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The creativity of authors in defining the concept of information

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Abstract
Purpose – The concept of information is central to several fields of research and professional practice. So many definitions have been put forward that complete inventory is unachievable while authors have failed to reach a consensus. In the face of the present impasse, innovative proposals could rouse information theorists to action, but literature surveys tend to emphasize the common traits of definitions. Reviewers are inclined to iron out originality in information models; thus the present bibliographical research aims to discover the creativity of authors attempting to define the concept of information and to stimulate the progress of studies in this field.
Design/methodology/approach – Because the present inquiry could be influenced and distorted by personal criteria and opinions, we have adopted precise criteria and guidelines. It could be said the present approach approximates a statistical methodology.
Findings – 1) We found 32 original definitions of information which sometimes current surveys have overlooked. 2) We found a relation between information theories and advances in information technology. 3) Overall, we found that researchers take account of a wide variety of perspectives yet overlook the notion of information as used by computing practitioners such as electronic engineers and software developers.
Research limitations/implications – We comment on some limitations of the procedure that was followed. Results 1 and 3 open up new possibilities for theoretical research in the information domain.
Originality/value – This is an attempt to conduct a bibliographical inquiry driven by objective and scientific criteria; its value lies in the fact that final report has not been influenced by personal choice or arbitrary viewpoints.
Keywords – Information definitions; information theory; theoretical production in information science; statistical methods.

1. Introduction

The importance of creativity

The notion of information is of central relevance to modern computing theory and practice. A shared and comprehensive conceptualization could enable people to cope with the challenges of the so-called information society. Over the years many major and minor efforts have been made to clarify the concept of information, nonetheless a definitive conclusion has not been reached so far. Although the existing literature on the subject is particularly rich, the scientific community appears to be in deadlock. This unresolved situation might be reinvigorated by means of studies characterized by imaginative thought. Unusual and even bizarre views have the ability to push researchers out of intellectual stagnation and toward progress. Original proposals could support a vibrant exchange of ideas and facilitate new discoveries. By way of illustration, we recall how quantum theorists react when encountering knotty issues, putting forward constructs that seem paradoxical at first glance. As an example, the 'many worlds' theory of Hugh Everett posits the existence of a very large – perhaps infinite – number of universes in addition to the one in which we live. In an analogous manner, creative inspiration could open up new veins of research in the information domain and help scholars to advance furthermore.

Bleached and distorting colors

Here, we make a couple of remarks.
a) Generally speaking, innovative ideas are not so easy to come up (Bloom et al 2017) and the reviewers of the information literature could at least shine a light on the original models that have already been put forward. Commentators could select well-known and even little-known intriguing interpretations of information, but this seems rarely to happen. They reason

within a collaborative logic and highlight the similarities between studies rather than their dissimilar features. For example, some commentators tend to focus on a certain type of contributions such as Jumarie (1996) who emphasizes the discussion of entropic models of information; Flükiger (1995) who gives prominence to the semiotics perspective on information. Other reviewers tend to gather definitions of information into groups in order to emphasize the intellectual traditions and look into logic symmetries. Some surveys offer insights into the antecedents of theoretical models; others describe the intellectual thread that connects certain patterns and, in this manner iron out any existing difference among the various bibliographic contributions, such as (Fox 1983), (Aspray 1985), (Stevens 1986), (Collier 1990), (Qvortrup 1993), (Cornelius 2002), (Capurro and Hjørland 2003), (Case and Given 2006), (Nafría 2010), (Kajtazi and Haftor 2011) and (Melnikov 2011). For the sake of completeness, we should also mention the few reviewers who deliberately emphasize the originality of contributions such as Levitan (1980) and Schement (1993).

b) The authors of the present inquiry have a certain scientific sensitivity and have noticed how personal philosophy can influence the very description of the published concepts, and how inevitably human factors distort a literature review such that readers might doubt that the ideas about information are really as they have been presented. It could be said that reviewers do not depict the colors as they really are in the literature but use bleached shades of color. The approach usually adopted by reviewers appears rather distant from the scientific method which minimizes arbitrary factors.

In summary, we find that current studies of information interpretations have the following features:

- **a.** They tend to iron out the disparity of ideas,
- **b.** They are influenced by the personal viewpoints of the reviewers.

