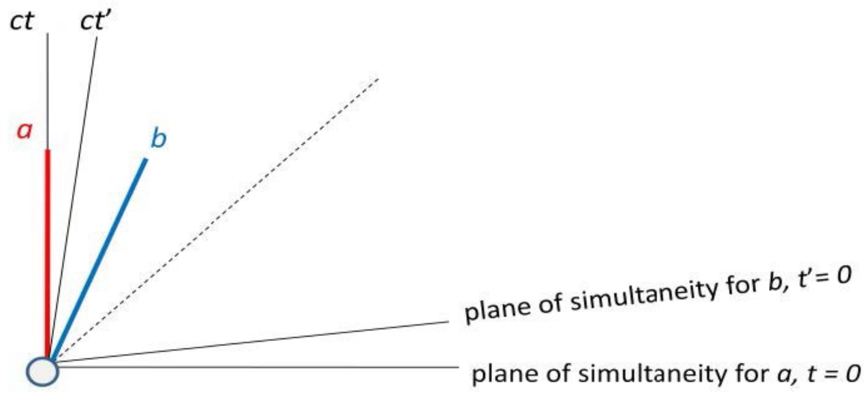

Fig.3: Representation of b's coordinate system with respect to a's

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

We can see clearly here what it means for simultaneity to be relative to a frame of reference. Consider Figure 4. Events F and G are some spatial distance from event E (at the origin). Now, although our observers a and b must agree that event G follows event F, they disagree over which event is simultaneous with E. (For a, the ambulance arrives after the start of the talk. For b, the ambulance arrives as the talk begins.)

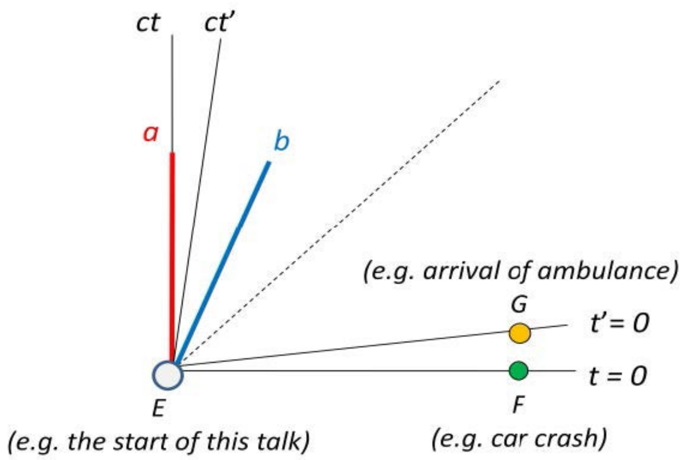

Fig. 4: Relativity of simultaneity

Those are all the facts about simultaneity which STR is prepared to allow. Or so says the orthodox interpretation of STR. But our question is: can we read off from these representational devices all there is to know about temporal relations between the events involved? In specifying the temporal relations between spatially separated events, can we say no more than 'E and F are simultaneous in a's frame of reference; E and G are simultaneous in b's frame of reference, and that's that'? Is there any space for asking whether there is a further fact of the matter that could make a absolutely right or b absolutely right, or both a and b absolutely wrong concerning their judgements of simultaneity? Not if we should believe in all and only those things which are required to do the physics of special relativity. For an absolute plane of simultaneity is not required for that. But not all reasons for believing in things have to come from physics. Even physicists must agree to that. Despite the importance that time in particular plays in physics, and the important results that physicists have established about time, time is hardly exclusively in the domain of the physicist. Further, the reason that Einstein gives for thinking that there is no further question to ask about absolute simultaneity is that: 'The definition [of simultaneity] should supply us with a method by which we can decide by experiment whether given events occurred simultaneously' (Einstein 1920, §VIII)

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

Clearly, if we are overly concerned with believing in the existence only of those things we can verify to exist, then since no experiment would ever show any physical difference between a and b (and any other inertial frame we include in Figure 4 – that's what the Principle of Relativity tells us), we would be disinclined to believe that there is any unverifiable further fact about the absolute simultaneity of the events. So our initial question about whether there is scope for believing in further facts about simultaneity not represented in STR depends on whether we think we may believe in facts which go beyond our ability to verify them. But of course we may! It is safe to say that the verificationist methodology is untenable. If we went along with it, we would have difficulty believing that anything was the case, will be the case, would be the case and could be the case. How could we believe universal general laws? Or believe that our favourite mug is fragile without smashing it on the floor?

This is not to give us license to believe anything we like. It just frees us from unnecessary and unjustifiable constraints when constructing our theories of how the world works. It certainly leaves open whether those who believe in the objective process of temporal becoming – such as presentists, who think that time passes as certain facts about the world come into existence and others drop out of existence – can use this metaphysical feature of the world to define an absolute plane of simultaneity. This may not be required in order to do physics, but, first, it is not as if it is incompatible with the physics. That STR does not represent the world as having this extra feature should not be confused with its representing the world as not having that feature. And if presentism is a good theory on other grounds, then that is reason enough to postulate facts about simultaneity which go beyond those recognised in STR. (For more detailed discussion, see Bourne 2006.)

b) Artistic Representations of Temporal Order

Compare STR with temporal order in fiction. Suppose we tell a (very short!) story:
'There was a sneeze and a car crash.'

