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The Emergence of Edgar Morin's *Complex Thinking*

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Abstract: Edgar Morin is more than 100 years old and has produced numerous original ideas. *Complex Thinking* is his approach to complexity and took almost thirty years to be written. He developed it based on many other thinkers but chiefly, we argue, on Wiener's Cybernetics, von Bertalanffy's General System Theory and Shannon's Information Theory. This article describes and discusses how those latter theories have been incorporated into Morin's thought, especially in *La Méthode*, his magnum opus, and presents, in a comparative fashion, his pros and contras on each of them. In our conclusion, we discuss how some of Morin's criticisms of the founding theories might be unjust and also present a summary of some judgmental appraisals of *Complex Thinking*.

Key words: Morin, *Complex Thinking*, Complexity, Cybernetics, General Systems Theory, Information Theory.

INTRODUCTION

Edgar Morin (Paris, 1921) turned 100 years old in 2021. His enormous work spans from the theory of the *Complex Thinking* to contributions in the history of cinema, including several themes in-between like education and society.

The present paper analyses aspects that relate Morin's *Complex Thinking* and three cornerstones of Complexity: Cybernetics, Open Systems and Information Theory. More specifically, we will compare how ideas of Norbert Wiener's Cybernetics (Wiener 1971), Ludwig von Bertalanffy's General System Theory (GST) (Bertalanffy 1972) and Claude Shannon's Information Theory (Shannon & Weaver 1949) are incorporated into Morin's work and how he criticized them as well as proposed enhancements.

As we will mention throughout this article, there are many other scientists and theories considered in Morin's oeuvre than those above mentioned but the delimitation of our approach is based on the importance of Cybernetics, GST and Information concepts and their frequent reference in the philosopher's work:

> In the beginning of *La Méthode* I thought to deal with the organization problem referring to the limits of systemic ideas (General Systems Theory) and Cybernetics. On midway these ideas and solutions became starting points and then, accumulations certainly necessary, which were dismantled as soon as they enabled me to understand the concept of organization (Morin 2003, p. 43).

What Morin tells us here is that ideas and concepts of Cybernetics and GST were of fundamental importance although he considers having outgrown them.

And where is Morin in the Complexity Science archipelago? (Li Vigni 2021). He is grouped with the cibersystemists together with other members of *Le Groupe des Dix* (The group

of ten) (Chamak 2019). Although he definitely interconnects with several other groups.

His wide interests and connections are clear from, perhaps, his first work on the field of complexity, *Le paradigme perdu* [Paradigm lost] (Morin 1973) where he already dialogs with natural, biological and social sciences being written after his return from a fruitful stay at the Salk Institute in the USA.

Finally, it is relevant to mention that Morin connects those three ideas highlighted in this study. In the volume dedicated to "Life of life", he writes:

> The paradigm of self-(geno-pheno-ego)-eco-re-organization (computational/ informational/ communicational), allows to integrate the physical-chemical processes of the living machinery. It *integrates systemic, cybernetic and informational ideas* **[emphasis added]** while operating the disruption of any organizational conception based on the artificial machine model (Morin 2005, p. 394).

The structure of this article is as follows: after this introduction, we provide some background information on Morin's intellectual history and explain some of his most important and known concepts or paradigms. Next, we present an analysis about cybernetics influence in Morin's thought, explaining pros and contra arguments he provides. Next, we draw similar considerations in systems theory, most emphatically in open systems. Lastly, we bring forward the discussion about information theory. The paper concludes debating specific aspects of Morin's analysis and theories. We close with acknowledgements and references. In the appendix we furnish a list of main referenced authors in Morin's work.

Where no original sources in English were found, citations were translated by the authors, either from the original French edition (Morin 1977, 1980, 1986, 1991, 2001, 2004) or the Brazilian Portuguese translation.

Philosophical, literary, and scientific references of Edgar Morin

In the context of this article, we analyzed the six volumes of *La Méthode*[1] (Morin 2003, 2005, Morin & Da Silva 2005a, b 2011a, b), Morin's development of his *Complex Thinking*. It is therefore relevant to note his most important theoretical references, which are presented in the appendix. His influences range from Ancient Greek Philosophy to references in quantum physics and genetic engineering. So, when thinking complexity, his thought is both broad and deep. In his book about his influences, he cites as most relevant: Heraclitus, Buda, Jesus, Montaigne, Descartes, Pascal, Spinoza, Rousseau, Hegel, Marx, Dostoyevsky, Proust, Freud, the Frankfurt School (Adorno, Horkheimer and others), Heidegger, Ivan Illich and Beethoven. Most importantly for this article, he mentions and group together: Bergson, Bachelard, Piaget, von Neumann, von Foerster, Bohr, Popper, Kuhn, Holton, Lakatos and finally Husserl (Morin 2013). Of course, this list does not contain all references of *La Méthode*.