Purposes of the present inquiry

The present inquiry has the purpose of addressing shortcomings **a** and **b.** We mean to shed light on innovative writers such as they are and not to conceal their differences, their contrasting relations to mathematics, their dissimilar attention to human consciousness and so forth. Second, we want to avoid classifying the various interpretations of information according to our own frame of reference. In summary, the aims or targets of this research are as follows:

1. To identify original ideas emerging from the information domain.
2. To produce a report that is not distorted by personal convictions or decisions.

2. Searching for a scientific method

Subjective criteria have no place in statistical sampling, and the present inquiry gets close to statistics by adopting an 'objective-scientific' method of study as opposed to the usual 'subjective-literary' mode. In particular we have established a procedure intended to guide this bibliographical survey and to pursue goals **1** and **2.** This procedure includes the following three sections.

Guidelines

A) If we choose unusual interpretations of information on the basis of our personal culture and knowledge, we would meet target **1** but miss target **2.** Hence in order to minimize arbitrary decisions we opted for the assistance of Google. We used this search engine with strings including keywords such as "information theory," "theory of information," "theoretical information," "information definition" and some combinations of them.
We could have explored research-oriented databases like ABI/Inform collection, Web of Science, or Library and Information Science Abstracts. However, we intended to access even works placed at the borderline of the official literature, and Google turned out to be good for this purpose.

B) We finetuned the selection process in order to avoid shortcomings **a** and **b**. Specifically, we adopted the following guiding principles of inclusion and exclusion:

#1 Rule of Formalism: Generally speaking, a theory expresses the highest point achieved by a researcher in a given domain; thus, we have inventoried the definitions of information that belong to a structured theory or anyway are situated within a theory; ideas expressed in informal discourses have been excluded. Theory had to be officially defined by the author(s) or in some way recognized in the literature. For example, Shannon labels his work 'Mathematical theory of communication;' Hartley does not mark his work with the title 'theory' but commentators concede that Hartley presents a consistent framework to calculate transmitted information. Finally, the present inquiry searched theories that were confined between 1900 and 2011.

#2 Rule of Indifference: The scope of the present survey was to illustrate the variety of ideas in the field (see point **1**). Therefore, being popular or unpopular did not matter: all ideas were included. We also accepted both simple and complex constructions.

#3 Rule of Centrality: At the present time the concept of information could be considered a 'fashionable' theme of research and some author inserts his definition inside a broader frame in which this definition is marginal or plays a secondary role. We have excluded such contributions; for example, we have separated out a number of semiotic, logic and cognitive science projects in which the notion of information appears somewhat subsidiary or has emerged as a by-product.

#4 Rule of Dissimilarity: Every author presents something new, but this inquiry focuses on original ideas and thus studies which have simply reused previously published definitions, have been discarded. Also works that have sought to complete, perfect or even mirror previously established models have been excluded.

In retrospect, rules #3 and #4 turned out to be the most significant and we shall discuss them in the final section.

	Attribute	Author(s)	Year		Attribute	Author(s)	Year
1	*Statistical*	Fisher	1922	**17**	*Organizational*	Stonier	1990
2	*Transmission*	Hartley	1928	**18**	*General*	Klir	1991
3	*Communication*	Shannon	1948	**19**	*Physical*	Levitin	1992
4	*Cybernetic*	Wiener	1948	**20**	*Quantum*	Lyre	1995
5	*Semantic*	Hillel; Carnap	1952	**21**	*Independent*	Losee	1997
6	*Engineering*	Powers	1956	**22**	*Social*	Goguen	1997
7	*Utility*	Kharkevich	1960	**23**	*Purpose-oriented*	Janich	1998
8	*Algorithmic*	Kolmogorov	1965	**24**	*Cybersemiotic*	Brier	1999
9	*Descriptive*	MacKay	1969	**25**	*Activity-based*	Karpatschof	2000
10	*Qualitative*	Mazur	1970	**26**	*Biological*	Jablonka	2002
11	*Anthropological*	Bateson	1973	**27**	*Mathematical*	Kåhre	2002
12	*Pragmatic*	Weizsäcker	1972	**28**	*General*	Burgin	2003
13	*Autopoietic*	Maturana; Varela	1980	**29**	*Philosophical*	Floridi	2004
14	*Cognitive*	Brookes	1980	**30**	*Sociological*	Garfinkel	2008
15	*Common-sense*	Derr	1985	**31**	*Unified*	Hofkirchner	2009
16	*Systemic*	Luhmann	1990	**32**	*Communicative*	Budd	2011

Table 1. List of the surveyed interpretations of information.

