Competing models of information in the history of cybernetics

Book Section

Chapter 2
Competing models of information in the history of cybernetics

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Abstract

Around 1950 a series of interdisciplinary conferences in the United States, later known as the Macy Conferences on Cybernetics, were key to the development of a number of fields and were especially influential on the concept of information. This chapter explores two views of information which emerged from the conferences: the hard view of Wiener and Shannon; and the soft view of Bateson, Mackay and Ashby. The hard view has information as an object in its own right which can be analysed mathematically while the soft view emphasises the context and meaning of information, and the role of the observer.

Information at the Macy Conferences

The information society has always been with us, as argued by Bissell in Chapter 3 of this book. Information, through its changing forms and media, has been always been a guiding principle for the organisation of society, and for many different forms of scientific understanding. Nonetheless, a key development in the centrality of information to society occurred in the late 1940s and early 1950s with the birth of the field of cybernetics.

The development of cybernetics in its Anglo-American form took shape during a set of conferences organised by the Macy Foundation. The Macy Conferences on Cybernetics, as they ultimately became known, were a series of ten two-day meetings between 1946 and 1953, largely held in New York City. As Bissell (2010) observes, there are other historical traditions within cybernetics, especially within Germany and Russia, but the Macy Conferences formed a dominant strain within cybernetics in the English-speaking world, and it is with that tradition that I will be concerned here.

The conferences had two aims: to explore feedback processes and circular causality within a range of disciplines, and to explore common behaviours between biological, social and artificial systems. They were thus explicitly interdisciplinary. The list of participants in the conferences is extraordinary: among the better-known were Norbert Wiener (mathematics), Gregory Bateson (anthropology), John von Neumann (physics and mathematics), Claude Shannon (communications), Warren McCulloch (neurophysiology), Margaret Mead (anthropology), Kurt Lewin (social psychology), Alex Bavelas (social psychology), Heinz von Foerster (physics), Ralph Gerard (neurophysiology) and Wolfgang Köhler (psychology).

The Macy conferences occurred at a key moment in the development of a number of fields, for several different reasons. First, coming as they did immediately after the Second World War, interdisciplinarity was part of the experience of many researchers. Second, the development of the digital computer during and immediately after the war acted both as an inspiration and as resource for the development of a wide range of theories on the nature of mind, control, communications and behaviour. Third, they reflected a growing view of the importance of circular causality across many fields – as Margaret Mead later said, "there wasn't a person in the country who was thinking hard about problems who didn't have a folder somewhere marked something like 'circular systems'" (Brand, 1976). Fourth, they drew on a number of key wartime research projects which all focused on control and communication processes within both man-made systems and biological systems.

These ideas came together in different ways from each of the key contributors to the conferences, but they had their most public expression in the work of Norbert Wiener, who coined the term 'cybernetics' and wrote a celebrated (albeit dense and difficult) book on the subject (Wiener, 1948). Wiener's work on cybernetics began with two research projects: on feedback within human and animal physiology; and on the building of control systems for anti-aircraft weaponry during World War 2. Wiener and his collaborators brought together these ideas in a crucial article in 1943 (Rosenbleuth *et al*., 1943), and he subsequently developed them in his 1948 book. The subtitle of this book was 'control and communication in the animal and the machine', and these two pairs of linked concepts were key to his understanding of the new field.

The Macy conferences created more than one new discipline – as well as cybernetics itself, the fields of artificial intelligence, computational linguistics, complexity theory and family therapy owe much to the discussions in the Macy conferences. The conferences were full of strong argument by people from very different backgrounds, who all saw the importance of the newborn field of cybernetics but wanted to shape it in quite different ways. Nonetheless, the conferences were hugely influential, and especially so in their influence on the developing concept of information.

I have written elsewhere both about the lives and key work of a number of the key Macy participants (Ramage and Shipp, 2009), and in Ramage (2009) I specifically contrasted the work of Norbert Wiener and Gregory Bateson, relating them to Donna Haraway's concept of the cyborg. My purpose in this chapter is not to focus so much on individuals as on ideas: on two concepts of information which arose during the Macy conferences, and can be seen as continuous traditions.