This fiction lacks the resources to tell us anything about whether these events are simultaneous. In this sense, this fiction and STR are analogous: each representation lacks content regarding the absolute simultaneity of events.

However, there is a difference between the two which illustrates our point that what inferences can be drawn about time from these representations is intimately bound up with a metaphysical view concerning their subject matter. The difference is this: STR leaves open whether there is a fact about the absolute simultaneity of spatially separated events even though STR has no means of detecting it; whereas in fiction, there certainly is no space for facts outstripping what has been represented.

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

What is true in a fiction differs in an important way from what we take to be true in a world like ours. Fictions always leave some things indefinite. This happens when the audience cannot glean information about a certain matter from the telling of the story. Suppose a fiction about a man called Bob never tells us whether Bob is married or not. Then it is not true in the fiction that Bob is married, but nor is it true in the fiction that Bob is not married. We do not conclude, on the basis of this, that Bob is in some odd state in-between being married and not being married. We take it to be true in the fiction that Bob is either married or he is not – the point is just that the fiction does not commit to which. Likewise, the story 'There was a sneeze and a car crash' is naturally taken to be about a fictional world in which there is some temporal relation between the sneeze and the car crash. Either they are simultaneous, or one is earlier than the other. But there is no fact, it seems, about which of these things is the case.

'There was a sneeze and a car crash' may have another implicature: namely, that the sneeze caused the car crash. The meaning of the sentence is just that both the events happened, so it would not be false if the car crash were caused in some other way. But we assume that the speaker is mentioning them both together because the sneeze is relevant to the car crash, and an obvious way for it to be relevant is if it caused the crash.

It is not entirely obvious that the sentence does have these implicatures. It depends on whether the fact that the sneeze came first and caused the car crash would be a competitive explanation, given the surrounding circumstances, for why the fiction-maker chose to write that sentence. But let's suppose it is. Then the short story 'There was a sneeze and a car crash' conveys considerably more than it first appears to. If we take the implicatures, not just the meaning, to play a role in establishing what is true in the story, then the story describes a fictional world in which a sneeze happened before a car crash and was the cause of the car crash. So there is a fact about the temporal order of the events, after all.

But, even if this holds for this case, it does not hold for all cases. Often a story neither says nor implicates what order the fictional events happen in. We often assume that the things done by different characters in successive scenes of a film or television programme take place at roughly the same time, but we don't take there to be any way of establishing whether (e.g.) one character's coughing in one scene happened before, after or simultaneously with another character's putting down a mug in the next scene.

It is important to reiterate that we should not conclude that fictions are about worlds in which some events are neither earlier than, nor later than, nor simultaneous with some other events. For this would mean the events did not take place in the same time-series at all. What we should conclude is that

Click here for the table of contents

the fictional events take place within the same fictional time-series, but that there are sometimes no fictional truths about their precise locations, relative to each other, within that time-series.

In the case of STR, we argued that whether there is a fact about which spatially separated events are absolutely simultaneous depends on which is the right account of the nature of time. In the case of fictional stories, whether there is a fact about which fictional events are simultaneous also depends in part on which is the right account of the nature of fiction. The way we engage with fiction does not create any pressure to think that there are fictional facts about temporal relations in cases where the representation exhibits indefiniteness. To understand that two fictional events, A and B, happen within the same time-series, we only need to understand that either they are simultaneous, or A is earlier than B, or B is earlier than A. We need not think of them as standing in a particular relation in order to completely understand the story; and, often, wondering about which comes first would be an unhelpful distraction.

Thus, our engagement with fiction does not give us a reason to believe in additional fictional facts lying behind cases of indefiniteness. In the case of STR, though, it was a philosophical account of the nature of time which would give us reason to believe in extra facts. Does a philosophical account of fiction provide a similar motivation? We think not. Indeed, we suggest that believing in such extra facts would obscure the nature of fiction. Cases of indefiniteness are cases where what the representation tells us – what information we get from the words and images the fiction-maker has used – does not fix the details of what happens – whether event A happens before, after or simultaneously with event B, for example. And there are no further facts which fix these details.

Closer comparison with the case of STR brings out this point. The representations of relative simultaneity produced within the resources of STR are taken to be representations of our world, as it actually is. The judgements of simultaneity which they capture differ from one another. But this does not mean that the representation gives an incoherent or impossible picture of what the world is like. For the reason the judgements of simultaneity differ is that they adopt different perspectives, according to the different speeds of the observer. Thus, they generate different representations of the same world. Whether there is a perspective-independent fact about absolute simultaneity, over and above what can be captured by these representations – and, if so, which events are absolutely simultaneous – depends on what the facts of our world are.

