# Systems Science and Collaborative Information Systems:

## Theories, Practices and New Research

Emilia Currás
*Autonomous University Madrid, Spain*

Nuria Lloret Romero
*Universitat Politècnica de València, Spain*

Information Science
REFERENCE

| | |
|---|---|
| Managing Director: | Lindsay Johnston |
| Senior Editorial Director: | Heather Probst |
| Book Production Manager: | Sean Woznicki |
| Development Manager: | Joel Gamon |
| Development Editor: | Myla Harty |
| Acquisitions Editor: | Erika Gallagher |
| Typesetters: | Adrienne Freeland |
| Print Coordinator: | Jamie Snavely |
| Cover Design: | Nick Newcomer, Greg Snader |

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com



Library of Congress Cataloging-in-Publication Data

Systems science and collaborative information systems: theories, practices and new research / Emilia Curras and Nuria Lloret, editors.
p. cm.
Includes bibliographical references and index.
Summary: "This book examines the impact of new information services on day-to-day activities from a range of contemporary technical and socio-cultural perspectives"--Provided by publisher.
ISBN 978-1-61350-201-3 (hardcover) -- ISBN 978-1-61350-202-0 (ebook) -- ISBN 978-1-61350-203-7 (print & perpetual access) 1. Information science. 2. Information organization. 3. Information retrieval. I. Curras, Emilia. II. Lloret, Nuria, 1966-
Z665.S895 2012
020--dc23
2011038480

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

# Chapter 3
# Information:
## A Multidimensional Reality

**José María Díaz Nafría**
*Universidad de León, Spain & Science of Information Institute, USA*

## ABSTRACT

*Making an incursion in the forest of problems and theories of information, beyond observing a lack of mutual understanding among information theorists, we find out that information can be understood as a multifaceted reality. The variety of theories is in itself a reflection of the complex nature of information. A systematic approach to these theories, looking for common and divergent understandings render– so to speak – a cubist picture of what information really is, showing for instance its multi-dimensionality. In other words, when we say there is information in cables and organisms, in antennas and societies, in robots and mental states, we do not have to be mistaken: information is considered in each case in different aspects.*

*Delving into the nature of observation, we will find a solid ground to pose information as a bridge between objects and subjects, therefore providing the possibility to overcome the inveterate segregation of the objectivist and subjectivist understandings. As we will see, such vision also provides the possibility to articulate an understanding of information in its multifaceted reality.*

## 1. INTRODUCTION

*"It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field." (Shannon, 1993, p. 180)*

*"And just as the same town when seen from different sides will seem quite different – as though it were multiplied perspectivally – the same thing happens here: because of the infinite multitude of simple substances it's as though there were that many different universes; but they are all perspectives on the same one, differing according to the different points of view of the monads." (Leibniz, Monadology, §57)*

DOI: 10.4018/978-1-61350-201-3.ch003

In the "information age," finding the current variety of meanings of information is surprising. What is understood by information in the streets, in the industry, in courts, in physics, biology, psychology, sociology, technology or philosophy is so diverse that we could hardly find a common understanding among all these points of view. In contrast to this current situation, in the "age of iron," it was very clear what iron was – probably not regarding its nature, but concerning its usage. The iron brought about a whole spectrum of new possibilities with respect to previous materials: its hardness with respect to cupper and its facility to find the raw material determined a clear difference that caused a change in the technical possibilities evolving in new tools, larger production, greater resourcing and subsequently a cultural and social change. The techniques for producing implements or the understanding about its cosmological origin could differ among different peoples, but the basic properties of hardness and abundance in addition to others common features of metals constituted a common point for any understanding of iron. On the other hand, the materiality of iron provided an ontological toehold for its apprehension, a sure reference – especially from an antique worldview – for the semantics of iron. However concerning information, neither a common understanding, nor a fixed ontological support can be found in the allegedly age of information.

Historically, the usage of information evolves from Greek and Latin roots embracing the fundamental beliefs of each epoch: the objectivist aspects in antiquity, the subjectivist ones in modernity (Peters, 1988; Capurro and Hjørland, 2003). In a bird's eye view, the ontological senses of antiquity (related, for instance, to the *corporaliter* – bodily – values of the Latin information; and coexistent with some epistemological uses in moral or pedagogical contexts) were superseded by the dominancy of pure epistemological senses in modernity. However, since the second half of the XX century this usage started to differentiate, driven by the particular visions of each discipline –either professional or scientific –, at the same time that the objectivist and ontological values of antiquity were recovered, mixed with the subjectivist and epistemological ones still dominant in the ordinary usage (Capurro, 1979, 2009; Segal, 2003; Díaz, 2010a). This differentiation in the use of "information" led to the following consequences: (i) scattering of the different understandings of information and the subsequent gaps among each use, (ii) the belief that information can be useful for anything, (iii) the possibility to bridge between apparently irreconcilable disciplines by means of delving into the common roots among each usage.

These three consequences, which can be observed by means of a detailed scrutiny in the evolution of the concerned scientific disciplines (Segal, 2003; Lyre, 2002), represent extreme positions. The two first poles could be metaphorically branded by the bible images of the Babel tower (complete misunderstanding of multifaceted usages: information for each) and Pentecost (perfect understanding by means of a too general abstraction equidistant from any position, though endangered by empty content: information for all). A third pole corresponds to a midterm mediating between the detailed specificity of the multifaceted usage and the complete abstraction of a general understanding too broad to be useful.

If we intend to vertebrate our information societies around the backbone of information, as the new culture of iron did with respect to the well recognizable new material, we also need a clearer and common understanding of information. Since we have to solve the many problems arisen in our societies and we allege to use information as a new means for bringing about a change in our cultures: we need a clear understanding of information for handling, managing producing and using information in order to meet social needs. If we pursue a *Babel* approach, cooperation, communication and knowing will enter a dissolving path; if we pursue a *Pentecost* approach, we will loss the possibility to come into the specific problems arisen in personal and social life. Therefore, we need the previously pointed out intermediate via in which different domains can bridge their particular endeavors with a common and articulated understanding of information in different realms.

For providing the necessary bridges between different professional and scientific domains, we must satisfy the following requirements:

1. The nature of information has to be clarified. First, because – according to the aforementioned duality in the historical uses of "information" (material/immaterial or objectivist/subjectivist) – we do not have a sure support for our semantics of information as in the case of iron. Second, because we use science for solving our technical problems, and science seeks for the nature of its investigated objects.
2. The multifaceted dimensionality of information has to be clarified in order to articulate the different uses in each professional or scientific domain, because the complexity of our technical and scientific system cannot be resumed in a holistic approach of everything capable to address the specificity of each realm.

## 2. THE NEED OF A NEW ORGANIZATION OF SCIENCES FOR THE UNDERSTANDING OF INFORMATION

### 2.1 Analyticity and the Historical Evolution of Modern Sciences

From the viewpoint of the positivistic organization of sciences, the crucial requisite to beware for a good division of the scientific labor concerns the fulfillment of the adequate methodology in the search of knowledge. This assumption is rooted in the very foundations of modernity, which seeks "the true Method to bring me to the knowledge of all […] things, of which my understanding was capable." As Descartes realizes, such method needs "to divide every [difficulty], which I was to examine into as many parcels as could be, and, as was requisite the better to resolve them." (Descartes, 2008, pp. 27, 30). Thus, the analyticity of reality (in the sense that it can be divided for its independent scrutiny and the subsequent addition of partial results) constitutes the cornerstone of the scientific method of modernity and the positivistic division of the scientific labor from XIX$^{th}$ century onwards. However, such division of scientific labor also depends on: (ii) the increase of observation means, (iii) the complexity of the observed reality and (iv) the complexity of the involved theories (Solis & Selles, 2005, §23).

If we inquire into the historical support to the philosophical *positivism* and its more radical beliefs, we observe a quite intricate evolution. Its foundations were refused since the beginning of the 20$^{th}$ century, then revitalized in a refined manner in the so-called *neopositivism*, which after the critiques of Popper and Kuhn – among others – lead to the development of the *postpositivism*. Finally, in our days, the basic stance of a non-radical positivism might be identified in a wide variety of forms supported in confrontation with other anti-positivistic stances (Bullock et al, 1999; Comte 1844; Kuhn, 1962; Rorty, 1988). However just focusing on the classical or positivistic division of sciences, we observe that in the articulation of the academic and scientific system such division has been deepened throughout the 20$^{th}$ Century until our days, crystallized in the current countless division of scientific domains. In contrast to this fact, the vanguard discoveries of the early 20$^{th}$ century in physics and mathematics (i.e. the two pillars of modern science) showed: (i) the non-analyticity of the simplest reality and (ii) the non-analytical verifiability of the most elementary mathematical theories (Calude 2005).

Highlighting these facts of the historical development of sciences, and stressing the non-analyticity of reality or thought, we are not pursuing to withdraw the validity of the very analytical method, but rather to underscore its limits and to mark off its domain of application. Thus, it is not that the analytical method is invalid in the inquiry of the investigated reality; simply, it does not suffice to support a valuable account of reality. If – in our inquiries – we analyze reality considering its parts, its properties, its relations among parts, its organization in structures, etc., we should right after come back to the actual manifestation of reality, being ready to refuse our previous analysis, to find new models and maintaining a critical stance among the theories devoted to explain each domain of reality. The circularity or non-analyticity of the scientific method, and even of the mathematical method, is paradigmatically expressed by the Quine-Duhem thesis (Duhem, 1962; Quine, 1953) and Gödel's theorem of incompleteness (1931). Such non-analyticity puts forwards that a critical stance is needed, that theories are not only analytically supported but also synthetically adopted and rejected, and therefore the scientific method is properly a combination of analysis and synthesis, evolving in endless cycles of analysis, theory building and confrontation with reality (Popper, 1959; Kuhn, 1962; Lakatos, 1978; Laudan, 1977). This is the sense we will adopt when referring to the non-analyticity of reality or theories.

## 2.2 Methodological Quest (The Articulation of Disciplines)

Despite the non-analyticity of our confronted reality, we cannot achieve a theory of all. As we mentioned above, that is because the division of sciences is not only grounded in the analyticity principle, but also in: the increase of concerned problems linked to the rise of observation means, the complexity of the attended reality and even the complexity of the set of accepted theories. All this is just too much to put in the same box. Therefore it defies the purpose of reconciling the diversity of problems of the social and scientific life with the necessary unity of the different approaches as to make them converge into the non-analytical challenge of our time (be it concern with the organization of matter, with the complexity of biological life, or the complexity of society). To this end, we need a proper articulation of disciplines into an inter- or trans-disciplinary framework capable to delve into the very complexity of our problems, and particularly into the multifaceted reality of information.

The multidisciplinarity, frequently claimed for the solution of complex problems, is not enough since it corresponds to the belief in the analyticity of reality that is to be overcome. On the other hand, transdiciplinarity might be seen as a long-term objective which feasibility is not proven – i.e. the integrative, abstract and united vision for all the involved disciplines. Therefore, interdisciplinarity is the intermediate via that seems to be more reasonable to pursue. Since no unified vision is beforehand assumed, it is methodologically feasible and furthermore it might asymptotically converge towards the erection of a unified vision – namely, the basic objective of the transdisciplinarity. Recalling the aforementioned poles of Babel and Pentecost: multidisciplinarity might be branded as a "disciplined Babel"; transdiciplinarity as an "articulated and moderated Pentecost".

## 2.3 Bridging Cultural Gaps

But not only among scientific disciplines, the evolution of science has built incommunicable walls, also between the science system as a whole and social life, what makes the incommunicability among disciplines deeper since the social level does not serve to bridge among sciences (Ortega, 1932, §12). This segregation of scopes brings about an allegedly irreducible difference among "the *manifest* and the *scientific* images of man-in-the-world" (Sellars, 1962, §I). While the former describes the way the world stands as grasped in the language commonly used in our interaction with it (therefore including: intentions, conventions, appearances, etc); the scientific image describes the world in terms of causality, regularities and theories, usually leaving apart moral claims. This presence or absence of normative vs truthful aspects might be regarded as a basis for the complementarity –as Sellars argued (1962)-. However, such complementarity is hindered by the reference to incommensurable realities.

This lack of understanding, pointed out by Sellars, is also close related to "the gap between the two cultures of (natural) science and social and human sciences that has to be considered in approaching information – a gap between the natural and the engineering sciences (including formal sciences) on the one hand and the arts and humanities (including the social sciences) on the other hand that dates back to the 17th century" (Hofkirchner, 2009). This cleft is often referred as the Snow's dilemma in terms of the opposition among these two cultures – of sciences and humanities – that this scientist and writer regretted in 1959 (Snow, 1998). Thus, the dilemma can also be translated into the relevance of objectivity – of the science image – vs the relevance of subjectivity – in which the manifest image and the humanities are rooted.

To this respect, the aforementioned blurred position of information between objectivity and subjectivity or material and non-material aspects – argued as a problem for a good understanding of information – might create the conditions for bridging this gap as we will see below. On the other hand, as Weaver pointed out at the early scientific development of the information concept, information is actually being "found when the parts are viewed in association", and it is in the assembly of the parts that other human and social values (for instance, ethical or aesthetical values) are discerned (Shannon and Weaver, 1949, p.28). Moreover, as Lyre (2002) argued, information might also serve for bridging over physical, biological and cognitive sciences. Hence, information might offer the possibility for interweaving the scientific and social fields, overcoming the traditional segregation of scopes, which has hindered the confrontation to the non-analytical challenges of our social life. However, to this end, information must be properly understood with respect to its nature, to its different dimensions, and to how it relates to the other realities, grasped by our system of scientific visions.

