Intelligent Systems Many Manners of Adapting to Environment

Lucia Urbani Ulivi and Primavera Fisogni

Abstract What is intelligence is a debated and still open issue. Psychologists have identified many different skills involved in intelligence, but there is no agreement on a general definition. Without entering in the debate, we will here adopt a definition pertaining to philosophical area, general enough to include most meanings currently used in psychology and in common sense and specific enough to distinguish intelligence from other capacities. *Intelligence is the ability to find adaptative responses to perturbations both of the internal and the external environment recovering proper equilibrium.* Most systems, artificial and natural, are intelligent in the sense of the proposed definition, as most of them have the capacity to restore their systemic balance in response to change occurring in both inner and outer milieu. We shall then investigate by which means different systems adapt to their environment and if—and in what aspects—human intelligence differs from every other kind of intelligence known to us. To answer both questions, we will distinguish objective—or intrinsic, or tacit—intelligence from subjective—or explicit—intelligence, characterized by mental activity, language, and auto conscience. We will finally support the thesis that in human being intelligence emerges thanks to the interplay among three actors: objective intelligence, subjective intelligence, and their environment(s).

Keywords Open systems · Intelligence · Objective intelligence · Subjective intelligence · Emergence

---

L. U. Ulivi (✉)
FTL-USI Lugano, Lugano, Switzerland
e-mail: urbaniul@teologialugano.ch

P. Fisogni
La Provincia di Como, Como, Italy
e-mail: pfisogni@gmail.com

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024
G. Minati and M. Pietronilla Penna (eds.), *Multiple Systems*, Contributions to Management Science, https://doi.org/10.1007/978-3-031-44685-6_6

1 Introduction

What is intelligence is a debated and still open issue. Psychologists have identified many different skills involved in intelligence, but there is no agreement on a general definition. In searching for a collection of definitions, Legg and Hutter (2007) found 70 different ways in which intelligence can be said, spanning from an individual property that interacts with the environment to the ability to succeed with respect to some goals.

Without entering in the debate, we will here adopt a definition pertaining philosophy, general enough to include most meanings currently used both in psychology and in ordinary language, and specific enough to distinguish intelligence from other capacities.

> *Intelligence is ability to find adaptative responses to perturbations both of the internal and the external environment recovering proper equilibrium.*

Most systems, artificial and natural, are intelligent in the sense of the proposed definition, as most of them have the capacity to restore their systemic balance in response to a change occurring in both the inner and the outer milieu, but each system adopts different strategies to catch such goal.

Within the systemic realm a further step is to frame this investigation into the multiple systems domain (Minati & Pessa, 2006), in which the elements that form the system itself play interchangeable roles and interact simultaneously or sequentially in different ways, giving rise to sequences of different systemic conducts and to different systems. Multiple systems are called collective beings when the elements are autonomous, being able to decide how to interact. An example that is in the experience of all of us is given by the Internet (Minati, 2022: 110).

This is not simply a kind of methodological premise. On the contrary, the dynamic, adaptable, and interchanging notion of intelligence sketched before should be thought as a system, or it would be better said, in terms of *multiple intelligent systems* with a plural identity, albeit grounded on a set of common features.

From this perspective, the present investigation is expected to introduce some remarkable novelties for both philosophy and systemic thinking that might bring about a change in the debate. Precisely, philosophy is invited to move forward the comfort zone of the cognitive approach to intelligence, focusing on the multiple layers of such a dynamic ability to reach a comprehensive view on animated/inanimate beings.

On the other hand, in systemic thinking it can be introduced the concept of *intelligence of the emergences* as both (1) the engine that identifies the establishment of coherence and self-organization in collective systems and (2) the process that generates singularities. To postulate such an intelligent texture, beyond giving reason of a 'greater systemic integration and harmonization' (Marconi & Penna, 2021: 87), can be valuable for explaining the failure of predictive conceptual frame only recurring to linear paradigms. An example? The Black Swan phenomena (the Covid-19 outbreak or the 9/11 just to quote two of them), whose dynamics seem to escape linear thinking (cause/effect) and belong to an implicit, however, well-directed strategy.

2 Intelligence is a General Feature of Open Systems

The first step to move into the multifaceted profile of intelligence calls for a short account of open systems: they radically differ from formal systems, which are closed, since the rules that establish them determine their outcomes in a complete and predictable way.

On the contrary, the interaction with the environment through processes of dissipation and acquisition is the landmark of open systems. Multiple filters of various levels allow open systems to maintain exchange relationships with the environment and to valuably support the acquisition of emerging systemic properties. All of them are, for the observer, the cues that the system is intact despite its process variations.

The capacity to be transformed through the interaction with the world, and at the same time to sustain its own integrity, makes of an open system a highly adaptive system. This complex ability in which not only homogeneous, but also heterogeneous aspects are finely tuned, should be seen as the most characteristic feature of what is generally viewed as intelligence.

Nevertheless, intelligence may be specified in different ways according to the type of system described. Intrinsically related to it, the creativity of emergences deserves a brief focus. It presents itself as unexpected, unpredictable, surprising, through the extraordinary variety and richness of the adaptation processes deployed by natural entities and to a certain extent also by artificial ones. We can conclude 'intelligence', 'adaptivity', 'creativity' are terms that refer to the same property, while each point out a different aspect of such ability.