Fictions are not to be taken as representations of our world as it actually is. So if there is an extra fact lying beyond the scope of the representation in a case of indefiniteness, this fact is not to be

Click here for the table of contents

understood as a part of our world. Rather, it is part of a fictional world; whichever fictional world the fiction represents. But how do we establish which fictional world a particular fiction represents? The only way to do this is to look at what information the representation gives us, and take the fictional world to be the one which fits the description given by the representation. But the fiction which leaves the temporal relation between A and B indefinite does not give us any resources for choosing between a world where A is earlier than B, a world where A is later, and a world where they are simultaneous. So the assumption that a specific temporal relation is built into the content of the fiction is untrue to how the content of fictions is determined.

The limitations of the representation in STR and in cases of indefiniteness in fiction looked similar, at least on the surface. We have shown that the conclusions which should be drawn concerning what is represented require quite different considerations in the two cases. In short:

Fiction case: indefinite over simultaneity question – no further facts
STR case: inconclusive over simultaneity question – may well be further facts.

The point: consideration of artistic or scientific representations alone cannot tell us everything about the nature of reality – the inferences we can draw from a representation are bound up with a proper understanding of the metaphysics of its subject matter.

Case-study 2: Time Travel to the Past: Science Fiction and Science Fact as Explorations of What is Possible

a) General Theory of Relativity
The equations which form the basis of the general theory of relativity (GTR) have solutions which generate a representation of a world in which time-travel to the past is possible. How?
The significance of GTR is that the path that anything takes through space-time is influenced by how the space-time is shaped. Gravitational effects are explained by a distortion of the geometry of space-time; and a distorted space-time will in turn affect the paths of light-rays. The light-cones themselves could tip over in its presence. Because of the relationship between rotation and gravitation, this is what happens in one (in)famous model of GTR discovered by Kurt Gödel (Gödel 1949). According to Gödel's model, light-cones tip in the direction of rotation, as in Figure 5.

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

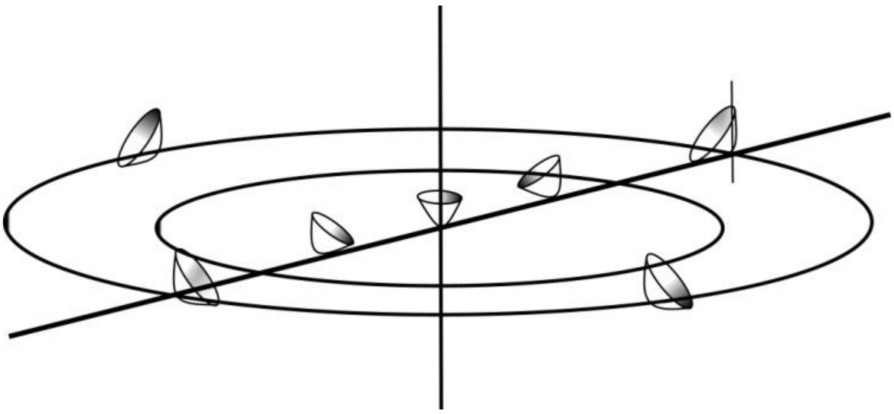

Fig. 5: Gödel's rotating universe

This figure is drawn such that we only see the future light-cones of various arbitrary points in the horizontal plane. Matter in this universe is rotating anticlockwise about the vertical axis; so as we move radially outwards, the future light-cones gradually start to tip in the direction of rotation. Note that the cones also get wider; so the vertical axis and trajectories remain time-like, as can be seen by the vertical world-line in the light-cone in the top right hand corner.

There comes a point on this journey outwards at which the cones open up such that locally an observer can travel into his future (i.e., along a path within the future light-cone, i.e., without travelling faster than the speed of light) but globally be travelling into his past. Every point can be reached from any point in this model. To see this, take the point at the origin of the axes. We can spiral upwards and outwards until we reach the critical point where the cones tip. We may then make our descent around this critical radius, such that we end up below the horizontal plane from where we began, gradually spiralling inwards and upwards to our starting point at the origin.

Thus, certain models of GTR seem to represent the possibility of time travel. But establishing its genuine physical possibility requires more than it being a feature of a solution to the equations of GTR. The logical and metaphysical possibility of time travel is what needs to be established first. But this is not peculiar to scientific representations; the very same considerations apply to artistic representations.

b) Artistic Representations of Time Travel

Many stories appear to represent time-travel. Some of them seem perfectly coherent. Others seem to involve an impossibility, such as Back to the Future (1985, dir. R.Zemeckis), in which the hero appears to change the past. This raises two interesting questions about fictional representations which purport to represent time-travel.

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

(1) Do the apparently coherent representations show that time-travel is possible?

(2) Do the stories which seem to involve an impossibility represent something impossible?

The questions are related. Some take artistic (and scientific) representations to be explorations of what is possible, which suggests a positive answer to the first question. But if even impossibilities can be represented, then we cannot reliably draw conclusions about what is possible from the contents of representations.