## 3. AN OVERVIEW ON INFORMATION VISIONS

For delving into the manifold understanding of information, let us start considering a historical common ground. Being the 1950s the period in which information science properly emerges as to acquire an active and notorious presence in science and society, Shannon's seminal work of 1948 ("A Mathematical Theory of Communication", in short MTC), undoubtedly represents a landmark in the development of the information understanding, or more properly, understandings. In this early formulation of MTC (which has also been branded as "information theory"), Shannon curiously starts referring to the common use of information with its semantic aspects (to which Weaver later adds the pragmatic ones). However, he immediately after redefines the concept within an engineering framework, losing these basic dimensions, and paying exclusive attention on the *syntactical* aspects of *information* (Shannon & Weaver, 1949; Floridi 2005a-c, Capurro 2009).

MTC focuses its efforts on the quantitative determination of information, deepening into those features of information that are indeed intuitively quantitative, especially in the contexts of encoding, storing and transmitting information. For instance, it is prima facie admitted that information may be additive, non-negative, depending on the number of distinctions that it permits to do, etc. (Floridi 2005a). Despite of this devotion to the syntactic aspects of information, Weaver admits that "the concept of information developed in this theory at first seems disappointing [...] because it has nothing to do with meaning", however he considers both semantics and pragmatics as strongly constrained by the syntactical analysis. Furthermore, "this analysis is so penetratingly cleared the air that one is now, perhaps for the first time, ready for a real theory of meaning." However, regardless of several attempts to clarify semantics and pragmatics of information, this does not seem to be the case (Floridi, 2005c), at least in a generally agreed sense.

Any qualitative approach to information shows the relevance of both its *semantic* dimension (whereby the signals or symbols considered by the MTC are necessarily referred to something) and its *pragmatic* one (whereby information is the foundation for action, either by intentional actors, living beings or automatic systems). This does not simply mean broadening the attributes or details of what we refer as information, but also an important negative limitation driving to exclude what could not be discriminated at a merely syntactical level, in which – going beyond Weaver's distinctions – we can even include more levels or aspect of information (Gitt 1996; Collier 2011).

As pointed out by Machlup and Mansfield (1983), this negative limitation can be illustrated by considering the requirements that human contexts normally impose on the legitimate meaning of information, i.e. need for truth, value, innovation, surprise or reduction of uncertainty. This would classify as non-informative those messages that – even complying with all syntactic requirements – were false, incorrect, useless, redundant, expected or promoters of uncertainty. To this regard, the MTC could not say much; neither could any other just syntactical approach. As Burgin stated, although MTC provided effective means for measuring information in some contexts, "without understanding the phenomenon of information, these formulas bring misleading results when applied to irrelevant domains" (2003, p.147). Thus, the multifaceted aspects of information had to be deepened as well as analyzed their respective constrains.

To this end, each discipline – after accounting the syntax in their particular fields – had to delve into the aspects of information beyond the syntactical ones. However, constrained to the objective of theoretical coherence at each discipline, this brought about a panoply of alternatives and criticisms since the MTC was formulated (often in a vague, limited and confusing manner). Such alternatives can be systematically overviewed considering: (i) what stance they take up concerning the objective-subjective dilemma; (ii) what dimensionality is being covered (particularly concerning how they cover the syntactical, semantic and pragmatic aspects of information); (iii) what disciplines has contributed to its development.

## 3.1 How Is the Nature of Information Conceived in the Information Theories?

The fact of being considered as something *objective* or not is perhaps the main distinction that can be made concerning what is understood by i*nformation* (Capurro & Hjorland, 2003). If it is objective, it will be independent from mental states or user's intentions; if it is *subjective,* it will necessarily depend on the interpretation of a cognitive or intentional agent. Between both poles, an intermediate approach might be adopted, according to which information does not need to be considered as something having its own entity or something belonging to subjectivity, but rather in terms of a *relationship.* This may enable an action to be executed, an order to be obeyed, a structure to be established, or simply it allows a behavior, adaptation or an interpretation – even though it might be referred to some type of intentionality.

**Objectivistic pole.** In the extreme position of *objectivist* categorization, information is deemed as a third metaphysical principle, in the sense expressed by the popular Wiener's adage: "Information is information, not matter or energy" (Wiener 1948, p. 132; Günther 1963). This principle is sometimes associated with a teleological description of the universe as it happens in Teilhard de Chardin's "noosphere", to which also Stonier refers (1991), or in an openly theological "cosmovision", as in Gitt (1996). Regarding the MTC, it remains unclear if the authors consider information as objective, substantial (as sometimes interpreted) or by the contrary it refers to the uncertainty concerning the identification of the received signals by the recipient. This second interpretation seems closer to the interests in which the theory was developed (Shannon 1948, 1949).

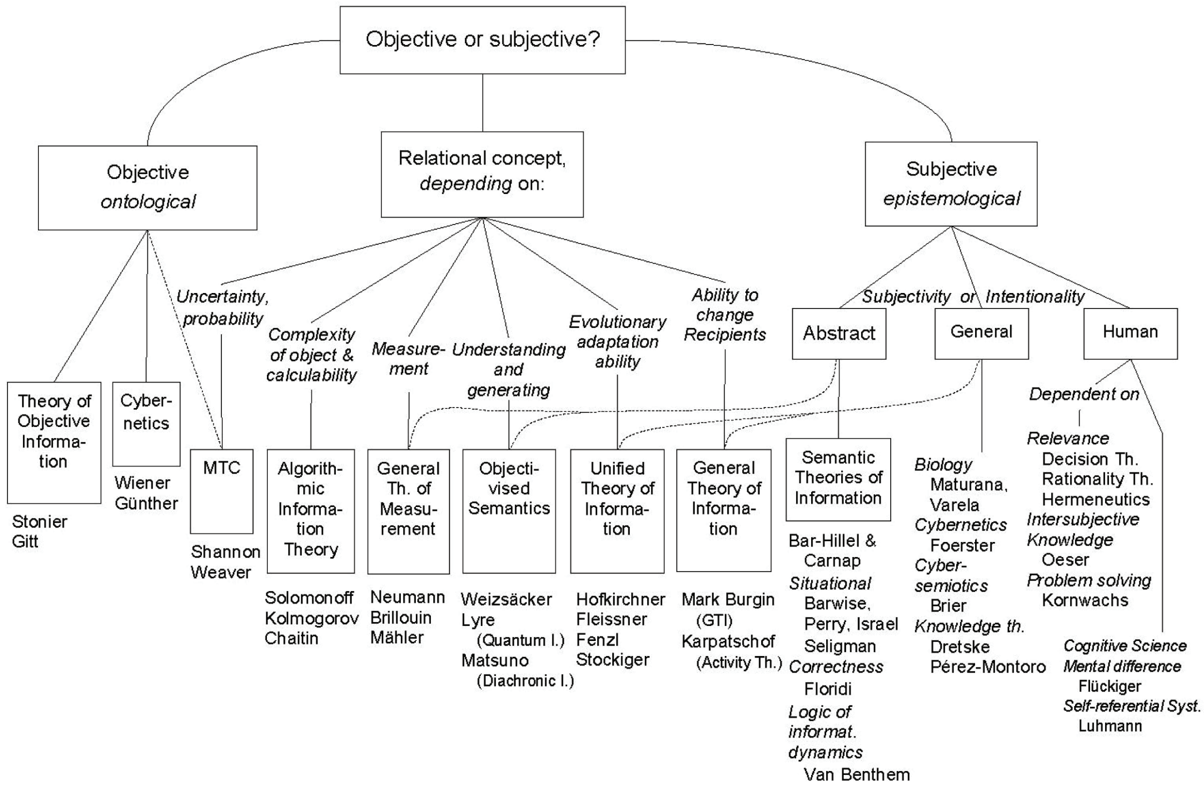
Figure 1 shows in a bird's eye view – without attempting to be exhaustive – a significant number of theoretical viewpoints. These theories are collected in groups labeled not always as the authors do, but referred to some key and common elements of the approaches, grouped together. This taxonomy arranges different information concepts with respect to its greater or lesser subjective nature. On the left, the most objectivist theories are placed; on the right, the most subjectivist ones, and centered, a range of intermediate theories that normally adopt a two-fold approach. This is, for instance, the case of Weizsäcker's dual concept of his *objectivised semantics*, in which information is defined as: (1) what might be understood (even if it is done by an abstract intentionality) and (2) what generates information (Weizsäcker 1974, p. 351).

**Relational pole.** As shown in Figure 1 for those visions in which information is conceived as a *relational* or mediating concept, the kind of relation that mediates between objects and subjects (considering the later in a broad sense) can be multifarious. Following the differences referred to in Figure 1, information might be dependent on:

- *Reception probability or uncertainty* of recipients as in MTC (Shannon, 1948).
- *Measurement* processes, as in the general theory of measurement (Neuman, 1932; Brillouin, 1956; Mähler, 1996);
- The *complexity of a referred object* to be reconstructed, or complexity of a process to be carried out, as in the "Algorithmic Information Theory" (Solomonoff, 1964; Kolmogorov, 1965; Chaitin, 1966; 1982a). Despite the apparently objective definition of "information content" within this theory, it has been branded as relational because, since it is actually referred to a non-calculable value, what is in fact calculable dependent on the actually available semantics (Lyre, 2003, pp. 38-40).
- The *understanding potentials and generating facts* of the mentioned "objectivised semantics" (Weizsäcker, 1974) and other related or similar approaches as Lyre's information-theoretic atomismus (1998) or Matsuno's informational diachronism of evolution (1998);
- The *evolutionary adaptation ability* of self-organizing systems as in the "Unified Theory of Information" (Hofkirchner, 1999);
- The *ability to change recipients* as in the General Theory of Information proposed by Mark Burgin, whose formal model provides a framework for the articulation of most points of view on information (2003, 2010) or in Karpatschof's *activity theory*, in which information is also regarded in its ability to cause changes in what the author names a *release mechanism* (2007).

As illustrated in Figure 1, this relational character implies sometimes the reference to a certain kind of subjectivity or intentionality. This is, for instance, the case of the *Unified Theory of Information* (UTI) which is frequently presented as a mediator of all points of views without falling into reductionism (bottom-up approaches) or holism (top-down approaches) (Fenzl & Hofkirchner, 1997). The UTI appeals to a certain degree of intentionality, not necessarily human, that we call *general*. The complexity may present different de-

*Figure 1. Taxonomy of theories based on information as something objective, relational or subjective*




grees depending on the process this theory refers to (i.e. adaptation of systems with a greater or lesser complexity, which is also related to the degree of intentionality achieved). Nevertheless, trying to give account of all processes and to explain the emergence of more complex auto-organizing systems, this approach also refers to the organization of physical systems without intentionality. Thus, intentionality belongs to the realm of the most complex systems (normally human or social) aiming to harmonize with diachronic structuring and organization from the most simple elements.

This kind of generality with respect to the complexity level of the system receiving information can be observed in the *General Theory of Information* (GTI). Here the recipient is modeled as a non-specific *info-logical system* that can be potentially changed by information. Such system may correspond to "a person, community, class of students, audience in a theater, animal, bird, fish, computer, network, database and so on", and therefore it is accordingly referred to different degrees of intentionality – even empty – (Burgin, 2010). If the recipient were just a physical system, information – as what represents potential changes in the system – coincides with energy, i.e., energy can be here envisaged as a kind of information in a broad sense, what does not represent a monist position. The embodiment principle stating that "there is always a carrier C" for information, which can be interpreted as a substance (2010) makes clear that monism is not the case of GTI.

**Subjectivist pole.** In case an *epistemological* point of view is fundamentally used (namely, information is considered as *subjective* or concerning some kind of intentionality – in a broad sense), the objective qualities of signals are left in a second plane, focusing on those regarded as relevant by subjects (interpreters). However, this does not mean that information is only interpreted from an anthropocentric point of view, or something just occurring inside minds. Sometimes indeed, an *externalist* viewpoint is adopted, reducing the role of intentionality with respect to information to a kind of correlation between facts, signals and behavior; or even as a reservoir in which previous received information is stored (Drestske, 1981; Díaz & Pérez-Montoro 2011a). In this broad sense, subjectivity is referred to an intentionality that can be:

1. **Abstract,** or formal, in the sense of a series of general conditions of representation and intellection of reality, as it happens in most of the semantic theories of information (Bar-Hillel & Carnap, 1953; Barwise & Perry, 1983; Barwise & Seligman, 1997; Israel & Perry, 1990; Floridi, 2004-2005c);
2. **General,** in the case of information as a construct of an observer (whether human or not), who finds differences in its circumstance, as suggested by Maturana and Varela (1980) from a biological approach, or by Heinz von Foerster (1981) from a cybernetic perspective (Brier, 2008; Dretske, 1981; Pérez-Montoro, 2007);
3. **Human,** in whose case the consideration of language (Wilson & Sperber, 1993), interpretation (Capurro, 2009), action (Benthem, 2003; 2008; Floridi 2005d), cognitive mechanisms (Flückiger, 2005) or social systems (Luhmann, 1987) become essential, while the quest for *relevance,* whether social or individual, *veracity* or relationship with *knowledge* turn into articulating aspects (Kornwachs, 1996, Oeser, 1976, Habermas, 1981).

If we intend to evaluate the epistemic relevance of each perspective, it is clearly neutral for objectivist conceptions (the value of information lies in itself and it is meaningless to speak of truth), while it can be considered subjectivist or not for those conceptions depending on intentionality, especially if they are linked to knowledge or semantic issues. To some extend when moving from left to right in Figure 1, we move from ontological to epistemological questions. The particular epistemic relevance will also depend on the attention paid to syntactical, semantic and pragmatic aspects.