Worth noting that with 'adaptivity' we refer to the ability to choose between different possibilities of answering a personal need or a question posed by the internal or external environment in the form of perturbation, while the thick term 'creativity' underlines the originality of the adaptive response, which invents forms, objects, scenarios, projects—and much more—entering the processes of the world and transforming them. 'Intelligence' especially refers to the capability to connect untied elements giving birth to a new scenery. Intelligence, adaptivity, and creativity undermine the possibility of understanding the behavior of open systems in a deterministic way and open to the vast and articulated spaces of freedom.

Intelligence—or adaptiveness, or creativity—is a common feature of the open systems that exhibit emergences. Through the lenses of systemics we can easily realize that there is no system without emergence; the ability to withstand emergences shows that a system to keep itself intact is using intelligence, adaptability, and creativity. Being a system, then, implies being intelligent (whether the converse is also true is a question that should be investigated).

Although intelligence is a common feature of open systems, it is far from being identical in all of them; on the contrary, each system uses such capability in its own manner, opening new paths and finding specific solutions to the ever-repeated problem of successfully kip connections with its environment. The way a giraffe is intelligent highly differs from the way a human is, and the degrees of adaptation are very different from one human to another. Given that intelligence is multiple, we want now to investigate in what way does human intelligence dwell a specific place in the rich scenery of intelligences active in our world.

3 Objective—or Intrinsic—Intelligence. The Tacit Dimension of Intelligence

When we say that we as humans are intelligent, we typically refer to the intelligence we are directly acquainted with, observable in what we do, in what we say and in what we think. In the terms introduced by Polanyi (1966) we are pointing to explicit intelligence, the one that has been exclusively or primarily taken in consideration by philosophy and entered the cultural discourse as a property that can be grasped and described discursively. But beside it, a tacit intelligence must be staged if we want to track the roots that nourish our explicit intelligence and if we want to explain the successful behavior of a system—both human and not human—in the reference environment. The need to consider an intrinsic intelligence has been reduce the space between the two lines neglected for centuries, with the remarkable exception of Aristotle, who distinguishes *noesis* from *dianoia.*[1]

If Freud was not the first to suggest the existence of a submerged ground of reality, not detectable in human self-observation, he was certainly the first to forge some useful tools for becoming aware of that realm. Nevertheless, the Freudian submerged dimension of reality mainly pertains to the sphere of emotional dynamics: it will be necessary to wait many decades before the neuroscientist Libet (2004) was in the condition to formulate the hypothesis of an unconscious mental activity and to test it experimentally.

Libet observed that many phenomena well known to scientists let us glimpse the tacit intelligence at work, as among others the correction of neuronal distortions, the solution of problems without the activation of conscience, the memory of something that was said when the subject was under anesthesia. It is also active in blind perception—when the body is oriented to reach the target without his movement being guided by conscious processes. These, and other similar behaviors, are performed according to a rational structure able to act pursuing a goal and cannot be understood in reductive terms such as chaotic or even occasional or simply casual phenomena.

To better grasp intrinsic intelligence, we shall start a trip, leaving the explicit dimension of the real to dig into the vast and uncertain domain of the implicit, guided by the Ariadne's thread of reason.

No doubt that the pandemic outbreak made the *implicit* or *objective* or *tacit intelligence* 'viral' and more actual than ever, even if such presence has been scarcely recognized. A radical shift occurred within the immunization processes in order

[1] *Noesis* is the basic level of knowledge, consisting in the immediate apprehension of things. This level ensures direct contact with the domain of ideas and of reality. The second level, called *dianoia*, is the realm of judgment, where the unity of *noesis* is splitted to form propositions and logical inferences.

to struggle the virus: two antiCovid-19 vaccines (Comirnaty by Pfizer; Spikevax by Moderna) used messenger ribonucleic acid (mRNA) molecules that contain instructions addressed to the cells in order to synthesize Spike proteins.

According to this microbiological path, it is not the virus to be introduced into the cell of the person, but the genetic information that the cell needs to build copies of the Spike protein. The method is as simple as effective. Blocking this protein, with which SARS-CoV-2 typically attacks the immune system, it can be reached a main goal. The immune system can recognize the virus, stopping it or at least reducing its powerful impact on the organism.

Objective intelligence is at work to reach such complex goals, since all these operations are not mechanical; mRNA vaccines need a certain capacity to be acquainted with the new environment, as well as the ability to spread information in time and to know the way to reach the right targets.

Many other phenomena can be better explained if we follow the path of intrinsic intelligence and could be an exciting exercise of investigation to detect other mystery cases losing their opaqueness if we shift from the paradigm 'intelligence is present to conscience' to the more comprehensive claim 'intelligence is at work also when nobody is aware of it'.

By the way of examples, we shall briefly investigate three complex systems, belonging to the ecosystem and the hyperconnected world, to detect how objective/implicit intelligence works, according to what relevant processes, with what results. Such systems are phototropism, metabolism, and cloud computing. Phototropism and metabolism play crucial roles in the world of life, while cloud computing dwells in the *onlife* domain, (Floridi, 2015) where the real and the digital are melted together.

3.1 Phototropism and the Intentional Responses of Plants

Phototropism (light + movement), the way green plants respond to the light source, is a biological phenomenon that can be easily observable. Let us think of a seedling kept in a room with little lighting: its stems are oriented toward the most intense light stimulus; if we change the direction of the light beam, the plant is able to perform a turn in that direction. It seems to move in a deliberate way, to ensure flowers, leaves, trunk, roots the optimal growth conditions.

