An Approach to Cybernetics (Gordon Pask, 1961)

Background

Gordon Pask's "An Approach to Cybernetics" was published in 1961 (Pask 1961). It is a slim volume of 128 pages. There is an erudite Preface by Warren McCulloch, which is well worth reading. The main text (102 pages long) is made up of 8 chapters. These are:

1 The background of cybernetics
2 Learning, observation and prediction
3 The state determined behaviour
4 Control systems
5 Biological controllers
6 Teaching machines
7 The evolution and reproduction of machines
8 Industrial cybernetics.

The book is eighth in the series "Science Today" published by Methuen (Harpers in the USA) as "…a new series of science monographs, each devoted to some scientific subject which the publishers believe can be covered fully yet concisely in 128 pages, and each written by a recognised specialist…"

The book probably fulfils this specification, although it is, actually, rather hard to position. It could almost be a text book, but it's too dense and there are no exercises. It might be a primer, but who would it prime? It is a demanding text, not because it's imprecise or badly written but almost for the opposite reasons. The exactitude and compression, without many user-friendly repetitions or reminders, and with little room for extended explanations or examples, lead to a book that is particularly terse. Reading it is demanding. As one who has had an involvement in the subject for 35 years, first read the book many years ago, and has the advantage of having been a Pask student, I still found it required great attention and concentration and I needed to read it in short sections.

Describing the book this way, I may sound negative. Nothing could be further from my intentions. Those who know Pask's three later books, produced in rapid succession, on Conversation Theory (Pask 1975a, 1975b, 1976) would be surprised were I to complain. These later books are long and difficult to understand in part because of the complexity of what Pask is trying to convey, in part because of his strategy of global adumbration (a favourite Paskian word deriving from the Latin for shadow), meaning that he pulls in as many items as possible to support his argument, on occasion submerging it. These later books are also somewhat loaded with formal statements and very complex diagrams, which also do not help general comprehension. In comparison "An Approach" is a simple and direct book, but it does make demands and does not patronise the reader; and is nothing like as easy to read as the more popular "MicroMan" (with Susan Curran—Pask and Curran 1982); and

"Calculator Saturnalia (with Mike Robinson and myself—Pask, Glanville and Robinson 1980).

So what exactly is the value of this little book? Why am I championing it from among Pask's more than 250 publications, as a canonical text in cybernetics? The reasons I have chosen it derive from three factors: its author, its time, and its terseness.

In 1961 Pask had already been established as a considerable figure in cybernetics for a decade, perhaps even its leading young light. He had more than thirty years to live, and the magnum opus, for which he is also probably best known ("Conversation Theory"), was a decade away. 1961 represents an important time in cybernetics, for the subject was both established and well funded. After the initial excitement of the Macy Conferences and the publication of Wiener's book, Ashby has consolidated the subject. "An Approach to Cybernetics," as Pask admits, could not have been written before Ashby's "Design for a Brain" (Ashby 1952) and "An Introduction to Cybernetics" (Ashby 1956). So the time was right both for the subject and for the author. Finally, the book's scope both implies a terseness and demands a precision, density and parsimony that can be found in much of Pask's very best work, and which characterised his thinking when I first met him half a dozen years later.

These factors, contributing to its value, lead me to chose to discuss this book—a book of distilled power and clarity that make a powerful (albeit idiosyncratic) argument for cybernetics and for what cybernetics might achieve.[1]

There is one final point I must argue before I enter into my detailed discussion of "An Approach." I believe many Pask afficionados and scholars will find my choice odd. Given the vast structure Pask created in "Conversation Theory" (a work that is dreadfully undervalued, much misunderstood, and is, today, frequently recreated to considerably lower standards by so-called "experts"—who are so ill-informed they do not know Pask's work), it would be reasonable to chose a writing explicitly on this subject to represent Pask's work. After all, there are the three books I mentioned (all, however, out of print, as is "An Approach").