C) The description of a construct could reflect the culture of the reviewer which would be contrary to target **2**. Hence, for each theoretical construction we prepared a record which includes the intended definition of information and with a few explications preferably written in the same language of the definition's author. The records do not include any remark from the authors of the present paper (who make their observations at the close of this survey). We left out any philosophical remark and embellishments that would be contrary to target **2.**

It may be said this inquiry is an attempt to progress on the scientific plane as it extracts a sample from the literary production employing statistical-objective rules rather than intellectual-subjective criteria.

3. Thirty-two interpretations of information

Applying guidelines **A), B)** and **C),** we have found 32 different interpretations of the concept of information as exhibited in chronological order in Table 1. A column qualifies the attribute of each theory established by the original author, commentators or the authors of the present study. The broad range of descriptive attributes reflect the diverging intellectual stances of the authors and gives a first idea of their inventiveness. We summarize the selected interpretations of information in the following manner in accordance with point **C).**

The statistical measure-related definition by Fisher

Ronald Aylmer Fisher (1922) first presented a scientific definition of information on the basis of pure statistical reasoning. He notes that prior to conducting an experiment there is objective uncertainty due to the fact that several possibilities for the result have to be taken into account. The outcome of the experiment furnishes information that reduces this uncertainty, and Fisher means to specify the amount of information related to the measurement process. By way of illustration, suppose an observer wants to measure the quantity *y* but he obtains *x* which differs from *y* by a random value because of the faults of the measurement process, for instance the variable *x* follows the normal distribution

$$f(x;\mu,\eta) = \frac{1}{\sqrt{2\pi\eta}} \exp\left(-\frac{(x-\mu)^2}{\eta^2}\right). \tag{1}$$

Fisher's information is a quantity associated with a parameter of the probability distribution. E.g. the mean μ and the standard deviation η are the parameters typical of the normal distribution (1). Fisher (1925) establishes various equations for defining information, the most straightforward form being the following

$$I_{x,\theta} = -\int f(x;\theta) \frac{\partial^2 \left[\ln f(x;\theta)\right]}{\partial\theta^2} dx. \tag{2}$$

The Fisher information (2) is a way of measuring the dispersion that the observable random variable *x* carries about the unknown unbiased estimator θ upon which the probability of *x* depends. That is to say the 'more random' the values of *x* are, the smaller the information value is. For Fisher:

Information qualifies the ability to know using a system of measurement.

The Fisher equations are calculated for measuring the unbiased estimator in many areas. For instance, Fisher information is used in optimal experimental design where maximizing the information corresponds to minimizing the variance of the variable *x*.

The transmission definition by Hartley

Basic observations on electrical transmissions and circuits led Ralph Hartley to search for a quantitative measure whereby the capacities of various pathways to transmit information could be compared. Hartley (1928) distinguishes the physical transmission of signals from 'psychological factors' and holds that from the engineering perspective

Information is determined by the number of possible messages
independent of whether they are meaningful.

Suppose that to convey *s* symbols out of a set of *n* symbols – that is to say the alphabet in use has *n* symbols – at the other end one has the possibility of getting s^n distinguishable messages. Hartley understands that the amount of information is proportional to the number of possible selections. An equal amount of information corresponds to an equal number of possible sequences, and obtains this function through some mathematical manipulations

$$H = \log_a s^n = n \log_a s. \tag{3}$$

Where *H* is the *amount of information*, *n* is the number of symbols in the message and s^n is the number of possible symbolic sequences of the specified length *n*. In substance, Hartly denotes with the word 'information' a measurable quantity reflecting the receiver's ability to distinguish one sequence of symbols from any other.