Clearly revealing of the adaptive behavior within the botanic realm, phototropism has become a relevant topic for a better understanding of the intelligent behaviors of green plants, rising several issues in the direction of plants cognition. The lack of a neuronal system, in fact, is no more considered sufficient reason to exclude a priori these living entities from the highest level of capabilities usually only attributed to the more evolved animated beings.

Among scholars there is a wide consensus that the photosynthetic and the phototropic world of plants is related to specific organs that collect, organize, and remodulate the external light stimuli, giving rise to the ability to choose among different and conflicting options, as well as the animated beings do. On one side, the focus is on the cells as the barycenter of the neuronal-like skills (Trewavas, 2009, 2014, 2016); on the other side, a 'root-brain' is seen as the central infrastructure of the plants (Baluška et al., 2008). They both search for a special type of cognition in plants.

According to the first theory: «intelligent behaviour exhibited by single cells and systems similarity between the interactome and connectome indicates neural systems are not necessary for intelligent capabilities». Intelligent leaf movement in low light, adaptively plastic and intelligent responses to light, intelligent responses to light resources, and adaptive variability to light in response to crowds can be experimentally detected. In these investigations, rooted in Darwin's intuitions, (1880) resound the discourse of plant biologist McClintock, on the occasion she was awarded the Nobel Prize.

> «A goal for the future would be to determine the extent of knowledge the cell has of itself and how it uses that knowledge in a thoughtful manner when changed» (McClintock, 1984, quoted from Trewavas, 2016: 2).

Plants neurophysiology, the other scientific path into plants intelligence, is grounded on plant neurobiology, in which many neuronal-like activities, based on plant synapses, appear to be not only theoretically justified, but experimented (Baluška et al., 2006; Baluška & Mancuso, 2007). A network of synapses, for example, transport auxin, the hormone for the growth related to phototropism. Roots' apices «emerge as command center» while «act as the posterior poles». In conclusion:

> «As plants are capable of learning and they take decisions about their future activities according to the actual environmental conditions, it is obvious that they possess a complex apparatus for the storage and processing of information» (Baluška et al., 2006: 19).

Beyond the different paradigms—cells or root-brain oriented—both the perspectives recognize in the light-foraging behaviors, a proper way of learning by association (Gagliano et al., 2016), an *intentional* response of plants, that is to say a finely grained skill of the intelligent beings. Intention, in fact, is the kind of knowledge that allows to reach a goal. For Anscombe (1957) intention is an act belonging to the class of «non-observational knowledge», or the «class of movements known without observation» (Proposition 8). Just to sketch an example, when we say «I open the windows» I make several operations in order to perform that act. What does it mean, from a cognitive perspective? Simply that intention is grounded on knowledge of the means with which a goal is achieved (to open a window) (Torralba & Lano, 2008, 2010). However, one thing is to say that plants are not passive systems, one is to relate their somehow sophisticated forms of behavior to a specific agency, goal-directed (intention), and another one is to follow McClintock when she suggests that plant cells not only have knowledge, but can know themselves. The notion of intrinsec intelligence can usefully support the first two statements, while McClintock hypothesis that plant cells can think themselves seems derived from a monistic concept of intelligence that should be abandoned in favor of a pluralistic idea of intelligence.

Actually phototropism—as the result of an effective, intentionally directed interaction of multiple systems (plant, environment, light, and metabolism)—recalls cognitive processes that are performed without a clear consciousness: through appetite, for example. In classical philosophy, this idea has been theorized by Thomas Aquinas in the doctrine of *connaturalitas*, which refers to the judgment *per modum inclinationis* and differs from the intellectual judgment, aka *per modum cognitionis* (Biffi, 1974). Natural inclination is recognized to be present everywhere in nature (Baldner, 2018) and strictly related to appetite, exactly the kind of 'movement' related to plant tropism toward a source of light (Keane, 1966).

3.2 Metabolism: Informational Exchange with the Environment

Metabolism could be understood as the most powerful engine for life growth because its processes are oriented to support living organism through biological reactions. At large, metabolic functions are also intended in a metaphorical way, as in the case of urban metabolism, that concerns flows within cities, in order «to quantify he inflows, outflows, and accumulation of resources (such as materials and energy) in a city» (Derrible et al., 2021: 85). The phenomenon of phototropism sketched above is a typical metabolic response of green plants to solar energy.

Biological reactions are hosted by each cell through a set of operations spanning from the transformation of food into energy, through enzyme-mediated responses, to the elimination of wastes. In biological terms, these activities depend upon two related phases, the catabolic reactions (the breakdown of bigger molecules into smaller) and the anabolic processes (the combination of simple molecules into bigger ones).

Among the multiple processes that characterize metabolism, the leading one is about the capacity to synthesize new materials/molecules, precisely amino acids, carbohydrates, and nucleic acids (the components of the DNA) and the proteins. This basic set of information throws light on metabolism as an 'agent' capable of a special type of intelligence (someone would prefer to speak of 'cognitive abilities', or of 'cognition'), selecting what is good and what is bad for life to flourish.

It is simply impressive to notice the way biological processes enzyme-mediated transform their own environment. The notion of complex system perfectly fits to metabolism, a process that can only take place in the macro-system of life that influences so many subsystems and acts through structural dynamics, showing itself in terms of a sequences of phase transitions. At least four phases can be detected:

(1) **Change of structure** It occurs, for instance, in the passage from food to new molecules.
(2) **Acquisition of a structure**, or passage from an unstructured to a structured configuration. In phototropism, the solar energy allows the production of auxine, the hormone that causes the cells of the plant to elongate on the shaded side. In this case, the acquisition concerns both a new material (the hormone) and a new organic process (the growth).