I have mentioned some of the generally held views of Pask's writing. One of the frequent criticisms raised against Pask is that he is terribly difficult to understand. Often, his writing seems unnecessarily complicated, and his general wish to adumbrate everything he can into his work can lead to underjustified claims, all of which put the student off from what are, anyhow, long and complex—even daunting—texts. (As a student of Pask's when he was

[1] Allenna Leonard, Stafford Beer's widow, told me that, when people remarked on the uncharacteristically clear writing in "An Approach", Beer had suggested they look at the acknowledgements. From this is is clear that the master of economic and elegant English, Heinz von Foerster, acted as Pask's stern editor.

developing this work, I have a privileged—and rather easier—route in.)

"An Approach to Cybernetics" gives the lie to the generality of these claims. Pask's brevity, intensity and clarity as he deals with the distillate of cybernetics is quite the opposite of what is often thought to be his style. This work deals with the familiar foundational concepts of cybernetics, as one would expect of a text published in 1961, with a focus and terseness that will surprise many. But it does more than that. I will argue that it provides an introduction to Pask's own work and world, to how he looks at things and what his interests are and what he appreciates. I will argue, then, (in the main subject of the discussion that forms the rest of this text) that he tells us the future. Looking back at this text with over 40 years of development, it is easy to see Pask foretelling both developments in the field, and, more particularly, developments in his own work. This text is thus both a masterly summing up of where cybernetics was in 1961, and a preparation for what was to come. It is a shame that the scope of a piece such as this prevents the weaving of the complex web of interconnections that Pask was part of, but reading this little book should help those who want better to understand the background to the development, in general, of Second Order Cybernetics, and in, particular, of Conversation Theory. And reading this appreciation may help such a reader better understand the content, context and the promise of Pask's work.

Discussion

In order to show the prescient nature of "An Approach", I have made a collection of quotes. In re-reading the book it occurred to me that, presenting the quotes under a number of headings, I could show just how remarkable Pask's little book is, how it not only throws a sharp light on cybernetics as it was and, in principle, remains; but also how it foreshadows developments both in the field and in Pask's own work. Through this, I hope to make the appreciation of Pask's later work somewhat easier). I am anxious to let Pask speak with the direct clarity and simplicity that many, mistakenly, believe was foreign to him. In effect, therefore, my critical discussion of the book consists of the selection and ordering of the quotes under headings I have chosen, plus a few words of commentary. That these headings were not used by Pask is evidence of just how prescient "An Approach" is.

I employ the following three conventions. I indicate the page from which the quote is taken at the start of each quote: where there is more than one quote from a page, a letter is added to the end to distinguish one quote from another. Within quotes, words in square brackets [] are mine. That material is quoted is also shown by indentation and the use of a different typeface.

Cybernetics

Let's start at the beginning with Pask's view on Cyberentics as presented in "An Approach." In 1961, Pask's view is essentially in line with the cross-disciplinary, classical view of circular causality, and communication and control in the animal and the machine that was proposed by the original, early cyberneticians:

> *015.* *The cybernetician has a well specified, though gigantic, field of interest. His object of study is a system, either constructed, or so abstracted from a physical assembly, that it exhibits interaction between the parts, whereby one controls another, unclouded by the physical character of the parts themselves.*
>
> *011b.* *Cybernetics...like applied mathematics, cuts across the entrenched departments of natural science; the sky, the earth, the animals and the plants. Its interdisciplinary character emerges when it considers economy not as an economist, biology not as a biologist, engines not as an engineer. In each case its theme remains the same, namely, how systems regulate themselves, reproduce themselves, evolve and learn. Its high spot is the question of how they organise themselves.*

He focuses us on the cross-disciplinary nature of the new subject in a way that can be seen to be leading towards his later description of cybernetics as "the art of the defensible metaphor."

Science

Pask's later, metaphorical description can be understood to accommodate the position of science and observation that Pask already shows in "An Approach." Considering when the

book was published, Pask had a developed what now appears to be an advanced attitude to science, and the relation of cybernetics to science. I shall deal with his position through 3 sub-headings.