The communication definition by Shannon

Claude Shannon (1948) starts from the question of how the capacity of a channel can be maximized and searches the amount of information that comes through the channel. He openly rejects semantics and writes, "Semantic aspects of communication are irrelevant to the engineering problem." Shannon agrees on the idea that information is the outcome of a selection among a finite number of possibilities:

Information is the measure of one's freedom of choice *in selecting a message out of the n messages.*

The greater this freedom of choice is, the greater the uncertainty is that the message actually selected is a particular one and the greater the information is. Equally likely messages convey the maximum information. Shannon merges and integrates the concepts of *information, choice* and *uncertainty*.

Shannon holds that the source S conveys *n signals* (or *messages*) with probabilities (p_1, p_2, ... p_n) and derives the function $H = H(S)$, which he calls *entropy* or *amount of information* conveyed by S on the basis of the ensuing postulates:

- Continuity: H should be continuous in the p_i ($i = 1,2 \ldots n$)
- Monotonicity: If all the p_i are equal, $p_i = 1/n$, then H should be a monotonic increasing function of n.
- Grouping: If a choice is broken down into two successive choices, the original H should be the weighted sum of the individual values of H.

These constraints lead to the following entropy function

$$H = -k \sum_{i}^{n} p_i \log_a p_i. \tag{4}$$

Where k is a positive constant, and the base a is usually 2. Shannon confines himself to the communication engineering aspect of information and explains the practical use of H that provides the average number of bits needed to implement the optimal encoding of the n messages conveyed by S. The essay (Shannon 1948) proves twenty-three theorems in all that calculate optimal data transmission.

The cybernetic definition by Wiener

Norbert Wiener's conception of cybernetics in (1948) involves the governing of action through the feedback of information; more precisely, he writes:

The amount of information in a system is a measure of its degree of organization.

Wiener understands information as a separate category of the natural sciences by stating that "information is information, neither matter nor energy." He notices how the transmission of a sole continuous signal can be suppressed without consequences; hence, one can convey information exclusively through the transmission of alternatives and the entropy is the most appropriate mathematical tool to get the amount of information. Wiener believes that the entropy qualifies the order in the information domain, but he employs the *negative entropy* in communication and transmission which some calls *negentropy.* Specifically, Wiener assumes the probability of a variable which falls between x and $(x + dx)$ is given by $f(x)dx$; he puts forward this integral as the measure of the total amount of information associated with the curve $f(x)$

$$\int_{-\infty}^{+\infty} [\log_2 f(x)] f(x) dx. \tag{5}$$

Wiener considers the probabilities calculated in advance of a certain event and after the event occurs. For example, we know 'a priori' that a variable lies between 0 and 1, and 'a posteriori' that it lies on the interval (a, b) inside (0, 1). Then the amount of information we have from posterior knowledge is

$$-\log_2 \left[\frac{measure\ of\ (a,b)}{measure\ of\ (0,1)} \right]. \tag{6}$$

Wiener calculates a number of different cases and attaches these topics to issues of decisions, communication and control in living beings and machines.

The semantic definition by Bar-Hillel and Carnap

The construct of semantic information theory has been brought up by Yehoshua Bar-Hillel and Rudolf Carnap (1952) who attempt to weave the probabilistic approach into a logical setting. By doing so, semantic information theory inherits an understanding of information as something that prunes uncertainty:

Information influences the cognition process, in the sense of a reduction of uncertainty.

The authors attempt to determine and compute the meaning of a sentence in a systematic manner. They strive for the objectification and quantification of the semantic aspect of information, assuming that a message contains no information for someone who is already aware of the message content. Bar-Hillel and Carnap consider the semantic probability $P(i)$ of the sentence i that can be computed according to the classic definition of probability as the ratio of the alternative descriptions of the sentence to the total number of descriptions. Obviously, the total probability of the descriptions is one. The probability distribution is the outcome of a logical construction of *atomic statements* according to a chosen formal language. Because information reduces uncertainty, the *semantic content* CONT(i) of i is the complement of $P(i)$; namely, it is equal to the total probability – which depicts total uncertainty – minus the semantic probability of the sentence i

$$\mathrm{CONT}(i) = 1 - P(i). \tag{7}$$

Bar-Hillel and Carnap establilsh some mathematical postulates and deduce the logarithm as the measure of information provided by the sentence i

$$\mathrm{INF}(i) = \log\left(\frac{1}{1-\mathrm{CONT}(i)}\right) = -\log P(i). \tag{8}$$

In substance, the authors put forward two kinds of information within the semantic frame:

- CONT(s) is the amount of semantic content or *substantive information*.
- INF(s) is the amount of semantic unexpectedness or *surprise information*.