(3) **Loss of structure**, as for instance transition from a structured to an unstructured configuration. Pathogenesis of neurodegenerative disorders, as a growing body of evidence seems to prove, depends on energy metabolism decline in aging (Błaszczyk, 2020).
(4) **Combination of structures**. They continually occur in metabolism. In human metabolism, the main business is given by the oxidation process. In the last phase, the transformation of indigestible dietary residues occurs through fermentation, and the leading actor becomes the intestine itself. This example is particularly interesting for diving into the hidden life of metabolic intelligence, not simply because it presents the search for an alternative way to reach a main goal (fermentation instead of oxidation), but because it unveils a functional interaction between metabolic activities and the brain. So that it has been theorized the connection between mood, food, or 'the psychobiotic revolution': the brain health and state of mind are related to microbiome, a population of microbes living inside the intestines (Anderson et al., 2017).

It is not possible here to account for the multifaceted dynamics of a process such as metabolism, nor is this the aim of the article. However, we are already in the condition to understand that in metabolism can be seen an intelligent behavior, albeit implicit. In metabolism we detect typical traits of intelligence: creativity—in the sense of adaptative behavior—information, and memory. Traditionally referred to art, creativity is basically the capacity to give rise to new and unexpected phenomena, links, and relations. In different words, but with similar meaning, there are no rules that can prescribe creativity. In metabolism the main resource for a successful adaptation to environmental changes is creativity: organisms not to perish find new paths.

Extreme environmental conditions allow metabolism to find effective adaptive responses. One can only be surprised by the plasticity with which this occurs in nature. Take the *Drosophila melanogaster*, for instance. The fruit fly is a master of food-feeding flexibility when nutrients are scarce, because the «larval growth period is extended to allow additional growth and to ensure an appropriate final adult size under unfavorable growth conditions» (Koyama et al., 2020: 4524). The key role here is played by hormones (insulin, peptides with glucagon-like function, and steroid hormones) that systemically exchange information and provide the other biochemical components with specific signals. Such a behavior makes scientists aware of the 'flexibility' of the *Drosophila*'s metabolism that «*must be able to sense* and respond to changes in external environmental conditions and their internal state» (Koyama et al., 2020: 4523. *Italic is ours*).

The recent global alert for the climate change has thrown light on how fishes adjust their metabolic activity in warm water. How does it happen? Scientists investigated the behavior of *Perca fluviatilis* near a nuclear power plant in Sweden, where water (5–10°) is warmer than in other environments. Although warming is known to be highly dangerous for the fish's metabolism «by causing a mismatch between oxygen demand and supply, and a consequent reduction in aerobic scope (AS) and performance» (Ripley et al., 2023: 1), it has been evidenced a lower oxygen consumption, that is to say an unprecedent adjustment of the metabolic rate (Clark et al., 2013; Jutfelt, 2020).

This phenomenon leads, on a theoretical level, to a couple of considerations about implicit intelligence. First, we are in presence of an adaptive response that clearly transcends the biochemical dynamics of the organism itself; secondly, we are dealing with an emergence, an adaptive capability not given in ordinary conditions, which is the result of multiple interactions between metabolism and the environment, when a perturbation (thermal increase) occurs, and a new dynamic response (the effort to adapt to the environment) is effectively found.

As the previously sketched examples highlight, metabolic processes are informational at core, because each molecule is expected to communicate a specific content to organism. This duty is primarily performed by proteins, which are synthesized by metabolism. As Giuliani underlines:

> «Unlike other biological molecules such as sugars and lipids, which are identical in all living species, proteins are called 'informational'; their composition is encoded by sections of the DNA sequence and is peculiar to the individual species (…) The ordered course of metabolism strictly depends on the ability of the protein molecules to recognize the molecular actors of the specific chemical reactions to be promoted or inhibited» (Giuliani, 2022: 68. *The translation is ours*).

Finally, it should be noted the increasing importance of metabolic memory, as it appears with great evidence in the treatment of diabetes. For memory is intended the capacity, for the metabolic processes, to collect historical data about their activity, but also to keep track of the transformation occurred within the organic life, as a sort of living archive. All these information have been proved highly fruitful to decrease, for example, the risk if diabetic micro-and-macro vascular complication. Recently theorized, this topic is going to become a main topic for scientists, in terms of promising therapeutical perspectives. As Testa notes: «Recently, epigenetic mechanisms have been hypothesized to be a crucial interface between genetic and reduce the space between the two lines environmental factors to explain metabolic memory»[2] (Testa et al, 2017: 3). As it has already been noted for plants, living organism can be understood as knowledge accumulating systems «because they allow the most rapid and efficient responses to changes in environment» (Baluška & Mancuso, 2007: 205). If we translate this statement in our systemic view, living organism possesses and exhibits it in what they do, intrinsic intelligence.

3.3 Cloud Computing, a Virtual Mind for Real Data

As stated in the *Onlife Age* by Floridi (2015), in our age the real and the digital are melted together, and interconnections have become more and more strategically relevant, for the individual as well as for the organizations. The cloud computing

[2] *Epigenetics* is the study of how behaviors and environment can cause changes that affect the way genes work.

technology is properly and effective, as well as business-oriented way to interconnect the cyber-physical space.