Let's address the first question. Some time-travel stories seem to involve a contradiction (something of the form 'P and not P') – Back to the Future, for example, appears to suggest that certain things both do and do not happen at the same time in a single past. Not all time-travel stories are like this. A time-travel story which does not purport to involve changing the past need generate no contradiction. Nevertheless, we should not take the mere logical coherence of such stories as proof that time-travel is possible. There may well be metaphysical reasons to rule out the possibility of time-travel. And this goes for scientific models too. For example, time-travel to the past involves backwards causation. Earlier events (such as somebody's getting out of a time-machine in 1900) are caused by later events (such as somebody's getting into a time-machine in 2000). A metaphysical theory of time may give us reasons to deny that the past can be causally dependent on the future. (See for example, Mellor 1998, 132-5)

The point we wish to make is that whether or not we agree with the metaphysical theories in question, consideration of them goes beyond mere consideration of apparent representations of time-travel, such as the stories in question. We must take such representations in conjunction with an understanding of the nature of time in order to work out whether something possible is being represented. Thus, we clearly cannot draw conclusions about what is possible from the representation alone.

Let's move on to the second question. Do those time-travel stories which apparently involve contradictions represent something impossible? We propose that stories which seem to involve impossibility are best interpreted not as representations of impossible things, but as representations of perfectly possible things structured in a way which creates the illusion that an impossible world is being represented.

To introduce this account, consider a case of seeming impossibility which is not to do with time: M.C. Escher's Waterfall (1961, lithograph). Various parts of this picture, taken on their own, represent perfectly possible things: instances of water flowing downhill. Taken as a whole, however, the picture does not add up: the cases of water flowing downhill are made to look as if they combine into a closed loop. If we 'follow' each piece of the waterfall we arrive back at the start, with yet another representation of water going downhill.

On what we may infer from scientific and artistic representations of time

Click here for the table of contents

This makes it look as if we have a representation of a loop in which water is constantly travelling downhill but ends up meeting its source. But this, we claim, is a false impression created by our ability to engage with the individual parts of the representation. To understand the nature of the picture is not, we propose, to recognise that an impossible waterfall has been represented. Once we grasp that no possible waterfall could be represented by the picture, we have already grasped what is significant about it.

The parts of Waterfall each represent something possible. But, we propose, the representation in its entirety does not represent a single, impossible waterfall. Rather, the way the representational parts are placed creates the illusion that an impossible whole is being represented. We shall apply this strategy to those representations which seem to be impossible time-travel stories involving changing the past.

Such stories represent distinct events which, despite apparently being supposed to happen at the same time, could not happen at the same time. Two series of past events, incompatible with each other, are represented. The question is: do those two incompatible series of events take place in the very same past? If so, then the fiction represents something impossible.

We propose that a better interpretation is to treat the two different sequences of events as taking place in two different fictional worlds. A story like Back to the Future involves two representations of two distinct worlds, each with a perfectly possible history. At some points in the film we are given a representation of one world, and at other points we are given a representation of the other world. When the film shifts from representing one to representing the other, there is a change on the level of the representation – a change from representing one world to representing a different world. But this change in the representation is disguised as a representation of change within the world represented. We are given the (false) impression that what changes is the past of a single world, whereas really what changes is which world is being represented.

This illusion is created by certain similarities between what happens in the two worlds. The people in one world are similar to the people in the other. Many of the events which take place in each world are of the same kind as some of the events which take place in the other world. In addition, by representing the two worlds alongside each other, the story allows us to draw conclusions about one world based on the other. We are invited to think that there is some relation between the worlds – for example, that events in the second world are the ones which would have happened in the first world had somebody acted differently in a certain way.

Click here for the table of contents

But note that even on the rival interpretation, in which the past of a single world is changed, it makes no sense for Marty to remember how things were in the 'original' version. If the past has been changed, then it was never the case that Marty's family ended up poor, so he couldn't have memories of it. So our account is at no disadvantage, since the rival is no help in understanding Marty's mental states.

Furthermore, we propose that a clear account of the situation can be given in our terms. We say that $Marty_2$ has quasi-memories which match $Marty_1$'s experiences. These quasi-memories are like the memories $Marty_2$ would have were he genuinely continuous with $Marty_1$, but they're not causally connected with $Marty_1$'s experiences in the way genuine memories would need to be. (They can't be, since $Marty_1$ and $Marty_2$ don't live in the same world.) Because the lack of causal connection is the only thing which distinguishes $Marty_2$'s quasi-memories from genuine memories, it is easy to think that $Marty_2$ really is the same person as $Marty_1$, and the illusion that a single world has been represented is further strengthened.

We do not deny that when watching this film it seems as if impossible things happen in the story. Rather, our claim has been that we can explain how the impression of impossibility arises by saying that more than one possible world is represented. The way the film moves from the representation of one world to the representation of another creates the (false) impression that we're dealing with something which is familiar from standard narratives, and which we are practised in understanding – the unfolding of a single series of events within a single fictional world with single continuous characters. But there are certain elements of the film which it is impossible to reconcile with this assumption. Whilst the structure of the film creates the impression of a single world, the events it represents are ones which we recognise cannot be happening within a single world. That is what makes films like Back to the Future intriguing. The way the various representations of different worlds are put together makes us engage with the fictional events as if they form a coherent series, while at the same time we realise that this impression must be wrong.