The first (which in short-hand I refer to as 'hard' information, and has been dominant in technical domains) derives especially from the work of Norbert Wiener and Claude Shannon. The second (which I refer to as 'soft' information, and is more influential in social science) derives from the work of Gregory Bateson, Ross Ashby and to a lesser extent Donald Mackay. I will examine the origins of these two approaches in the early work of cybernetics, and then trace through some of their later implications within cybernetics and the disciplines it helped to create. In earlier work (Ramage, 2009) I referred to these traditions as two schools of thought in cybernetics, hard and soft cybernetics – my focus here is more closely on approaches to information rather than schools of cybernetics, but this is a fine distinction given that in the earlier work I argued that their approach to information was a key distinguishing feature of these two schools.

My argument in this chapter is that information is a contested concept, that we can identify at least two highly influential ways to understand it that go back more than sixty years, and that both of these approaches can equally be considered legitimate .

Wiener, Shannon and the ‘hard’ view of information

The first and most prominent view of information within the cybernetics domain has been one that treats information as an object in its own right, removed from its original physical and cultural context. For example, information may have begun as a set of words in a book, but the words (once digitised) can be analysed independently of the physical book. This is a familiar phenomenon, as discussed elsewhere in this book – the way by which very many parts of the world that once had a largely physical form can now be seen as forms of information (such as books, music, money and even social networks). These can thus be treated analytically, using mathematical tools and looking at the ways in which the information is stored, processed and transmitted.

This perspective is crucial to the way modern society is organised, and has enabled the development of information and communication technologies of all kinds. Nonetheless, it depends on what is at first sight a peculiar double manoeuvre: information was (and is) simultaneously disembodied and reified – it “lost its body” (Hayles 1999, p.2) in the sense of being taken out of its original physical context (disembodiment), but was then treated as an object in its right (reification). As Hayles (1999, p.ix) further puts it, information is treated as “an entity distinct from the substrates carrying it … a kind of bodiless fluid that could flow between different substrates without loss of meaning or form”.

The hard view of information derives from the related work of Norbert Wiener and Claude Shannon in the late 1940s, as well as earlier work by Ralph Hartley. Shannon’s theories and approach are covered in some detail in Chapter 4 of this book, by Chapman, and so my focus in this chapter is on the work of Wiener (who was more explicitly identified with cybernetics, although Shannon was a participant in three of the Macy conferences) and the links between Wiener and Shannon, rather than on Shannon’s work directly.

For both Wiener and Shannon, information (and especially its transmission, which was Shannon’s focus given his work for Bell Labs, the research arm of the telecoms firm AT&T) was treated using the mathematics of statistical mechanics. The information content of a message was treated in terms of its probability – a message that was more probable was held to carry less information – “the more probable the message, the less information it gives. Clichés, for example, are less illuminating than great poems” (Wiener, 1954, p.21).

Closely linked to probability in Wiener’s mathematical work was a link between information and entropy (the degree of disorder in a physical system, a key concept in thermodynamics) – he regarded information as the opposite of entropy, and referred to it as ‘negentropy’. As he wrote, “just as the amount of information in a system is a measure of its degree of organization, so the entropy in a system is a measure of its degree of disorganization; and the one is simply the negative of the other” (Wiener, 1948, p.11).

This link between information and organization was crucial for the parallels Wiener developed between machines and biological systems. Organization became important in theoretical biology in the 1930s (not least through the work of Ludwig von Bertalanffy, the founder of general systems theory with which cybernetics would gradually converge). As Wiener’s biographers have observed, “it was that new, dynamic quality of organization that Wiener brought to his conception of information … he joined the animate and inanimate worlds, and completed his bridge across the no man's land of science" (Conway and Siegelman, 2005, p.190).

There were close parallels between Wiener and Shannon's treatments of information – both treated information as if it were an independent object, analysing it in terms of probability. A mutual acknowledgement of their links can be found in each author's work. Shannon writes that "communication theory is heavily indebted to Wiener for much of its basic philosophy and theory" (Shannon, 1948) and Wiener that "this idea occurred about the same time to several writers, among them the statistician R.A. Fisher, Dr. Shannon of the Bell Telephone Laboratories, and the author" (Wiener, 1948, p.10). Indeed, the two worked closely together in the early 1940s (although Shannon was 20 years younger than Wiener). Wiener's collaborator Julian Bigelow later recalled that "in the time I was associated with Wiener, Shannon would come and talk to Wiener every couple of weeks and spend a hour or two talking with him" (Conway and Siegelman, 2005, p.126).