He often feels that this mix-and-matching of different sciences is a characteristic that bothers traditional science as his perspectives move seamlessly from one area to another, from knowledge to knowledge, giving a very different scientific approach compared to other scientists, including those in complex systems and other complexity areas. In the sense of transdisciplinarity, it is interesting to realize, as Montuori writes (Morin 2008, p. xiv), that he is very esteemed in Latin America and little

[1] We maintain the original title because there are no authoritative translation into English and translated Morin's articles keep this form in their references.

translated, therefore known, in Anglo-Saxon culture.

A brief discussion of Morin's *Complex Thinking*

La Méthode was Morin's magnum opus which was written from 1977 to 2004. Each volume had a subtitle, from Nature of Nature, followed by Life of Life, Knowledge of Knowledge, The Ideas, Humanity of Humanity and concluded with Ethics.

It was a daring scientific enterprise where he analyzed and explained what he considered complexity and, at the same time, he (psycho) analyzed himself and posed doubts about his own findings. In that way he defied how normal science is made, in which the observers put themselves out of the system, as an impartial and omniscient judge. And that role he condemns completely.

To develop his complex approach to everything, he created some ideas that could be labelled as paradigmatic although according to a Kuhnian view (Kuhn 1996), they would need a widespread adoption to be considered so. We present next some of them.

Apparatus and Machine

For Morin, both notions of Apparatus ("*Appareil*") and Machine ("*Machine*") are complex ideas. Therefore, worth it to be explained here as they are needed to understand the cybernetic, systemic and informational topics discussed further on.

Apparatus

It is an original arrangement which, in a complex organization, links information processing to actions and operations, thus ensuring the organization of the action (Morin 2003, p. 288).

Machine

The term machine is by no means limited to artificial machines produced by humans. Before the industrial era, the word designated complex assemblies or arrangements whose operation is regular and regulated. It can be the political and administrative machine. In *La Méthode*, it designates any entity, natural or artificial, whose activity involves work, transformation, production.

Further, the machine produces the organized or the organizing from the unorganized, the more organized from the less organized. It involves transformations both chemical and energetic, where forms are undone, destroyed, but also remade, renewed, metamorphosed. It produces organization from disorganization. Machine beings (as Morin often refers to machines) participate in the process of growth, multiplication, and complexification of the organization in the world. Through them, genesis is prolonged, nourished and metamorphosed in and through production. The activity of the living machines is not reduced only to manufacture, where the repetitive work and the multiplication of the same predominate, but it also includes creation, where the ideas of generativity and novelty predominate (Morin 1977).

Self (*"Autos"*)

The term designates both the return of the same through the cycles of reproduction (*idem*) and the emergence of individual beings (*ipse*), the identical that defines a species (*idem*) and the identity that defines an individual (*ipse*) (Morin 1977).

Tetragram order/disorder/interaction/organization

It represents the connection between order/disorder/organization, mediated by interactions among them. This will be discussed further on.

The organization itself is the agency of relations between elements, components, actions, or individuals and possesses new qualities and properties compared to those of individual elements; those properties can be called emergent.

Self-(geno-pheno-ego)-eco-re-organization

Once the concept of organization is settled, Morin creates a complex notion of the self-(geno-pheno-ego)-eco-re-organization. Mostly focused on living organizations, the idea here, for each prefix is: the self contains the autonomous process, decided/executed by the being; geno means it is determined by its genome, its hereditary load but not only that, as the phenotypical characteristics (pheno) appear, as an emergence, through the interaction between the chromosomic heritage and the environment. Concerning the being's decision, comes an egocentric (ego) notion and, for the influences of the environment, the ecological (eco) ones. Lastly, there is a *re-* prefix, which provides the repetition of the process, both for an individual being, its society and future generations. It takes Morin several hundred pages through several volumes to describe these terms for which we provide a simple glimpse here. He employs these concepts choosing which prefix shall be used and which not, emphasizing a certain context.

Dialogic

It is another important paradigm. Inspired by Hegel's dialectics, it differs from it in that you do not end up with a synthesis from two opposing ideas but remain and live with those two concepts that exist at the same time and they influence each other (e.g. individuum/society, body/soul, brain/mind). They are, at the same time, complementary/concurrent/antagonistic) (Morin & Da Silva 2005, p. 110).

Hologrammatic principle

This concept that was introduced in *La Méthode* volume 3 (Morin & Da Silva 2005, p. 60). With it, Morin wishes to convey the idea that the organization of the whole is found in the parts that are within that whole, like the way holograms are built. An example could be our DNA. Each cell contains the information that creates the whole body, as much as the body has all the cells.