We have suggested that fictional stories which appear to represent impossibilities are better understood as representing possibilities. An alternative account would be that Back to the Future really does represent a world where certain contradictions are true, because Marty changes the past. We think there are good reasons for believing that what can be represented by fiction is limited to what is possible. One is the neat analyses which this approach allows us to give. It enables us to make good sense of the representations in question while also providing an explanation of how they create the impression of impossibility. But there are some additional reasons. If fictions cannot represent the impossible, we have a good explanation of exactly what is striking about those stories

Click here for the table of contents

which create the (false) impression of doing just that. If, on the other hand, we maintained that fictions can represent the impossible, it is unclear why confronting an apparent impossibility in fiction would be any more striking than confronting a possibility in fact.

Taking Back to the Future to represent a world where certain contradictions are true raises another question, too: what else would be true in this impossible fictional world? According to classical logic, anything follows from a contradiction. So it would be true in Back to the Future not only that Marty is human, but also that Marty is a pig, for example.

We do not claim that this is a conclusive argument for rejecting the view that fictions can represent impossibilities. The point is just that such a view should not be taken for granted. For example, it may require the development of an alternative, non-classical logic (e.g. Priest 1997; 2005).

Our view has the nice feature of bypassing any motivation for thinking an impossibility has been represented. The fundamental point we wish to make, however, is that the appearance of impossibility generated by the representation is not sufficient to establish whether or not something impossible has been represented. Detailed technical discussion, requiring expertise in logic and metaphysics, is required in order to come anywhere close to resolving this issue.

The Moral

The moral to draw here is that interpreting stories which appear to represent time-travel requires a fairly complex philosophical framework. As in the case of GTR, the representations themselves do not settle questions about time-travel and the nature of time, but rather need to be supplemented by careful philosophical analysis.

We have shown that what conclusions we should draw from representations depends, in part, on a philosophical understanding of their subject matter and of the nature of representation itself. Our argument has focused on a particular case: the representation of time by art and science. But it illustrates a more general conclusion.

During the conference at which the papers in this volume were given, there was much discussion over how, if at all, scientists and artists could collaborate to provide new knowledge about how the world is. Some claimed, for example, that only scientific representations deliver genuine knowledge; others that there are some truths about the world which can be identified using artistic media, so must be known through artistic rather than scientific representations.

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

At the level of the representations themselves, an artist may well learn a lot from a scientist, or vice versa. The structure of a scientific representation might inspire or be inspired by the structure of an artistic representation. Further, identifying what is it that an artist aims to represent may influence what a scientist aims to represent, or vice versa. A scientific representation which is supposed to represent that simultaneity is not absolute may influence an artist to attempt to represent the same thing. The question is whether the representations succeed in representing what they attempt, or are supposed, to represent; in other words, how we are to establish what is represented by a scientific or artistic representation.

If our argument is correct, then neither artistic representations, nor scientific representations, nor collaborations involving both types of representation, are the end of the story. We should hesitate before claiming to know something (for example, that relations of simultaneity are not absolute, or that time-travel is possible) on the basis of a representation alone, be it scientific or artistic. For these representations require a philosophical framework in order to be interpreted. If we take them at face value, and attempt to read off what is represented from the representation alone, then, far from acquiring knowledge, we may end up obscuring our subject matter. In order to have a full understanding of what their representations are of, scientists and artists should work not just alone or with each other, but also with (informed) philosophers.

Acknowledgements

Emily Caddick gratefully acknowledges the support of the Arts and Humanities Research Council.

5.5 On what we may infer from scientific and artistic representations of time

Click here for the table of contents

References

- Bourne, C. 2006. A Future for Presentism. Oxford: Clarendon Press
- Einstein, A. 1920. Relativity: The Special and General Theory. London: Methuen & Co.
- Escher, M.C. 1961. Waterfall. Lithograph. https://sla2007-geo-e.wikispaces.com/Q1+Project+-+MC+Escher , accessed 03/12/11.
- Gödel, K. 1949. “An example of a new type of cosmological solutions of Einstein’s field equations of gravitation.” Review of Modern Physics 21:447-50.
- Grice, H.P. “Logic and Conversation.” In Syntax and Semantics Vol.3, eds, Peter Cole and
- Mellor, D.H. 1998. Real Time II. London: Routledge
- Morgan, J.L. 1975. New York: Academic Press.
- Priest, G. 2005. Towards Non-being: The Logic and Metaphysics of Intentionality. Oxford: Oxford University Press. 1985.
- Zemeckis, R. 1985. Dir. Back to the Future, film.

Contact

Dr Craig Bourne
Senior Lecturer in Philosophy
School of Humanities
de Havilland Campus
University of Hertfordshire
Mosquito Way, Hatfield, Herts.
C.Bourne@herts.ac.uk.
http://cpb.blueorange.net

Emily Caddick,
Institute of Continuing Education
Madingley Hall
Madingley
University of Cambridge
Cambridge, Cambs
CB23 8AQ.
erc36@cam.ac.uk

5.6 Between Zero and One: On the Unknown Knowns

Click here
for the table
of contents

Simon Biggs, Edinburgh College of Art, University of Edinburgh

> *There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. These are things we do not know we don't know.*
> *(US Secretary of State for Defence, Donald Rumsfeld, February 12, 2002)*