However, it cannot be denied that it is to Shannon that phrases like "the father of information theory" are attributed (ironically, given that he consistently referred to his work as 'communication theory' and denied the anthropocentric implications of the term information) – it is Shannon's version of mathematical information that has been influential. This is particularly because he wrote his work in the context of digital telecommunications, an area that was to develop hugely in the following decades; it is striking that his work is still so widely quoted, with a modern writer like Vedral (2010) writing of quantum information theory in a way that draws heavily on Shannon's work.

A distinction between Shannon and Wiener's concepts of information was that Shannon confined his area of application of the concept to telecommunications, while Wiener was interested in a more general application. He wrote that: "The process of receiving and of using information is the process of our adjusting to the contingencies of the outer environment, and of our living effectively within that environment. … To live effectively is to live with adequate information. Thus, communication and control belong to the essence of man's inner life, even as they belong to his life in society" (Wiener, 1954, pp.17-18).

Notwithstanding the reification process to which I have referred above, Wiener was very clear that information was not a physical concept, and was quite different from energy in particular: "information is information, not matter or energy; no materialism which does not admit this can survive at the present day" (Wiener, 1948, p.155). However, for both Wiener and Shannon, the *meaning* of the information was not relevant. Shannon famously wrote that the "semantic aspects of communication are irrelevant to the engineering problem" (Shannon, 1948, p.379), and Wiener likewise took meaning as outside of his area of relevance. As Hayles (1999) observes, this was an appropriate choice in the context of telecommunications, because of the need to ensure that information remains stable as it moves from one context to another.

In fact, a current thinker within second-order cybernetics, Søren Brier, has observed that within the specific context of telecommunication, Shannon's choice made good sense, and that it was Wiener's extension of these ideas to a wider context that cause problems:

> Shannon's information theory is thus a quantitative theory used on a set of messages that are presumed to be meaningful. It is a technical theory about how to quantify and mathematically model information as a tool but always operating on human social communication. As such it presents no problems. The problem arises with the reification of information by connecting it to thermodynamics, as Wiener did, that raises foundational problems that reflect back on the prerequisites for science itself. (Brier, 2008, p.236)

It was the absence of meaning from information that was the dividing line with the other main school of information within cybernetics that I will now move on to consider.

Bateson, Mackay and the 'soft' view of information

From the beginnings of cybernetics in the Macy conferences, an alternative view of information to the Wiener/Shannon hard view has also been present. This view finds the *context* of information to be highly important, especially its meaning and the people who work with it. This view closely links information with two other concepts that were later to become central to certain forms of cybernetics: that of the *observer*, and the *mental processes* of those who create, share or make sense of the information.

It might seem that this view of information is created in opposition to the hard view described earlier, not least because that view is very widely known, and widely associated with the techno-centrism that many associate with the term cybernetics. While the soft view of information has at times sat in opposition to the hard view, it also has its origins in the Macy conferences and other early work in cybernetics. This school is more diverse in its history than the hard school – it is especially associated with the early work of Gregory Bateson (who was a key participant in the Macy conferences), Donald Mackay and Ross Ashby (both of whom attended one Macy conference). It is connected with, but not identical to, the school that I have called 'soft cybernetics' (Ramage, 2009), which includes the second-order cybernetics work led by Heinz von Foerster; the differences between this work and second-order cybernetics are discussed in my earlier paper. It is worth noting that Bateson, Mackay and Ashby were British, while Shannon and Wiener were American, although there is not an obvious link to national culture in either group's work.

