A Reconstruction of Epistemological Foundations of Cybernetics. The First Steps in Epistemologies of Complexity

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The purpose of this article is to present epistemological justifications for the cybernetic programme drawing on a historical reconstruction of cybernetics, although this is not a philosophical discipline. To do so, I use the scientific paradigm introduced into the cybernetic programme, based on which the philosophical premises are applied. This article counters the claim that cybernetics has brought philosophy to its end by arguing for a philosophical underpinning of cybernetics. In doing so, I point to the epistemological principles of cybernetics, not as inferential theoretical paradigms of control mechanisms, but as a turn to a new way of thinking. Historical revisionism is about a discursive reconstruction of cybernetics beyond control systems, as a new way of thinking, which I describe as an epistemological and philosophical approach to the paradigm of complexity. The reconstruction is done by paying special attention to irreversibility. The introduction of the one-way arrow of time into cybernetics leads to the problem of predictability being presented as an epistemological problem. In this respect, cybernetics is justified as a propaedeutic epistemology and philosophy for the thought model of complexity (uncertainties and unknown abilities).

— EPISTEMOLOGY
— COMPLEXITY
— CYBERNETICS
— SYSTEMS
— PREDICTABILITY

A. Cybernetics and Philosophy

Cybernetics is not based on a philosophy. Its origins lie in the post-war period, although, if we consider its nature in control systems and control engineering, its inception in fact goes back to the technical inventions and physiological discoveries of the control mechanisms of the 19th and 20th centuries. Key examples of this include Carnot's ideal circuits and the development of Walter B. Cannon's homoeostasis theory.

Situating the emergence of cybernetics in control engineering inventions supports the construction of the history of cybernetics. Norbert Wiener, considered the founder of cybernetics, published a collection of essays in 1948 under the title *Cybernetics*, in which he explained the engineering of control as a way to calculate feedback systems and made control dependent on the flow of information. He adopted the Greek term for governor used in James Clerk Maxwell's 1868 article *On Governors*, in which the author discussed the regulatory mechanisms of temperature. The word governors first appeared in antiquity as a description of political leadership, called κυβερνητική (*kybernētikḗ*). Homer used the term *kybernē* to refer to the helmsman of a ship, as an allegory for a leader and purposeful political action. Plato is credited with interpreting the ability to govern based on managing a ship, when he spoke of a "man at the helm of a government".

For example, Norbert Wiener ambiguously linked the foundation of cybernetics to "control" and "regulation". The ambiguity that characterised the birth of cybernetics would permeate its history and lead to a situation in which talk of control revolved around control and regulations. Despite their apparent similarity, technical control mechanisms and control systems are opposed. The intention of this paper is to provide a historical reconstruction of the spirit of cybernetics that pervades Cybernetics II, an order in which regulation precedes control. From this perspective, it is possible to speak of a new way of thinking that opposes the thesis of the end of thinking. It will be argued here that cybernetics, as a discipline of regulatory mechanisms using information, has nevertheless left behind an epistemology and a way of thinking, even a philosophy, by means of which only process-like, irreversible and complex descriptions are possible.

Norbert Wiener, however, provides neither a definition nor a systematic description of what cybernetics might be or is about. Rather, he uses cybernetics as a name for technical inventions based on the automation of control systems that resulted from the intertwining of electrical engineering and mathematics. It is no coincidence that the founders of cybernetic systems conducted their research at Bell (Gleick 2011, 208), where, in 1987, the first mathematician was hired; George Campbell set out to mathematically and electrotechnicallly solve the occurrence of noise in the transmission of messages over electricity (Gleick 2011, 11). Norbert Wiener's contribution to electrical engineering message technologies was the finding that the control of a system depends on communication. The innovation in control technology that was undoubtedly attributed to this work at the time was that he, a mathematician, made control dependent on the flow of information. With the invention of messaging systems in mathematical technologies, the formal and conceptual boundary that had until then kept social, biological and machine entities apart broke down.

Control would no longer be a quality of technically determined or trivial machines (in the words of Heinz von Foerster), but a quality of messaging or communication systems that make up both social and biological systems. The author considered cybernetics first and foremost to be a programme of a new strategy that described interacting behaviours of organisms, social systems and machines on an equal footing. This invention led cybernetics to try to establish itself as a universal science. Whether such universalist claims legitimise the discipline of communication and control systems as a science remains an unresolved problem for science historians.

Norbert Wiener attributed the status of a real science to his subject in the preface to the second edition of his book *Cybernetics*: «Now I believe the time has come to reconsider cybernetics, not merely as a program to be carried out at some period in the future, but as an existing science» (Wiener 1965, vii). In this respect, the attempt to underpin cybernetics with a philosophical idea has already failed. However, the abolition of the ontological distinction between species (man, animal, stone, machine), which removed the centrality of man, had widespread consequences for both the social sciences and the humanities. Although cybernetics is not based on a philosophical idea supporting its establishment as a unified field of science, the programme of control systems has, in a figurative sense, led to a caesura in thinking and thus in philosophy, which deserves to be reconstructed here. «I think that cybernetics is the biggest bite out of the fruit of the Tree of Knowledge that mankind has taken in the last 2000 years» (Bateson 1972).

