A Cybernetic Clarion Call to the Arts’ Community

Terry Trickett
Trickett Associates
Barbican, London, UK
terrytrick@mac.com

Cybernetics was a subject that captured the attention of some of the sharpest minds in the USA and UK from the 1940s onwards. For me, in my previous role as an architect and designer, cybernetics played a key part in solving the ‘exceedingly complex’ problems associated with the way large companies occupy buildings. In the 1960s Roy Ascott predicted that the cybernetic approach would ‘assist in the evolution of art, serving to increase its variety and vigour’. This is an attribute exemplified by the behaviourist art of Gordon Pask whose ‘Colloquy of Mobiles’ took centre stage at Cybernetic Serendipity – an exhibition, held in 1968, which represented the heyday of cybernetics in the UK. But even today, in the arts’ world, a bright annulus of cybernetic light continues to shine, a phenomenon that I explain with reference to a piece of Visual Music called SHAPES. We’re on the brink of a cybernetic renaissance, which is why I’m issuing a clarion call for the arts’ community to turn towards the task of enhancing our chances of survival for the future.

Cybernetics. Feedback. Cybernetic Serendipity. Visual Music. Space planning.

1. WHAT IS CYBERNETICS?

Recently, I’ve taken a journey back in time to rediscover the part that cybernetics has played in many aspects of my life and professional career only to reveal that my discoveries might herald a way into the future for all of us. I should point out that I’ve never promoted myself as an exponent of cybernetics per se although, at times, it’s a science that has risen to the surface of my consciousness to the extent that I’ve introduced cybernetic principles into my work as an architect and designer and, more recently, into my new found involvement in Visual Music. But what are these principles and how were they first established?

Cybernetics was a subject that captured the attention of some of the sharpest minds in the USA and UK from the 1940s onwards. Notable amongst these was Norbert Wiener who titled his book on the subject, written in 1948, ‘Cybernetics or Control and Communication in the Animal and the Machine’ (Wiener 1948). It’s a remarkable treatise on how and why the science of cybernetics came to be invented in the first place and then, for a time, prospered. The book begins by telling the story of Wiener’s work, in the USA, as a mathematician during the Second World War when he was charged with solving a particularly complex problem (Figure 1). As he states:

“[I]t had become clear that the speed of the airplane had rendered obsolete all classical methods of the direction of fire, and that it was necessary to build into the control apparatus all the computations necessary. These were rendered much more difficult by the fact that, unlike all previously encountered targets, an airplane has a velocity which is a very appreciable part of the velocity of the missile used to bring it down. Accordingly, it is exceedingly important to shoot the missile, not at the target, but in such a way that missile and target may come together in space at the same time in the future.”

Figure 1: Norbert Wiener at the Massachusetts Institute of Technology. ‘The nervous system and the automatic machine are fundamentally alike in that they are devices which make decisions on the basis of past decisions.”
Norbert Wiener was a brilliant mathematician but he couldn’t solve the artillery problem without help from a disparate group of MIT scientists, all with highly specialised skills that complemented his own. Together, as a team, they were able to put forward new theories of prediction and proposals for the construction of apparatus to test these theories. It was after the artillery problem had been solved that engineering design took on a completely new aspect; what had been regarded previously as more of an art than a science became a statistical science, which made Wiener and his colleagues realise that there was a whole region of similar design problems that could be tackled by methods involving the calculus of variation. They decided to call this new field of control and communication, in the machine or the animal, ‘Cybernetics’, from the Greek for ‘steersman’. At an inaugural meeting to discuss their new science, held in Princeton in 1944, it became clear to the engineers, physiologists and mathematicians present that there was a common basis of ideas between their different disciplines, and that some attempt should be made to achieve a shared vocabulary (Figure 2).

Figure 2: The list of attendees at an inaugural meeting in Princeton, in 1944, to discuss cybernetics included some of the sharpest minds in the US.