Bateson's view of information is quite well-known, although it largely developed after the Macy conferences. It was most clearly expressed in a lecture he gave as late as 1970, but his ideas were present from the mid-1950s onwards. Bateson started from the concept of 'difference', a non-mathematical statement of Shannon's concept of information – the difference between multiple potential states. Drawing on the example of a piece of chalk, which Kant said contained an infinite number of potential states, Bateson extended the argument to difference:

> I suggest that Kant's statement can be modified to say that there is an infinite number of *differences* around and within the piece of chalk. … Of this infinitude, we select a very limited number, which become information. In fact, what we mean by information – the elementary unit of information – is a difference which makes a difference. (Bateson, 1972, p.453)

This last phrase, the ‘difference which makes a difference’, is crucial to Bateson’s understanding of information and distinguishes it clearly from Shannon and Wiener’s concepts. For Bateson, true information is not present until meaning has been attributed to the difference by some kind of observer – until a process of selection has occurred. The concepts of information and communication were as closely linked for Bateson as they were for Shannon, but in a broader way. During the latter part of the Macy conferences, Bateson’s main research was on the psychological basis of communication, and he wrote during the conferences of the importance of information going beyond the simple system, arguing that:

> Negative entropy, value, and information, are in fact alike in so far as the system to which these notions refer is the man plus environment, and in so far as, both in seeking information and in seeking values, the man is trying to establish an otherwise improbable congruence between ideas and events. (Ruesch and Bateson, 1951, p.179)

A key part of the distinction between Bateson and Wiener’s concepts of information reflected their different disciplinary origins – Bateson in anthropology and psychology and Wiener in mathematics and engineering. Concepts of meaning are crucial to the social sciences – the great German cybernetic sociologist Niklas Luhmann (1990, p.21) later called meaning the ‘basic concept’ of sociology – but of less relevance to technical subjects. However, meaning was also of crucial importance to the next information theorist I want to consider, Donald Mackay, who was a physicist at Kings College, London. While equally strongly based in mathematics – and just as keen to measure the amount of information in a given exchange – Mackay argued for a broader definition of information than Shannon and Wiener. In a paper at the eighth Macy conference in 1951 (republished in a 1969 collection), he distinguished between two approaches to information:

a) that of the physicist, “who wants to make a representation of physical events which he must not prejudge” (Mackay, 1969, p.159). This results in what Mackay referred to as *scientific information*, with two linked components – the structural information content (the number of different independent variables to be described) and the metrical information content (the weight of evidence about those variables).

b) that of the communications engineer, “whose task is to make a representation at the end of a communication channel, of something he already knows to be one member of a set of standard representations which he possesses” (Mackay, 1969, p.159). This results in what Mackay referred to as *selective information*, in that its principal goal is to select between a set of pre-determined elements – the approach taken by Shannon in particular.

From a historical point of view, it is worth remarking that Mackay’s model of scientific information was developed independently of Shannon’s ideas, rather than in reaction to them. Mackay argued further that the two components of scientific information were quantifiable, and he presented scales for measuring each of these components – ‘logons’ to measure structural information content, drawing on earlier work by the physicist Dennis Gabor, and ‘metrons’ to measure metrical information content, drawing on the earlier work of the statistician R.A. Fisher (also drawn on by both Wiener and Shannon).

Katherine Hayles, in discussing Mackay’s appearance at the Macy conferences and his differences from Shannon, argues that meaning was an explicit part of his approach: “Mackay’s model recognized the mutual constitution of form and content, message and receiver … subjectivity, far from being a morass to be avoided, is precisely what enables information and meaning to be connected" (Hayles, 1999, p.56). However, the concept was somewhat implicit at that stage, as he wrote quite explicitly in his Macy paper that "the term 'information' means something quite distinct from 'meaning'" (Mackay, 1969, p.160).

Following a year spent working in Warren McCulloch's lab, Mackay moved his focus towards studying the way that the human brain worked in its storage and processing of information, which was to occupy him much more than his initial theory of information. However, within this context he worked to expand the idea of Shannon's selective information content to incorporate meaning, in particular that to the recipient. While noting that selective information did not incorporate meaning by itself, he noted that we might identify the richness of meaning of a set of information with "the complexity of the selective operation (or of the features of the state of readiness organised by it)" (Mackay, 1969, p.71 – originally published 1953), and he presented a means to quantify that complexity.

Partly because this later model required an understanding of the internal state of the recipient's brain, something that was neither physically nor theoretically possible in the early 1950s, it was regarded by the physicists and engineers of the time as simply too difficult to quantify, and so Shannon's model became the standard approach. Mackay's approach is an intriguing alternative to the context-free ideas of Shannon, however, and Hayles notes that as late as 1968, the information theorist Nicolas Tzannes tried to build Mackay's ideas into a quantifiable theory of information transmission, arguing that "whereas Shannon and Wiener define information in terms of what it *is*, Mackay defines it in terms of what it *does*" (Hayles, 1999, p.56).