1. Universal Science

According to a general view in German media studies, cybernetics is a universal science that emerged in the post-war period (Hagner 2008, 38-71). Arising from the enthusiastic idea of inventing a discipline that finds a common language beyond the details and specialisation of each scientific discipline and whose application in social, biological and technical systems upend the isolation of individual sciences, cybernetics was strongly influenced by the expectation of creating a scientific discipline with universal application (Hagner 2008, 40). However, the expectation of a universal field of science was only fulfilled for those who hoped to diminish the divergence of the humanities from the natural sciences that had been established for centuries. Cybernetics promised a new level of communication between them (Hagner 2008, 38). This took place via information technologies, a new field of science that originated among electrical engineers and mathematicians in the Bell Laboratories (Gleick 2011, 256). Never before had a philosophical programme – such as the successful promises of positivism at the time – or the innovations in the sciences produced a field of knowledge in which there was an interface between social, biological and technical systems. A common vocabulary was found in information technology, in that it also gave rise to the claim of establishing a new universal science (Bowker 1993, 107-127).

This new field was embraced with enthusiasm and hope by utopian technocratic pundits, such as Max Bense, who placed his faith in a technical being that, after the failure of the Enlightenment revealed and witnessed by the Second World War, must be able to rebuild a better society via technical means and to remedy the contradictions of culture. The philosopher and anthropologist Arnold Gehlen stated that cybernetics was science of a higher order that relieved people of the physical apparatus and oriented them more towards the life of the mind (Gehlen 1957, 18). This prosthetic argument, which follows McLuhan's media anthropological thesis, seems to be at the heart of the discussion about cybernetic influences in the social sciences and humanities. Media anthropologists argue for an expansion of the mind, while other humanist philosophers lament a kind of expulsion of the mind and the dissolution of thought.

2. The End of Thinking

The enthusiasm and excitement over a new framework on thinking was accompanied by concern about the end of thinking. In general, this foresight is considered to diagnose a constantly increasing mechanisation of spheres of life.

The abolition of the ontological differences between living beings and machines is effected by rewriting nature's entities – man, animal and machine – into information units, which are given via control. As there is no reason for the determination of any world process except the process of control itself, Heidegger complains that cybernetics cannot be «characterized as a basic science» (Heidegger 2000, 622). «The unity of the thematic districts of knowledge is no longer the unity of reason. It is technical in the strict sense» (Heidegger 2000, 622). With the cybernetic, modern technology has reached a stage of technicity where humanity is «posited, claimed by a power which he himself does not control» (Heidegger 1976, 209). This power reveals the nature of technology and humanity is helpless against it in that it could be devastating.

Modern technology is in its essence subsumed under Heidegger's term *Gestell*. This does not refer to the instrumental determination of technology through which domination over nature is expressed by forcing material into a form where it becomes instruments serving man. *Gestell* rather refers to a further level of technicity of the object, where humanity is «posited, claimed by a power which he himself does not control» (Heidegger 1976, 209).

Neither philosophy nor thinking can save humanity, nor is it true that «God can save us» (Heidegger 1976, 193). This helplessness of thinking in the age of modern technology also heralds the end of philosophy (Heidegger 1976, 209). What then is to take the place of philosophy? Heidegger declared in an interview in the German weekly «Spiegel» that «the place of philosophy now» (Heidegger 1976, 12) – in 1966 – had been appropriated by cybernetics (Heidegger 1976, 212).

2.1. The End of Thinking in Discussion

Heidegger's laconic statement: «Philosophy has reached its end in the present epoch. It has found its place in the scientific point of view. [...] The fundamental characteristic of this scientific determination is that it is cybernetic, i.e., technological», underpins the idea that the rationalistic project of cybernetics, based on logarithmic and mathematical calculations, means the end of thinking (Heidegger 1976, 178). In the early days of the design of neuronal networks, an abstract symbolic language was invented, with the help of which neuronal interaction could be transcribed into propositional functions and conversely translated into material compositions, be this cathode ray tubes, synopses or switches. Consequently, mathematics and its application in communications technology, namely computer science, remained the language that equates the behaviours of different beings (Hörl 2008, 170-182).

The translation of systems and their behaviour by means of discrete signals of describable stochastic processes also led to the critique of the quantification of human, social and biological behaviour as formulated by the anthropologist Lévi-Strauss (1967, 176-188). As soon as any kind of behaviour that produces homeostatic dynamics in biological and social systems and communication machines can be translated into operators and functions, it is open to all forms of control. The post-war period was dominated by strong algorithmic government policies. The Second World War was the experimental laboratory of the new regulatory technologies and their implementation into the art of governance took place after 1945. This established a new model of government, its application as a socialist planned economy and as a capitalist market economy (Heims 1991). The implementation of operational research in the UK, as well as in the US by the CIA, and the failed application of a planned economy by the government of Chile in 1970-1973 are insightful examples. The fact that the cybernetic program took place against the background of a post-war rearmament does not, however, exhaust its philosophical approaches and the announcement of a new style of thinking that it welcomed (Glasersfeld 1982).

The fourth turn in the history of science triggered by communication technologies, as described by Norbert Wiener in the article *Behavior, Purpose and Teleology* (1950), marks the "fourth mortification of man" when humanity was deprived of its central position and a network of relational and interactive multi-agents was put in its place.