Energy or Information

Although cybernetics is primarily concerned with information, Wiener was insistent that its systems should follow The Laws of Thermodynamics. (I believe Wiener could never quite stop himself from thinking of cybernetics as somehow a part of physics. Certainly he saw cybernetic systems as significantly subject to the laws of physics (Wiener 1948).) Giving unwarranted precedence to considerations of energy often disguises the circularity of cybernetic systems and even their nature as cybernetic, dividing, for instance, the roles of controller and controlled so the controller has more "power" and "significance" (a master-slave relationship). Pask, however, already in 1961 explicitly downplays the importance of energetics:

> *018a. Although ...the energetics do not immediately concern us..., the assembly embodies one or many more or less regular modes of dissipating the energy as a result of which it produces an unlimited supply of observable events.*
>
> *031. ...the behaviour in a phase space is an account of observable events and makes no direct comment upon the energetic aspects of the assembly.*
>
> *012. The signalling arrangement is independent of energetic considerations, and it is legitimate to envisage the governor as a device which feeds back information in order to effect speed control.*

It is not that Pask denies the significance of physics (for instance the need for energy transfer in making an observation), more that he understands that an informational view is not the same as an energetic one, but is equally valid.

The (Ever) Present Observer

Pask was well aware of the intentionality and active involvement of the observer. His earliest machines constructed in the early 1950s (SAKI, Musicolour—Pask 1962, 1982) were genuinely interactive in a way few systems are even today, recognising the necessarily active nature of observation for interaction to occur. Of course, the importance of the observer's role in (for instance) particle physics was understood. But the general need to recognise the significance of the observer was not so well accepted. Pask's attitude to the observer precedes the development of second order cybernetics (von Foerster's cybernetics of observing systems (von Foerster 1979) by more than a decade. The notion of the observer-as-learner is powerful in itself, as well as being epistemologically profound.

021. *[footnote]. We take it, as a matter of belief, that the world is such and we are such that we see some order in the world. As Rashevsky puts it, this much must be admitted in order to make science possible.*

018b. *Observers are men, animals or machines able to learn about their environment and impelled to reduce the uncertainty about the events which occur in it, by dint of learning.*

047-8. *...the phrase "self-organising system," entails a relation between an observer and an assembly. It also entails the observer's objective (an assembly may be a self-organising system for one observer but not another, or for one objective but not another)*

102-3. *An evolving hybrid is a self-organising system,...in terms of its relation to an observer, for an observer must continually change his reference frame to make sense of it. But, in this context, to "change our reference frame" only means that we perform different conceptual experiments, try to make sense of unitary actions, sequences of actions and so on, in short, that we "converse."*

019. *...we do not make a prediction about a piece of the real world, an "assembly" as such, which is unknowable in detail. Rather we make predictions about some simplified abstraction from the real world—some incomplete image—of which we can become certain...*

035c. *Most observers are not content to watch and wait. They act upon the assembly and induce the system to change states in a satisfying manner...Notice, they need have no more knowledge of what they are doing than they have of what they are measuring. But we know omnisciently. The logical position is that an observer of this kind, a so-called participant observer, is provided with a set of...possible actions, and he is told, at least, that each action induces some cogent change of state in the system.*

Notice that Pask includes, with his interest in the observer, self-organisation, reference frames, partiality of view and the urge to act. Partiality of view seems to be a particular pre-occupation. I believe that Pask has a strong wish to sustain a notion of an actual world, and, no matter how much he recognised differences in points of view, he needed to believe they were of the same thing. Nevertheless, in 019., he anticipates much of Ernst von Glasersfeld's Radical Constructivism (von Glasersfeld 1990). When told of Pask's death, von Glasersfeld told me that he had learnt an enormous amount from Pask and owed him a great debt, perhaps a reference to this and other similar quandries.

Omniscience

However, Pask's approach was not the Radical Constructivist's. The omniscient observer remains, I think, implicit in all Pask's work, providing access in principle to a complete and correct understanding against which our individually flawed observations may be seen.

035a. ...speaking omnisciently...

037. ...the whole concept of a subsystem is "arbitrary," in the sense that it depends not only upon the "regularities" in the assembly which, from omniscience, we know to exist but also upon those the observer chooses to recognise.

022. Individuals circumvent their imperfections by forming a simplified abstraction of the real world, through learning and concept formation (as a result of which, amongst other things, they learn to recognise new percepts). This abstraction, of course, is a private image, but it allows them to deal with and decide about their environment. On the other hand, just because of our human limitations there is advantage to be gained if a group of observers, anxious to make the same sort of predictions, communicate with one another and in place of many private images, build up one commonly understood abstraction (such as the hypothetico-deductive structure of science). This will be a public image of the world within which all observations are assimilable and in terms of which behavioural predictions are made. An observer who subscribes to the plan, must limit himself to observations that are mutually intelligible and which can be assimilated. Again, the rules of deduction which apply in the abstract structure (and on the basis of which these predictions are made) must be rules which have met with public approval.