## 3.2 What Aspects of Information Are Considered in the Information Theories?

### 3.2.1 Aspects, Dimensions and Levels of Information

The aspects or dimensions of information that each approach considers are also illustrative of their respective scopes and intentions. As mentioned above, both epistemological and ontological consequences will result from the aspects of information being covered by each specific information vision. For instance, if just the syntactical level is considered (as it was Shannon's intention in 1948), the question about the truth of the content is meaningless, whereas the way toward the objectification of information is maximally feasible. On the other hand, when pragmatics comes on stage, other issues, such as value or utility, substitute the question of truth.

For the sake of simplicity, we will just compare how different information theories cover the three fundamental aspects of information referred to by Shannon and Weaver (1949). These fundamental aspects comes from the disciplinary division proposed by Morris, following Peirce's definition of sign as what is linked to the sign itself, to the object, and to the subject respectively (Morris 1938). Nonetheless, we could broaden the dimensions of information as to consider in a hierarchical vision other levels, enriching the distinctions introduced by Morris' categories. For instance, Gitt (1996) proposes a *statistical* level under the syntactical one, and an *apobetic* level above the pragmatic one. The former is conceived as exclusively referring to stochastic properties of signals, without any consideration of syntactical rules or structures as used in our linguistic communications, i.e. not distinguishing grammatical correctness. On the other hand, the apobetic level (from the greek *apobeinon*, purpose) is concerned with the fact that the result of the information reception is based on the purposes, objectives, plans… of the partakers. However and despite the relevance of distinguishing these aspects, these and other distinctions can be subsumed within the limiting levels (the statistical aspects in the syntactic one; the apobetical aspects in the pragmatic ones).

Hence, we will here just consider the *syntactic*, *semantic* and *pragmatic* dimensions, which can be characterized by means of three major questions: 1) concerning the *syntactical* content, "How is it expressed?"; 2) for the *semantic* content, "What does it represent?" as well as "with which truth value?"; and, 3) for the *pragmatic* content, "What value and utility has it?".

Although in communicative or information-transmission processes, speaking about transmission of semantic contents without expression is clearly meaningless, and such contents are in turn necessary to identify the pragmatic contents, it is still unclear to what extent each question determines the other two. Although the three regarded dimensions are usually regarded hierarchically (being the syntactical aspects at the lowest level and the pragmatic aspects at the highest level), such hierarchy will not be considered here for comparison because different positions are held to this concern. On the one hand, the degree of freedom that each aspect lets the others depends on the adopted point of view; on the other hand, usually some of the mentioned levels are not considered at all, and furthermore, sometimes the levelism is simply avoided.

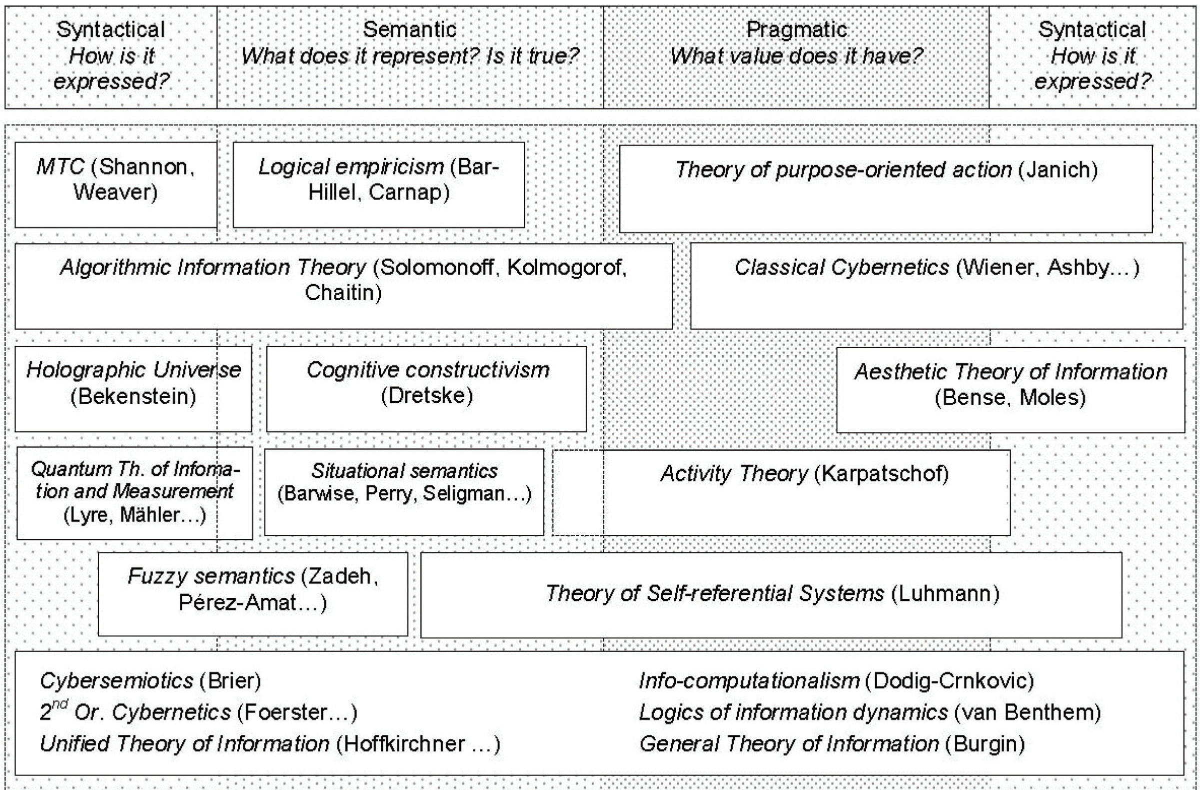
Thereby, whereas the MTC is only related to the syntactic dimension – regarding the other two beside the point –, some semantic approaches consider the semantic question strongly restricted by Shannon's information – such as in Weaver (Shannon & Weaver 1949) – and others consider it as a weak restriction that allows a larger margin of freedom (Sloman 1978, Floridi 2005c, §4). To this respect, it is worth mentioning there are good reasons to consider that a simple noise (for instance, due to the thermal erratic movement of electrons in a resistor) does not meet the requirements commonly attributed to information, though it were maximally pondered by the MTC in terms of entropy or amount of information. On the other hand, a single bit might tell us if the Ptolemaic universe is or not the case or if a war has begun, which might drastically change our worldview or our expectations, i.e. with mostly significant syntactic or pragmatic consequences at each case. Weizsäcker's distinction between *potential* and *actual* information might provide –as we will later argue– some clarity to this confusion (1974).

### 3.2.2 The Coverage over Syntactic, Semantic and Pragmatic Aspects

In Figure 2 (which, as Figure 1, does not intent to be exhaustive), the extent to which each concept answers to the posed questions about the multi-dimensionality of information is shown.

**Syntactic dimension.** Shannon's information and those developments trying to supersede the inconsistencies with respect to modern physics epistemology are chiefly located at the syntactical plane (e.g. quantum information theory, or information according to the holographic principle). The last-mentioned cases are represented as partially covering semantic aspects, since – contrary to the classical MTC concept – there is a certain degree of indeterminacy in the description of reality by means of data, implying that information is necessarily mediated by theory. However, this consideration rather belongs to an epistemological level concerning the observation and measurement of reality, therefore not referring to

*Figure 2. Aspects of qualitative content, covered by different information concepts. To facilitate the representation of inclusion/exclusion of dimensions for each theory, the syntactical one is located both on the left and on the right.*




what is commonly understood as semantic aspects of information. To some extent, it can be regarded as an additional limitation at the syntactical level with respect to MTC assumptions. For instance, the fact that Von Neumann's entropy, related to quantum states, is smaller than Shannon's entropy, since the latter assumes the possibility of independency among the parts of a system, namely the analyticity of reality previously discussed (Neumann 1932).

**Semantic dimension.** If only semantic questions are to be accounted – in many cases intending to complete Shannon's programmatic neglect to this question –, there are a significant number of proposals. These semantic approaches present important internal differences hardly reconcilable, as they are rooted in atavistically opposed assumptions, such as empiricist, constructivist or rationalist positions. Thus, although the semantic value of a proposition – assumed as informative – is usually referred to probabilistic computations (inspired by Shannon's quantification model) and the "Inverse Relationship Principle" is followed, linking the increase in information to the decrease in possibilities (Barwise, 1997), a different probabilistic approach can be found in each case:

- For Bar-Hillel's and Carnap's *logical empiricism* (1953), the probability space is based on the result of a logical construction of atomic propositions in a formal language;

- In Dretske's *cognitive constructivism*, the probability of the observed state of affairs is accounted (Dretske, 1981);
- In *situational semantics*, the probability of the space of states and the consistency from a certain contextual situation are accounted (Barwise & Seligman 1997);
- In Zadeh's *fuzzy semantics*, the categories used to define descriptors are associated to elastic constraints and fuzzy quantifiers (Zadeh 1986).

In a more integrated framework (i.e., bringing together several information dimensions) and differing from combinatory and probabilistic approaches, the *algorithmic information theory* conceives *information content* in terms of the minimal resources to reproduce (compute) something, whether a mere binary structure, an object, or the development of a certain operation (Somolonoff 1964, Kolmogorov 1965, Chaitin 1966, 1982a). Hence, by referring to the expressive resources required to perform something, this approach covers both the syntactic and the semantic issues. But, on the other hand, taking into account that certain codes are just aimed at doing something – purpose oriented – the pragmatic questions may also arise. Indeed, the complexity limit studied by Chaitin in relation to Gödel's incompleteness theorem and Turing's halting theorem can be interpreted as having a practical scope, since the knowledge background or the used/selected semantic frame actually limits what can be done, and therefore what can be pursued (Chaitin 1982a, 1982b, Lyre 2002, §1.4.2).

**Pragmatic dimension.** In an explicitly pragmatic sense, Janich's theory of information (1998) refers to purpose-oriented human actions seeking the replicability of such actions through artificial anthropomorphic devices articulated by standard interrogative dialogues, qualified by information predicates. Hence, a two-fold attention to pragmatic and syntactical dimensions is here found.

In a higher degree of abstraction regarding informative pragmatics, *Karpatschof's activity theory* (2007) reduces the syntactical field to that of qualities of signals with regard to a "release mechanism" which – so to speak – rules the roost. Thus, Karpatschof's approach focuses on the characteristics of this mechanism as a system containing potential and stored energy that can be released in a specific way, whenever trigged by a signal fulfilling certain conditions. One of the benefits of this proposal, concerning the possibility of finding an integrative framework for the understanding of information, is the lability of the signals requirements and the characteristics of the release mechanism. For instance, if the imposed requirements concern the satisfaction of certain truth or veracity constrains, the model will be linked to the knowledge problem, ready to delve into the semantic dimension of information. On the other hand, if the requirements are of aesthetic nature, the model will be linked to the problem of artistic information; and analogously, it could be adapted to the investigation of information in biological contexts (evolution or adaptation to the environment), social coexistence, etc. However, this model – though heuristically valuable – provides not enough theoretical resources to articulate such a framework as we can find in other integrative perspectives. However the complexity of our awareness, as well as the communication and interactions processes shows that this requires a detailed inspection and a subtle frame to give account of them, as it has been studied in the binding problem (Treisman, 1996), the perception-cognition-action cycle (Bruni, 2008), semiotics (Brier, 2008), hermeneutics (Díaz & Capurro, 2010), the complexity of social systems (Luhman, 1987).

**Integrative perspectives.** One of these – though biased towards the pragmatic pole – is Luhmann's *theory of self-referential systems* (1987). In this vision, information is conceived as a mediating instance between the "meaning offer" (typical of the cultural circumstance) and "understanding". Thus, semantic and pragmatic dimensions are closely related here, whereas social systems can be considered as both worlds of meanings or problem-solving worlds. This interrelation of pragmatic and semantic dimensions constitutes in Lyre's Quantum Theory of Information (1998) or Weizsäcker's semantic theory (1974) the condition for the possibility of the objectivisation of semantics. These theories address and unify the three fundamental dimensions of information (Lyre, 2002), while solving for the syntactical one the aforementioned epistemological defects of the MTC –especially in relation to the certitudes of quantum mechanics.

In a more hierarchical sense of the three dimensions of information, the *unified theory of information* intends to cover all problems related to information, such as physical-, organic- or social phenomena, by means of the self-organizing paradigm (Hofkirchner 1997, Fenzl & Hofkirchner 1997). In this approach, the three referred dimensions are considered as levels: the constitution of the syntactical level is the condition and substratum for the articulation of a semantic level, and this one is, in turn, the condition and substratum for the self-re-creation of a pragmatic level (Hofkirchner 1999a, 1999b). Such hierarchical approach is also shared by the objectivised information theories of Stonier (1999) and Gitt (1996) or in Collier's nested hierarchies of information (2011). For the latter, who arranges different kinds of information in a hierarchical or nested relation from the physical substratum to a kernel, represented by intentional information, each level imposes a restriction on the preceding levels; being such restrictions "created by the formation of cohesion through self-organization within the preceding level" (p. 8).

In the so-called *first order* or *classical cybernetics*, the pragmatic paradigm of achieving a proper behavior to cope with the surrounding reality, worked out as a fertile frame in which many different scientific visions could fit into a transdisciplinary approach. The results obtained, for instance, in control theory and the development of automatic systems speak by themselves. However, the posed outer vision, which meta-scientifically entails an epistemological anachronism, implies that the proper semantic dimension of information shall be sacrificed, what is understandable if animal or human intentionality had to be jostled with the motion of automata (Wiener, 1948; Díaz & Aguado, 2010). Considering the necessity to surpass this epistemological voids, von Foerster proposed a *second order cybernetics*, in which (reviewing the basic model of cybernetics, i.e., a system pursuing some goals and being observed from the outside) now the observer is an effective part of the system, asserting his own goals and his own role within the system. Although the semantic dimension was gained, this stance also branded as radical constructivism has been criticized as providing a cognitive closure in which objectivity is denied.