Nevertheless, the announcement of the end of philosophy, i.e. the love of knowledge, as an immediate consequence of the implementation of the cybernetic program in the sciences, is a greatly exaggerated and false claim. Here, I want to support the hypothesis of a scientific breakthrough in the representation and meaning of thought. Hannah Arendt expounded the ethical and political consequences of thoughtlessness or, rather, the absence of thought. For her, it is the execution of an instrumental and functional thinking that heralds the end of thought. There is no better proof of this than sterile and sober compliance with orders, according to which Adolf Eichmann had no guilty conscience and consequently denied his moral guilt (Arendt 1965). Although his actions are among the most egregious crimes in the history of mankind, he was merely following orders and supposed himself free from any kind of evil and immoral behaviour. We could say he acted operationally. In this sense, the operative action remains a sign of the dissolution of (human) thought, which is opposed to other forms of thought for critical self-reflection.

The statement of the dissolution of thinking or its degradation as a marker of a technicistic worldview dominated by instrumental reason requires a meaning in relation to it. The end of thinking neither reverts to operative action, nor to rationalist ruling by force of technology; rather, thinking has previously been degraded by the conquest of science over other forms of knowledge appropriation. According to Heidegger, scientific calculation is essentially not thinking, just as science does not think. It does not think «because, by the nature of its procedure and its tools, it can never think» (Heidegger 2000, 133). It does so as a preference for its assertion.

Hannah Arendt's genealogy of the adoption of thinking from antiquity to modernity shows that thinking is essentially a mental occupation. It originated in antiquity when the contemplative occupation acquired the dignity of being called philosophy. "Thinking" does not refer to an activity of the mind, as is the case with arithmetic; it is a mood and readiness of mind that enables one to see with «the eyes of the mind». Thinking refers to opening the eyes of the mind. Aristotle considered thought to be an organ that sees and looks at truth. Thus, «thinking aims at observation and fulfils itself in it, and contemplation is not activity but passivity; it is the point at which mental activity comes to rest» (Arendt 1971, 16).

It is thus clear that thoughtlessness, when governing the operationality of the execution of the cybernetic program, leads to a blind thinking. In the context of mobilisation during the post-war period, cybernetics demonstrated its technical advances (Hacking 1986, 237-260; Galison & Hevly 1992) and this also led to the establishment of a "big science" that claimed execution beyond the boundaries of nations and their geopolitical mythologies of domination. However, the philosophical reading of cybernetics also arrived at the important insight that blind thinking or the blind soul does not necessarily remain blind to observation.

B. Epistemic Turn to a New Style of Thinking

Based on the consequences of its implementation in social systems, cybernetics has led to such a turn in the social sciences that we speak of a new style of thinking. As already stated in the introduction, a single technical guiding principle is not sufficient to bring about a turn in thinking. I would like to speak here not of the guiding principles of the former but of the latter, which prepare the way for a new scientific paradigm, with philosophical consequences: irreversibility and the question of behaviour, rather than the nature of a thing leading to a new understanding of dynamic processes upon which philosophy had closed the door. Interdisciplinarity enabled dialogue between sciences and opened the way to a new style of thinking. Systemic thinking was rediscovered as a research method after the excess of analytical procedures in the sciences, which offered the advantage of a new perspective on complex and dynamic processes and forced a new approach to cognition.

With the cybernetics collapse, the foundations of rationalist and scientific thinking, the epistemology of classical paradigms are collapsing. In their place emerges thinking of and for paradoxes, a radical statement of becoming, constitutive of a multi-valency instead of an identity-logical ontology. The subject is replaced by multiple orders of observation and uncertainty remains one and perhaps the only imaginable part of reality with which cognition and the drive for knowledge must come to terms. However, a reconstruction of the epistemological consequences of the cybernetic field of knowledge supports the thesis that cybernetics has contributed to a new description of reality in terms of complexity. The introduction of irreversible time as a fundamental pattern of predictable technologies is central to this argument. At the same time, however, this implies that the unknowns and uncertainties are perceived as part of thinking.

1. The Introduction of the Arrow of Time

Norbert Wiener's book lists the focal points of the new science and includes some philosophical aspects, but merely as a reference to illustrate the turning point towards the age of communication technologies. The most significant break in the turn towards automation was not least made by the concept of thermodynamic time, because cybernetic systems consider processes that undergo transformations in a non-returning, irreversible timeframe. They deal with dynamic processes. The one-sided arrow of time, time which aims at the future, is the time of cybernetics. The transformation remains a continuum, the values and variables of the system never stay the same; rather, they vary depending on time.

Wiener purposefully devotes the first chapter of his book *Cybernetics* to the opposition of Newtonian and Bergsonian time. Although he does not offer an explanation of "Bergsonian time", the chapter deals with the opposition between classical and complex sciences using examples of astronomical and meteorological concepts of time. The latter is considered a concept of time for self-regulating systems, while the first is determined by movement according to mechanical laws of attraction. It is reversible, so the position of the planets can be predictably determined. Meteorological time, on the other hand, is an irreversible determination of time. This is irreversible because what happens at any given moment is never the same in relation to any previous moment. From the perspective of irreversible time, objects can no longer be described by Euclidean space-time coordinates. Neither a spatial nor a temporal determinacy can be assigned to them. Their nature is already given within a time, and so their determination remains both indeterminate and uncertain. This means that the calculus of dynamic and irreversible processes reaches the limits of predictability. The scope of cognition is limited.