Maybe Wiener was somewhat reluctant to enter a world which lay way beyond his own disciplines of mathematics and science but his work on the predictive mechanisms of missiles had led him inevitably to realise that the concept of ‘feedback’ was endemic to any complex additive system of control. The circular processes of feedback are as applicable to the steering of a ship to keep it on course as they are to the movement of a human hand or finger, which involves a system with a large number of joints. In both these situations, control cannot be exercised by a simple single feedback as Wiener (1948) illustrates with reference to the way we steer a car on an icy road:

“Our entire conduct of driving depends on a knowledge of the slipperiness of the road surface, that is, on a knowledge of the performance characteristics on the system car—road. If we wait to find this out by the ordinary performance of the system, we shall discover ourselves in a skid before we know it. We thus give to the steering wheel a succession of small, fast impulses, not enough to throw the car into a major skid but quite enough to report to our kinaesthetic sense whether (or not) the car is in danger of skidding and we regulate our method of steering accordingly.’

Figure 3: The concept of ‘feedback’ is endemic to any complex additive system of control.

This is an example of ‘control by information feedback’; it’s a process that we all take for granted in living our lives (Figure 3). But it took the discoveries of Wiener and his colleagues to forge, from these animal and mechanical systems, a complicated theory which had a huge impact in the central decades of the last century. On both sides of the Atlantic, the potential that cybernetics held for creating improvements in complex systems was quickly recognised. In the UK, in particular, exponents of the new science extended its role into management systems, architecture, art, morphogenesis and much more besides.

2. HOW AND WHY I BECAME INVOLVED IN CYBERNETICS

Architects are not known for their skills as ‘steersmen’ but I’ve always advocated that, by dint of their training and as a result of experience, they can perform roles, which extend well beyond the traditional boundaries of ‘architecture’. Partly by default and partly by design, I found myself, from the 1970s onwards, straddling the worlds of cybernetics and design. I certainly didn’t call myself a cyberneticist but I realise, retrospectively, that I was applying the processes of control and information feedback as it affected the way large organisations occupied buildings, as can be illustrated with reference to one particular project.

In the late 1970s, the directors of the Financial Times (FT) asked me to undertake a comprehensive study of the whole organisation so that the environmental and space implications of introducing new technology could be assessed. At that time, the intention was that the FT would lead the way in Fleet Street in emulating papers such as
the Washington Post and the Baltimore Sun by installing new electronic methods for both editing and printing the paper. Early in the life of Trickett Associates, I set up and led a small team to carry out this work which involved examining the FT’s administrative, editorial, and production areas, visiting equivalent newspapers in the USA and producing a report to document the extent to which Bracken House, the FT’s then headquarters in the City, could be reconfigured to embrace major change. At the end of the process, a three-dimensional ‘space planning’ model was used to explain available options to the FT Board (Figure 4). It was in arriving at these options that the disciplines of cybernetics came into play.

![Figure 4: Space planning model showing the Financial Times’ options for change, 1978.](image)

The project I’ve described comes into the category of ‘exceedingly complex’ according to an analysis of comparatives prepared by the UK cyberneticist, Stafford Beer (1959). In distinguishing between three classes of systems – ‘simple’, ‘complex’ and ‘exceedingly complex’ – Beer gave six examples of the first two types (subdividing them further into ‘deterministic’ and ‘probabilistic’ systems). Under ‘simple’ came the window catch, billiards, machine shop layout, penny tossing, jelly fish movements and statistical quality control; under ‘complex’ we find electronic digital computers, planetary systems, automation, stockholding, conditional reflexes and industrial profitability (Figure 5). Clearly, Beer’s lists demonstrate a wry sense of humour, which serves to underline his definition of each system’s predictability and its susceptibility for control by well-tried scientific methods. For instance, physics tells us about billiard balls; statistics about penny tossing; Operations Research about stockholding and industrial profitability. Under ‘exceedingly complex’ systems (which can have only probabilistic forms) we find just three examples: the economy, the brain and the Company. About the Company, Beer (1959) states:

> “It is certainly not alive but it has to behave much like a living organism. It is essential to the Company that it develops techniques for survival in a changing environment; it must adapt itself to its economic, commercial, social and political surroundings and it must learn from experience.”