Unitas Multiplex

The system, if considered as the whole, is homogeneous. If considered by its parts, is diverse and heterogeneous. The complexity of the system is its unity and diversity at the same time, as they repel and exclude each other. (Morin 2003, p. 134)

Organizational recursion

As explained above, the *re-* prefix incorporates many different meanings and characteristics of the organization. They include replication, restart, reinforcement, reproduction, repair, representation (in the mind), remembrance and so on (Morin 2005, p. 373-388). As it is clear from these attributes, Morin shows through some key terms, the multitude of concepts included in the complex organization. The notion of recursion in the organization is ampler than of the recursive circuit in that the feedback in the organization changes it entirely (e.g. culture in society) whereas the circuit just control some part of the behavior (Morin 2013, p. 140-145).

Ecology of action

The multiple interactions and feedbacks within the environment in which effects take place after the action is triggered, often escapes the agent's control, and causes unexpected effects, sometimes even contrary to those originally planned. There are two guiding principles: 1.

action consequences depend not only on the agent intentions, but also on the conditions of the environment in which it takes place and, 2. the long-term effects of actions are unpredictable (Morin 2005, p. 100).

The list presented above is not exhaustive but might be helpful to better understand the rest of the article and also arise the reader's curiosity to discover more about *Complex Thinking*.

CYBERNETICS

The ideas that came up with the appearance of cybernetics had a profound influence on Morin. Many concepts were adopted in his theories and others he rejected to create his own ideas. As mentioned before, not just Wiener (1971), but also Ashby (1956), Bateson (1967), von Foerster (2003) and von Neumann (1958) are frequent references of those that created and evolved the cybernetical framework (François 1999; Kline 2015).

He explains: "During my discourse, I have both supported and opposed cybernetic theory" (Morin 2003, p. 300).

What speaks in favor of cybernetics?

Therefore, it is clear that cybernetics had influenced Morin and several concepts were adopted and others, adapted. Here we mention some of them, according to our notion of their relevance.

Organization as study object

Morin has several conceptual building blocks for the construction of complexity. Organization is one of them. Wiener, he states, has the merit of isolating the machine physical being and also included the feedback in the interaction, highlighted the circuit instead of the process, the regulation instead of stabilization and teleology in relation to causality. He concludes affirming that "[they] have connected all these terms in an organizational way and, therefore, originated the first general science (that is, physical) that has as its object the organization" (Morin 2003, p. 300).

Implosion of scientific divide

For Morin, every science has to overcome the separation from other sciences defying the classical approach followed in the past by Descartes' method and make an effort to become more transversal and inclusive.

Morin, when considering the aspects that structure cybernetics views, cites in one paragraph Maruyama, von Foerster, Ashby, Walter, Ducrocq, Sauvan, Beer, Boulding, Bateson, Moles, Pask and Günther (Morin 2003, p. 301).

This plethora of scientists from different specialties and backgrounds, who were involved in the cybernetics project have, according to him, imploded this scientific discipline divide and made it an open science with many "facets" as can be seen in works of synthesis like Klir (1991) or Altmann & Koch (1998).

Feedback

The concept of feedback is perhaps the most striking feature of cybernetics. It was the scientific modelling of this effect that gave its importance in theoretical and applied sciences.

In the second-order cybernetics (cybernetics of cybernetics) (Foerster 2003, p. 283–286), due to, among others, Maruyama (1974) and von Foerster (2003), the ideas of positive and negative feedback are highlighted, especially if one considers the feedback causality.

Soon both positive and negative feedback have been incorporated into the realm of complexity as one of the mechanisms that enabled emergence of system behavior.

Morin relies on the several modes of feedback and often uses them to explain the self-organization behavior, the regulating mechanisms of life and even how culture molds societies and society molds culture.

Extending the concept of machines

Morin considered a very important step the understanding of the artificial machine. Due to the efforts of cybernetics, machines could be controlled more efficiently.

He also describes the production of self. This idea connects the concept of the self-controlled machine with the living. Although there is a clear shortcoming in the artificial machine, as it cannot repair and replicate itself, the ideas of communication and control from cybernetics and concepts of open systems were of fundamental importance.

What speaks against cybernetics?

Lack of a theory of the machine

"The first notion of machine comes from the Wienerian revolution. We have to consider the machine as a physical being" (Morin 2003, p. 200). So, what Morin does is to expand the notion. Machines are not only those that exist in factories and at home but an "extended" view where they are classified as entities that produce diversity. Consequently, they can be stars, living beings and societies.

In that sense, what Morin resents is that Wiener did not develop a theory about the machine, which he does in his first volume of *La Méthode*.