The essential differences are the designation of objects and the relation of the respective "objects" to time. The introduction of this turn is the hallmark of cybernetics. Thus, we can already talk about philosophical underpinnings of a new science in which the two basic building blocks can be summarised by the following themes: 1) the appearance of complex objects in the paradigm of social systems and as an object of thought; 2) the unpredictability and uncertainty as a prerequisite for the possibility of any cognition about or of complex objects. In fact, they are not objects. Norbert Wiener says, by way of example, that a cloud does not exist as an object; it is the synthetic representation of a pile of moving particles attributed to a signifier (meaning) because people can refer to the cloud (as an object) by means of the purpose of language.

The assumption of irreversible time for the technical programme has led control and communication technologies into a revolution in terms of thinking and philosophy. In this respect, the philosophical underpinning of cybernetics lies in the machine implementation of a becoming (*Werden*). The technical-mathematical program of cybernetics

– the amalgamation of messaging technologies and mathematical calculations – would not have succeeded without the inclusion of irreversible time. The integration of irreversibility (one-pillar/one-sided/the arrow of time) makes the technical-mathematical discipline an epistemology and leads to new thinking or new philosophical approaches beyond the development of information technologies: towards an epistemological model of complex processes.

1.1. Short Excursus about Complexity

Cybernetics did not invent complexity, but it established complexity as a descriptive model. Complexity is a concept that has undergone several rediscoveries in the history of science. In the 1960s, complexity was "rediscovered" using Ilya Prigogine's dissipative structures as a term for thermodynamically open organisations (Prigogine 1985, 488). It was followed by the rediscovery of complexity towards the end of the 20th century in complex adaptive systems (CAS) (Holland 1996; Michel 2009).

I speak of rediscovery because complexity has its origins in thermodynamics (Stengers), where phenomena occur but the processes are inexplicable within the framework of mechanical laws; they are then found a technical application. With complexity we first mean not the contrast with simple objects, but a designation for new problems and challenges, which stem from the uselessness of the mechanical laws for the explanation of new physical processes. If time is not supposed to denote a return, all time-dependent processes are per se indeterminate and meanwhile unpredictable. This signifies a rupture in the worldview of a new age, in which the harmonious, orderly, reliable world – the mechanical age – is replaced with an unpredictable and uncertain worldview. In this philosophical context, where complexity is assumed based on dissipative structures or far from thermodynamic equilibrium, Prigogine has praised Wiener's efforts towards a mathematics of irreversibility (Prigogine 2000, 826).

However, if we note that Wiener's contribution was to equate control engineering with communication engineering, the object of the problem changes. It is not that a communication paradigm models or modifies physical irreversibility. Instead, physical irreversibility – which Prigogine found based on dissipative structures to which Boltzmann attributed a probability value introducing the paradox of time by explaining the tendency of disorder and entropy – is tantamount to the miracle of emergence of new orders, new patterns, transfers this to a communication model. Cybernetics is the technical transfer of irreversibility or complexity to communication systems. In this respect, social systems are described as complex because they consist of communication. From this follows an irreversible turn with epistemological consequences: complexity becomes not a matter of reality, but a matter of description by means of communication.

2. From the Metaphysics of Objects to the Behaviour of Systems

A theorem of cybernetics states that the acquisition of knowledge of irreversible processes is characterised by indeterminacy. This can be explicitly read about in Norbert Wiener, Julian Bigelow and Arturo Rosenblueth's 1943 article *Behavior, Purpose and Teleology*, noting that purposefulness is an unpredictable yet computable phenomenon inherent in biological systems and self-regulating machines. The authors clearly state that teleology does not mean the determination of a goal, as in Aristotle, from which the cause of the system's behaviour is to be derived. The ultimate goal or aim is not equal to the cause of the system. On the contrary, the inherent purposefulness of any system is said to be equal to the voluntary activity of the system (Rosenblueth et al. 1943, 18-24). This means that dynamic systems and time-dependent irreversible processes possess purposeful behaviour despite their unpredictability. They are unpredictable because their purposiveness is a free-floating activity: their autonomous self-regulation.

The outstanding thesis, in my opinion, is not, as is usually said, that a method has been found to equate the behaviour of living beings and machines, but rather that, for the first time in the history of science, systemic behaviour, whether biological or artificial, is considered as a dynamic and irreversible process. This is because, in this sense, the system is thermodynamic, i.e. open to energy. It is a matter of defining the behaviour of a dynamic system in terms of its relationship with the outside world and its environment.

3. Systemic Thinking and Interdisciplinarity

A year before the publication of *Behavior, Purpose and Teleology* by Wiener, Bigelow and Rosenblueth and *A Logical Calculus of the Ideas Immanent in Nervous Activity* by Pitt and McCulloch, the seminar *Cerebral Inhibition* took place in 1942, organised by Frank Fremont Smith, the head of the Macy Foundation. The seminar fundamentally aimed at new approaches and initiatives in mental research. It was followed by a series of interdisciplinary meetings of scientists, including the social anthropologist Margaret Mead, the epistemologist and social scientist Gregory Bateson, the psychiatrist and psychoanalyst Lawrence Kubie, the neurophysiologists Warren McCulloch, Arturo Rosenblueth, and others. These meetings were followed by a series of so-called cybernetics conferences, led by Frank Fremont Smith and Warren McCulloch, who tried to bring together an interdisciplinary group of scientists with the aim of establishing a general science of research on the human brain.