A network digital infrastructure, cloud computing can be equated to an enormous system in which are stored data from public and private organizations, hospital, schools, universities, energy sources, banks, and many more. At least three primary services are hosted on the cloud, divided into infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS). The remote data center—aka 'the cloud'—is interconnected with a network of users that, through the on-demand access can store their data, also having the possibility to exchange information with the other clients. As it has been noted: two important factors that trigger cloud computing systems (CCS) are reliability and energy efficiency (Dhawale & Dhawale, 2023). On the other side, a main concern is about the data sharing that «may contain some tactful or sensitive information». Thus, a main issue related to digital infrastructure deals with security and ethical concerns. However, another consideration to be done, which is also an area of interest in cloud computing, is the *autonomous capacity to operate*. We have reached the very heart of a leading infrastructure of the Fourth Revolution, in which the artificial intelligence is going to make a step forward.

> «It is expected that such resources can make independent decisions on their state to avoid human intervention in monitoring the state of these resources which have their direct and indirect cost implication monitoring regime toward the smart city applications» (Millham et al., 2023: 2251).

This possibility is far from remote. But before trying to understand why cloud computing is so promising in terms of *sui generis* intelligent thinking, it is worth noting how much the design of this digital infrastructure intertwines the human and virtual worlds. The operations center, the real cloud, recalls a brain in shape, while the network of the various users suggests the ramifications of the nervous system. The interactions between nodes (users) and the central system (cloud) evoke the plasticity of the messages transmitted from the center to the periphery and vice versa. Continuous inputs reach, like synapses, the stored data. As an example of a multiple system, cloud computing moves on at least three levels:

(1) man–machine interaction;
(2) the interactive processes between data;
(3) the emerging dynamics generated by the two previous interactions and by the dialogue, so to speak, of these new properties.

This is not science fiction. It already happens, as a consequence of the machine learning models, on which also the cloud computing technology is grounded. The infrastructure is expected to generate insights from big data. For instance, organizations can use machine learning to build models that automatically generate insights from big data, such as identifying trends or predicting future outcomes. Machine learning is a subset of artificial intelligence that involves the use of reduce the space between the two lines algorithms and statistical model to enable computers to 'learn' from data.[3] Nonetheless, one should not think of science fiction scenarios. There is a growing interest in developing artificial intelligence systems that are transparent and understandable or explainable AI, so that their decisions and predictions can be made available to humans.

What has been succinctly said about cloud computing opens a series of considerations in the light of this investigation.

It is important to underline that artificial entities are inherently intelligent, but their intrinsic intelligence, also in the case of artificial intelligence (AI) and machine learning (ML), results from the algorithms made by creative human beings. Compared to the processes that occur spontaneously in the world of life, they are the work of the intelligence that introduced them into the world as new phenomena. Thus, from this point of view, artificial entities are intelligent in an objective or intrinsic way, and in this sense the expression 'artificial intelligence' finds a proper and literal justification.

It is necessary to dispel a misunderstanding. Having conceived, and designed and engineered an artificial object, does not offer even to its creator any guarantee of full knowledge of the behavior of that object. Launched into the world, endowed with an autonomous dynamic, exposed to changes, the artificial object will often assume behaviors that are not only factually, but also theoretically unpredictable: artificial objects almost always have a considerable margin of self-organization and as the Golem of the Jewish tradition escape to varying degrees, even notably, from the intentions and expectations of those who designed and built them.

This observation can only advise us to adopt a principle of prudence: what we put into the world has unpredictable outcomes, and the unpredictable does not only include the favorable, but also the unfavorable, the destructive, and the dangerous.

4 Subjective—or Explicit—Intelligence

As noted before, explicit intelligence is the sort of human intelligence more investigated and definitely best known. Nor does it surprise, because it is directly observable through self-awareness, the exclusively human ability to take oneself as objects of observation and knowledge. Traditionally investigated by philosophy and logic, in recent times it has also become the object of other disciplines, including psychology and neuroscience. To explicit intelligence belong all the processes we directly know as part of our mental life, such as thoughts, reasoning, judgments, evaluations, choices, decisions, appreciations, as well as narratives, resolutions, projects, ideas, hopes, and much more. Subjective intelligence expresses itself in discoursive language, properly using both semantic and syntax rules. While sinking its roots in

[3] The use of the term 'learn' referred to digital machines is obviously metaphorical: Humans are said to learn because they are connected to their environment, both physical and cultural, while digital machines are said to 'learn' when thanks to their algorithm they select all the variables they have been exposed to during their training and find the best combination of these variables to solve a problem without being explicitly programmed.

the objective intelligence on which it depends and which feeds it, subjective intelligence is featured by its own traits, among which there is the constant search for the links that connect ideas and objects which are distant and disconnected at first sight.

The formal structure of inferences, regardless of the material content, has become the main topic of reasoning studies and explicit intelligence has quickly been identified with logical correctness. As a consequence, logic has assumed the powerful, but tacit and unproven premise, that the only correct inferences are those that can be formalized according to given rules and logicians set to work to formalize the rules of manipulation of symbols.

It follows that whatever cannot be formalized, i.e., most thought processes, is excluded from the investigation of human explicit intelligence. Most logicians have totally neglected that there are many fit and correct reasonings where conclusions do not necessarily follow from premises.