This infamous comment of February 12, 2002, by US Secretary of State for Defence, Donald Rumsfeld, concerning the lack of evidence linking Iraq's government to the supply of terrorist groups with weapons of mass destruction, was widely ridiculed at the time and, since 2002, has been referenced widely as evidence of the lunacy, paranoia and sheer stupidity of the Bush era executive. Amongst many other accolades it received was the Plain English Campaign's 2003 "Foot in Mouth Award". Slavoj Žižek felt subsequently compelled to respond to Rumsfeld's apparently bizarre logic. In his riposte in The Guardian, Žižek suggested that Rumsfeld had overlooked something:

> *What he forgot to add was the crucial fourth term: the 'unknown knowns', things we don't know that we know - which is precisely the Freudian unconscious. If Rumsfeld thought that the main dangers in the confrontation with Iraq were the 'unknown unknowns', the threats from Saddam we did not even suspect, the Abu Ghraib scandal shows where the main dangers actually are in the 'unknown knowns', the disavowed beliefs, suppositions and obscene practices we pretend not to know about, even though they form the background of our public values. To unearth these 'unknown knowns' is the task of an intellectual." (Žižek 2005)*

Putting aside Žižek's particular, if probably reasonable, interpretation of Rumsfeld's statement as evidence of a paranoid Freudian subconscious at work within the US defence system, whilst accepting his assertion that the territory of the "unknown known" is an appropriate frontier for intellectual inquiry, Rumsfeld's knowledge matrix could be regarded as evidence of an, admittedly inadvertent, subtle appreciation of epistemology. The implication of this matrix is that knowledge can exist in a variable and uncertain state and yet still function as useable and applicable knowledge upon which action can be based.

As Žižek has observed, one thing that is evident in Rumsfeld's Boolean matrix is that one possible form of (un)knowing is absent from its logical array, the "unknown knowns" - things we do not know that we know. This form of knowing is often referred to as "tacit" and has become a popular subject of inquiry in the arts and other practice based activities where knowledge of techniques,

Click here for the table of contents

methods and relationships are often accepted a priori, as being embedded in the skill-sets and processes of certain practices learned through the careful rehearsal and subsequent adjustment of acquired ability.

David Pye (1968, 21) distinguishes between two modes of workmanship which might be employed to evidence how tacit knowledge can evolve and be applied. Pye identifies the "workmanship of risk" and the "workmanship of certainty". Regarding the first of these constructs, Elizabeth Hallam and Tim Ingold state:

> *In the workmanship of risk the quality of the outcome depends at every moment on the exercise of care, judgment and dexterity. The practitioner has continually to make fine adjustments to keep on course, in response to the sensitive monitoring of the conditions of the task as it unfolds. (Hallam & Ingold 2007, 13)*

By contrast the workmanship of certainty "proceeds by the way of a pre-planned series of operations, each of which is mechanically constrained to the extent that the result is predetermined and outside the operative's control" (Hallam & Ingold 2007, 13). However, Hallam and Ingold problematise this duality, noting earlier in the same text that "life is unscriptable" and "cannot be codified", for the world is not a fixed but fluid phenomenon. Thus, in practice, the workmanship of certainty is never fully realised as no system or set of phenomena is so predetermined and known that we can complete a task in respect of it whilst on auto-pilot. All of our activities are, to some degree, creative and engage the real-time evaluative processes inherent to tacit knowledge. In this sense tacit knowledge and the creative impulse are not the preserve of those engaged in the creative arts but are aspects of life, both extraordinary and quotidian.

When creative practitioners find themselves working within an academic knowledge economy of qualified and quantified knowledge they are often required to submit to the same measures of rigor and transparency as their colleagues in more conventional academic subjects. Key in this is the principle that knowledge is of most value when it has been rendered open and transparent to critical evaluation by others. In order to achieve this it is required that knowledge be inscribed in a manner that ensures the means by which it was arrived at is qualifiable and quantifiable by others. The larger part of contemporary academic research infrastructure is dedicated to this evaluative process.

However, as some have observed, perhaps most acutely Stephen Scrivener (at a conference convened at the University of Hertfordshire in 2002), the requirements of academia and those of the creative arts are not so readily reconcilable. Scrivener asks why "has knowledge become such a hot topic? At least part of the answer can be found in the very idea of research, which is generally understood as an

Click here
for the table
of contents

original investigation undertaken in order to gain knowledge and understanding" (Scrivener 2002). As Scrivener points out, if the creative arts are to function within an academic epistemology then art, when undertaken as research, "must contribute to knowledge" (Scrivener 2002).

However, is the primary objective of creative practice to achieve a contribution to knowledge? Conventionally the answer to this question would be in the negative. Arts practitioners have not been historically required to develop or propose new knowledge. The creative practitioner's role has generally been quite distinct to this.

Creative practitioners, however, work within and do develop their own knowledge frameworks, and to engage with the outcome of a creative process, whether as author or reader, requires knowledge about the subject and its context as well as the artifact and the relevant discourses of the culture within which the artifact is produced. Thus, whilst it might be the case that creative practice rarely engages the propositional character of scientific knowledge production, on the one hand it nevertheless does depend upon, participate in and represent a form of highly contextualised and shared critical knowledge. On the other hand, as observed above, even the most rigorous of pursuits of knowledge will involve a degree of tacit knowledge and intuition in its realisation.