The result was neither the establishment of a general nor a universal science (Galison & Hevly 1992). The Macy conferences were most successful in establishing interdisciplinarity. Across the boundaries of all disciplines, they succeeded in creating a multidisciplinary exchange by developing a common vocabulary to refer to what was later called cybernetics:

> As an anthropologist, I have been interested in the impact of the theories of cybernetics on our society. I am not referring to computers or the electronic revolution as such, or to the end of knowledge's dependencies on writing (...) In particular, I want to point to the importance of the interdisciplinary terms we initially called 'feed-back', then 'teleological machine', and then as 'cybernetics' – a form of interdisciplinary thinking that enabled members of many disciplines to communicate in a language that all could understand. (von Foerster 1993, 61)

Interdisciplinarity is considered the primary working method and the philosophical cornerstone of cybernetics. The aim was not to establish a universal science that unified all disciplines under a single umbrella, but rather to develop a systemic way of thinking that allowed communication to be interdisciplinary. In this respect, cybernetics, beyond being a scientific discipline, can be said to be a systemic discipline that prepares the way for philosophical principles. While a scientific method prioritises analytical thinking, systemic thinking seeks connections and relationships between the particles that make up a surrounding structure. The technical approach of a control system, in which the cause-effect relationships favour the composition of individual elements, makes use of a theoretical mode called "system".

"System" comes from σύστημα (*systēma*), a whole composed of several individual parts. Systemic thinking draws attention to the relations and bonds with each other and how new patterns and orders can emerge from them. In contrast to the analytical scientific method, systemic thinking focuses on relations and seeks wholes. It draws attention to the relations and bonds with each other and how new patterns and orders can emerge from these relations. Therefore, it can be considered a philosophical starting point. Philosophy has used systemic thinking as a holistic way of looking at things. The systemic approach of cybernetics already allowed for a philosophical starting point, especially relations and interactions via the particularity of the particles that make up the system. Everything is connected and forms a wholeness whose representation and representability can be called a pattern or a certain order.

Interdisciplinarity and systemic thinking paved the way for a new field of science that dealt with interrelationships of effects in a whole. Each acting operator does not have a local effect on the operator subject to that effect (Ashby 1974) but, in a kind of butterfly effect, the systemic starting point presupposes a holistic effect context in which a local intervention has far-reaching consequences (von Bertalanffy 1928). Cybernetics addresses the behaviour of the components of a system over time. It directs attention to the possible relations and the behaviour of the system components in relation to the system as a whole (Ashby 1974, 89), the behaviour of which depends on time (Ashby 1974, 13). It searches for the principle of interaction between the inner relations of a system and the system as such, in the context of the dynamic of change. Cybernetic systemic behaviour is mutually conditioned, interactively presupposed and does not follow Aristotelian logic, so the totality of all lines of behaviour of a system constitutes a field of behaviour.

Within reflexive feedback loops, information was defined by Claude Shannon as a measure of probability, and the development of the first mathematical scheme of a neuronal network was enforced by Pitts and McCulloch as a novelty, heralding the first research on artificial intelligence. However, the assertion of such concepts, which paved the way for artificial intelligence, robotics, operational research, etc., was not possible without the methodological approaches of interdisciplinarity and systems theory.

After the Macy conferences, cybernetics became more than a scientific program that brought different disciplines and sciences together in one field of feedback mechanisms and found application in electronic computing machine models. With the Macy conferences, problems arose out of conversations between participants, such as the notion of uncertainty and the question of knowledge as an order of observation, the treatment of which required new philosophical approaches. The inherent unpredictability of irreversible processes was also discussed, which required a new formal interpretation. Heinz von Foerster suggested a title for the series of conferences that took place between 1946 and 1953, the documentation of which he was responsible for: *circular causality*. A teleology of the 20th century had emerged (von Foerster 1997, 145).

C. New Challenges of Thinking

1. Circular Teleology

In his book *Cybernetics* Wiener had already dealt with the scope of non-linear dynamics beyond the fields of application, and the fact that it is about the change of the state of a system of couplings and interactions between system/environment and coupled systems that influence each other. A self-regulating causality also underlies the non-linear processes, which every system strives for in the face of the respective expediency achieved and accomplished through negative feedback. This technical model responds to a logic of circularity. Hence, the Macy conferences were entitled "Cybernetics, circular causal, and feedback mechanisms in biological and social systems". This was a philosophical starting point that ushered forth a new logic, a new mode of organising systems and of thought, with decisive epistemological effects and, above all, a break with the traditional, linear model of thought.

First, circular causality describes cause-and-effect interactions: A causes B because via a feedback system B causes A (Klaus 1963). Only when feedback is almost 0 can we speak of linear causality, which means that the linear causal chain is only a special case of the feedback movement (Ashby 1974, 77), and not vice versa. However, this determines an organisation and a structure, which can be considered particularly circular if its own structures can only be built and changed through its own co-operations (Luhmann 1997, 93).

2. Paradoxes of Self-referentiality

The form of organisation derived from circular causality is called operative closure: «By closure I mean essentially nothing other than what the expression means in normal language usage: closed, beginning and end coincide, self-referral, uninfluenced, autonomous, etc.» (von Foerster 1987, 144). Closure is the formal representation of operative closure: of self-referential statements and recursive functions. Closed systems operate self-referentially.