The FT challenge, at first glance, had appeared to be irredeemable. Even the task of defining ‘the problem’ had been elusive and controversial to the extent that a better term might have been ‘tangle’. Now, in applying, retrospectively, the language of cybernetics, which I didn’t do at the time, I can see that the FT tangle could be characterised as being ‘wicked’. According to Horst Rittel, a design theorist at the Ulm School of Design in Germany, a problem becomes ‘wicked’ when it is difficult or impossible to solve because of incomplete, contradictory and changing requirements that are often difficult to recognise (Rittel & Webber 2006). At Bracken House, my aim had been to uncover a process by which radical change could be accommodated and then, if necessary, revised and re-accommodated over time. I have vivid memories of investigating the environmental, social, technological and logistical aspects of a tangle where, at every turn, expressions of considerable doubt were voiced by all those whose lives would be radically changed, for better or worse, by an unknown future. The FT was a company that had suffered over a long period from on-going changes based on intuition, anecdote and casual observation rather than a close study of requirements through consultation (at the time, in the UK, this was a common trait in company life). Given the radical nature of the FT’s ambitions, this approach had to change to embrace the behavioural realm: the way buildings affect people, the way people communicate one with another, and the nature of their interface with new and unfamiliar working tools. As Robert Sommer (1969) states in his book, The Behavioral Basis of Design:

> “[D]esigners need concepts that are relevant to physical form and human behavior – an approach which presupposes that it is possible
to define and understand the determinants of people's behavior at work in some depth. Behavior which results from formal organisational demands, informal activities and individual needs for self-fulfilment must all be taken into consideration to successfully uncover the 'unique pattern of activity' by which an organisation generates its own success."

3. THE ALL-EMBRACING MAGIC OF CYBERNETICS

I'm indebted to a recent article by Nick Lambert (2017) for knowledge on how cybernetics was first embraced by the art's world. It happened in the UK when Roy Ascott was a student of Victor Pasci in the late 1950s. As Roy relates:

"Whilst looking through the book stacks in the University of Newcastle Library, I found this really weird book called Cybernetics and Business by F. H. George. At the time I didn’t know what cybernetics was, I just thought ‘what?’ So I opened it up. It had inside special words like ‘feedback’, ‘retro-action’, ‘black box’, all of which were magic to me. I thought ‘Jesus, what is this stuff?’"

It was some time later that Roy set up his ‘Groundcourse’ at Ealing College of Art, which was all tied together by the idea of systems and process. His students both here and later at Ipswich Civic College were introduced to cybernetics as a means of understanding what things do and how they do them and the processes by which they behave. There was more than a touch of the shaman in Ascott’s teaching method – a belief that “we are moving towards a fully cybernated society where processes of retroaction, instant communication and automatic flexibility will inform every aspect of our environment” (Ascott 2003). And that’s the society where “the cybernetic spirit finds its expression in the human sciences and in environmental technology, the two poles between which we act out our existence?” The laboratory environment that was developed at Ipswich gave stress to ideas and creative problem solving; it was the ideal place for a curious student like Brian Eno who remembers being set problems that he couldn’t understand and criticised on a basis that he couldn’t recognise as being relevant (Scoates 1992). But, nevertheless, he fell under the spell of the Groundcourse and was the first to admit that he had been made to think out what he was doing and why.