According to Morin, every theory might have a simplifying or complexifying approach. And, due to paradigmatic, technocratic, and sociological forces, cybernetics has followed the simplifying way. It has reduced all machine-beings, both natural and living as equivalent to artificial machines, which are far more limited and restricted. This concern was equally shared by Wiener himself (Wiener 1954).

Absence of positive feedback and more

Cybernetics lacked the concept of positive feedback which has been eventually included later by Maruyama. This author discussed the important concept of relational mutual causality (Maruyama 1974). Yet another concept cited by Morin, from von Foerster, is the development of circular causality (Foerster 2003, p. 230), also a pivotal idea.

As Morin further analyses cybernetics, he finds other aspects that were not at first considered by Wiener and some of the forerunner cyberneticists. Besides the absence of positive feedback, as already mentioned above, he notices that complex causality and uncertainty of teleology were not thought of.

Perhaps Morin is too strict in his criticism and may not consider the fact that cybernetics, like any other theory or paradigm, was not born as a finished set of concepts but would evolve in time. These evolutions are exactly what Maruyama, von Foerster and others did, especially regarding rigorous mathematical formalism (Mesarović & Takahara 1975).

Communication and control as a means to subdue society

The understanding of how communication and control act in a system or a machine was strongly praised but then, on another level, Morin considers that these kinds of interactions prevailed over society which began to be commanded and controlled as a machine. Accordingly, this effect is not considered a consequence of the paradigm but classified as an ideological use of science.

Disorder and Self

Morin has brought many original ideas to complexity. Two of them are mentioned as lacking in the early cybernetic approach. One is disorder as a kind of force. The other is the self, as recognition of the personality who observes.

Disorder is for him just as important as order, organization, communication, and computation, to mention the most relevant concepts. What Morin emphasizes is that all processes and systems depend on disorder. Without disorder to deregulate, disentangle and dismantle objects and beings, the movement in the direction of order and organization could not exist. The ideas of disorder and order and how they lead to organization come especially from Order out of Chaos (Prigogine & Stengers 1984) and Noise as a self-organizing principle (Atlan 1972).

He depicts this idea with the ring or cycle (Figure 1), showing how each concept influences the other. Actually, it is very much like the depiction of the feedback process.

The other missing aspect, he highlights, is the self (ego) which is normally recognized in psychology. But it is important to consider it in the other sciences, especially emphasizing the role of the scientist's personality behind the theory, avoiding the so-called neutral approach that would produce impersonal theories that, in reality, do not exist.

Teleology vs. teleonomy

Despite scientific evolution, there are some issues that persist due to their ontological intricacies, aporia in Moranian terms. Teleology is such a case. The famous paper Behavior, Purpose and Teleology (Rosenblueth et al. 1943) laid out ground to cybernetics but, according to Morin, the authors had a simplistic approach to teleology because they avoided to clarify the origin of all reasons and justifications. In one passage, he states:

> [...] unlike the artificial machine, conceived by a superior being who constitutes its providence and gives it its program and objectives in advance, the living machine comes from a lower state of physical organization, with no deus pro-machina, no "information", no program: where does the "program" come from? Where does the "information" come from? Where does the purpose come from?" (Morin 2003, p. 314).

Interestingly enough, Morin answers his own questions and gave a solution to this puzzle: after considering the importance of the article mentioned above, he affirmed that cybernetics needed a finality and it came from the machine itself, but it was teleonomic (that is, from within). This is exactly the creation-of-self. Finality is an emergence from the complexity of the living organization, it is an immanent finality. And that is the conclusion: the purpose of life is immanent within itself, and so the purpose of life is to live. On the other hand, this finality is not sufficient to define life.

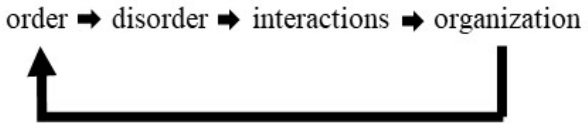

Figure 1. Logical ring of order and disorder.

SYSTEMS

Morin's viewpoint about systems in general and GST (Bertalanffy 1972), in particular, is less focused than that about cybernetics. This happens probably because the latter has a more specific purpose and underlying theory whereas the former is a more generic take on diverse areas and applied with various premises

in different sciences. But other causes can be equally plausible (Pouvreau 2013).

Nevertheless, in his first volume of *La Méthode*, Morin presents several definitions of systems ranging from Leibniz, von Bertalanffy, Maturana, Ackoff, Rapoport, Mesarović, Saussure. Finally, he presents his own definition: "[...] we could conceive a system as an organized global unity of inter-relations among elements, actions and individuals" (Morin 2003, p. 131). Here it is important to emphasize the use of the notion of "organized", a concept which is not present in the other definitions.

But organization is one of the most important concepts in Morin's thought. Connecting the idea of system and organization is the trinitary concept shown in Figure 2.