For me, this postulation of omniscience (while leading to some very interesting points) is a limitation in Pask's thinking, as the precedence of physics is in Wiener's. I take the view of science Pask expresses here as a stage he believed was well on the way to omniscience. However, Pask himself chose to live recognising omniscience, in later life joining the Roman Catholic church.

Pattern, uncertainty and human limits

Part of Pask's (informal) view on the observer comes from the appreciation of the limits of human beings, which came to be formally reflected in both Ashby's view on variety and restrictions raised by Bremerman's transcomputability limit (Ashby 1964, Bremmermann 1962). These tell us about limitations to information processing capabilities. His position that, because of these limitations, we might treat all systems as essentially statistical is inventive and interesting, but I recall him later talking of the dangers of "phony statisticising."

021b. From the whole gamut of orders that appear in the world we can recognise only a few and these we can only assimilate at a limited rate...

043. Since inductive procedures do not lead to complete certainty it is, perhaps, better to say that all systems are statistical. "Determinate" is the name we give to a system with particularly "consistent" statistics.

039-40. There is no guarantee that an observer...will achieve a state determined system....

In this case the observer may either:

(i) Examine a system of greater detail and diversity...

(ii) Resort to statistical observation.

066-7. As indicated...any level of the system will learn those regularities which enable it, as a whole, to keep in equilibrium with its environment, and receive a reward.

086-7. When it comes to making cognitive "pattern recognisers" there is argument over the merits of "pre-programmed" and "learning" machines. A wholly inflexible device has little practical value for even printed characters come mutilated or displaced from their reference position. The most stereotyped but still useful machines...work at frog level [a reference to "What the Frog's Eye tells the Frog's Brain:" Lettvin, Maturana, McCulloch and Pitts' classic paper]. At the other extreme, Frank Rosenblatt has a particularly malleable network, the "Perceptron," that can be trained (essentially by operant conditioning) to recognise characters. Facilitated paths in the trained network determine the attribute filters. By comparison with a structured automaton the Perceptron learns slowly. However, this is no real criticism...and this device would come into its own if we did not know exactly how or what to recognise at the at the outset.

021c. Whilst the ultimate restriction is imposed by our own capabilities, we are commonly up against other and artificial difficulties. Because of these the object of the study appears to be enclosed in a container, the so called "Black Box," to which we, as observers, have incomplete access.

021a. A "Black Box" situation gives rise to either structural or metrical uncertainty or both.

It is interesting to see the appreciation of the value (even necessity) of ignorance promoted here, by the device of the Black Box, the discussion of pattern recognition, and the notion of the incomplete picture. Recognising the value of ignorance is essential for learning.

Stability and Closure

Pask's views on stability are particularly lucid and to the point. Stability is critical to describability, but Pask is proposing an advanced understanding: of stability as dynamic and invariance as a process.

011a. The crux of organisation is stability, for "that which is stable" can be described; either as the organisation itself, or some characteristic which the organisation preserves intact.

011-2. Jim Jones is in dynamic equilibrium with his environment. He is not energetically isolated and his constituent material is being continually built up and broken down and interchanged. When we say "Jim Jones is stable." we mean the form, the organisation that we recognise as Jim Jones, is invariant.

018c. The behaviour of a statue is a special case [of the observed], for the statue is immobile, or to use an equivalent formalism, it changes at each instant of time into itself.

029. ...a state determined behaviour must either converge...to a fixed state called the "equilibrium point," or enter a behavioural cycle...

The last two quotes are especially remarkable. The first can be seen as close to a formulation of "Autopoiesis" some years before Varela, Maturana and Uribe (1974), and the second as a precursor to what I called the Behaviour of Objects (Glanville 1975), and von Foerster's Eigen-Objects (1976). Autopoiesis is characterised as a potential that becomes an organisation through generating and then maintaining its organisation; von Foerster's Eigen-Objects approach and then maintain stable values; my Behaviours can be seen as the averaging of the collection of all observations of Objects, becoming more and more all embracing, and stable. (In "Calculator Saturnalia" Pask, Robinson and I develop computational games that explore these concepts. Louis Kauffman (2003) has recently explored in depth the nature of recursion and how it tends towards the making of Eigen Objects.)