Related to this radical constructivist position, Søren Brier (2008) considers that information is not enough to account the reality of communication and cognition proposes, proposes a cybersemiotical approach to information connecting Peirce's semiotics (*sign*) with the *cybernetics of the second order*. Brier defines *cybersemiotics* in terms of a dynamic and contextually adaptive relationship between a sign, an object and an interpreter; while Capurro (2007) argues that Brier's approach can be regarded as a "hermeneutics of the second order that extends the concept of interpretation beyond human knowledge, relating it to all kinds of selective processes".

In the *info-computationalism*, proposed by Gordana Dodig-Crnkovic (2010) as a means to supersede the traditional mechanistic worldview, information is conceived as the ontological basis of the universe (its structure), whereas computation – in a broadened sense – represents its dynamics. This approach intends to cover from the physical, to the ethical domains going through biological and cognitive realms by means of levelism on the complexity of information. Dodig-Crnkovic argues that this frame opens a space for logical, epistemological and ethical pluralism. However, van Benthem and Martínez (2008) considers – regarding this pluralism – that "having several complementary stances in a field is fruitful itself" (§9), therefore instead of unification, they propose *dynamics of logics* for a wide inquiry of information in its variety of aspects (Benthem, 2003).

Finally, the *general theory of information*, proposed by Burgin (2003, 2005, 2010) – aware of the irreducible variety of information kinds –, instead of pursuing a unitary definition of information, seeks for a parametric definition in which information stands for a capacity to cause changes in an infological system. Thereby, this class of systems plays the role of a parameter, which allows embracing any kind of information from the most elementary, namely energy – as previously discussed – to cognitive and social changes. As Burguin argues (2003), this frame enables to integrate the syntactical, semantic and pragmatic aspect, as well as other significant distinctions involved in information phenomena, by means of refined definitions of the infological systems, at the same time that it provides a flexible means to measure and evaluate information (2003).

### 3.2.3 Dialogical vs. Syncronical Understanding of the Information Multidimensionality

As we have seen in the integrative approaches, delving into the reality of information requires crossing its multifaceted manifestation and finding the interrelation of its different aspects. However, we can distinguish two kinds of approaches according to the role played by the evolution of systems in the emergence of new properties of information. This dichotomy can be branded as diachronic vs synchronic, representing a dissimilar endeavor in different explanation domains.

In a *diachronic* account of information as in the UTI – considering here several strives in the same direction –, understanding is sought on how the manifold reality of information phenomena can evolve from the most simple to the most complex cases. On the other hand, an account as the GTI provides a framework for representing any kind of information synchronically. Although GTI refers to systems dynamics, and even in a very detailed way, it does not focus on how the systems evolve in order to make, for instance, new properties emerge. In both cases, crossing through the many aspects of information – namely being able to cover its multidimensional reality – is a toehold of the complete theoretical building.

In diachronic accounts, information phenomena can evolve from the very simple organization of matter to higher organization of more and more complex structures. Here, the effects of information are dependent – in a decreasing deterministic way – of subsystems that interact with each other and manifest the many aspects of information. Let us for instance consider three cases: cognition, communication and cooperation. In case of *cognition*, the involved subsystems can be regarded – in the syntactical level – as the sensitive structures that arrange sensation in different modalities of perception. By means of interaction, these modalities allow to grasp a sensed reality – in a semantic level –, which bring about some kind of change in the system state depending on the pragmatic situation. Here, it is the pragmatic situation what mainly opens the system to its environment. In case of *communicative* processes, one of the fundamental subsystems is the symbolic system shared by a community, which represents an openness of the system at the semiotic level, or just the necessity to be chiefly referred to social systems. In case of *cooperative* processes, the system of goals, means and agents become essential.

Nevertheless, such diachronic accounts – as in the case of biological evolution – are hindered by circularity: the changes that are produced are those been produced. We do not have a path to predict them. In other words, the footprints left by the evolution in the complexity of the involved systems are not enough to distinguish what path the systems really followed. However, it heuristically provides a ground for understanding the dynamics of the system evolution, as well as a simple hypothetical ground that avoids the necessity to maintain a more complex system of assumptions.

On the other hand, in the synchronic account pole, the flexibility of the framework provided by the GTI allows us to adapt the different types of information (unfolded in its multifaceted dimensions) into an explanatory system. This perhaps does not give account on the long-term evolution of complex systems in its interaction with information, but it is suited to provide a perspective on its short and mid-term dynamics as well as on "how to measure or, at least, to evaluate information" (Burgin 2003, p. 148), which in the age of information is a major concern.

## 4. NATURE OF INFORMATION: IN THE INTERFACE BETWEEN OBJECTS AND SUBJECTS

As we argued in section 2, it is the blurred position of information between objects and subjects – instead of a problem – a privileged standpoint for bridging over the traditional gap between the objectivist and subjectivist stances, and moreover among specialized sciences. For deepening into this radical position of information, let us consider the problem of observation.

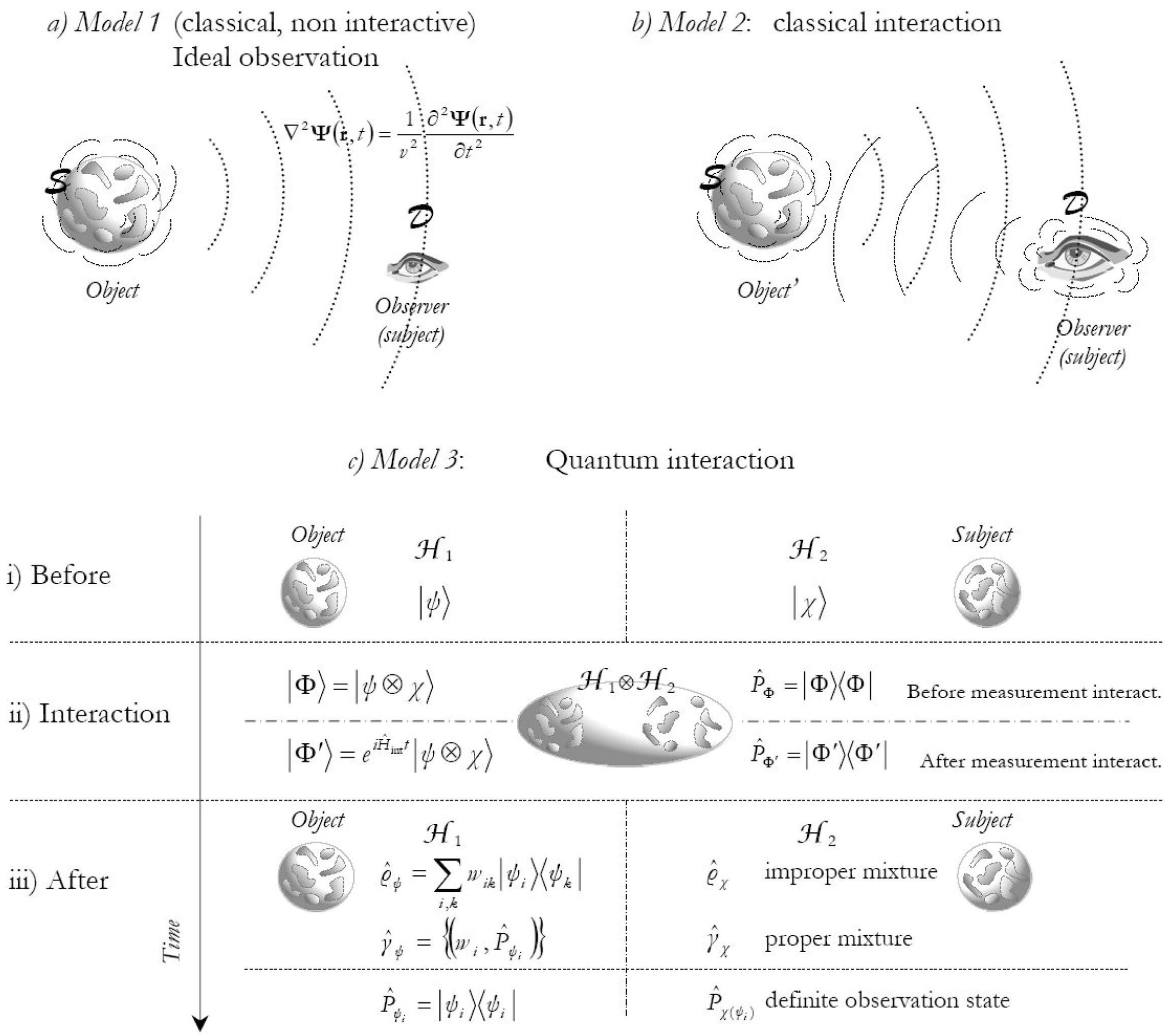
### 4.1 Observation Scenarios

When a subject is confronting an object of observation, this scenario can be modeled in different ways concerning the relevance and nature of the interaction between them. As we know from the quantum mechanics, the interaction is actually inherent to the nature of observation (Lyre, 1999). However, such interaction can be minimized as to consider the classical picture of neutral observation as approximate enough (model 1: ideal observation), and we can even develop a model of interaction in which a classical approach can be followed to delve into the complexity of observation (model 2: classical interaction). Nonetheless, as we know, quantum interaction provides a more proper and exact account on the real interaction process (model 3: quantum interaction).

An exact account on what is really happening is strictly out of reach since the non-locality of quantum theory might bring us to the extreme consequence that we should consider the Universe as the collection of all physical objects into one and the same wave-function. Regarding this theoretical extreme stance, Heisenberg said: "if the whole Universe were included into the system, the physics would disappear, leaving only a mathematical schema" (Heisenberg, 1930, p.44 –my translation).

For the sake of simplicity, we have restricted here our scope regarding a very simplified universe constituted by an object and a subject of observation. Figure 3 represents this simplified situation for the aforementioned three models of interaction. Although, the ideal observation (Figure 3.a) is not exact, the model might be accurate enough when the intensity of the interaction is so weak that it makes no significant difference, for instance, when the observer is far apart and its dimension is small with respect to the distance between relevant differences of the wave phenomena. In this case, the structure of the wave phenomena $\boldsymbol{\Psi}$ occurring in the allegedly homogeneous space surrounding the sources is described by the wave equation as represented in the figure, and the changes produced in the observation means are in direct relation to this phenomenon. We will later on delve into this case to inquire into the limits of the manifestation of the object, since – being this an ideal case of observation – the other models add even more limitation to the knowledge that can be achieved from the information, provided by the observation (§4.2). But before going into these details, let us glance into the other models.

*Figure 3. Three models of observation: a) ideal (valid for too weak interaction); b) classical interaction in which the energy detected by the observation system acts as a new source that affects the object; c) quantum interaction*




**Classical interaction**. For the classical interaction (Figure 3.b), the relation between the object and observation system can be interpreted in a recursive way, by using a linear relation as the one that will be used below to describe the ideal observation. Such relation shall be determined between a set of equivalent sources properly distributed over the surface surrounding the object S and the phenomena, represented by another set of equivalent sources over the observation domain D. In a first step, the set of equivalent sources at D is modified by the particular distribution of equivalent sources at S. Subsequently, the equivalent sources at D affect the object sources by means of a new wave phenomenon – weaker than the former one –, producing a transformed set of sources – slightly different to the original ones. In subsequent iterations the sets of phenomena at the observation domain, and the set of sources will asymptotically tend respectively to what has been observed and to the modified object. To some extent, the observed phenomena is directly related to the modified object, not to the observed object, as it was before being observed, although this can be figured out. Concerning the interaction and despite of this invertibility, what matters is that the object has changed, and the fact that the object at this moment is something indivisible from such interaction. However, it is also true that from this classical point of view the initial state could be recovered.

**Quantum interaction.** Something else happens with the quantum interaction (Lyre, 1998; Vedral 2006). Here the object and the observing systems – formerly at an original state in their respective Hilbert spaces $k_1$ and $k_2$ – mix into a new quantum system at the product Hilbert space. The state of this mixture $|\Phi\rangle$ (a pure state with a projection operator $\hat{P}_\Phi$) is changed by the measurement interaction into another pure state $|\Phi\rangle$ by means of the Hermitian operator corresponding to the observable being sought. Right after and to make the observation possible, both systems must be separated again. After this separation, the states of both systems are not any more pure, but improper mixtures that can be described by density operators. These mixed states $\hat{\rho}_\psi$ allow an infinite number of decomposition into states $\left|\psi_i\right\rangle$. Selecting one of these decompositions, the improper mixture turns into a proper mixture described by $\hat{\gamma}_\psi$, i.e. the collection of possible pure states and the corresponding probabilities. Finally, one of these possible pure states is determined by observation at the subject system, linked to the value of the observable object (for which the observation system was prepared, i.e. some observable can be determined while other observables are left apart).

In this process, it is worth mentioning two relevant features: i) by observing the object, it is changed in an irreversible way; ii) some characteristics of the former states get to be scarcely known or completely unknown. In other words, as in classical observation (model 1 in which we will delve below and model 2) the object can not be completely determined; but unlike classical observation, the object is here irremediably changed as to intend a further inquiry. We can also say that the subject has got materially "informed" about some features of the object, which in turn has also been "informed" by the interaction. Neither of them will get to be the same after observation. Before the observation, the wave function of the object system represents a catalog of what can be potentially measured (i.e. changed) in the subject, thus we can speak here – following Weizsäcker – of "*potential information*". After the observation, the subject has been changed according to how the object was, i.e., it has been actually informed; it has received "*actual information*" (Weizsäcker, 1985).

## 4.2 Ideal Observation

The aforementioned model 1 of observation, though may not suffice to give a proper account on the "actual information", it will be very useful to deepen into the limits of the potential information and to probe the indetermination of the object, even in a classical interpretation.