Morin considers that, in normal science, the concepts of system and organization are normally presented dissociated from each other, that is, either the scientific approach focus on the system, or it focus on the organization. And he proposes that those concepts are aspects of the same reality, and he aims at connecting them through a possible interrelation. Therefore, each concept is distinguishable in itself but, at the same time, they are to be united in this relation (Morin 2003, p. 132-134).

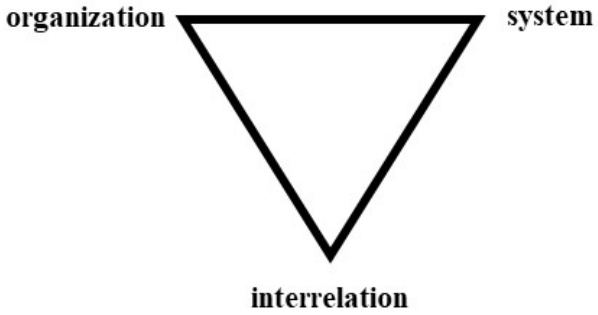

Figure 2. Trinitary relation.

What speaks in favor of a general systemic approach?

Systems are important units of analysis as described above. Consequently, Morin makes use of this idea throughout his work. When used, the idea of system focusses more on the whole, while organizations tend to highlight the parts.

The concept of system

Morin, just like other system thinkers, sees ensembles of parts and sets as systems. Therefore, he classifies them as a kind of global unity. One difference from other scientists might be a relatively lesser importance attributed to the system as a representation of the whole. He impinges more relevance to the idea of the organization:

> The system is the basic complex concept because it is not reducible to elementary units, to simple concepts, to general laws. The system is the unity of complexity. It is the basic concept because it can develop into systems of systems of systems, in which natural machines and living beings will appear. These machines, these living beings, are also systems, but they are already something beyond that. Our goal is not to make a reductionist systemism. We will use our concept of the system universally, not as a key word of totality, but as the root of complexity" (Morin 2003, p. 185).

To be able to move up or down on the grouping of systems level, he employs terms like metasystem, suprasystem, subsystem, ecosystem.

The open system concept

Another important feature of systems theory is attributed to von Bertalanffy: the idea of open system.

> An open system is defined as a system in exchange of matter with its environment, presenting import and export, building-up and breaking-down of its material components (Bertalanffy 1972, p. 141).

Morin takes it to extremes showing that there is not such a thing as a closed system just as there is not a completely open one. To preserve its characteristics, any system must have some kind of opening and some sort of closure, allowing it to interact with an inevitable environment that always exists, while preserving its identity.

In an interesting passage (Morin 2003, p. 152), Morin establishes a link between systems theories and cybernetics. He observes that a complex system has antagonistic forces at play. Therefore, feedback (from cybernetics) is an intrinsic internal mechanism of any complex system.

Ecosystem (oikos-system-organization)

Maybe the expansion of the system concept gets him to use the notion of ecosystem, which is an archetype of an open system.

He starts discussing oikos, the Greek term that defines the habitat. From there, emerges the self-organization, the ecosystem as a living machine, full of life and death, invention, and creativity. He links matter, living being and energy, forming a loop. For him, opposing factors create this complex environment.

So, he joins all the elements, physical and living, through associations, to make sense of the whole. Again, this is an important conceptual element to his theories. Although not innovative, is used in a peculiar way.

What speaks against it?

Either holism or system of parts

Morin considers that normal science sees a system as either a whole or as a collection of parts.

He affirms that holism (treating systems as wholes), as conceived by von Bertalanffy, lacks an important aspect: when seen as a whole, systems become static, that is, a specific given entirety in time.

But, as scientific observations show, these wholes sometimes grow larger because of emergences or even shrink as some aspect fades away.

As Morin puts it, the whole is more than the whole, and less than the whole (Morin 2003, p. 158–161). And a holistic approach might miss this phenomenon.

On the other hand, the second approach handles systems as ensembles of interacting parts. In those cases, a system could be studied considering the characteristics of these individual parts. But this perspective will not understand emergence which is a phenomenon that happens through the system but cannot be ascribed to individual parts. The proper treatment of this problem can only be solved taking into account ontological questions not only methodological ones (Bunge 1977, 1979).

Reclosure

Morin argues about the impossibility of either a complete openness or total closure of a system. In that sense, he considers some systemic ideas simplistic. If a system is completely open, it would lose its own identity, without borders and self. Whereas a totally closed system could not even exist. As an example, he mentions that the very fact of its existence causes the system own weight and therefore implies the effect

of gravity, which is field interaction, that is, an external effect onto the system.

INFORMATION

For both cybernetics and systems theory, the information concepts are of paramount importance.