Scientists, if they are to fulfill one of the key criteria of their activities, that of originality, and whilst they might undertake their activities with extreme diligence to documentation and critical reflection, would seem to need to engage the "workmanship of risk". By definition they must go beyond the limits of their practice and knowledge if they are to satisfy such a key objective, and they can only do so when they rely on processes of judgment and mental or technical dexterity that are born of the long exercise of a set of skills, such that they have become second nature. In this sense the scientist, like the artisan, exercises tacit knowledge, almost unconsciously, operating beyond the evaluative processes of scientific rigor. It is in this condition that the eureka moment can unexpectedly emerge. Indeed, science incorporates the unpredictable and improvisatory into its fundamental methods, valuing the unpredictable negative outcome as equal to the positive affirmation of a hypothesis whilst appreciating that such an unpredictable outcome counters the epistemologically foundational processes of conjecture and refutation. Artists and scientists can thus be considered to share an interest in something more fundamental than a particular form or method of knowing; that is, wonder.

Charles Peirce argued that artists, and others, can arrive at choices through a hunch, a form of reasoning he termed abductive (Peirce 1934, CP 5.182). Within this epistemological model elements of knowledge might be considered of uncertain status but nevertheless able to be reasonably

Click here for the table of contents

employed on the basis of an intuitive sense that something might be so. The argument here is that what is the case for creative practitioners, in the exercise of their pursuit of insight and affinity (a kind of knowing), is also the case for those working within those domains concerned with the rigorous pursuit of knowledge.

Peirce identified three methods of reasoning: deduction, induction and abduction. He regarded all three as integral to the scientific method. Peirce suggested that scientific method starts with abduction, an hypothesis where a conjecture is postulated, seeking to explain a phenomenon. The method then proceeds to deduction where, through a series of inferences, conclusions can be drawn from the provisional hypothesis and further conclusions reached about other phenomena that must be so if the hypothesis is true. Finally, the method proceeds to the stage of induction, where experiments are carried out to test the provisional hypothesis by ascertaining whether the deduced results do or do not obtain. Peirce did not regard this as a strictly linear process as he proposed various feedback loops between such methods so that various entry and exit points at the various stages could be employed, thus allowing for a non-linear apprehension of knowledge creation. In this model knowledge is often in a contingent and uncertain state but nevertheless the methodological framework can be pursued and outcomes arrived at. Thus, as we have already observed at the outset of this text, knowledge can exist in a variable and uncertain state and yet still function as useable and applicable knowledge upon which action can be based.

Another example of reasoning that is less than black and white in its methods is found in computing theory. The notion of fuzzy logic, derived from fuzzy set theory (Zadeh 1965, 310), has gained popularity in data analysis applications designed for dealing with complex real-world data-sets. This is a method of algorithmically modeling decision making processes where much of the data required to make a choice is in an unknown state, neither a zero nor a one but something in-between.

Lofti Zadeh has argued that “the conventional quantitative techniques of system analysis are intrinsically unsuited for dealing with humanistic systems or, for that matter, any system whose complexity is comparable to that of humanistic systems”. He has postulated that:

> *as the complexity of a system increases, our ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance ... become almost mutually exclusive characteristics (Zadeh 1973, 28)*

Between Zero and One: On the Unknown Knowns

Click here for the table of contents

He has suggested an approach to understanding human thinking as a process not founded on the key elements of numbers but “labels of fuzzy sets ... classes of objects in which the transition from membership to non-membership is gradual rather than abrupt” (Zadeh 1973, 28). Zadeh has proposed that human reasoning is not binary, or even multi-valued, but a “logic of fuzzy truths, fuzzy connectives, and fuzzy rules of inference” (Zadeh 1973, 28). Whilst Zadeh’s language is quite distinct there are uncanny echoes of Peirce’s theories at play in an approach to computing that has become very influential in the areas of artificial intelligence and specifically in language and voice recognition systems. It is therefore perhaps not surprising that both Pierce, with his work on semiosis, and Zadeh, who proposes a linguistically rather than numerically based system of logic, both can be seen to regard language as key to understanding how knowledge is made and valued as a human activity.

It is possible, indeed likely given the large class of potential signs, that what is the case for language is also the case for images. The image is a powerful means for determining and describing classes of things. The image can be simultaneously concise and general, precise but vague, in its status. This is perhaps the poetic property of all signs, regardless of the sign system to which they belong; the polyvalence of the sign exhibiting the fuzzy and uncertain characteristics of things that both Peirce and Zadeh explore and thus able to sustain multiple states and sets of relations with other things. This would seem to be the natural territory of the artist and poet. Thus we can suggest that if what Zadeh proposes is a system of knowledge, then what creative practitioners routinely do, as they play with the indeterminate multilayered and dimensioned relations in the elements of their creative work, is a form of knowledge creation as well. This is not only in the sense of exercising a tacit knowledge associated with their skill-set, as noted in the observations on Pye, but through the presenting of a knowledge-representation which evidences Pierce’s three key elements of reasoning - abduction, induction and deduction - in the dynamics of the interplay of the components of the creative work.