Peirce was the first in modern times to observe that the two main reasoning forms studied by logic, i.e., deduction and induction, are only small parts of our reasoning strategies. Furthermore, both show strong limitations: deduction produces only tautologies, and inductive reasoning limits itself to classifying similar cases under a general law. Peirce searching other arguments we reason by, identified a different inferential form, and called it 'abduction'.[4]

As Peirce writes, abduction is «the process of forming an explanatory hypothesis. It is the only logical operation that introduces some new idea». Abduction 'explains' a challenging issue by formulating the hypothesis that there is another fact, or a law, very different from the observed one—from which the observed one derives—which makes it possible an inverse inferential ascent, from effect to cause. The scientific method itself, in Peirce's words, begins with an abduction, formulating a hypothesis that explains an unexpected or surprising phenomenon and brings it back to normal by reorganizing the entire scenario according to a new perspective.

Logicians, who recently have begun to study abduction, have often tried to normalize it as the 'best explanation theory', which sounds as an attempt to get rid of the burden accounting for creativity, which exceeds logical rules and subverts the known formal order. Systemic thinking, being familiar with the emergences (II level systemic properties), which cannot be deduced from the first level ones, has appreciated abduction as a valuable cognitive tool for 'discovering' aspects, laws, entities not present in the available data.

Abduction is widely used by human intelligence in many domains: medical diagnosis, criminological investigations, politics, and also ordinary discourse, when one says to a friend 'He/she said he/she would do this, but I think that he/she has no intention to fulfill his/hers promise'.

Abduction, with deduction and induction, is one of the tools used by subjective intelligence to proceed in the comprehension of the world, but if we ask ourselves which is the main and proper characteristic of subjective intelligence, its common

[4] Aristotle in *Prior Analytics* uses the sintagm '*apagoghé'* to refer to the syllogism whose conclusions are 'believable', though not formally necessary.

seal, we should point at our meta-level capacity, as commonly experienced in self-awareness, the special moment where we take ourselves as objects under observation and also at work when we observe and describe the world. In philosophical jargon we speak of ‘objectivation’ to refer to such meta-level capacity.

Although this type of knowledge, concerning the self and the world, is limited and partial, it remains the highest product of explicit intelligence, which has been transmitted to us and which we can transmit in the forms of literature, poetry, the arts, the sciences, and philosophy.

5 The Emergence of Global Human Intelligence

As we summarily sketched in the previous paragraphs, objective and subjective intelligence could be thought in terms of the two faces of a same coin. In human beings their texture is so thick that they mutually recall each other. Quite differently, the sole objective intelligence does not allow to manage complex cognitive operations that must be supported with a language grounded on semantics and syntax. The animated beings that are endowed with only intrinsic intelligence lack of the ability to find reasons for their operations; it is impossible for them to share choices and to argue effectively in support of their activities and decisions.

Although it obeys to multiple constraints, objective intelligence does not have laws, nor rules or a moral system, neither shared culture, and not even literature, history, art, science, and philosophy. It would be impossible for human beings to even imagine a world devoid of the traits that most and best characterize us, in which we recognize ourselves.

A human being lacking intrinsic intelligence, on the other hand, does not even constitute him–herself as a human subject, because he/she is devoid of all the emergences that make him/her as such, starting from the bodily organization which requires a very high level of intelligence to constitute itself.

There is a significant asymmetry between our two main modes of intelligence: intrinsic intelligence can be maintained even in the absence or latency of the subjective one. Just think of sleep, states of brain-death, anesthesia. If in all these circumstances the body remains alive and vital, it is because its intrinsic intelligence is working, making animation possible. The reverse is not true: subjective intelligence simply fades when is not—or no more—preserved by the support of objective intelligence. Thus we can conclude that intrinsic intelligence has an ontological–anthropological primacy over subjective intelligence as this subjective property sinks its roots on the intrinsic intelligence.

It can be easy to realize how powerful consequences this conceptual frame is expected to have in bioethics, through the re-conceptualization of intelligent behavior in non-conscious states, like the coma. If a green plant—as briefly described before—has so many abilities to intelligently relate to, use and dominate its environment, how could its life be considered a not-life state? Thus, while terms like ‘persistent vegetative state’ (PVS) or post-coma unresponsiveness (PCU) should acquire a new meaning, this novel approach to 'intelligent behaviors' ought to bring about a change in the ongoing debate about the health care to patients in PVS or PCU.

A question arises at this point of the paper: what is the relationship between intrinsic intelligence and subjective intelligence? The problem is questioned by scientific literature in somewhat different terms, being the concept of intrinsic intelligence only recently proposed.

Concerning human intelligence, Ingold wonders whether the 'making' precedes the 'ideation' phase or it just follows it, if, in his words, 'making through thinking' precedes or follows 'thinking through making' (Ingold, 2013: 6). He concludes solomonically «making things is tantamount to a process of growth» (Ingold, 2013: xi).

If, in search for a neat answer, we turn to self-observation of artists, writers, philosophers, we nevertheless discover that they are often discordant in their answer to Ingold dilemma. Precisely, many authors report observing themselves in the act of making even in the absence of an idea or project explicitly present to their consciousness («I know what I'm saying only after I've said it…»).

Others, perhaps the majority, place conception before planning and making.

The fact that the evidence is discordant and heterogeneous does not allow reaching a so-called 'sociological' explication. As we suggest, a meta-level or conceptual clarification is needed.

In this case, introducing the concept of objective intelligence alongside the subjective one allows us to solve the dilemma: between the two conceptual frames there is no fixed antecedent relationship, in some cases the objective precedes the subjective one; in other cases, and without any scandal, it is true just the reverse.