In cybernetics, from Wiener's original book (Wiener 1971), there were already two chapters concerning information. It is relevant to mention that already then, both meanings differ. Specifically, in one chapter information is used in the sense of data in time series and in another, Society and Language, as high-level communication content.

Concerning GST, von Bertalanffy considered information as in Shannon and Weaver's theory (Shannon & Weaver 1949). He correlated information with entropy but often emphasized that this theory was not enough to deal with complexities of the organism. On the other hand, in his GST work, information is not mentioned as high-level elaborate content.

Morin delves deeply into informational issues. He highlights the importance Shannon's theory but subsequently started a stark criticism. For him, informational concepts structure all subsequent theory of communication and control.

He explains how information and entropy are comparable to each other. Brillouin, when analyzing Maxwell's demon concluded for their correlation (Maruyama et al. 2009). Further, Atlan connects the idea of information to entropy and organization (Atlan 1988).

The discovery of DNA results in information becoming part of the living. But the duplication of chromosomes is prone to errors. At the same time, those errors enable evolution, as explained in "Order from noise" (Foerster 2003).

A very important aspect Morin draws attention to, is the need to consider the generativity of information, namely, the capability of creating new information. This he terms "informationalization". But he also comments that it is not possible to isolate information from the apparatus that generates it. He also states that it is inconceivable to disconnect information from the biological or the human and sociological contexts as if it would exist by itself.

Considering the exchange of information, he affirms that an ecosystem is therefore a very complex communication universe as signals are exchanged in multiple ways: chemically, visually, sound wise, and by gestures.

As it is possible to perceive, the levels of abstraction of the concept of information are wide and dissimilar. Floridi quotes Shannon in writing that "it is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field" (Floridi 2010). Weaver explains that information analysis deals with 1) quantification, 2) semantic problems and 3) influential problems in human behavior. (Floridi 2010)

A broader discussion about philosophy of information in this paper would be out of our scope. But it is relevant to mention that current ideas about information indicate that it is "a distinction that makes a difference" (Floridi 2010), as, for example, the absence of noise might be also meaningful (e.g. silence when an engine should be running).

What comes to mind for a contemporary reader is that several authors in the past mixed different meanings and levels of abstraction of information thus proposing concepts and theories, that in modern interpretation, seem imprecise or confusing. As an example, the reader can take into account unifying efforts to

deal with the concept of information in a broad sense with the scope to solve terminological ambiguities (Brier 2008; Hofkirchner 2016).

Morin has a clearer picture about the several layers information dwells. One example is how he refers to the various levels of DNA: as (binary) data, in the chromosomes; as means of communication in the replication process, as (part of) the program that creates beings and therefore life.

Aspects in favor of an information theory

Given Morin's acknowledgement and utilization of a large part of information theory, there is no doubt that it represents a pillar upon which he develops his ideas.

He employs concepts not just from Shannon and Weaver but also from Brillouin, Atlan, Prigogine, and other fundamental thinkers of information theory. He returns often to Maxwell's Demon (Maruyama et al. 2009) and discusses how information is stored in the brain, in the DNA and is part of culture and society.

Use of fundamental concepts (communication, control, negentropy)

Morin explains in a considerable level of detail the concepts of Shannon, the statistical information from Boltzmann and even provides the equations and their equivalence. He considers that cybernetics united communication and control with information. And he also defines the organization, an important concept as already discussed, as being structured through information.

Morin ponders that Brillouin solved Maxwell's Demon problem through the necessary gain of information from the loss of entropy, that is, gain of negentropy, id est, gain of organization.

Generativity is the capability to create new information. It is directly related to life. Morin understands that this capability is very important and must be present in information theories.

Use of information in biology

When the negentropy concept was about to be introduced in the theories of life by Schrödinger ideas (Schrödinger 1945), the discovery of the chromosomes and genes by Watson and Crick, transformed the logic of living in a chemical and informational process.

Morin writes that we cannot underestimate the importance of the introduction of information in biology. If for nothing else, it drove away the mechanistic and vitalistic conceptions still considered as arguments.

Complementing what was explained previously, he develops a complex idea of the auto-(geno-pheno-ego)-eco-re-organizational paradigm that integrates several other paradigms, namely, the systemic, cybernetical and informational. Although too far-fetched to be completely explained here, his approach encompasses the living being as an autonomous system, controlled by the cybernetic model which uses communication to control and manage processes, using the biological resources of genotype and phenotype that determine how the living being should be and behave, and the notion of information stored in the genes which is processed through the DNA -> RNA -> proteins reproductive system. That, altogether, conveys the aspects that produce life.

Use of information theory in society

When dealing with society, Morin highlights five aspects of information (Morin 2003, p. 402–403): the hypercomplexity of the human brain, the double-articulation of language, culture as a genophenomenal structure, the appearance of the State (army, religion) and the development of urban centers.