> In the general case of circular reasoning, A implies B; B implies C; and to the general horror, C implies A. Or, in the reflexive case: A implies B; and B implies A. And now the devil's split-foot in its purest form, in the form of self-reference: A implies A. (von Foerster 1993, 65)

By self-referential systems, we mean systems whose actions refer back to themselves. In algebra, closed algebraic systems are defined as follows: «An algebraic system is said to be closed if the elements and operators are chosen in such a way that the operations on the elements always yield only elements of the system» (von Foerster 1987, 146). In biology they are called "autopoietic systems" (Maturana 1999, 149-168) and in formal language "theory of recursive functions". «Recursive means to run through again, and by this is meant that the result of an operation is taken anew as the starting point for these operations» (von Foerster 1987, 149).

According to Western thought, self-referential propositions are nonsensical propositions because they fall into a paradox when an element takes on two contradictory values. The paradox of Epimenides capably illustrates the paradoxes of self-referential propositions. «The proposition, 'I am a liar' is false (F) when taken to be true (W) and becomes true (W) when taken to be false, thus: W-F-W-F-W-F» (von Foerster 1995, 52).

Aristotle declared all statements that do not fulfil the condition of being either true or false to be nonsensical. The excluded third (*tertium non datur*) is the description of any syllogistic construction that knows only two values: true or false. The theorem of the excluded third uses the principle of two-valued logic, which knows neither a non-linear dynamic concept of time nor perceives contradictions (Aristotelian logic was right about all logical systems for thousands of years). Modern mathematics and 20th century formal logic assigned value to contradictory statements and paradoxical thoughts, so that self-referential paradoxes or, in a strict formalism, logical relations, were not merely peripheral but played a central role in a consistent logical calculus.

Bertrand Russel, for example, recognised philosophy's problem with self-referential paradoxes and gave it a position in logic. With Whitehead's *Principa Mathematica*, it became clear that the contradictions were trivial. With type theory, he tried to solve the contradictions of self-reference, as did Gödel's incompleteness theorem. Self-referentiality, however, denotes an operational model for cybernetics. «Self-referentiality necessarily generates paradoxes and those logical structures that we need for a deeper understanding of the sensorimotor, autonomy and organizational closure to be discussed later» (von Foerster 1987, 137). The sentence "I am a liar" in fact says nothing more than that the truth value is presupposed by another value and that the self-referentiality of the sentence reveals a logical structure – circular causality – by which we mean that the result of an operation is taken once more as the starting point of these operations, etc. A position or operator can take on two values. If this sentence is understood statically, it is paradoxical, but if it is understood dynamically and with recognition of its complexity, it is operationally closed and the vicious circle opens up to the creative circle (von Foerster 1997, 51). True-false-true-false is the starting point of a non-stationary logic.

An epistemology of self-referentiality only appears with the features of second-order cybernetics. With the problem of observation described by second-order cybernetics, an epistemological upheaval has taken place that bears the name of constructivism. Thus «constructivism does not understand the loss of 'objectivity' as a dilemma, but on the contrary as a fruitful question directive» (Baecker 1997, 22). The constructivist thesis states that the world of knowledge and experience, our world of order, symmetry, concepts, numbers, laws of nature, even objects, is invented, not discovered. Niklas Luhmann, Heinz von Foerster, Humberto Maturana and Francisco Varela had all argued for the epistemological consequences of operational closure. The inner recursive closed organisational structures of complex systems do not raise the problem of control and regulation of discourse, but of observation.

3. Observing Objects

The consequences of the logical model of circular causality are crucial for the justification of a cybernetic epistemology. Circular causality refers to processes whose internal emergence of order is not imposed by external causes, but rather brought about by the system components themselves. This means that within outside observation there can no longer be cognition, unless we define observation as a self-referential process, as Varela and Maturana define cognition: an autopoietic closed operation. Cognition is a possibility like perception and observation, whereby no outside is known, perceived or observed; it consists of operations that happen and come about in the circuit of cognition itself.

The cohesiveness of the observing and observed system results in a whole and inseparable unity. This process must assert itself as the unfolding of a central paradox that Ranulph Glanville once summed up as: the same is different (Glanville 1988, 61-79). The point is that an object is self-observing and self-observed. However, this leads to a second contradiction: the paradox that the objects or subjects are the same and different, as Glanville suggested, «for the objective [has] been developed as something that knows it exists; it is different from other objects and in this respect unique. But if the object, in order to be itself, fills two roles, how can it be only one?» (Glanville 1988, 61). Things never become the same, but neither do they always become different; instead, they are both, insofar as observation comes about as an operation and is recognised through differentiation.

Second-order cybernetics overcomes the subject/object dichotomy because there is neither a reality confronting the subject nor an entity recognising reality, i.e. the subject. In this respect, it is a matter of observational operations, observations that observe and observations that observe observation. In this way, objects are not realities external to observation; they are exclusively enclosed in the experience of a subject's own sensorimotor coordination, i.e. "objects" are thoroughly subjective because they are perceived or, in the words of second-order cybernetics, observed objects. Conversely, it can also be argued that subjects are at the same time objects, as Glanville states, insofar as they, the subjects, can be observed. However, the conversion of subject/object into observation operations does not solve the problem. The conversion from subject/object to observation operations nonetheless encounters epistemological objections.

The first objection addresses the question: how can objects be grasped, recognised at all, if there is no more operation than that outside observation? It thus deals with a danger that has always been discussed within the philosophy of the subject's identity in connection with the problem of alterity, when the subject is so caught up in its own observation that no social knowledge comes about and it is unable to recognise others. If this exists that I can know it and if I exist thanks to, I knowing that I exist, how could this exist if it does not know that it exists? (Glanville 1988, 23-24).