Roy Ascott (1992) later commented about Eno:

"Brian was the first of my students to understand that cybernetics is philosophy and that philosophy is cybernetics.………When I first established a rather radical approach to art education in Britain, identity, role playing and the variable persona were very much on the agenda, the goal of which was the construction of Self. Throughout his career, not only has Eno explored identity, he has provided the context, employing light, sound, space and colour in which each participant can playfully and passionately share in the breaking of the boundaries of Self.”
Brian Eno’s career owed a lot to his ‘grounding’ at Ipswich where he’d been given free license to think that anything was possible and that no subject was out of bounds. It was later, in the 1970s, after being introduced to the ideas of Stafford Beer, that he was challenged to rethink the process of making music and to connect cybernetic ideas to his composing method and the studio environment in which it was produced. Beer’s publications included many diagrams that mapped various systems and, similarly, Eno’s 1975 album ‘Discreet Music’ included Beer-like diagrams that outlined its recording process.

The ideas and vocabulary of visual information that underpins the making (and performing) of SHAPES was generated by much the same circular loops of feedback as those that enabled me to define a ‘system’ for the FT’s advance into an unknown future. There is a difference, of course; the FT project had taken the efforts of numerous people, designers, journalists, planners etc. to become closely involved in a continuous process of feedback and reassessment to arrive at a way ahead whereas, the production of a piece of Visual Music had taken only the creative efforts of one person. Mel Ranulph Glanville (2009) provides an apt description of how such a conversation with oneself occurs:

“The designer, sketching or doodling, switches between the roles of marker and viewer or, to be pedantically precise, the-drawer-who-then-listens-before-drawing-again, and the listener-who-then-draws-before-listening-again, a visual equivalent of talking and listening. The mark is often made without intention; it’s not the shape of something, it’s an exploration, a vague question. Make a mark, view it, remake (change) the mark, review it. This is a type of play, full of unspoken “What if?” questions, the form of a conversation held with oneself: statement uttered, statement heard, statement restated.”

It’s a brilliant description of the cybernetic process but don’t take it completely literally. Doodling, which conveys the idea of ‘pencil in hand’ can mean using any available media, which can facilitate the conscious mind of the artist ‘looking from the inside in the knowledge that everything is new’. In our contemporary world, analogue tools (e.g. a brush and palette) are rapidly being replaced by new methods of discovery where the artist is breaking through the canvas to reach new digital areas of expression – an idea I explored some years ago in a paper called ‘The breadth of the Source-Code becomes the Brush of the Artist’ (Trickett 2012). It described the nature of the digital ‘tools’ that I use to make my Visual Music (of which SHAPES is an example) – codes to generate a series of image sequences of colour and movement where each sequence contains at least 2000–3000 individual frames. In my role as marker, I can then opt to select a single frame, or sequence of frames, which, in my role as viewer, I can choose to either accept or feedback into the system so as to eventually find images that match both my own
guiding vision and the mood and notation of my chosen music. This is a cybernetic system; the choices an artist makes, in his dual roles of marker and viewer, give him the freedom to act as an ultimate decision maker rather than as a mere artisan.

So where has my visual communication of musical counterpoint taken me? The results are surprising; what I see appearing at certain points within my image sequences are apparently coincidental similarities between specific images and the styles adopted by nine well-known abstract artists. I find that I’ve created, maybe subconsciously, a series of digital simulacra of abstract works of art – nine of them in all (Figure 8). This result seems to bear out Roy Ascott’s (2003) prediction that: ‘it (a cybernetic approach) can assist in the evolution of art, serving to increase its variety and vigour’. He made his comment in the journal ‘Cybernetica’ where, as long ago as 1967, he foresaw that, for the future, the programming of computers would require of an artist a great deal more than the vague artistic flair that he relies on at present. As ever, well ahead of his time, he went on to say (Ascott 2003):

“This purposes a decisive shift of emphasis in our aesthetic sensibilities. A shift that is endorsed by the observed behavioural tendency of modern art; a shift, in short, towards an art of systems and process. This implies that our appreciation of the beautiful, and the delight, stimulation, satisfaction, and regeneration that it induces in us resides in our perception and awareness of a system rather than an object.

There is no reason to suppose that the art of process should be any less visual or poetic or musical than the art object or art of object. Beauty can reside in relationships of structural processes as well as in the traditional relationships of fixed parts in a product’s structure. Beauty, thus defined, in which space is shaped by time and form relate to function, is the beauty of a cybernetic vision.”