He discusses how the brain stores information, learns, classifies and so on. Language is also analyzed when considering that it forms the individuals, and they form and are part of society. Language, spoken, written or otherwise, is also the means to transmit culture in form of information.

Information is also embedded in forming a specific culture. He classifies it as genophenotypical because culture works just like DNA: human beings have it ingrained in their character.

The State is also a result of the articulation of information. It is the sophisticated structuration that allows control of society through laws and enforcement.

Lastly, he describes how urban centers are the product and owe their existence to information as it articulates agents, enable social life, and even promotes the interest of living together.

Tool to understand cybernetics trough information

Morin sees a clear and direct connection between information and cybernetics and often cites both together. He is correct as the relationship of both theories and even the scientists themselves have a complementary approach to the objects of their study: "Communication theory is heavily indebted to Wiener for much of its basic philosophy and theory" (Shannon & Weaver 1949, p. 52).

One of the aspects that Morin points out is the fact that, when Wiener adopts a model based on communication and control, he changes the signification of information. It becomes the program, that is, a set of compulsory instructions to be followed and obeyed.

Drawbacks and limitations of information theory

But Morin is overly critical about some aspects and scientists of information theory. His views often condemn others for using a classical approach (dividing and studying parts to understand the whole) or not seeing dialogic relationships.

He also criticizes how information dominates science through command and control, accepting the idea of what is good for the machine or for the computers, is good for humans. He considers this a stupidifying notion.

Limits of Shannon's Information Theory

Morin complains that Shannon does not consider meaning in his theory and hides the anthroposociological metasystem that is implicitly considered. He also explains that living being organizations are far too complex for Shannon's approach, which do not provide complexity measurements. It could be developed though, Morin states, according to Atlan's ideas.

Another limitation is the absence of considering a true language. It does not make sense to transmit anything (and measure it) if real emitters and receivers are not defined. In his criticism, we can link information and cybernetics when he prompts: "the introduction of information into life, instead of being just a cybernetic-Shannonian application, should have been, should be, begins to be [...] the occasion for a revision and a complexification of the theory" (Morin 2003, p. 377).

There are two relevant ideas in Shannon's framework that are questioned in the *Complex Thinking*. One is noise and the other, redundancy. For the Information Theory, noise is a disturbing effect that prevents the receiver to correctly decode the emitter message. Therefore, is something to be avoided. Redundancy is

excessive, unnecessary data and might be prevented.

Morin has a different understanding. He shows how noise (which can be translated as errors) is actually an important factor to create variations, change and ultimately, provokes evolution. Were it not by the "mistakes" introduced in duplication for the DNA for example, living beings could not evolve.

The second point is redundancy. In a simplistic approach, it can be seen as unnecessary data in the transmission of information. But, Morin argues, if there was no redundancies, all errors would cause problems, disruptions, and chaos. So, in the end, errors and redundancies compensate each other and provide an intelligent solution for existence and evolution of life (Morin 2003, p. 418-419).

Imperialism of information

Morin writes ironically that "the queen information riding her luxurious cybernetic car explains Nature, Life and Society" (Morin 2003, p. 429).

He condemns the way all phenomena were suddenly explained through information. From kinetics to life, all that existed was just information organized. He showed that, in many situations, there is no information involved. This happens with entities that are not alive like stars, whirlpools, and such. Although possible to derive information from these appearances, data was not what caused them and is not necessary for their existence. Information becomes essential when life is involved. Because life, which requires reproduction, demands the self-replication of beings as well. And this is an informational phenomenon.

Information of information

We conclude the information section analyzing two main rings:

disorder/interaction/order/organization (physical)

and

noise/information/redundancy/organization (psychological)

These rings provide the equivalence or relationship between negentropy and information. The former being a physical measure whereas the latter, related to the mind. In the case of the second ring, noise represents uncertainty and doubt, information means knowledge, redundancy provides reassurance and security and, eventually, both rings close with the organization.

Morin also discusses two contradictory points of view: one that considers the organization as an informational phenomenon and the other which considers information as an organizational notion. He affirms that the latter would be more precise because the information is generated by the organization but could not exist alone and independently.

Another aspect worth mentioning is the idea of complex information: a concept with double focus and multiple inputs. One of the focuses is the object, the other, the psyche of the subject. The inputs are the physical, the biological and the anthroposociological.

Yet the complex information foresees two kinds of difficulties: the error and the apparatus. For the error, at the same time that it disturbs and interferes, it allows for change and evolution. As for the apparatus, it requires an adequate theory but represents the generative source of the organization.

CONCLUSIONS

In this paper we presented Morin's *Complex Thinking* contrasted to cybernetics, open systems, and information theory.