Between the two terms referring to intelligence, there is a link of both interaction and interference, a kind of dance in which roles can be exchanged in the incessant process of our being in the world.

The continuous connection between intrinsic intelligence and subjective intelligence, according to which human intelligence emerges in its fullest sense, does not take place within a self-referential and solipsistic horizon.

The process of thinking originates in connection with what is other-than-us.

We call in question the environment.

We cannot treat the great topic of environment as it deserves, but we would at least warn from the mistake of thinking of the environment in a singular way: we are connected in multiple relationships and mutual transformation with multiple environments. In addition to the physical environment—in the multiple senses of chemical, biological, ecological, astronomical, architectural, economic environment, etc.—we are deeply influenced by the cultural, emotional, intellectual environment, and many others. We are aware of some of these connections, others transform us without us being able to grasp them explicitly.

In brief, we connect to them in a way that only rarely reaches consciousness and mostly happens at a subliminal level that, thanks to the activity of objective intelligence, let us participate in the fascinating and ever new process in which life consists of.

We project expectations of intelligent organization onto different environments, because only if the world in its many aspects is intelligent, we—who take a part in it—can hope to increase and ameliorate our knowledge of what surrounds us.

Finally, we can draw a conclusion from a systemic perspective: human intelligence is an emergent property of the human being system, which is structured thanks to the intertwining of objective intelligence, subjective intelligence and the different environments with which both are related. It is a skill of a high degree of complexity; consequently, there is no discipline that can claim to describe it exhaustively. Its various facets will be the subject of investigation by philosophy, logic, psychology, and neuroscience, but also by anthropology, sociology, economics, jurisprudence, medicine, and the arts, which will give their brushstroke to create the large fresco in which the 'human' narrates its self-representation.

A fresco to which every era adds its touch and to which we hope that this article will add a useful contribution to fade away problems created by obsolete paradigms and open and develop new perspectives in contemporary knowledge.

References

Anderson, S. C., Cryan, J. F., & Dinan, T. (2017). *The psychobiotic revolution. Mood, food, and the new science of the gut-brain connection.* National Geographic.

Anscombe, G. E. M. (1957). *Intention.* Blackwell.

Aristotle. (1924). In W. D. Ross (Ed.), *Metaphysics.* Clarendon Press.

Aristotle. (1949). In W. D. Ross (Ed.) *Prior and posterior analytics.* Clarendon Press.

Baldner, S. (2018). Thomas Aquinas and natural inclination in non-living nature. *Proceedings of the ACPA, 92*, 211–222.

Baluška, F., Volkmann, D., Hlavacka, A., Mancuso, S., & Barlow, P. W. (2006). Neurobiological view of plants and their body plan. In F. Baluška, S. Mancuso, & D. Volkmann (Eds.), *Communication in plants* (pp. 19–35). Springer.

Baluška, F., & Mancuso, S. (2007). Plant neurobiology as a paradigm shift not only in the plant. *Sciences Plant Signaling & Behavior, 2*(4), 205–207.

Baluska, F., Schlicht, M., Volkmann, D., & Mancuso, S. (2008). Vesicular secretion of auxin; evidences and implications. *Plant Signaling & Behavior, 3*, 254–256.

Biffi, I. (1974). Il giudizio "per quandam connaturalitatem" o "per modum inclinationis" secondo San Tommaso: analisi e prospettive. *Rivista Di Filosofia Neo-Scolastica, 66*(2/4), 356–393.

Błaszczyk, J. W. (2020). Energy metabolism decline in the aging brain-pathogenesis of neurodegenerative disorders. *Metabolites*, *10*(11), 450. https://pubmed.ncbi.nlm.nih.gov/33171879/

Ceriello, A. (2012). The emerging challenge in diabetes: The "metabolic memory." *Vascular Pharmacology, 57*(5–6), 133–138.

Clark, T. D., Sandblom, E., & Jutfelt, F. (2013). Aerobic scope measurements of fishes in an era of climate change: Respirometry, relevance and recommendations. *The Journal of Experimental Biology, 216*, 2771–2782.

Clarke, A., & Fraser, K. P. (2004). Why does metabolism scale with temperature? *Functional Ecology, 18*(2), 243–251.

Darwin, C. (1880). *The power of movement in plants.* John Murray.

Darwin, C. (1891). *The movements and habits of climbing plants.* John Murray.

Derrible, S., Cheah, L., Arora, M., & Yeow, L. W., et al. (2021). Urban metabolism. In W. Shi (Ed.), *Urban informatics* (pp. 85–114). Springer.

Dhawale, C. A., & Dhawale, K. A. (2023). Review on reliability and energy-efficiency issues in cloud computing. In J. Wang (Ed.), *Encyclopedia of data science and machine learning* (pp. 790–802). IGI Global.

Drzewoski, J., Kasznicki, J., & Trojanowski, Z. (2009). The role of 'metabolic memory' in the natural history of diabetes mellitus. *Polskie Archiwum Medycyny Wewnetrznej, 119*(7–8), 493–500.

Fisogni, P. (2023). Machine learning and emotion. In J. Wang (Ed.), *Encyclopedia of data science and machine learning* (pp. 961–970). IGI Global.

Floridi, L. (2015). *The onlife manifesto. Being human in a hyperconnected era.* Springer.

Gagliano, M., Renton, M., Depczynski, M., & Mancuso, S. (2014). Experience teaches plants to learn faster and forgets lower in environments where it matters. *Oecologia, 175*, 63–72.