Conversation

Conversation, the careful analysis and formulation of it and the introduction of it as a serious means of communication, is possibly Pask's greatest contribution to cybernetics and the understanding of human behaviour. It is almost certainly his best known. Conversation is a particularisation of interaction (Pask later worked on the generalisation of conversation to interaction in his "Interaction of Actors Theory," rather as Einstein worked on General Relativity after Special Relativity). Here, in "An Approach," Pask introduces the concept and mechanism of conversation throughout the book. It has appeared in some quotes I cited earlier. Here are some particularly focussed passages.

102. ...it is possible for an observer to make sense of what goes on—to adopt a good regarding procedure—providing he "converses" like the student in a teaching system. But, as a result of this close coupled interaction he fashions the system in his own image.

035b. If two people are in conversation, for example, their discourse takes place in a object language and we make comments about the conversation in a metalanguage, possibly in terms of psychology.

047. Man, for example, may be specified anatomically..., or alternatively as a decision maker.... In conversation, when trying to control a man, to persuade him to do something, how do I define him? Manifestly I do not, at least, I continually change my specification in such a way that he appears to me as a self-organising system.

093. The "conversation" that leads up to this state entails two formally distinct activities:

1. ...must "keep the student's attention"...

2. Problems must be matched to the student....

This is not the whole story. Problems are not appreciated as unitary entities, and their sequential ordering is equally part of the matching process....

To summarize; in conversation [a controller] is aiming:

1. To keep the student's attention. This action is competitive...

2. To adapt the object language, which is a largely co-operative affair.

In a skill like fault detection we cannot practically separate 1 and 2. But these functions are separable when there is a well-defined method of stage-by-stage learning.

The view of the changing specification one conversational partner creates for another (047.) seems to me to precede the Conversation Theory notion of the psychological individual, many of which, in Pask's conception, could co-exist in one mechanical individual (ie, body). "Conversation Theory" also makes use of an object- and meta-language (035b.), though Pask and I later argued over the need for a third, substrate-language.

Control

Control is one of the central, initial concepts of cybernetics. It is not, therefore, surprising that it features extensively in this book. But what is interesting is how, already, Pask is integrating control with his more personal concepts, such as conversation, point of view, learning, and biological circularity.

075. ...if the environment is another man (in conversation), or an adaptive machine..., where does one control system end and the other begin? That depends upon how and why you are looking at it.

082-3. ...we have seen that some controllers "learn" how to "solve problems" and the change of words brings us to the crux of this learning process. For it is not remarkable to find a system has responsive characteristics altered by past events. Given appropriate stjmuli this is true of a chunk of iron or a slab of gelatine, certainly of any system with richly coupled subsystems and multiple equilibria.

071. It does not alter the identity between control systems to point our that most biological controllers are quite unmechanical. Often it is impossible to say "that is the controller," or "that is the input." But in biology we must be more than ordinarily careful to think of systems, not things.

The Macy Conferences were particularly concerned with "Circular Causal, and Feedback

Mechanisms in Biological and Social Systems" (von Foerster, Mead and Teuber 1950). Pask here reminds us of the essentially circular notion of control (an understanding Wiener's enthusiasm for Thermodynamics encouraged many to ignore or hide). Here he is almost asserting what became the Second Order Cybernetic position of the essential (and recursive) circularity of control.

Learning and Teaching

Conversation Theory was developed to support learning, especially computer aided learning. Pask's very first machines were special purpose teaching and learning machines of enormous sophistication (he later came to think of them as learning environments and to hate the notion of teaching machines and most implementations of such machines, as he wrote in "Anti-Hodmanship"—Pask 1972). Pask's early machines from the early 1950s remain advanced even by today's standards.

Pask's approach was always based in interaction. He understood and worked to get into the environment the sort of flexibility and ability to "switch" and "jump" so typical of human behaviour. In "An Approach," his criticisms of what was then (and, tragically, still too often is) a naive educational position and willingness to bend the (human) learner to the convenience of the machine were both obvious and simple, yet radical. His distinction between the (unlearning) brain and the system developed in the brain that does learn is acute and as critical and tragically misunderstood today as in 1961.