In the early days of cybernetics in the UK, a few exponents were straining towards creating art as a system, none more so than Gordon Pask. He described himself as a ‘mechanic philosopher’ although those who knew him regarded him, with some awe, as a poet, scientist and humourist. All agreed that he possessed a rare intelligence bordering on that of a ‘maverick genius’ that enabled him to bridge the worlds of science and art. As a student at Cambridge, Pask had met Norbert Wiener, who was due to give an oration on cybernetics, and within just a short time span, no more than it took to escort Wiener from the station to the speaker’s venue, Pask decided that his life’s work would lie in cybernetics. Prior to that he’d attempted and failed to study medicine but his life’s work started with Musicolour. As Pask (1968) explains in his ‘A comment, a case study and a plan’, ‘The Musicolour system was inspired by the concept of synaesthesia and the general proposition that the aesthetic value of a work can be enhanced if the work is simultaneously presented in more than one sensing modality.’ He was drawn to the synaesthetic qualities of Walt Disney’s ‘Fantasia’ as was I in producing SHAPES – a fact that establishes some sort of common ground between Pask’s Musicolour and my own less ambitious exercise in cybernetic art. In both instances, sounds created by a live performer are translated into form and colour, on a projection screen in the case of SHAPES, and on any available surface in the case of Musicolour. But the similarities stop there. As Pask (1968) explains:

‘[T]he interesting thing about Musicolour was not synaesthesia but the learning capability of the machine. Given a suitable design and a happy choice of visual vocabulary, the performer (being influenced by the visual display) could become involved in a close participant interaction with the system. He trained the machine and it played a game with him. In this sense, the system acted as an extension of the performer, with which he could co-operate to achieve effects that he could not achieve on his own.’

A Musicolour performance, then, was a joint product of human-machine interchange; the human performer didn’t control the performance, nor did the machine. As one of Beer’s ‘exceedingly complex systems’ Musicolour gave the human performer opportunities to explore an open-ended range of possibilities in the form of musical sequences. The machine converted these sounds into electrical signals, which were then presented to a bank of filters that ‘listened to’ the performance in various ways; Pask’s machine-learning process was chiefly a matter of ‘learning to listen’. From the performer’s point of view, training became a matter of persuading the machine to adopt a visual style, which fitted the mood of his musical utterances with the result, that, over time, the performer came to regard the machine as an extension of himself rather than as a detached or disassociated entity.

Pask’s ideas for a ‘theatrical lighting machine’ emerged in the early 1950s when he was designing sets for ‘Footlights’ productions and writing lyrics for songs – formative experiences, which explained why, for him, theatrical processes of interaction, were paramount. They caused him to quickly abandon the idea that cybernetic systems should, by definition, pursue fixed goals (e.g. improving the accuracy of anti-aircraft artillery); in Musicolour, his aim was to create a system that supported human interaction (and human-machine interaction) – a second order of cybernetics which enabled others to have conversations, to learn and to act. His
hands-on approach to building Musicolour in his bedroom, where all circuits and connections were constructed from war surplus components, was not only a test of his mechanical skills but, also, a philosophical venture into the science of machine learning which led eventually to his 1964 PhD in psychology. Aesthetically, I'm sure the hardware of Musicolour was neither refined nor beautiful but it did exemplify what Roy Ascott later extrapolated as art as a system rather than as an object. It moved the observer (performer) right into the messy chaos of natural and social systems like those, for instance, that I had encountered at the FT.