Gagliano, M., Vyazovskiy, V., Borbély, A. A., Grimonprez, M., & Depczynski, M. (2016). Learning by association in plants. *Scientific Reports*, *6*, 1–9, https://www.nature.com/articles/srep38427

Giuliani, A. (2022). L'intelligenza del vivente. In L. Urbani Ulivi (Ed.), *L'intelligenza della natura* (pp. 47–89). EUPRESS FTL-Cantagalli.

Ingold, T. (2013). *Making: Archaeology, art and architecture.* Routledge.

Jutfelt, F. (2020). Metabolic adaptation to warm water in fish. *Functional Ecology, 34*(6), 1138–1141.

Keane, H. V. (1966). *Knowledge by Connaturality in St. Thomas Aquinas* [PhD dissertation, Marquett University]. Wisconsin.

Koyama, T., Texada, M. J., Halberg, K. A., & Rewitz, K. (2020). Metabolism and growth adaptation to environmental conditions in Drosophila. *Cellular and Molecular Life Sciences, 77*, 4523–4551. Retrieved online: https://link.springer.com/article/10.1007/s00018-020-03547-2

Legg, S., & Hutter, M. (2007). A collection of definitions of intelligence. *Frontiers in Artificial Intelligence and Applications, 157*, 17–24.

Libet, B. (2004). *Mind time. The temporal factor in consciousness.* Harvard University Press.

Manera, S. (2021). *Cervello intestino. Un legame indissolubile. Il ruolo del microbiota intestinale nelle nostre relazioni fisiche, mentali e psicoemozionali.* Macrolibrarsi.

Marconi, P. L., & Penna, P. (2021). The reaction of complex systems to symmetry braking events: A mathematical simulation model for neurosciences and social sciences. In G. Minati (Ed.), *Multiplicity and interdisciplinarity* (pp. 85–92). Springer.

McClintock, B. (1984). The significance of responses of the genome to challenge. *Science, 226*, 792–801.

Millham, R. C., Agbehadji, I. E., & Freeman, E. (2023). Nature-inspired algorithms and smart city applications. In Wang, J. (Ed.), *Encyclopedia of data science and machine learning* (pp. 2251–2270). IGI Global.

Minati, G. (2022). Sistemi: origini, ricerca e prospettive. Proprietà sistemiche emergenti e intelligenza. In L. Urbani Ulivi (Ed.), *L'intelligenza della natura* (pp. 91–127). EUPRESS FTL-Cantagalli.

Minati, G., & Pessa, E. (2006). *Collective beings.* Springer.

Peirce, C. S. (1857–1866). On the logic of science (Harvard lecture of 1865), Lecture II e Lecture VIII. In M. H. Fisch, C. Hartshorne, & P. Weiss (Eds.), *Writings of Charles S. Peirce* (Vol. I 1857–1866). Indiana University Press. *passim.*

Peirce, C. S. (1932). *Collected papers* (Vol. II, par. 636, 381). Harvard University Press.

Polanyi, M. (1966). *The Tacit dimension.* Doubleday.

Ripley, D. M., Quinn, F. A., Dickson, J., Arthur, J., & Shiels, H. A. (2023). Correction: Thermal preference does not align with optimal temperature for aerobic scope in zebrafish (Danio rerio). *Journal of Experimental Biology, 226*, 1–5.

Testa, R., Bonfigli, A. R., Prattichizzo, F., La Sala, L., De Nigris, V., & Ceriello, A. (2017). The "metabolic memory" theory and the early treatment of hyperglycemia in prevention of diabetic complications. *Nutrients*, *9*(5), 437.

Torralba, J. M., & Llano, A. (2008). *Intention.* Conference paper held in Rome, at the Pontifical University of the Holy Cross, international conference about G.E.M. Anscombe, 28–29 February.

Torralba, J. M., & Llano, A. (2010). Representación y conocimiento pràctico. In *Thémata. Revista de Filosofía. Número* (Vol. 43, pp. 435–461).

Trewavas, A. J. (2009). What is plant behaviour? *Plant and Cell Environment, 32*, 606–616.

Trewavas, A. J. (2014). *Plant behaviour and intelligence*. Oxford University Press.

Trewavas, A. (2016). Intelligence, cognition, and language of green plants. *Frontiers in Psychology, 7*(588), 1–9. https://www.frontiersin.org/articles/10.3389/fpsyg.2016.00588/full

Urbani Ulivi, L. (2016). L'abduzione come momento della scoperta in contesti di realtà. Abduction is the inference that discovers a solution in problematic contexts. *Cassazione Penale*, *LVI*(5), 2240–2251.

Urbani Ulivi, L. (2022). Leggere il libro del mondo. In L. Urbani Ulivi (Ed.), *L'intelligenza della natura* (pp. 129–156). EUPRESS FTL-Cantagalli.

Whippo, C. S., & Hangartner, R. P. (2006). Phototropism; bending towards enlightenment. *The Plant Cell, 1*(8), 1110–1119.

Wuchty, S. (2014). Controllability in protein interaction networks. *Proceedings of the National Academy of Sciences, 111*, 7156–7160.

Zhang, Y., Liu, G., Yan, J., Zhang, Y., Li, B., &. Cai, D. (2015). Metabolic learning and memory formation by the brain influence systemic metabolic homeostasis. *Nature Communications, 6*, 6704. https://doi.org/10.1038/ncomms7704