Under the circumstances and approximations already mentioned when an observer pays attention into the manifestations of an object (no matter whether they are due to mechanical or electromagnetic interactions with the environment, as in the case of sound or light respectively), the observing properties of such an environment respond – where the observer is located – to the well-known wave equation:

$$\nabla^2\Psi\left(r,t\right) = \frac{1}{v^2}\frac{\partial^2\Psi\left(r,t\right)}{\partial t^2} \tag{1}$$

where **Ψ** represents the properties of the environment to which the observed is allegedly sensitive (e.g. the air pressure or the light), **r** is the position vector, $t$ the temporal variable, and $v$ a constant depending on the environment characteristics and corresponding to the propagation speed of the wave phenomenon. The pertinence of (1) implies that the observation domain (or domain of manifestation of the object) is homogeneous and isotropic (i.e., the interactions independent of either the direction or the position in which the parts are located).

The relative complexity of (1) may be smoothed if any temporal variation is expressed – by means of the Fourier theorem – as a linear combination of harmonic variations. Thus, we can separate a relation for each involved frequency, $f$ (a subsequent combination of single-frequency variations may render the full temporal evolution), namely the Helmholtz equation:

$$\nabla^2\Psi\left(r\right)+k^2\Psi\left(r\right)=0 \qquad (2)$$

where the wave number $k = 2\pi f/v = 2\pi/\lambda$, being $\lambda$ the wavelength for the involved frequency, and $\mathbf{\Psi} \in \leq$ reflects the amplitude and phase of the $f$ component of the temporal phenomenon

$$\Psi\left(r,t\right)=\int_{\forall f\ \in B}\Re\left\{\Psi_f\left(r\right)e^{-i2\pi ft}\right\}df$$

In other words, though for the sake of simplicity, we delve into the Helmholtz equation (2) instead of the wave equation (1) in which the dynamics are explicit, the reference to time variations are implicitly reflected in the frequency parameter, or the inversely related wave length $\lambda$. On the other hand, due to the symmetry shown by the wave equation regarding space and time, the conclusions that will be derived for the space dimensions can be easily translated into any set of space-time dimensions, i.e. the actual problem is four dimensional, but we analyse any three dimensions at the same time.

If we now apply the Fourier Theorem in the spatial dimensions for the phenomenon **Ψ** described by the Helmholtz equation (2), we can find a linear combination of harmonic variations in each of the spatial directions which allow us to represent any spatial distribution of the observed property **Ψ**. Thus, it can be expressed as a linear combination of distributions of the following type:

$$\begin{aligned}&\Psi\left(r\right)=\Psi_x\left(r\right)\cdot\Psi_y\left(r\right)\cdot\Psi_z\left(r\right)\\&with\quad \Psi_u=A_u e^{-ik_u u}+A_{-u}e^{ik_u u}\quad .\end{aligned} \qquad (3)$$

where $u$ represents any spatial direction, and $k_u$ its corresponding spatial frequency or the wave-number in the direction $u$.

By limiting $k_u$ to real values, it can be easily noticed that a valid type of solution for equation (2) has not been considered, namely the one corresponding to exponentially decaying distributions, which are named evanescent modes. Thus, (3) and the following discussion just refer to harmonic distributions. However, we should stress that although the absence of evanescent modes is not strictly the case (i.e. there are indeed evanescent waves around the object) in a practical sense such waves do not go beyond the very vicinity of the object in an observable level. That is, its actual level may be underneath noise level, or even under the sensibility of the observer.

Now applying (3) to equation (2), we obtain:

$$k_x^2+k_y^2+k_z^2=k^2 \qquad (4)$$

These wave-numbers for each spatial direction might be interpreted in terms of spatial frequency components (i.e. sinusoidal distributions in the corresponding spatial direction). Hence, relation (4) implies that the harmonic variations that may be expected in each direction are limited to a fundamental constraint, which may be geometrically expressed as a spherical surface or radius *k* in a space of three spatial frequencies.

### 4.2.1 Inquiry into the Dimensionality of Ideal Observation

Considering the previous analysis of the wave phenomenon according to its structural constraints, particularly the constraints referring to spatial variations, we can straightforward arrive – by means of the sampling theorem (e.g., Shannon, 1949, p.11) – to the *general discretizability theorem for radiation fields* (T1):

*The minimal distance between independent intensity values of a field generated by an arbitrary object is λ/2. (Díaz & Pérez-Montoro, 2011b, §2.1)*

If based on this theorem we now consider the spatial limitation of the object within the boundary S, the validity of the Helmholtz equation at the interface (i.e. right besides the object), as well as the uniqueness theorem of this equation, we immediately arrive to the *theorem of the essential dimensionality of the radiation problem* for a bounded object (T2):

*The maximum number of details of an object, inscribed in an sphere of radius a, which is causing an observed field distribution, is* $16\pi(a\chi/\lambda)^2$*. This is the essential dimension of the observation problem. (Díaz & Pérez-Montoro, 2011b, §2.2)*

If we now add the restriction of an observation located at a minimal distance with respect to the object of observation (more explicitly, at a distance *d* from the centre of a ball containing the object), it can easily be demonstrated – appealing to the features of the spherical harmonics – *the special discretizability theorem for distant radiation*(T3):

*The minimal distance between independent values of the field corresponding to the manifestation of an object inscribed in a sphere of radius a, whose centre is at a distance d, is:*$\lambda d/2a\chi$*. (Díaz & Pérez-Montoro, 2011b, §2.3)*

### 4.2.2 Reframing the Ideal Information Problem

Using these theorems, the relation between the sources of radiation (object) and the observed field can be expressed by means of a linear transformation:

$$\begin{pmatrix} \Psi(u_1, v_1) \\ \vdots \\ \Psi(u_M, v_M) \end{pmatrix} = \begin{pmatrix} G(u_1, v_1, x'_1, y'_1, z'_1) & \cdots & G(u_1, v_1, x'_N, y'_N, z'_N) \\ \vdots & \ddots & \vdots \\ G(u_M, v_M, x'_1, y'_1, z'_1) & \cdots & G(u_M, v_M, x'_N, y'_N, z'_N) \end{pmatrix} \times \begin{pmatrix} f(x'_1, y'_1, z'_1) \\ \vdots \\ f(x'_N, y'_N, z'_N) \end{pmatrix} \quad (5)$$

where (*u, v*) represent curvilinear coordinates over the observation space; 1… *N* the cardinals of the samples over the observation domain; (*x', y', z'*) the locations of the founts or sources – i.e. the object –, properly discretized; 1…*M* the cardinals of these samples; and *G*(*u,v,x',y',z'*) the Green function, which at the same time satisfies the wave equation (2) in the homogeneous space and establishes a direct relation to the non-homogeneity, to which the presence of the object (or one of its infinitesimal parts) intrinsically responds: between the location (*x',y',z'*) at the sources and (*u,v*) at the observation domain.

More densely, the relation between field and its corresponding sources can be expressed grouping the field distribution into an *M*-dimensional vector Ψ, the sources into an *N*-dimensional vector *f*, and representing the transformation among them through a matrix operator $T$:

$$\Psi = \begin{pmatrix} \Psi_1 \\ \vdots \\ \Psi_M \end{pmatrix} = \sum_{n=1}^{N} \begin{pmatrix} \psi_1 \\ \vdots \\ \psi_M \end{pmatrix} \cdot f_n = \sum_{n=1}^{N} \psi_n \cdot f_n = T \cdot f$$

$$where \;\; \psi_n = \begin{pmatrix} G(u_1, v_1, x'_n, y'_n, z'_n) \\ \vdots \\ G(u_M, v_M, x'_n, y'_n, z'_n) \end{pmatrix} \quad (6)$$

which can be interpreted as the wave function for each discrete source of unitary amplitude, located at $(x'_n, y'_n, z'_n)$.

Considering this formulation, the forward problem (namely, the prediction of the field when the sources distribution – namely the object – is known) does not have any difficulty: if we indeed knew the distribution of sources, described in terms of $f$, it would suffice to apply the former relations to know how actually the manifestations are in terms of $\Psi$. We do not care if $N$ is bigger or smaller. However, this is – so to speak – a pseudo-problem if we give for granted the way the environment transmits the changes in one part of the space (in our case, the validity of the wave equation in our real environment), and of course, it does not correspond to the observation problem as we have stated it.

Generally, our knowledge about the objects is not *a priori* but *a posteriori*, that is, reckoning with its manifestation. This is the so-called *inverse problem*, which in our formulation implies obtaining $f$ from $\Psi$. In this case, it is evident that the dimension $N$ is important, since we would never invert the relation if $N>M$. It is also important the independency of the wave functions $\psi_n$, or at least, that the dimensionality (or complexity) of the space developed by an arbitrary set of $N$ sources corresponds to the dimensionality (or complexity) of an arbitrary observation.

Theorems T2 and T3 establish fundamental limits which enable a proper arrangement of our problem: according to T3, the actual dimension of the observed phenomenon does not depend on how detailed the observation is, since we often have to move quite distant to find some independent value of the considered phenomenon. The number of spatial details that we can perceive can never be higher than the essential dimension predicted by theorem 2. Thus, it is also the maximal number of details that might be specified concerning the object. It is here relevant to remind that such dimension does not depend on the volume ($\propto a^3$) but on the bounding surface ($\propto a^2$). Thus, since the complexity of volumetric distribution may wroth with the volume, whereas the complexity of the field only grows with the surface, this leads us to a fundamental conclusion: the volumetric distribution of the object is inscrutable. In this case, what might we know about the object?

At this point, it is worth remembering the Huygens principle (1690). It establishes that "each point on a primary wavefront can be considered to be a new source of a secondary spherical wave and that a secondary wavefront can be constructed as the envelope of these secondary spherical waves." This principle can be justified by means of the aforementioned uniqueness theorem of the Helmholtz equation, which for the electromagnetic problem was rigorously stated by Schelkunoff in terms of the equivalence theorem (Schelkunoff, 1936). Thus, it suffices to refer to the secondary sources (or *equivalent sources*) distributed on the surface bounding the object, which is properly located at the homogeneous space. As we have just shown, the dimensionality of the observation and that of the radiated field around the object implies that we can only obtain from the object a superficial knowledge, which can be interpreted as a projection of what is inside. But coming into such "inside" is forbidden solely based on *a posteriori* knowledge.

To clarify this last condition, we must take into account that if the inner complexity of the object structure is smaller than the essential dimension $N$, then the observer could grasp an idea of the volumetric distribution. However, such 'idea' would be achieved based on an assumption of the inner structure, since there is in principle an unlimited number of inner structures whose projections over a bounding surface are equal.

Considering the separation required for the independence of the equivalent sources at the bounding surface (here translated into the independence of the fields generated over the observation domain, D), a good way to make our problem well-posed is by locating punctual equivalent sources over S regularly spaced at a distance $\lambda/2\chi$. The space of radiated fields that shall be generated by this discrete distribution of equivalent punctual sources over S is equivalent to the one that might be generated by any inner (discrete or continuous) volumetric distribution. It can be shown (Díaz, 2003, §3.2.1) that if a quadratic norm is defined for the mentioned space of radiated fields, as well as a distance between field distributions based on such norm, $d(\psi_i, \psi_j)$, then there will only be a unique distribution of equivalent punctual sources over S that optimally matches the observed phenomena. This distribution can be understood as an orthogonal projection of the observed field Ψ on the source domain $f$:

$$\Psi = \begin{Bmatrix} \Psi_{OBSERVED} \\ T \cdot f_{projection} \end{Bmatrix} \Rightarrow \exists f_{projection}$$
$$= [T^+ \cdot T]^{-1} T^+ \cdot \Psi_{OBS.} \Big/ \min_f \left\{ d\left( T \cdot f_{projection}, \Psi_{OBS.} \right) \right\} \quad (7)$$

where $T^+$ represents the adjoint matrix of $T$.

### 4.2.3 Observational Limits and Perception

Based upon the previous analysis of the ideal observation problem, the following fundamental conclusions can be forward extracted concerning what can be maximally known about the object causing an observed wave phenomenon. In other words, how much can be the subject informed about the object from its very manifestation:

1. The number of details to be found in the environment due to the presence of the object is finite.
2. Such number depends on the surface bounding the object and not on its volume.
3. The volumetric distribution of an object cannot be known only based on its manifestations on the environment.
4. The description of the object that can be achieved corresponds to a projection of the inner inhomogeneities over a bounding surface.

These four conclusions establish fundamental limits to the observation problem, not attached to the specificity of our organs of animal or human sensibility, but to the differences that can merely be found in the environment and the maximal knowledge that might be derived about the object causing these differences. Using Kantian terminology, these are the limits in the determination of an object of knowledge by means of a transcendental subject, to which the intimate knowledge of the object is withheld – as we previously showed. In other words, in spite of the actual complexity of the object, the complexity of the manifestations in the space surrounding the object – due to its presence – is constitutively smaller than the complexity of the object. We could argue that this is the case unless the object is completely described by its projection over the bounding surface. But even in this case, observation does not suffice to conclude that this completeness is the case, we must also know, for instance, that the inner part is empty, since there is a whole set of possibilities regarding the inner configuration. As previously pointed out, another possibility for a complete determination is that the observer intends to find out the specific configuration of a structure whose degrees of freedom are equal or smaller than the complexity of the field in the surrounding space, which obviously implies an important amount of previous knowledge.