4. CYBERNETIC SERENDIPITY

Cybernetics experienced a brief Indian Summer of warmth and public acclaim when, in 1968, Jascia Reichardt put on 'Cybernetic Serendipity' at the Institute of Contemporary Arts (ICA), London – a gem of an exhibition which I well remember visiting long before I'd put a finger on a computer keyboard (that happened only 30 years later!) The exhibition was divided into three parts, computer generated graphics, cybernetic devices as works of art, and a demonstration of the uses of computers. Here, I'm going to focus on the middle category and, within this middle category, I'm giving pride of place to Gordon Pask's 'colloquy of mobiles'. It demonstrated, par excellence, the inventor/maverick's genius to the extent that, only now, are we beginning to realise how far ahead of his time he was in straddling the worlds of science and art to achieve a cybernetic symbiosis of the two disciplines (Figure 9).

Figure 9: Gordon Pask’s ‘colloquy of mobiles’ took centre stage at ‘Cybernetic Serendipity’, an exhibition held at the Institute of Contemporary Arts (ICA), in London, 1968

In Pask’s own document describing his work ‘A Cybernetic Clarion Call to the Arts’ Community’, he wanted to extend the ‘aesthetic potency’ that determines the framework in which communication can take place; his group of objects, the individual mobiles, are not passive but, instead, they engage in a discourse that competes, co-operates and enables them to learn from one another (Reichardt 1968):

“Their discourse evolves at several levels in a hierarchy of control and a hierarchy of abstraction. The trick is that you find them interesting so that, then, you can join in the discourse as well as bring your influence to bear by participating in what goes on. It is a crude demonstration of an idea that could be developed indefinitely.”

Pask’s mobiles are of two sorts, male and female:

“Whereas males compete amongst themselves and so do females, a male may co-operate with a female and vice-versa, for one possesses programmes that are not in the repertoire of the other and jointly a male and female pair can achieve more than both individuals in isolation. Ironically, this property is manifest in the fact that a male can project strong beams of light but it cannot satisfy an urge to have them play on its periphery, whereas a female (who cannot shine light) is able to reflect it back to a male (and, when she is competent, to reflect it upon the right position). To co-operate or even to orient themselves and to engage their programmes, the mobiles must communicate.”

Jumping ahead, now, to the year 2018, many celebrations have taken place commemorating Cybernetic Serendipity’s 50th anniversary but none are more apposite than the decision by the College of Creative Studies in Detroit to mine Colloquy’s legacy for the benefit of future generations by replicating it (Pangaro & McLeish 2018). The physical form of the replica is close to the original, although it is driven by modern digital software. Not only does this replica enable machine-machine and human-machine interactions as Pask implemented them in 1968 but it also provides opportunities for the exploration of what new technologies – voice interfaces, motion sensors, facial sentiment analysis and AI – imply for the future of human-machine interaction. When and if this replica visits London, we will all be able to recapture the spirit of Cybernetic Serendipity and indulge in ‘what if’ speculation on what the combined intellects of the cybernetic community might have achieved in a world more sympathetic to their ideas. But not all is lost; there are signs now that the various surviving strands of cybernetic activity are beginning to coalesce into a powerful force for change and action. As I will show, it is vital that such a cybernetic renaissance occurs.
5. TAKING A CYBERNETIC STANCE

For the last 50 years or so, artists have been embracing new forms of discovery, as evidenced by the Cybernetic Serendipity exhibition, which (to use Roy Ascott's [2003] definition) can best be described as behaviourist. In fact, my own Visual Music appears to act as a 'behavioural trigger' by causing an optical response in the eyes of observers, which, however fleeting, might enable them to pick out apparently coincidental similarities between specific images and the styles adopted by nine well-known abstract artists. SHAPE'S exploration of digital technology, and its extension into performance art, reveals that my acknowledged engagement with the cybernetic process does engender some form of behavioural responses of survival. No doubt, the environmental response I obtained long ago from FT journalists in a newly equipped newsroom was more profound but this doesn't alter the fact that in both instances, Visual Music and Architecture, I was primarily concerned in a shift towards an art of systems and processes. It's this type of cybernetic approach, combined with a close concern with change and people's reaction to it, which can reap rich rewards when applied to any form of artistic expression. The common factor is that an artist's (or architect's) aim needs to be clearly focused on gaining an engaged behavioural response from his or her audience.