> *046b.* *When primates are learning to solve their problems, their behaviour, though not strictly stationary, remains approximately so; the learning curves can be extrapolated with confidence, and the behaviour is predictable. Then, rather suddenly, the creature learns a new concept and subsequently deals with problems in a different way which it sticks to for a further appreciable interval. Once again, the learning curves can be extrapolated and a different kind of behaviour becomes predictable. But between the two behavioural modes there is a discontinuity and prediction of the subsequent mode, given the initial mode, is impossible unless we make use of averages over an ensemble of animals.*
>
> *089a.* *There is plenty of evidence that teaching machines work passably well. But because of the fixed programme which embodies it, the method can only be best for the average student for those aspects of behaviour which are stationary when averaged over an ensemble of individuals (by definition, the student who learns is non-stationary. What the programmer assumes is an invariant sequence of stationary states, that characterises optimum learning of the skill).*
>
> *Now this puts the onus for adaptation upon the student. He must accept the probably laudable dogma of the machine—and he does. In contrast, a real life private instructor, although he knows what he wants to achieve, has few preoccupations about how to achieve it—and he continually adapts his teaching method to the changeful quirks of each individual. Like the*

fixed programme machine he observes the student's response. Unlike it, he changes his decision rule, even his syllabus, and the interaction has the logical status of a conversation, which entails compromise between the participants at each stage. The private instructor is at least an adaptive controller and there is reason to believe that, for some skills, he is more efficient than a fixed programme device.

092-3. *To make sense of the process [the student entering into a conversation with the teaching machine] we must talk about systems. A brain is modified by its history, but, like any other evolutionary network, it does not learn. The student who does learn is a system developed in the brain. When the system as a whole is stable the two subsystems, man and machine, are indistinguishable and the student uses bits of the machine like bits of his brain in solving a problem.*

092. *...[in conventional teaching machines it is not too difficult to find a measure, but it] takes no account of information derived from mistaken responses (since we do not know the significance of mistakes) and is descriptive if and only it a correct response occurs within the allowed interval.*

This last quote offers a profoundly cybernetic insight—that error is not per se bad. I have since often asserted that cybernetics is the first subject to accept error both without condemnation and as a fact of life.

In Conclusion

Andrew Gordon Speedie Pask

Reading "An Approach to Cybernetics" I am as near to the Gordon Pask I first met and later studied with as I have ever been since then. The precision of thinking, the terseness of presentation, the clarity and style of questioning shine forth for me in the book, as I hope the quotes above may shine for those who were not as fortunate as I to meet Pask like this. So, too, the amazingly prescient foresight. This is what leads me to claim this work as canonical: both in Pask's work and in Pask's place in cybernetics.

It is this Pask who, the first time I met him, telling him in very confused terms about a student project I was undertaking, summarised what I had tried so hard and at such length to say (and failed), with an understanding and diamond-like sharpness and light that I had never come across before, and which seduced me to cybernetics, eventually becoming one of his students.

In my view, the daunting often appears less so after an appropriate briefing and preparatory introduction to the preceding thinking, concept range and ways of explaining. I hope that the qualities of this little book are sharable, and that sharing its qualities will open up the great worlds Pask made later in his life, for in this book he tells us in advance so much about these worlds. Perhaps the formidable volumes on Conversation Theory will make an easier and clearer sense after having read "An Approach" in the light of this discussion.

Pask was an astonishing man who did astonishing work. His work and his thinking are represented above. I end with some quotes from "An Approach to Cybernetics" that show something more personal of the quality of the man, and his visionary character.

110a. *...management cannot be efficient as well as authoritarian. It is an issue of persuasion, compromise and catalysis. He [Stafford Beer] always knew that men and machines were cussed. Cybernetics offers a scientific approach to the cussedness of organisms, suggests how their behaviours can be catalysed and the mystique and rule of thumb banished.*

112a. *You cannot add wisdom by adding heads on a committee. That is the fallacy of team research (you cannot buy a research team. With luck it grows, making its own common language and thriving on personal interplay which has nothing to do with research).*

110b. *Among the next batch of computers there will be some that are chunks of polymer, made to exist inside reaction vessels, and catalyse reactions with which they are in contact. The sensing and computing will not be distinct and maybe the effectors will also form part of the same thing.*

A further possibility, amusing in its own way, is an animal computer, which could be valuable for slow speed, essentially parallel data processing. Skinner once used pretrained pigeons as pattern recognising automata in a guidance mechanism, and they have also been used in

industry. Working along somewhat different lines Beer and I [Pask] have experimented with responsive unicellulars as basic computing elements which are automatically reproducing and available in quantity.