Our analysis might be considered trivial if we just think in its correspondence to the visual problem, since there is a danger to confuse the limits to acknowledge the inner part of an object with its opacity. Even if some degree of transparency were ascribed to all the inner parts, the limit concerning the complexity of the field generated by the object leads us to the same conclusion: the three dimensionality of the inner distribution cannot be determined by the two-dimensionality of the object manifestation, which is also coherent with the *holographic principle*. According to this, the maximal entropy contained in a limited space depends on the bounding surface and not on its volume (Susskind, 1997, Díaz, 2010b). As a corollary of the holographic principle, Bekenstein proposes that if the physics of our real (tetra-dimensional) universe were holographic, there would be an arbitrary set of physical laws which could be applied to some tri-dimensional space-time boundary. Therefore, there is a radical indeterminacy between this *holographic universe* – as he names it – and the physics, used to interpret it. (Bekenstein, 2003). Concerning the determination of the object, we arrive to the same conclusion.

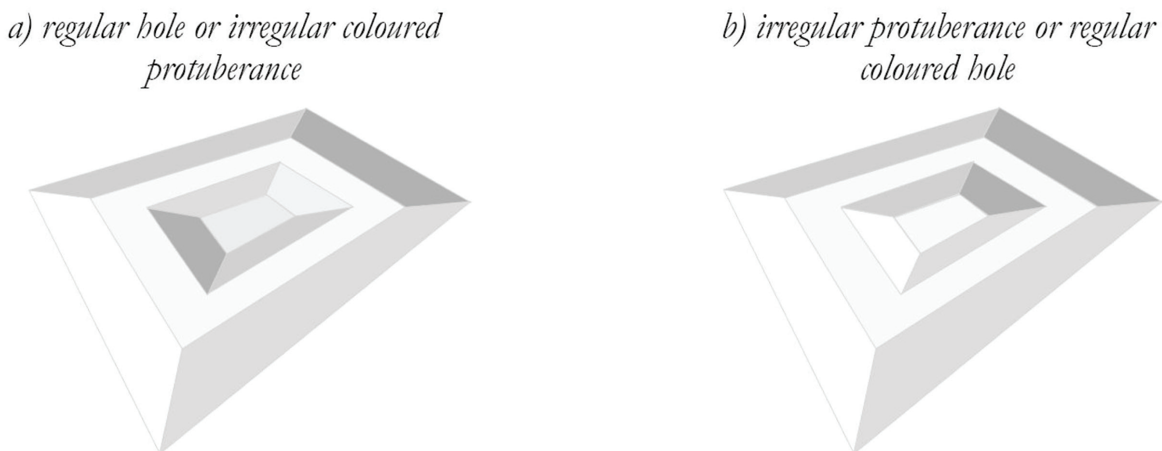
### 4.3 Sensation, Perception, Intellection and Nature of Information

**Sensation and Perception.** If we now reckon the specificity of the animal sensitivity, we would encounter further limits concerning the amount of differences that a perceiving subject can acknowledge about the object. The more complex its sensitive organs are, the closer it can reach the stated limits. For instance, the eagle vision is closer to this boundary than what the human vision is (Díaz, 2008). But in the impression of the reality gathered by the subject there is an essential element which is consistent with our former conclusions: the differences encountered in sensation points to a radical incompleteness in relation to the reality which is being felt. As we have seen, there is an essential ambiguity regarding the possible volumetric configurations of the objects, as there is ambiguity in many illusory images considered in theory of perception (Rock 1984). Although there is some kind of autonomy in perception with respect to the whole act of apprehending reality, this seems to be a unitary act in which different sensitive structures take part (synchronic or diachronically) together with an intellective moment.

To illustrate this, let us consider a simple example. In Figure 4, we try to deal with the ambiguity of the visual image of an object. In Figure 4a, it is normally perceived a big square bump in whose middle there is a regular hole. Both the geometrical regularity and the shadowing drive us to perceive the bump with a hole. However, Figure 4b brings us about the sensation of a more ambiguous object: the geometrical properties drive us to see again a hole that is differently colored than the rest. However, the shadowing invites us to see a smaller but irregular protuberance into the bump. According to an externalist interpretation of perception – for instance in Dretske (1981; Díaz & Pérez-Montoro, 2011a) –, if we only assume informational relations holding a deterministic condition (i.e. the related parts are linked with probability $p$=1), we might say that we perceive in Figure 3b a bump with {(a regular hole) or (an irregular protuberance)}. But this is not the case of what we really perceive. We can alternatively perceive either an irregular protuberance or a regular and colored hole (different intellectual moments are taking part at each time, understood as different intellectual apprehensions of the object).

Moreover, a different percept can also be obtained from Figure 3a: a colored and irregular protuberance. Although this last percept is much lesser probable, it has been experimentally shown that, in spite of geometrical and color visual

*Figure 4. Perception of ambiguous figures. It illustrates the dependence of complexity of percepts in perception. In (a) the simplest corresponding figure is perceived: a regular hole. However, in (b) because of geometrical regularity we may perceive a hole, but shading tends us to perceive an irregular protuberance.*




properties, the preferred visual percept might turn to be an irregular protuberance if the subject has the tactile sensation that something juts out (Robles-de-la-Torre et al. 2001, 2006). Furthermore, even when the object is touched and the ambiguity – so to speak – is solved, the subject can visually perceive it as a hole, although (s)he is aware that a protuberance exists. This property allows us to speak of the aforementioned relative autonomy of perception (Rock 1984), at the time that the awareness and intellection of reality forms some kind of unitary act in which different notes of reality, as well as different modes and structures of sensing take part.

As different experiments, carried out in the study of perception, have shown: the preferred perceptions tend to be those corresponding to the simplest configurations. For instance, in the previous example, a symmetrical bump, a homogeneous colored object, etc. In other words, perception seems to apply Ockam's razor: if something admits a simpler description, then this is preferred. To this respect, it is relevant to mention that the mathematical regularization methods to solve inverse problems also appeal to this same principle.

**Complexity of sensation vs. ambiguity of perception.** The more complex the sensitive structure, the greater the ambiguity of its perception and the more accurate the determination of the object. For instance, if we consider the simplest case of a cell, it has several means to sense the environment and to adapt to those variations that are relevant for its survival. More specifically, the unicellular organism *Euglena viridis* (among others of the same genus) has an eyespot apparatus, which filters sunlight into the light-detecting, photo-sensitive structures at the base of its flagellum. This eyespot enables the cell to sense the strength and direction of light, and straightforward to move accordingly towards a medium of moderate light (away from darkness and bright light). In the Euglena the afferent structures of the cell – sensing the environment – are directly connected to the efferent ones – the flagellum which causes the necessary movement towards a more suitable environment (Lemmermann, 1913, PEET 2010). The ambiguity of perception is here very low: the strength of light is high or low, and it comes from this or that direction. In addition, it is also low the accuracy in the determination of the environmental state. In the animal vision, as we have shown before, the ambiguity can be much higher as it is the accuracy in the determination of the observed reality. Grasping more notes of reality, especially if they have different modality (e.g. visual and tactile notes) the ambiguity left by some partial perceptions (e.g. a visual percept) can decrease although new kinds of ambiguity may appear. Reality is more accurately sensed, feeling at the same time that the non-felt part of reality is bigger. In our previous analysis of observation, sensation may grow in two dimensions, whereas the non-observed part is three-dimensional.

**Intellection.** The constitutive indeterminacy of the manifestation of reality and the ambiguity of sensation (both closed related but not the same) might bring about, on the one hand, the feeling that there is a part of reality beyond its manifestation; on the other hand, an invitation to find further notes to delve into the sensed reality. Probably, if sensation were sufficient for a particular being in its interaction with its world, this invitation might not be felt. But in this case some kind of deterministic relation should provide univocal perceptions of what is being sensed allowing it to successfully deal with the perceived objects. This relation can be interpreted as a fixed assumed solution to the ambiguity of sensation. The Spanish philosopher Xabier Zubiri refers to this kind of apprehension as "apprehension of stimulation", characterized by a "formality of signitivity", which in evolutionary sense precedes the "formality of reality". Here formality is conceived as what allows the apprehension of anything, therefore being independent of the content. In the formality of signitivity, the act of signing is in question, and this is in turn linked to a particular reaction of the subject – in a broad sense – (Zubiri, 1999); but in the formality of reality, the hypercomplexity of the intellectual-sensitivity allows to go beyond the limits of the given notes, i.e. the "informed" sensitivity. Such formality of reality, rooted in the hypercomplexity of the broaden sensitivity (intellectual sensitivity), permits the apprehension of the reality itself, including the transcendence of such information, i.e. the insufficiency to determine what the sensed reality really is.

Human sensation is clearly characterized by feeling the necessity of searching beyond the given sensations. The history of science as a whole might be interpreted in this sense, including deep changes in the sensed realities, as when the dawn star is beginning to be perceived as Venus, human as an evolved primate, atoms as something particularly empty, etc.

In a lower level of intellection, the "formality of reality" can be conceived as linked to the necessity of dealing with the world when the system of signs and reactions is not enough to cope with the environmental dynamics. In an evolutionary sense, we might say that the structures of sensation evolved bringing about such formality of reality.

**Information.** Considering the aforementioned constraints in the manifestation of an object, information can be understood as a relational entity between the objective world and the subjective one that brings about some changes in the subject. Here subject is understood in a broad sense, in which simple systems can be included, as well as complex organism or individuals, immersed in even more complex environments.

A paradigmatic case of information is the one considered above of a field through which an object manifests to a subject, namely the observation problem. Such understanding of information requires broaden the concept of subject, just as what is being subject to the changes coming from an object (which in turn might become also subject to the changes due to the interaction). From this point of view and as we advanced in section 2, information represents a bridge between the object and the subject; between the ὄντος and the ἐπιστήμη; between the scientific world driven towards the objective world and the manifest world oriented to the subjective one.

However, according to our analysis of the nature of the manifestation of the object in its surroundings and the way this manifestation can be reflected in the subject: information is not enough to explain the changes produced; that is, there is not a causal determination chain in general. We can use the aforementioned distinction of Weizsäcker between potential and actual information to distinguish respectively the ability to cause changes and the changes already caused.

Despite the general non-deterministic causation of information, in the simplest systems, a more direct causation can be founded out. At this elementary level of system complexity, there is no difference between syntactic, semantic and pragmatic aspects (if we deal with physical systems, energy is a kind of potential information). However, in more complex systems, as the biotic ones, the syntactic aspects differentiate from the semantic-pragmatic ones, which remain together (observing a light is equivalent to beat the flagellum as to advance towards brightness). In the most evolved systems, the semantics and the semantics aspects differentiate: some kind of autonomy allows the subject to decide upon the grasped information (including the inherent ambiguity) in its epistemic realm, though in relation to some pragmatic commitments (Díaz & Pérez-Montoro, 2011a, §2.5). Due to the ambiguity of the manifestation of reality, a *heterarchical* process drives the course of causing higher-level changes under particular constraints determined by a particular pragmatic situation. Besides the concept of heterarchical systems – which allows the approach to open and adaptative systems of high complexity as biological, nervous systems and cultural systems (Bondarenko, 2007) –, this process can be understood using the concept of *analogical-digital consensus* proposed by Luis Bruni (2008). According to this concept, a determined amount of information qualified by the heterarchical structure in relation to the given situation, shall be grasped as to satisfy some threshold for a change in the higher level, for instance, 'what I am seeing is bump', or 'I will start to run to get away of a danger'. The information, grasped before the change is produced, is interpreted as analogical because it is not yet associated to a digital change. The information can be qualified as digital when the change at the higher level is produced. However the set of conditions that defines such quality is not given once and for all, but dependent of the given situation.

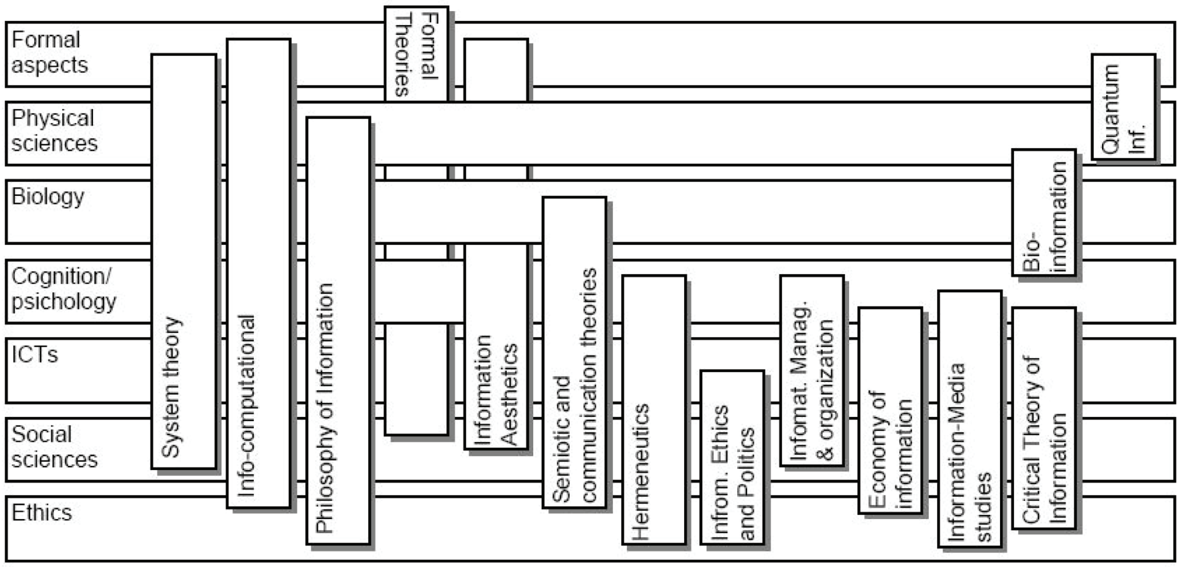
Such an understanding of information permits on the, one hand, to delve into the syntactic, semantic and pragmatic dimensions, on the other hand, to focus on the physical, chemical, biological, psychological, social, technical, ethical and philosophical aspects of information.