The danger of solipsism has been considered by both Heinz von Foerster and Ranulph Glanville:

> HvF: My friend Gordon Pask once made a beautiful drawing illustrating this situation. You see a man with a bowler hat who claims he is alone. And this man imagines another who is also wearing a melon; he too thought that the other whom he in turn imagines does not exist at all and is solely a concoction of his imagination. Now the following case could arise in our imagination: A man who thinks solipsistically meets another who holds the same view.
>
> BP: Now the question arises as to who is right: the first or the second solipsist.
>
> HvF: That is the crux of the matter. At this point in our conversation, to clarify the matter further, I would like to serve you the so-called principle of relativity. The principle of relativity says that a hypothesis that is true for A and B can only be acceptable if it is also true for A and B together (...) The principle of relativity creates a form in which the environment and the other person can be talked about again. And the moment I postulate the existence of the other and my own existence, I live in a relationship and community, participation arises; one suddenly becomes a co-sufferer for whom it is no longer possible to find an excuse for one's own indifference through references to an external reality. This decision, which I am proposing here, makes one a social being. To conceive of the world as an invention is to conceive of oneself as its maker; responsibility for its existence arises. (von Foerster 2006, 28)

Thus, the operative theories propose a collective epistemology as a way out of the problem. To this end, we will not use doubt as the methodological path: the alienation of the self for the sake of self-realisation; but rather, the solipsistic opinion of the Cartesian method is rejected in favour of a cooperative and collective network of observations or observational positions.

The way out of solipsism is as self-evident and simple as the fact that the observer is an observer: an observer and observer. Insofar as the person is an observer, observation is enclosed in operative closure, so that the realisation of observation succeeds in the network of observations. This means that objects and subjects are produced by an attestation. «Obviously this happens only when a subject S establishes the existence of another subject S, not unlike itself, which in turn asserts the existence of another subject, not unlike itself, which may be identical with S» or subject becomes object, insofar as the objects can observe themselves through others (Glanville 1988, 29). Through the eyes of others suggests that the operative response to uncertainty is the affirmation of the blind spot of every observation as a methodological approach to collective cognition.

As we have already seen, the deconstruction of the ontological standpoint falls neither into relativism nor solipsism but forms the basis of an epistemology of complex objects, phenomena and interactions, whose ontological claim lies less in the truth value than in the operative act of making distinctions as a means of constructing realities (Glanville 1988, 108).

D. Thinking Complexity: When Uncertainity Becomes Operative

1. Metaphor of Unknown I: Blind Spot

A solipsistic position, which falls into both relativism and absolute truth claims, follows the approach that the observer is always identical and congruent with their observations. However, cognition adhering to an operative point of view is excluded in the case of being able to see everything. The statement that there is no external position of observation results from the approaches of operative unity results. «The unity of the world cannot be observed from the outside» (Luhmann 1997, 95). If it can, this can only be a blind observation. These statements summarise the principle of an epistemology of operational closure, whereby a border or an event horizon is presupposed for all observation, since we cannot observe everything.

Humberto Maturana dealt with the neurocognitive research of perception and cognition of reality, in particular with field research on the retina of frogs (Maturana 2012, 23) and their neurobiological equipment of the nervous system. He noticed that the blind spot – that part of the visual field where there are no light receptors of the retina – plays a decisive role in mammalian perception. This neurobiological fact enabled Maturana and Varela to understand observation as an autopoietic process: that no knowledge can be gained outside of observation. In the same sense, the neurobiologists Maturana and Varela attribute the blind spot to the environment, "autopoietic systems are blind to their environment" in that the environment is a τόπος (*topos*) external to the orders of systemic observation. As already mentioned, the blind spot does not deny a world outside observation, as relativist or solipsistic positions claim. It also would not make sense to suggest that there is an environment affirmed, but as a difference between system and environment, otherwise the concept of the system boundary, which presupposes that there is another side. The thesis of operational constructivism does not lead to a "loss of the world"; it does not deny that reality exists. It does presuppose the world not as an object, but in the sense of phenomenology as a horizon, unattainable but perceivable. Thus, there remains no other possibility than: «Constructing reality and possibly: observing observers constructing reality» (Luhmann 1996, 18).

Establishing limitations of observation by using the metaphor of the blind spot reflects that there cannot be a world as an object or as a subject, just as there is no object without an observing subject and no subject without an observed object. The correlative and interacting level between the classical concepts of logical identity (I versus you) presupposes that an outside represents a blind spot for perception and for cognition (Luhmann 1990, 15). Yet this does not mean that its perception is excluded from cognition. It is observable as a blind spot.

The limitation of observing refers to the unobservability of inner observing, since the observer cannot observe themself. This is based on second-order observation. The observer, after all, remains unobserved in a first-order observation. However, their gaze does not necessarily remain fixed on the thing; they are responsible for observing observations.

Operational theories, especially those of the neurobiologists Maturana and Varela, as well as the socio-cybernetics of Niklas Luhmann and Gotthard Günther, interpret the loss of sight of the blind spot not only as a phenomenon of the absence of perception, but as a condition of the possibility of cognition, that is, the non-seeing as a condition of the possibility of seeing. Cybernetics combines indeterminacy and non-perception as a condition for the expansion of cognition. Non-seeing is neither a limit nor a restriction, but an opening for possibilities. The incompleteness of all observations, the fact that a person cannot see everything, becomes a transcendental or possible presupposition of a theory of cognition for the operative theory.