From the mathematical definition quoted above, it follows that the lower $P(i)$ is – namely the less probable the description conveyed by the sentence i – the more semantic information is carried on. Therefore, unrealistic descriptions – whose probability is zero – contain the highest amount of semantic information. This is called the 'Bar-Hillel-Carnap semantic paradox'.

The engineering definition by Powers

Kerns H. Powers (1956) names his theory as the 'unified theory of information', but in reality he follows purely engineering and mathematical perspectives that is why the title adopted here. He assumes that information is typically associated to the process S which is qualified by the triple

$$S = (X, \sigma, P).$$

Where X is the space of the variables of the process, σ is the sigma-algebra adopted for the calculus of the probability P. For Powers

Information is the change of probability determined by the functioning of the process.

He introduces ρ and ν that are the prior and posterior probabilities associated with the process, and calculates the probability variation in the following terms

$$I = \int_X \log\left(\frac{\partial \nu}{\partial \rho}\right) d\nu. \tag{9}$$

Power explains the general coverage of his construct using mathematical justifications such as the indifference of the definition to continuous and discrete probability functions, the set X is an abstract space, etc.

The utility definition by Kharkevich

Aleksandr Aleksandrovich Kharkevich (1960) assumes a realistic stance and sees information as the function of the *purposes* or *states* that the system R has to pursue in the physical reality. For the Russian author, information is *entelechy*; this term – deriving from Aristotle's philosophy – means "containing the purpose inside". Information should be thought of as a purpose combined with a system; thus he claims:

Information is related to the goal achieved through the use of information items.

The problem of information is reduced to the problem of purposes, and this concept leads to some intriguing conclusions. In fact, the use of information depends on the definition of life goal, which inevitably suggests that a living system originated from nothing or was born from above, namely the biological life could lead to opposite philosophical views.

Kharkevich's theory centres on the *value* or *quality of information* which he determines by means of the probabilistic approach. In particular, the value I_{ij} of information has this form

$$I_{ij}\left(W,M\right)=\log_2\left(\frac{P_{ij}}{P_j}\right). \quad (10)$$

Where:

- W is the total number of the goals (or future states) of the system R;
- M is the total number of the information items necessary to control the W goals of R;
- j denotes a goal: $1 \le j \le W$;
- i denotes an information item: $1 \le i \le M$;
- P_{ij} is the probability of getting the goal j as long as the information item i has been received;
- P_j is the probability of reaching the goal j without any piece of news.

The system R can reach the prefixed objective or can even move away from the objective, and in consequence the value I_{ij} may be positive or even negative. The positive value of information is determined by the increase of probability P_{ij}; namely, R achieves its purposes using the information item i. It is evident how the quality of information has no direct relation to the truth of information. According to Kharkevich, the purpose plays the role of *meta-information* because it gives the meaning to all additional information useful for its achievement. As the purpose is a sort of information, it is possible to construct a *hierarchy of pieces of information*, each of them being evaluated by the purpose of the next level.

The algorithmic definition by Kolmogorov

The algorithmic information theory was introduced independently and with different motivations by Andrey Kolmogorov, Ray Solomonoff and Gregory Chaitin in the early 1960s. Current literature recognizes three fathers to the overall theory but probably the major contribution to the definition of information is with Kolmogorov (1965).
Kolmogorov looks at the sequence of symbols X and defines:

Information of X *is the minimum size of the program necessary to generate the sequence* X.

More precisely, given the universal Turing machine U, the algorithmic information content H(X) of the string X is the length of the *shortest program* p on U producing the string X. In fact, also p is a string since any computer program is a sequel of characters in symbolic form or a string of bits in executable form. Let us call X* the string associated to the shortest program p, the following equation formalizes Kolmorogov's definition of information

$$H(\mathrm{X}) = |\mathrm{X}^*|. \quad (11)$$

Where |X*| is the size of X*. To explain (1) take these two strings that have the same length (26 characters):

X1 = xyxyxyxyxyxyxyxyxyxyxyxyxy
X2 = ahfm7wsxvbaoopfqba3jskemwg.