In our opinion, given the evidence, *Complex Thinking* is very much based on those three pillars, although not restricted to them. Much on the contrary.

When using concepts developed by those sciences, Morin praises at the same time that he criticizes them. His reproaches would be justifiable if one disregards the way normal science is being done since the XVII century, that is, through distinction and separation of objects. On the other hand, some of his criticisms seem to ignore the evolution of thought that happens in any knowledge area. In that sense, he condemns the theory of those forerunners of science, namely Wiener, Shannon and von Bertalanffy, forgetting that their works have been the cornerstones of those areas and evolution was to follow.

By the same token, Morin's *Complex Thinking* is also denounced by contemporary scientists (Thom 1980). As this is beyond our scope, we just mention some criticisms that relate more directly to our analysis. For example, although Morin proposes a new science (*Scienza Nuova*), he hardly explains how to reach it. In the same reference, he is also blamed for not providing a self-criticism of his points of view. And lastly, that his complaints to science at large are normally too general and abstract (Holmqvist 2022). Other critics indicate that his knowledge of logic is very limited (Maldonado & Gómez Cruz 2011, p. 60) and his theory suffers from an epistemic relativism (González 2020).

Specifically in the information theory, one can point out that Morin misunderstood the underlying concepts. His criticism of Shannon's theory having to cope with language and meaning was beyond the objective of the theory (Shannon & Weaver 1949, p. 3), as Shannon clearly states. Because of the many layers implicit (from symbols to message and meaning) in the communication of information, it is unreasonable to consider that the theory that predicts and corrects the transmission of characters should also model the aspects of semantics and redundancy. So, although his criticism on incompleteness of information theories could be acknowledged, it would not be fair to put those shortcomings on Shannon's account.

Another aspect that might be noticed is the absolute lack of any mathematical theory by Morin. If compared to other complexity approaches, he does not try to model or simulate, establish formulae and other formal methods (González 2020, p. 32). Although this absence might be comprehensible due to his mostly sociological standpoint, it renders his theory less prone to be employed in the natural and applied sciences. But of course, there are less benevolent critics that either dispraise Morin's *oeuvre* (Maldonado & Gómez Cruz 2011, p. 57-62) or dismiss it as a whole (Reynoso 2009).

But Morin's *Complex Thinking* is very convincing. His approach contrasts with Complex Adaptive Systems (Frei & Marzo Serugendo 2012), Econophysics (Arthur et al. 2020) and Network theories (Hausmann et al. 2011) among others. While Morin tries to connect micro and macro levels, society and particles, mathematics and ethics, new areas of complexity try to discover simple laws that guide matter, life, and the universe. These approaches still avoid the agency of the subject, the bias of the observer, the event, which is unforeseeable and unleashes innovation, and they even try to model the unexpected as the edge of chaos.

Somehow Morin's approach is more realistic although abstract. Judging based on his ideas, it seems like some branches of complexity sciences, with some exceptions (Le Moigne 1994, Mainzer 2004, Simon 1962) not having learned with the attempts of unification of the past,

still try to find unity using simplistic paradigms through disciplinary science.

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Appendix. Most cited personalities in Morin's La Méthode.

Area	Surname	Name
Philosophy	Aristotle	
Cybernetics	Ashby,	Ross.W.
Philosophy	Bataille,	Georges
General Systems Theory	von Bertalanffy,	Ludwig

Physics	Boltzmann,	Ludwig
Neuroscience	Changeux,	Jean-Pierre
Biology	Danchin,	Antoine
Philosophy	Descartes,	René
Physics	Einstein,	Albert
Cybernetics	von Foerster,	Heinz
Psychology	Freud,	Sigmund
Logics / Mathematics	Gödel,	Kurt
Biology	Gros,	François
Philosophy	Hegel,	Georg Wilhelm Friedrich
Philosophy	Heraclitus	
Biology	Jacob	François
Philosophy	Kant,	Immanuel
Philosophy	Laplace,	Pierre-Simon
Philosophy / Physics	Lupasco,	Stéphane
Philosophy	Marx,	Karl
Physics	Maxwell,	James
Philosophy	Pascal,	Blaise
Psychology / Education	Piaget,	Jean
Philosophy	Bachelard,	Gaston
Information	Shannon,	Claude
Economy	Simon,	Herbert A.
Logics / Mathematics	Tarski,	Alfred
Mathematics	Thom,	René
Biology	Varela,	Francisco J.
Cybernetics	Wiener,	Norbert
Philosophy	Wittgenstein,	Ludwig

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Enio Alterman Blay: conceptualization, methodology, investigation, writing - original draft preparation. José Roberto Castilho Piqueira: supervision, writing - review & editing.