> As today's widely accepted operative epistemology teaches us, all observing takes place in the world as a process that is itself observable; all observing presupposes a demarcation across which the observer can observe something else; all observing thus constitutes the incompleteness of observations by withdrawing itself and the difference that is constitutive of it from observation; observing must thus engage in a blind spot, thanks to which it can see something (but not everything). (Luhmann 1997, 95)

2. Metaphor of Unknown II: Black Box

The blind spot that extends cognition to the areas of unobservability, due to which unobservability becomes observable, is equal or analogous to a fundamental component of classical cybernetic machines: the control machines. The theoretical input/output term invented by James Clerk Maxwell, which is called the "black box", and which Norbert Wiener uses in his book, functions as the basis for this. Thanks to him, the machine can keep running by guaranteeing its dynamic non-linearity and fulfilling its purposeful behaviour, its self-regulation.

The black box is contrasted with the white box by describing the latter as an obviously recognisable mechanism, in contrast to the black box, whose determinacy is hidden from the view of observers (Glanville 1988, 101). To the outside, if the relationship cannot be revealed, we speak of the black box; the transformation that is observed does not necessarily correspond to what is actually playing out within (Glanville 1988, 102), but is instead a description of the observers (Glanville 1988, 102). Once again it is confirmed that the description of the observer can never be complete or, in other words, is always limited, because the observer cannot see everything. The inability to see everything is based on an immediate principle of operative thinking, second-order cybernetics. If we were to reveal the black box, we would trivialise a regulating machine and, with a classical view of determining causal chains, destroy the self-regulating machine. According to von Foerster, the mechanism of the black box underlies every information machine, even a non-trivial machine. Ashby defined the black box as part of the cybernetic machine, as that space «in which the transformations and transmutations of the system» occur (1974, 175). The observed transformation of the input that takes place within the black box is interpreted as its structure.

3. Re-entry of Uncertainty as the Foundation of Thinking

Philosophically, this is a profound and fundamental notion, for it allows us to accept that our means of observation are ultimately in no way sufficient to give us a complete picture of whatever is going on, but that this does not prevent us from creating images and acting accordingly, even if we do not know what is going on inside the black box. (Glanville 1988, 101)

According to cybernetic-operational thought, the only thing we can be certain of is the limitations of cognition, of observation. This epistemological standpoint has its ontological correlate, since indeed a non-observable reality may be the only conception «which we, as apparently independent observers, can entertain of things» (Glanville 1988, 103). From this, Glanville draws a correlation between the black box and the observer's uncertainty, making ignorance the condition of the possibility of cognition (Glanville 2012, 427).

Second-order cybernetics came to the realisation that it had designed an epistemology that precisely creates unobservability as a precondition for cognition. This turn in the epistemology of the history (and philosophy) of the occident had already been announced by physics, but it could not have been implemented without the insights of first-order cybernetics, as a design of circularity and as the design of circular causal machines, to which the inclusion of irreversible time is owed.

Whether the thesis of cybernetics is correct, that humanity experiences the fourth wounding (Sloterdijk 2017, 227), and whether knowledge saves us from it and shows us new ways of knowing the world, depends very much on whether we remain with the technical description of cybernetics or allow the philosophical background of a knowledge to emerge. This pays attention to interrelations, systems, interactions, paradoxes and irreversibility as principles and the basis of a worldview.

The notions of becoming, uncertainty and blind spot announce the loss of all classical truth values about a reality whose processes run independently in permanent dynamics and transformation. The maintenance of these processes only occurs when the intervention of the observers admits their indeterminacy, as a condition of their development. In fact, such dynamics are not comprehensible, any more than the subject is able to grasp everything through different methods. They can only be understood in cooperative forms of cognition when we do not see our own observation.

3.1. Operational Epistemologies: Operability of Uncertainty for a Thinking Complexity

Experts from different branches of complexity research, such as biology, ecology, economics and neuropsychology (Casdagli & Eubank 1992; Cowan & Meltzer 1999), agree that the concept of complexity cannot be assigned to a single field (Harold 1995). Complexity is the main subject of a whole range of disciplines using methods so diverse that complexity research cannot be attributed to a single problem or method (Lloyd 2001, 7-8). Heylighen, Cilliers and Gershenson even claim that complexity science is an amalgam of models, methods and metaphors from a variety of disciplines, which does not indicate an integrated science (Heylighen et al. 2007). Ladyman, Lambert and Wiesner also argue that a general definition of complexity science would compromise its diversity because it would be reductionist and contradictory (Ladyman et al. 2013, 34). Nevertheless, there is agreement on its scientific model. This points to a decisive break with classical science (Heylighen 1997) and its place in the paradigm of post-Newtonian science (Waldrop 1992). This assumption can be linked to the theses of Isabelle Stengers and Ilya Prigogine, who used the term "science of the complex" to refer to the turn from the mechanistic to the thermodynamic paradigm of science (Prigogine & Stengers 1981, 109ff.). This turn has led to the conclusion that our knowledge of the world is fundamentally uncertain (Prigogine & Stengers 1997).

Complexity simply means that it is impossible to build a model that accounts for the sudden and unexpected "changes" in the state of the system. The cybernetic model of thought, with its notion of blind spots, provides solutions and opens research avenues to redefine the transformations of the classical conditions of epistemic parameters.

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