## FUTURE RESEARCH DIRECTIONS

Among the scientific approaches mentioned in section 3, several of them are in progress (e.g., GTI, UTI, cybersemiotics, infocomputationalism, logical dynamics of information, situational theory…), other has the potentiality to be continued in specific fields or generalized to other fields (e.g., the objectivised semantics, the theory of measurement…).

A major pitfall for the development of a general understanding of information concerns how to articulate the relation among different theoretical frameworks in order to delve into the many aspects of information and to gain the insight provided by each approach. In the 4$^{th}$ International Conference on the Foundations of Information Science (celebrated in Beijin, August 2010), several proposals for reconciling the diversity of informational approaches were offered. Among them, the author (Díaz & Salto, 2011) has proposed a transversal coordination between research domains (understood as objects of investigation) and different theoretical frameworks (understood as points of view in the research of information) aimed at furthering an effective interdisciplinary in study of information. Figure 5, synthesize this proposal – showing some relevant frameworks. As complement, the creation of a virtual research community is proposed based upon electronic-

*Figure 5. Articulation of research domains and theoretical frameworks in the author's proposal for interweaving the field of information studies (Díaz & Salto, 2011)*




infrastructures, aimed at avoiding the problem of scientific and geographical divides.

## CONCLUSION

We have posed the necessity to achieve a common understanding of information as a must in the allegedly age of information, and we have stressed the dual usage of information connected to the cultural divide of objectivist *vs* subjectivist understanding. We have also argued the necessity to supersede the methodological positivism or specialism of sciences, particularly in information concerns, since it manifests in a rich variety of fields and aspects (referred to as multi-dimensionality of information).

Seeking a comprehensive view in the forest of information theories, we have seen the variety of scopes concerning their stance with respect to: (1) the nature of information (especially in the dichotomy: objective-subjective), and (2) their coverage over the multifaceted aspects of information. Beyond the differences – which prima facie seems to be in many cases irreducible –, on the one hand, some common points has been highlighted; on the other hand, some insights on several approaches or trends has been given, which could provide a good ground for a common understanding of information.

Finally, through an inquiry in the reality of observation, we have essayed an answer to the nature of information that might provide the bridge between the objectivist and the subjectivist realms, formerly posed as a must. From the perspective achieved, information corresponds to the 'real' manifestation of the object interacting with the subject (both understood in a broader sense). Information is fundamentally characterized by its potentiality to produce changes in the subject, but it is not enough – in the general case – to understand causally the derived consequences, especially in the semantic and pragmatic dimensions. Neither is information enough to provide the intentional values, related to the object – in the case of high complexity subjects. Nonetheless, it provides a 'real' link between objects and subjects.

## AUTHOR NOTE

José María Díaz Nafría, Department of Psychology, Sociology and Philosophy, Universidad de León, Spain; Director of Communications, Science of Information Institute, USA.

The matters discussed within this chapter proposal are framed into an interdisciplinary and international project aimed at the elucidation of the information concept that I coordinate since 2008 under the name BITrum (http://www.en.bitrum.unileon.es). Its name allegorically refers to the conjunction of the information unit "BIT" and *vitrum* (Latin name for the stained-glass windows in which a multiplicity of colors and nuances are assembled into a common picture). BITrum gathers over 60 European and American scholars representing a wide variety of scientific disciplines from telecommunications to philosophy, from biology to sociology, from mathematics to ethics... To date, the project has been materially supported by Spanish institutions as the Ministry of Science, the University of León and others, but it promotes several initiatives to be supported by international institutions in the European Union and abroad.

Correspondence concerning this chapter should be addressed to José María Díaz Nafría, Department of Psychology, Sociology and Philosophy, Dcho. 254, Facultad de Educación, Campus de Vegazana s/n, 24071 León, SPAIN. E-mail: jdian@unileon.es.

## REFERENCES

Bar-Hillel, Y., & Carnap, R. (1953). Semantic information. *British Journal of Science*, *4*, 147–157. doi:10.1093/bjps/IV.14.147

Barwise, J., & Perry, J. (1983). *Situations and Attitudes*. Cambridge, MA: MIT Press.

Barwise, J., & Seligman, J. (1997). *Information Flows: The Logic of Distributed Systems*. Cambridge, RU: Cambridge University Press.

Bekenstein, J. D. (2003). Information in the Holographic Universe. *Scientific American Magazine*, *289*(2), 58–65.doi:10.1038/scientificamerican0803-58

Bondarenko, D. M. (2007). Approaching "complexity" in anthropology and complexity studies: The principles of sociopolitical organization and the prospects for bridging the interdisciplinary gap. *E:CO, 9(3)*, 62-74. Retrieved January 22, 2011, from http://emergentpublications.com/eco/ECO_papers/Issue_9_3_6_PH.pdf

Brier, S. (2008). *Cybersemiotics: why information is not enough*. Toronto: University of Toronto Press.

Brillouin, L. (1956). *Science and Information Theory*. New York: Academic Press.

Bruni, L. E. (2008). Hierarchical Categorical Perception in Sensing and Cognitive Processes. *Biosemiotics*, *1*(1), 113–130. doi:10.1007/s12304-008-9001-9

Bullock, A., & Trombley, S. (1999). *The Fontana Dictionary of Modern Thought* (pp. 669–737). London: Harper-Collins.

Burgin, M. (2003). Information Theory: a Multifaceted Model of Information. *Enthropy*, *5*, 146–160. doi:10.3390/e5020146

Burgin, M. (2010). *Theory of Information: Fundamentality, Diversity and Unification*. Singapore: World Scientific Publishing.

Calude C.S. and M.A. Stay (2005). From Heisenberg to Gödel via Chaitin. *Int. J. Th. Phys., 44*(7). 2005. pp. 1053-1065.

Capurro, R. (1978). *Information. Ein Beitrag zur etymologischen und ideengeschichtlichen Begründung des Informationsbegriffs* [Information: A contribution to the foundation of the concept of information based on its etymology and in the history of ideas]. Munich, Germany: Saur. Retrieved September 3, 2010, from http://www.capurro.de/info.html

Capurro, R. (2007). Epistemologia y ciencia de la información. *Enl@ace: Revista Venezolana de Información, Tecnología y Conocimiento, 4(1)*, pp. 11-29. Retrieved December 29, 2010, from http://www.capurro.de/enancib.htm

Capurro, R. (2009). Past, present, and future of the concept of information. *TripleC*, *7*(2), 125–141.

Capurro, R., & Hjørland, B. (2003). The Concept of Information. Retrieved September 3, 2010, from http://www.capurro.de/infoconcept.html. *Annual Review of Information Science & Technology*, *37*(8), 343–411.

Chaitin, G. J. (1966). On the length of programs for computing finite binary sequences. *Journal of the Association for Computing Machinery*, *13*, 547–569.

Chaitin, G. J. (1982a). Algorithmic Information Theory. In *Encyclopedia of Statistical Sciences*, 1, 38-41. New York: Wiley.

Chaitin, G. J. (1982b). Gödel's theorem and information. *International Journal of Theoretical Physics*, *22*, 941–954. doi:10.1007/BF02084159

Collier, J. (2011). Kinds of Information is Scientific Use. *Triple*, *C*, 9.

Comte, A. (1844). *Discours sur l'Esprit positif*. [*A general view of positivism*]. London, 1856. Retrieved September 3, 2010, from Google Books: http://books.google.com

Descartes, R. (1649). *A discourse of a method for the well guiding of reason, and the discovery of truth in the sciences*. London: Thomas Newcombe. Retrieved September 3, 2010, from Guttemberg Project: http://www.gutenberg.org/files/25830

Díaz Nafría, J. M. (2003). *Contribución en métodos inversos para la caracterización de sistemas radiantes* ("Contributions in inverse methods for the characterization of radiant systems" in Spanish). Madrid: Universidad Politécnica de Madrid. Retrieved May 2010 from Novatores: http://www.novatores.org/html/es/eprint/show.html?ePrintId=119

Díaz Nafría, J. M. (2008). The interminacy of observation. In Díaz & Salto (eds.) *¿Qué es información?* (What is information? Proceedings of the I International Meeting of Experts in Information theories. An interdisciplinar approach). León: Universidad de León, pp. 489-502. Retrieved September, 2010 from http://wp.me/pzKNC-58

Díaz Nafría, J. M. (2010a). What is information? A multidimensional concern. *TripleC*, *8*(1), 77–108.

Díaz Nafría, J. M. (2010b). Holographic principle. In Díaz, Salto and Pérez-Montoro (eds.) *Glossarium BITri: Glossary of concepts, metaphors, theories and problems regarding information*. León: Universidad de León. Retrieved September, 2010 from http://glossarium.bitrum.unileon.es

Díaz Nafría, J. M., & Aguado, J. M. (2010). Cybernetics. In Díaz, Salto, & Pérez-Montoro (Eds.). *Glossarium BITri, op. cit.*

Díaz Nafría, J. M., & Capurro, R. (2010). Hermeneitics. In Díaz, Salto, & Pérez-Montoro (Eds.). *Glossarium BITri, op. cit.*

Díaz Nafría, J. M., & Pérez-Montoro, M. (2011a). Is information a sufficient basis for cognition? (Part 1: Critique on Dretske's vision). *Triple*, *C*, 9.

Díaz Nafría, J. M., & Pérez-Montoro, M. (2011b). Is information a sufficient basis for cognition? (Part 2: physical foundations). *Triple*, *C*, 9.

Díaz Nafría, J. M., & Salto Alemany, F. (2011). Towards a transdisciplinary frame: Bridging domains, a multidimentsional approach to information. *Triple*, *C*, 9.

Dodig-Crnkovic, G., & Stuart, S. (2010). *Computation, Information, Cognition – The Nexus and The Liminal*. Cambridge, UK: Cambridge Scholars Publishing.

Dretske, F. I. (1981). *Knowledge and the flow of information*. Cambridge, MA: MIT Press.

Duhem, P. (1962). *The aim ans structure of physical theory*. New York: Atheneum.

Fenzl, N., & Hofkirchner, W. (1997). Information Processing in Evolutionary Systems. An Outline Conceptual Framework for a Unified Information Theory. In Schweitzer, F. (Ed.), *Self-Organization of Complex Structures: From Individual to Collective Dynamics* (pp. 59–70). London: Gordon and Breach.

Floridi, L. (2004). Outline of a theory of strongly semantic information. *Minds and Machines*, *14*(2), 197–221. doi:10.1023/B:MIND.0000021684.50925.c9

Floridi, L. (2005a). Information. In Mitcham, C. (Ed.), *Encyclopedia of Science, Technology and Ethics*. New York: Macmillan.

Floridi, L. (2005b). Is Semantic Information Meaningful Data? *Philosophy and Phenomenological Research*, *70*(2), 351–370. doi:10.1111/j.1933-1592.2005.tb00531.x

Floridi, L. (2005c). Semantic Conceptions of Information. In E. N. Zahlta (Ed.) *Stanford Encyclopedia of Philisophy*. Stanford: The Metaphysics Research Lab. Retrieved September 3, 2010, from http://plato.stanford.edu/entries/information-semantic/

Floridi, L. (2005d). Consciousness, Agents and the Knowledge Game. *Minds and Machines*, *15*(3-4), 415–444. doi:10.1007/s11023-005-9005-z

Flückiger, F. (2005). Mathematical Foundation of Information Theory. A Set Theoretical Approach. In Michel Petitjean (ed.) *Proceedings of FIS2005, The Third Conference on the Foundations of Information Science*.

Gitt, W. (1996). Information, Science and Biology. *Technical Journal*, *10*(2), 181–187.

Gödel, K. (1931). Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme. *Monatshefte für Mathematik und Physik*, *38*, 173–198. doi:10.1007/BF01700692

Günther, G. (1963). *Das Bewußtsein der Maschinen. Eine Metaphysik der Kybernetik. Krefeld/Baden-Baden*. Germany: Agis Verlag.

Heisenberg, W. (1930). *Die physikalische Prizipien der Quantentheorie*. Leipzig: Hirzel.

Hofkirchner, W. (1999a). Towards a Unified Theory of Information. The Merging of Second-Order Cybernetics and Semiotics into a Single and Comprehensive Information Science. In: *15e Congrès International de Cybernétique, Namur 1998*, Namur, pp. 175-180.

Hofkirchner, W. (2009). How to achieve a unified theory of information. *TripleC*, *7*(2), 357–368.

Huygens, C. (1690). *Traite de la Lumiere*. Leyenden. Translated to English by Thompson, S.P., London, 1912. Retrieved July, 2010 from Project Gutemberg: http://www.gutenberg.org/etext/14725

Israel, D., & Perry, J. (1990a). What is information? In Hanson, P. (Ed.), *Information, language and cognition* (pp. 1–19). Vancouver, Canada: University of British Columbia Press.

Janich, P. (1998). Informationsbegriff und methodisch-kulturalistische Philosophie. *Ethik und Sozialwissenschaften*, *2*, 169–182.

Karpatschof, B. (2007). *Human activity. Contributions to the anthropological sciences from a perspective of activity theory.* Lund, Sweden: InformationR.net. Retrieved in 12/11/09 from http://informationr.net/ir/12-3/Karpatschof/Karp00.html

Kolmogorov, A. N. (1965). Three approaches to the quantitative definition of 'information'. *Problems of Information Transmission*, *1*(1), 3–11.

Kornwachs, K. (1996). Pragmatic information and System surface. In Kornwachs, K., & Jacoby, K. (Eds.), *Information. New questions to a multidisciplinary concept* (pp. 103–118). Berlin: Akademie Verlag.

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lakatos, I. (1978). *The methodology of scientific research*. Cambridge: Cambridge University Press.

Laudan, L. (1977). *Progress and its problems*. Berkley: University of California Press.