100. *The von Neuman machine and its environment are commonly represented by the states of a computer, but if, as I do, you like a mechanical analogy for the logical prerequisites of reproduction, you should read...*

053. *Do not despise the machines even if you cannot spare my childish wonderment. I have seen a kind of pianola made in 1920, which includes a fourth order non-linear servo system, and the most elaborate code transformation from the input music roll. These beautiful machines reached a peak of ingenuity years ago and, for all the talk, automation, in the classical sense, is a hoary old art.*

111. *...it is both distasteful and dangerous to regard man as a cheap substitute for an automaton—dangerous because there is a vicious circle and ultimately man will lose.*

References

Ashby, WR (1952) Design for a Brain, Chichester, John Wiley and Sons

Ashby, R (1956) Introduction to Cybernetics, London, Chapman and Hall

Ashby, WR (1964) Introductory Remarks at a Panel Discussion in Mesarovic, M (ed) Views in General Systems Theory Chichester, John Wiley and Sons

Bremmermann, H (1962), Optimisation Through Evolution and Re-Combination in Yovits, M, Sawbi, G and Goldstein, G (Eds.) Self-Organising Systems Washington DC, Spartan Books

Glanville, R (1975) A Cybernetic Development of Theories of Epistemology and Observation, with reference to Space and Time, as seen in Architecture (PhD Thesis, unpublished) Brunel University, 1975, also known as The Object of Objects, the Point of Points,—or Something about Things

Kauffman, L (2003) Eigenforms—Object Tokens for Eigenbehaviours, Cybernetics and Human Knowing vol. 10 nos. 3–4

Lettvin, J. Maturana, H McCulloch, W and Pitts, W (1959) What the Frog's Eye Tells the Frog's Brain,' Proc. IRE 47

Pask, G (1961) An Approach to Cybernetics, London, Methuen

Pask, G (1962) Musicolour, in Good, I.J., (Ed.), The Scientist Speculates, London, Heinemann

Pask, G (1972) Anti-Hodmanship: A Report on the State and Prospect of CAI, Programmed Learning and Educational Technology, vol. 9, no. 5

Pask, G (1975a) Conversation, Cognition and Learning, Amsterdam and New York, Elsevier

Pask, G (1975b) The Cybernetics of Human Learning and Performance, London, Hutchinson

Pask, G (1976) Conversation Theory, Applications in Education and Epistemology, Amsterdam and New York, Elsevier

Pask, G (1982) SAKI, Twenty Five Years of Adaptive Training into the Microprocessor Era, Int J of Man Machine Studies

Pask, G and Curran, S (1982) MicroMan, London, Century

Pask, G, Glanville, R and Robinson, M (1980) Calculator Saturnalia, London, Wildwood House

Varela, F, Maturana, H and Uribe, R (1974) Autopoiesis, BioSystems, vol. 5

Von Foerster, H (1976) Objects: Tokens for (Eigen-)Behaviours, Cybernetics Forum 8

Von Foerster, H (1979) Cybernetics of Cybernetics, in Krippendorf, K (ed) (1979) Communication and Control, New York, Gordon and Breach

Von Foerster, H, Mead, M and Teuber, H (Eds.). (1950) Cybernetics: Transactions of the Sixth Conference, New York: Josiah Macy, Jr. Foundation[2]

Glasersfeld, E von (1990) An Exposition of Constructivism: Why Some like it Radical, in Davis, R, Maher, C and Noddings N Constructivist Views on the Teaching and Learning of Mathematics, Reston Va, National Council of Teachers of Mathematics

Wiener, N (1948) Cybernetics, Cambridge Mass, MIT Press

[2] Although the 6th conference, this is the first with proceedings. Five more followed.