A cybernetic stance comes into its own when the going gets tough, when tackling what Stafford Beer described as 'extremely complex' systems. If he were alive now, I feel sure he would add climate change to his short list of the economy, the brain and the Company. And it's on this subject that artists (and architects and designers) have much to offer; a process that has started with the Balance-Unbalance series of conferences held recently in various venues including Manizales, Colombia and Plymouth in the UK. But such meetings cannot, in themselves, co-ordinate the massive changes in human activity and consciousness that will be required to prevent a catastrophe. It's time, therefore, for a cybernetic renaissance where, as in those long-ago days after the Second World War, the sharpest minds from all walks of life are brought together to face up to the most 'extremely complex' system of all. We need now the mathematical genius of a Wiener combined with the computational and scientific genius of a Turing, acting in his role as a cyberneticist, to give a cybernetic focus to the greatest challenge facing mankind. But even this degree of brainpower will fail if it is not aligned with the creative imagination of an art's world dedicated to unleashing cybernetic processes of radical change aimed at enhancing our chances of survival for the future. Hence, my clarion call to the arts' community to turn towards this formidable task.

6. REFERENCES

Ascott, R. (1992) Foreword: Extended Aesthetics. Brian Eno Visual Music. Chronicle Books, San Francisco, California.

Ascott, R. (2003) Behaviourist Art and Cybernetic Vision. In Edward A. Shanken (ed.), Telematic Embrace, Visionary Theories of Art, Technology and Consciousness. University of California Press, Berkeley, Los Angeles, London.

Beer, S. (1959) Cybernetics and Management. English Universities Press, London.

Glanville, R. (2009) A (cybernetic) musing: design and cybernetics. Cybertechastic and Human Knowing, 16(3–4), pp.175–186.

Lambert, N. (2017) The cybernetic moment: Roy Ascott and the British cybernetic pioneers, 1955–1965. Interdisciplinary Science Reviews, 42(1–2), pp.16–17.

Pangaro, P. and McLeish, T. J. (2018) The Colloquy of Mobiles 2018 Project. Paper given at symposium on Cybernetic Serendipity Reimagined, Liverpool. https://www.pangaro.com/published/Pangaro-McLeish-Colloquy-2018_AISB-2018_distro.pdf (retrieved February 2019).

Pask, G. (1968) A comment, a case study, a plan. Cybernetics, Art and Ideas. https://pangaro.com/pask/Pask%20Cybernetic%20Serendipity%20Musicolour%20and%20Colloquy%20of%20Mo biles.pdf (retrieved February 2019).

Reichardt, J. (1968) Cybernetic Serendipity, the computer and the arts (A Studio International special issue). Frederick A. Praeger, New York.

Rih, C. and Dubbertly, H. (2006) Why Horst W. J. Rittel Matters. Design Issues, 23(4), pp.72–81.

Scoates, C. (1992) The Aesthetics of Time, Mistakes and Random Errors: Chance Systems and Process. Brian Eno Visual Music. Chronicle Books, San Francisco, California.

Sommer, R. (1969) Personal Space: the behavioral basis of design. Prentice Hall, Englewood Cliffs, New Jersey.

Trickett, T. (2012) The Breadth of the Source-Code becomes the Brush of the Artist. ATINER's Conference Paper Series, ART.2012–0255. https://youtu.be/6WEXof-BWAw (retrieved February 2019).

Trickett, T. (2019a) Four excerpts from J.S. Bach's first Suite for Cello arranged for clarinet. https://youtu.be/xeTdxxmgtw (retrieved February 2019).

Trickett, T. (2019b) Five excerpts from J.S.Bach's first Suite for Cello arranged for clarinet. https://youtu.be/8WEXof-BWAw (retrieved February 2019).

Wiener, N. (1948) Cybernetics or Control and Communication in the Animal and the Machine. MIT Press, Cambridge, MA.