Leibniz, W. (orig. 1714, trans. 2007). *Monadology*. Trans. J. Bennett. Retrieved September 6, 2010 from http://www.earlymoderntexts.com/pdf/leibmon.pdf

Lemmermann, E. (1913). In Pascher, A. (Ed.), *Eugleninae* (pp. 115–174). Jena: G. Fischer.

Luhmann, N. (1987). *Soziale Systeme*. Frankfurt am Main: Suhrkamp.

Lyre, H. (1998). *Quantentheorie der Information. Zur Naturphilosophie der Theorie der Ur-Alternativen und einer abstrakten Theorie der Information. Viena*. Springer.

Lyre, H. (2002). *Informationstheorie. Eine philosophisch-naturwissenschftliche Einführung* [Theory of information. A philosophical and scientific introduction]. Munich, W.: Fink Verlag.

Mähler, G. (1996). Quantum Information. In Kornwachs, K., & Jacoby, K. (Eds.), *Information. New questions to a multidisciplinary concept* (pp. 103–118). Berlin: Akademie Verlag.

Matsuno, K. (1998). Dynamics of time and information in a dynamic time. *Bio Systems*, *46*, 57–71. doi:10.1016/S0303-2647(97)00081-6

Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and congnition: the realization of the living*. Dordrecht, Netherlands: Reídle.

Morris, C. W. (1938). *Foundations of the theory of signs*. Chicago: International Encyclopaedia of Unified Science.

Oeser, E. (1976). *Wissenschaft und Information*. Vienna, Austria: Oldenbourg.

Ortega y Gasset, J. (1932). *The revolt of the masses*. New York: Norton.

PEET. (2010). The Euglenoid Project (web). Partnership for Enhancing Expertise in Taxonomy-National Science Foundation. Retrieved September, 2010 from http://euglena.msu.edu

Pérez-Montoro, M. (2007). *The Phenomenon of Information. A Conceptual Approach to Information Flow*. Lanham, Maryland: Scarecrow Press.

Quine, W. O. (1953). Two dogmas of empiricism. In *From a logical point of view*. Cambridge: Harvard University Press.

Robles-De-La-Torre G. (2006). The Importance of the Sense of Touch in Virtual and Real Environments. *IEEE Multimedia 13(3)*, Special issue on Haptic User Interfaces for Multimedia Systems: 24–30.

Robles-De-La-Torre, G., & Hayward, V. (2001). Force Can Overcome Object Geometry In the perception of Shape Through Active Touch. *Nature*, *412*(6845), 445–448. doi:10.1038/35086588

Rock, I. (1984). *Perception*. New York: Scientific American Library.

Rorty, R. (1982). *Consequences of Pragmatism*. Minneapolis: University of Minnesota Press.

Schelkunoff, S. A. (1936). Some equivalence theorems of electromagnetics and their application to radiation problems. *The Bell System Technical Journal*, *15*, 92–112.

Segal, J. (2003). *Le Zéro et le Un. Histoire de la notion scientifique d'information*. Paris: Syllepse.

Sellars, W. (1962). Philosophy and the scientific image of man. In Colodny, R. (Ed.), *Frontiers of Science and Philosophy* (pp. 35–78). Pittsburgh: University of Pittsburgh Press. [Also online. Retrieved September 3, 2010, http://www.ditext.com/sellars/psim.html]

Shannon, C. E. (1949). Communication in the presence of noise. *Proc. IRE, 37(1)*, 10-21.

Shannon, C. E. (1993). *Collected Papers*. New York: IEEE Press.

Shannon, C. E., & Weaver, W. (1949). *The Mathematical Theory of Communication*. Urbana: The University of Illinois Press.

Snow, P. C. (1998). *The Two Cultures. A Second Look*. Cambridge: Cambridge University Press.

Solomonoff, R. J. (1964). A formal theory of inductive inference. *Inf. Control, (7)*, 1-22 (I part), 224-254 (II part).

Stonier, T. (1991). Towards a new theory of information. *Journal of Information Science*, *17*, 257–263. doi:10.1177/016555159101700501

Stonier, T. (1999). The Emerging Global Brain. In Hofkirchner, W. (Ed.). *The quest for a unified theory of information. Proceedings of the Second International Conference on the Foundations of Information Science*. Amsterdam: Gordon and Breach. pp. 561-578.

Susskind, Leonard (1997). Black holes and the information paradox. *Scientific American*, Special Issue "The edge of physics", April 1997, 52-57.

Treisman, A. (1996). The binding problem. *Current Opinion in Neurobiology*, *6*(2), 171–178. doi:10.1016/S0959-4388(96)80070-5

van Benthem, J. (2003). Logic and the Dynamics of Information. *Minds and Machines*, *13*(4), 503–519. doi:10.1023/A:1026296600182

van Benthem, J. (2008). Tell It Like It Is: Information Flow in Logic. *Journal of Peking University*, *1*, 80–90.

Vedral, V. (2006). *Introduction to quantum information*. Oxford, UK: Oxford University Press. doi:10.1093/acprof:oso/9780199215706.001.0001

von Foerster, H. (1981). *Observing systems*. Seaside, CA: Intersystems Publications.

Von Neumann, J. (1932). *Mathematische Grundlagen der Quantenmechanik*. Berlin: Springer.

von Weizsäcker, C. F. (1974). *Die Einheit der Natur*. Munich: Deutscher Taschenbuch Verlag.

von Weizsäcker, C. F. (1985). *Aufbau der Physik*. Munich: Hanser.

Wiener, N. (1948). *Cybernetics: Or Control and Communication in the Animal and the Machine*. Cambridge, MA: MIT Press.

Wilson, D., & Sperber, D. (1993). Linguistic form and relevance. *Lingua*, *90*, 1–25. doi:10.1016/0024-3841(93)90058-5

Zadeh, L. A. (1986). Test-Score Semantics and a Basis for a Computational Approach to the Representation of Meaning. *Literary and Linguistic Computing*, *1*(1), 24–35. doi:10.1093/llc/1.1.24

Zubiri, X. (1999). *Sentient Intelligence. Tr. by Thomas B. Fowler*. Washington: Xavier Zubiri Foundation of North America.

## ADDITIONAL READING

For an introductory reading to the many aspects of information, the books of Luciano Floridi and Holger Lyre are recommended:

Floridi, L. (2010). *Information: A very short introduction*. Oxford: Oxford University Press.

Lyre, H. (2002). *Informationstheorie. Eine philosophisch-naturwissenschftliche Einführung* [Theory of information. A philosophical and scientific introduction]. Munich, W.: Fink Verlag.

Some other concise reviews of information visions in a broaden perspective can be found in the following contributions:

Capurro, R., & Hjørland, B. (2003). The Concept of Information. *Annual Review of Information Science and Technology*, Ed. B. Cronin, *37*(8), 343-411. Retrieved November 12, 2009, from http://www.capurro.de/infoconcept.html

Floridi, L. (2005). Information. In Mitcham, C. (Ed.), *Encyclopedia of Science, Technology and Ethics*. New York: Macmillan.

Probably the best historical perspectives in the evolution of the information understanding are the books of Rafael Capurro, who delve into the evolution of the information concept throughout western history of thought, and Jèrôme Segal, who explores the evolution of the scientific notion of information in the twenty century:

Capurro, R. (1978). *Information. Ein Beitrag zur etymologischen und ideengeschichtlichen Begründung des Informationsbegriffs* [Information: A contribution to the foundation of the concept of information based on its etymology and in the history of ideas]. Munich: Saur.

Segal, J. (2003). *Le Zéro et le Un. Histoire de la notion scientifique d'information* [Zero and One. History of the scientific notion of information]. Paris: Syllepse.

For deepening into the diversity of information theories, as well as in the potentiality to unite these perspectives it is highly recommended the book of Mark Burgin, where further references can be found:

Burgin, M. (2010). *Theory of Information: Fundamentality, Diversity and Unification*. Singapore: World Scientific Publishing.

Concrete overviews of the different theoretical proposals have been referenced throughout the text of this chapter. Another valuable resource for deepening into the manifold understanding of information is the *Glossarium BITri: glossary of concepts, metaphors, theories and problems concerning information*, conceived as a tool in constant growth to reflect the different points of view in information research. It has book and online editions:

Díaz Nafría, J. M., Salto, F., & Pérez-Montoro, M. (Eds.). *Glossarium BITri: Glossary of concepts, metaphors, theories and problems regarding information*. León: Universidad de León. Retrieved September, 2010, from http://glossarium.bitrum.unileon.es

## KEY TERMS AND DEFINITIONS

**Cybernetics:** The name of this well settled scientific discipline derives from the Greek word Κυβερνήτης, which means the art of steering a ship and was used by Plato in the sense of guiding or governing men. In coherence with this Greek sense, Cybernetics nowadays refers to the study of the control and communication of complex systems, whether they are living organisms, machines or organizations, paying special attention to the feedback as the main way of regulation.

**Cybernetics of the First order or Classical vs Cybernetics of the Second Order:** In 1958, Heinz von Foerster conducted a critical review of

Wiener's cybernetic theory. He argued that, though this theory was introducing significant changes regarding previous conceptions of regulation and control, it did not involve an epistemological break with the traditional conception of science. As Foester criticized, the model in which the observer is able to contemplate the object or the system from outside – without perturbing it and achieving an objective knowledge of it – continued to be applied, whereas cybernetics of the fist order can be synthetized through the question: "What and how are the mechanisms of feedback of the studied system?," cybernetics of the second order raise the question: "How are we able to control, maintain and generate this system through feedback?" In the last case epistemology plays a central role, which was absent in the classical approach.

**Cybersemiotics:** By means of connecting Peirce's semiotics (*sign*) with the *cybernetics of the second order*, Søren Brier defines *cybersemiotics* in terms of a dynamic and contextually adaptive relationship between a sign, an object and an interpreter (Brier 2008).

**General Theory of Information:** In this approach proposed by Mark Burgin under the awareness of the irreducible variety of information kinds, instead of pursuing a unitary definition of information, a parametric definition is offered. By this means, information stands in a very flexible way for a capacity to cause changes in an infological system. The flexibility of these infological systems enables the adaptation of this approach to the multifaceted reality of information by means of formal models. On the other hand, this approach provides tools for measuring and evaluating information.

**Infocomputionalism:** In this approach proposed by Gordana Dodig-Crnkovic (2010), information is conceived as the ontological basis of the universe (its structure) whereas computation – in a broadened sense – represents its dynamics.

**Interdisciplinarity:** articulation of different disciplines into a common objective (scientific, technical or social), providing each one its particular point of view, contrasted with the others and therefore pursuing a mutual understanding of their respective points of view (especially concerning shared fields of interest). It does not intend to provide an integrative and unitary theoretical perspective, but (i) a good and useful articulation of perspectives to broaden the scope of the common objective; (ii) smoothing any phenomenological discrepancy at shared fields of observation; (iii) maintaining a critical stance among perspectives. It may also pursue the objective of seeking for a minimal set of primitive abstract theories (eventually one), each of them being consistent with different sets of disciplinary theories, which also contain specific components to grasp the particular reality being attended and not covered by the corresponding primitive theory. If just one unitary theory were feasible, the interdisciplinarity might converge into transdisciplinarity.

**Multidisciplinarity:** Articulation of different disciplines into a common objective (scientific, technical or social) through division of tasks/objectives among the partaking disciplines. The interplay between different participants must be carefully coordinated through protocols for the mutual understanding of the partial results provided by other parties. A key factor in the work division, which follows the scheme of modularity, concerns the specification of the requirements that each party must satisfy for meeting the global objective. It intends neither the mutual understanding among partaker's visions, methods or theories, nor the critical stand among parties. It just considers that the addition of the "positive" results (i.e. satisfying the validity requirements) of each discipline converge into the common objective. From this point of view, it can be branded as a "positivistic" approach to the integration of knowledge, rather pragmatically than epistemologically oriented. Interdisciplinarity and transdisciplinarity can be regarded as different levels of integration of knowledge beyond multidisciplinarity, in which the later represents the most integrative level.

**Positivism:** In a very wide sense, it can be understood as a doctrine attained to the relevance of the positive, i.e., what is certain, effective, true, etc. It can also be regarded as attained to what is given, in opposition to what is supposed, assumed. Thus, positivism represents a fundamental rejection of metaphysics. Although historically a wide variety of schools has been branded as positivism, two main stances can be highlighted. The first related to *Auguste Comte* who understood "positive" as a last evolutionary stage after the metaphysical one, in which the praxis is rooted on the predictions provided by a knowledge based on facts. The second referred to as *logical positivism* (also branded as empirical positivism and neopositivism) which sprang up in the Vienna Circle, and later developed within the Anglo-American philosophy as well as in the analytical tradition. This later is chiefly characterized by an anti-metaphysical inclination and the development of verification thesis.

**Transdisciplinarity:** Articulation of different disciplines into a common objective (scientific, technical or social), gathering each discipline into an integrative, abstract and united vision, being consistent with all the involved disciplinary theories, which are completed with specific components to grasp the particular reality being attended and not covered by the united theory. As in the case of interdisciplinarity, a critical stance among disciplines is a basis for its articulation, but in this case aiming a common theoretical frame for the smoothing of phenomenological discrepancies. The transdiciplinarity can be regarded as a principle for the unity of knowledge beyond disciplines.

**Unified Theory of Information (UTI):** This approach aims at a theoretical articulation embracing all processes and structures related to the creation, transformation and the crystallizing out of information in cognitive, communicative and cooperative contexts, by means of (a supposedly feasible) blending of the concepts of self-organization and semiosis. This approach has been mainly advanced by Peter Fleissner, Wolfgang Hofkirchner, Norbert Fenzl, Gottfried Stockinger and Christian Fuchs.