A further thinker on information who combined human and technical perspectives was the psychiatrist Ross Ashby, author of the first textbook on cybernetics, creator of the concept of self-organization, and inventor of an early working model of an electronic brain. At the core of Ashby's work was the concept of 'variety', which relates to the number of distinct elements of a set and which he notes is a concept "inseparable from that of 'information'" (Ashby, 1956, p.140). Variety in Ashby's work gained its greatest application in his Law of Requisite Variety, which states that the complexity of a regulatory system (the amount of information it can handle) needs to be as great as the complexity of the system that it is regulating.

While Ashby was comfortable with describing information in Shannon's terms – he observes that it can be measured in bits – he stressed the importance of context in measuring variety. He wrote that "a set's variety is not an intrinsic property of the set: the observer and his powers of discrimination may have to be specified if the variety is to be well defined" (Ashby, 1956, p.125) – a helpful involvement of the importance of the observer (a key defining feature of second-order cybernetics, to which Ashby served as a key inspiration) in a quasi-mathematical manner. Indeed, he explicitly linked his conception of variety to Mackay's ideas on selective information content, writing that "throughout, we shall be exemplifying the thesis of D.M. MacKay: that quantity of information, as measured here, always corresponds to some quantity, i.e. intensity, of selection, either actual or imaginable" (Ashby, 1956, p.252).

It might seem that the distinction between hard and soft information (or between hard and soft cybernetics) is a fine one, linked more to discipline than to a specific conception. However, it is my contention that we can clearly see two models of information, present in cybernetics from their start, and differentiated around their understanding of the importance of meaning, context and to some extent the role of the observer. These forms of information, and of cybernetics, were to develop significantly in the decades following the Macy conferences, as I shall briefly outline in the next section.

The later role of information in cybernetics

The purpose of this chapter is to explore the early treatment of information within cybernetics, and thus it is not the place for a comprehensive treatment of later work within cybernetics. There are many discussions of various aspects of the history of cybernetics, such as Heims (1991), Dupuy (2000), Scott (2004), Ramage and Shipp (2009), and Harkin (2009). However, a brief overview of developments relating to the ideas discussed here will be useful.

There are many fields which have developed via Wiener's harder view of information and thus of cybernetics. I have already mentioned artificial intelligence and computational linguistics, and clearly fields such as robotics and prosthetics take direct inspiration from hard cybernetics. It is hard cybernetics that forms the template for the many uses of portmanteau terms involving the prefix 'cyber-' in popular culture (especially science fiction), from William Gibson's conception of cyberspace and cyberpunk, through the Cybermen of the television series *Dr Who*, to cyborgs such as in the film *The Terminator.*

However, Harkin (2009) argues that hard cybernetics has had a strong influence on our society as well, and that the way it handled and gave primacy to the concept of information, operating within feedback loops, has created a cultural and intellectual basis for the primacy of information discussed elsewhere in this book. In particular, Harkin argues that this has led to the pervasive use of information through Web technologies such as social networking. Tracing a link through the work of the media theorist Marshall McLuhan (strongly influenced by cybernetics), he observes that "the world we now inhabit is one in which messages are rapidly becoming the medium: electronic messages sent back and forth between us at breakneck speed on a never-ending electronic information loop" (Harkin, 2009, p.xiii).

Harkin is very clear that this information loop derives directly from Wiener's conception of information and the importance he placed on feedback. He traces the way this process developed both through the military and through semi-utopian technologists such as Stewart Brand who created the *Whole Earth Catalog* which eventually led to publications such as *Wired* magazine as well as the early but influential virtual community, the WELL. He argues that "as our enthusiasm for life on an electronic information loop has spread outwards into the culture it has influenced our perspective and given us some thrilling new ways of looking at the world" (Harkin 2009, p.249). Like Wiener himself, Harkin regards this information loop as having both positive and negative aspects, arguing that:

> Cybernetics has brought us a long way, but now that its global information loop is fully built it is in danger of leaving us lost. Its gurus were so mesmerised by the medium that they made the mistake of trying to push us into it head first, of trying to remake us in its image rather than the other way around. Now we need to spend some time thinking about the message. … If we use the medium for our own purposes rather than following

> slavishly in its thrall, we can imagine new ways of working, exciting new kinds of art and culture, new ways of organising ourselves and getting things done. (Harkin, 2009, p.256)

The soft view of information has likewise led to many different applications, in particular in the fields of family therapy, human communication and management theory. Gregory Bateson took and developed his ideas of information through studying communication patterns in both psychiatric patients and animals. This work led to an understanding of mental processes as existing on multiple levels (the concept of meta-communication), governed by paradoxes and taking place within a wider systems than just that of the individual. He led a research programme in Palo Alto, California, which formulated the ‘double bind’ theory of schizophrenia. This theory (at the time highly influential) looks at multiple levels of communication, and argues that schizophrenia can arise when information at some levels is strongly in conflict with that at different levels but all are required to be held true simultaneously.

Bateson’s work on communication was taken up and developed by his collaborators in Palo Alto, many of whom were the founders of the Mental Research Institute where significant early work on family systems therapy developed. Their work on human communication and family therapy (e.g. Watzlawick et al., 1967) drew quite explicitly on Bateson’s conception of communication at multiple levels. Others within family and individual therapy have drawn heavily on Bateson’s model of information, notably the Mara Selvini-Palazolli and her colleagues in the Milan School of family therapy (Stagoll, 2005); and in a different way the radical psychiatrist R.D. Laing, much of whose work is strongly based on Bateson’s conception of paradox and levels (e.g. Laing, 1970). In later life, Bateson became very concerned that faulty mental models and epistemologies were contributing directly to environmental degradation, an idea deeply linked to his view of information and which has fed into the environmental movement (as recounted by his daughter Mary Catherine Bateson, 1972).

The work of Ross Ashby had a considerable effect on the field of cybernetics. His approach to information was taken up heavily within the field of management and organisation theory, in two separate ways. First, his concept of variety (which as discussed above is closely related to information) was crucial to the work of Stafford Beer, creator of the field of ‘management cybernetics’ (e.g. Beer, 1979). Second, his concept (not previously discussed in this article) of ultrastability – self-regulation of a system’s behaviour in response to its environment – formed the basis of Argyris and Schön’s (1978) distinction between single- and double-loop learning and hence their theory of organisational learning.

Mackay’s work on information has been less taken up by later theorists and practitioners, partly because of the difficulty of implementing his ideas, but he left a rich seam of ideas, and many pieces of work on “information, mechanism and meaning” (Mackay, 1969). Gradually this work is being drawn upon – a recent article by Kettinger and Li (2010) builds on his concept of information as “the state of conditional readiness” (Mackay, 1969, p.22) to distinguish between the three classic terms of data, information and knowledge.

Conclusion

My aim in this chapter has been not so much to argue for the primacy of one approach over the other, but to establish that both have roots deep in the history of cybernetics. It is often supposed, and even asserted, that there was a single original form of cybernetics (that of Wiener), from which various divergent forms have arisen, in reaction to the original. Likewise, it is frequently asserted in literature on information that Shannon's definition is the original form, and that other ways of understanding information are reactive and secondary. I hope I have shown in this chapter that an alternative reading of the history of information within cybernetics is at least possible – that the soft view of information has been present within cybernetics from its earliest days, just as much as with the hard view of information.

It is possible to argue that my case above is too dualistic, that in practice the two versions of information are much closer together and the differences small. I have some sympathy with this view. The question as to the role of meaning in Shannon's theory is still an open one (and argued in somewhat different terms by Chapman in Chapter 4 of this book). Likewise, some of Mackay's work could be placed within the hard view of information just as much as the soft. I have addressed the question of dualism in distinguishing between the works of Wiener and Bateson in Ramage (2009), and specifically tried to see a way out of this dualism via the feminist cyborg epistemology of Donna Haraway (1991). However, it seems clear to me that the question of meaning is absolutely crucial to an understanding of the development of the concept of information within cybernetics, and it is on that question that a clear distinction can be made between two competing models of information within cybernetics.

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