This returns us to Hallam and Ingold’s conception of improvisation, not only as a form of creativity but a form of problem solving, where the creative practitioner is constantly adjusting their activity as they pursue their “workmanship of risk”. This might be regarded as the exercise of the abductive and fuzzy in practice.

Perhaps we can consider whether there is value in seeking to determine what the “unknown knowns” might be and in what sense they are, and remain, unknown? In attempting to shift the register of our logical knowledge matrix, in order to render the “unknown known” in relation to a “known known”, the intrinsic value of this form of knowing might be compromised. In uncertainty, knowledge can be considered to retain a certain value. Indeed, the uncertain might be regarded as

Between Zero and One: On the Unknown Knowns

Click here
for the table
of contents

of a very particular value that only this particular kind of knowledge can contain. Thus, in contrast to the conclusion drawn in Žižek's re-reading of Rumsfeld, if we do seek to erase the "unknown knowns" and replace them with the "known knowns" we, arguably, risk losing a way of knowing that could be of significant value. Without wishing to support a false social dichotomy, implicit in Žižek's proposal, that the task of the intellectual is to "unearth the 'unknown knowns' ", is perhaps the task of the artist to nurture the imminent seed that is the "unknown known"?

However, if we accept this, then the problem emerges that we risk indulging the Romantic ideal of the artist as one with a capacity to access a form of proto-knowledge which might be compromised if we hold its source up to the light of critical analysis. The resolution to this problem is not a question of epistemology, but ontology, for we now need to ask what, in this context, the artist might be? If we choose to employ a model of the artist founded upon the ideal of the solitary genius, whose creativity is a function of, and finds value in, its difference from the body of society, then the problem becomes intractable. If instead we accept Hallam and Ingold's proposition of creative practice as a pervasive and defining quality of communities and societies, where the foundational creative act is the making of people through the dynamic inter-relations of people, we can then regard the performative value of individual instances of creative practice as emblematic of those processes.

This arguably allows us to appreciate more fully the contribution of the individual creative act, or its outcome, whilst recognising that its value is a function of the social, not something established in oppositional isolation to it. Such an understanding has echoes of Michel Foucault's conception of knowledge as a pervasive social quality, as he outlined in his foundational work addressing discipline and sexuality (Foucault 1979; 1998). This is an economy of knowledge where all members of society are implicit in the creation, and destruction, of value. In this context the value of the "unknown known" can be regarded as politically significant and perhaps this suggests why Rumsfeld did not, or could not, consider the full range of possibilities in his incomplete knowledge matrix. To have done so would have required Rumsfeld to accept the social value of the "unknown known", a pervasive and tacit route to knowledge that stands in contradistinction to the top-down and centrally determined models of knowledge with which he would most likely be comfortable. In this respect Žižek is correct to propose that it is the "unknown knowns" that form the background to our values and that these should be subject to critical evaluation if we are to avoid forever repeating ourselves.

5.6

Between Zero and One: On the Unknown Knowns

Click here for the table of contents

References

- Foucault, M. 1979. Discipline and Punish: the Birth of the Prison trans. Alan Sheridan. London: Penguin.
- Foucault, M. 1998 (1976). The History of Sexuality. 3 vols, vol. 1. London: Penguin
- Hallam, E. & Ingold, T. 2007. Creativity and Cultural Improvisation. Oxford: Berg.
- Peirce, C. S. 1934. "Abduction and Perceptual Judgments", in Collected Papers of Charles Sanders Peirce, eds. Hartshorne, C and Weiss, P. Cambridge Mass: Harvard University Press. 8 vols, vol. 5 Pragmatism and Pragmaticism, 1958, CP5.182) (pp 1741, electronic edition), http://www.nlx.com/collections/95, accessed 01/11/11.
- Plain English Campaign. 2003. Past Winners. http://www.plainenglish.co.uk/awards/foot-in-mouth-award/foot-in-mouth-winners.html
- Pye, D. 1968. The Nature and Art of Workmanship. Cambridge UK: Cambridge University Press.
- Rumsfeld, D.H. 2002. "US Department of Defense News Transcript". February 12. http://www.defense.gov/transcripts/transcript.aspx?transcriptid=2636
- Scrivener, S. 2002. "The art object does not embody a form of knowledge". Working Papers in Art and Design 2. Retrieved 13.05.2008 from URL http://www.herts.ac.uk/artdes/research/papers/wpades/vol2/scrivenerfull.html.
- Zadeh, L. 1965. "Fuzzy Sets", in Information and Computation 8 (3): 338-353.
- Zadeh, L. 1973. "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes". IEEE Transactions on Systems, Man and Cybernetics 3 (1): 28-44.
- Žižek, S. 2005. "The Empty Wheelbarrow". The Guardian, February 19 2005, http://www.guardian.co.uk/comment/story/0,3604,1417982,00.html

Contact

Simon Biggs,
Professor of Interdisciplinary Arts
Edinburgh College of Art
University of Edinburgh
Lauriston Place, Edinburgh.
simon@littlepig.org.uk
http://www.littlepig.org.uk/

University of Hertfordshire UH

Vol 5 Writing Visual Culture ISSN 2049-7180