The first string can be programmed using the following software program p1 that is 15 characters in length:

Put xy 13 times.

X2 has more information and requires more characters to be programmed. The shortest program p2 that prepares X2 could include the string itself that is 26 characters in length: 26 > 15. More information is conveyed by X and X is more complex; thus, H(X) is also called *algorithmic complexity*. Chaitin extended the use of H to define complexity for biological systems. The complexity of an arrangement of cells is, for example, determined by draping a grid over the cell space and finding the minimum algorithm that can reproduce the original cell topology.

The descriptive definition by MacKay

Donald M. MacKay (1969) writes, "Suppose we begin by asking ourselves what we mean by information. Roughly speaking, we say that we have gained information when we know something now that we didn't know before; when 'what we know' has changed." For MacKay, information improves our knowledge:

Information is linked to an increase in knowledge on the receiver's side.

Knowledge is interpreted as a coherent representation which includes *information elements*. Information elements are related, and this makes the recognition by the receiver easier. Information improves the receiver knowledge, and thus MacKay classifies three kinds of information contents:

- *Structural information content*, dealing with a priori logical aspects and measured by 'logons'.
- *Metrical information cont*ent, dealing with posterior, empirical aspects measured by 'metrons'.
- *Selective information content*, measured by 'bits'.

MacKay labels the first two measures as *constructive*, while the third measure corresponds to Shannon-type information and is labelled *selective* as Shannon calculates 'selectable' signals. The methods of the present descriptive theory are similar to inferential statistics in a way, though the author intends them to be still more general than that.

The qualitative definition by Mazur

The Polish cybernetician Marian Mazur notes how information and informing are of a transdisciplinary nature and derive from a variety of perspectives. Thus, he feels it necessary to embrace the entire domain through accurate cataloguing of entities involved in the information process, which is why the attribute *qualitative* is used for his theory. Mazur (1970) begins with the notion of *factor*, which is anything that affects the results of actions and phenomena. He distinguishes the *factors in substance*, which are physical entities, from the *factors in form*, which can be observed, communicated and/or transported. Mazur concludes:

Information is anything in form.

At this point, the author proceeds to analyse the various kinds of information and the systems handling information. He starts by distinguishing the *macro* and *micro views of information*: the first involves influential decision-making while the second investigates elementary signals in communication systems. In order to develop a micro analysis, Mazur places information inside the cybernetic model of feed-back/feed-forward, in which the information flow moves from the *controlling system* toward the *controlled system*. Mazur calls *originals* the output signals of the controlling system, and calls *images* the input signals of the controlled systems. In Mazur's view, *informing* consists of the transformation of originals into images; as an example, the transformation of points of landscape into points on its map constitutes an informing process. Mazur continues with the accurate analysis and cataloguing of the various information processes. The Polish author uses the term *trans-informing* for faithful or perfect informing process and labels *imperfect informing* the process with greater practical importance but less accurate content. Mazur classifies three basic types of processes that are *unbalanced:*

- *Simulating*, when images contain more information than originals;
- *Dissimulating*, when images contain fewer information than originals; and
- *Confusing*, a combination of simulating and dissimulating informing.

Mazur dedicates separate chapters to *degenerated informing*, such as *pseudo*-informing and *dis-informing*. He also distinguishes different degrees of simplified or reduced informing, called *para-informing*.

The pragmatic definition by von Weizsäcker

This theory was first outlined in (Weizsäcker 1972) and later explained in the book *The Unity of Nature* (1980). The label of this theoretical frame was established by the author Carl Friedrich von Weizsäcker, a German physicist and philosopher who saw the notion of information in relation to *pragmatics*, namely in relation to the information use. He traces back to the classical thinkers to show how the concept of information regards the *form* or *structure of the signs*; thus, information is a property of material entities. He holds that the quantitative measure of the *form* is linked to the number of alternatives that must be decided in order to describe this form. For Weizsäcker, the amount of information contained in a form is exactly the measure of that form:

Information measures the form.

But information should not be conceived as perennial; it is changing over time and Weizsäcker concludes that the probability provides a measure of evolving conditions. If $P(E)$ is the probability of the possible event E, the author holds that the amount of information obtained when one observes E is calculated by

$$I = -\log_2 P(E). \tag{12}$$

The lower $P(E)$ is, the more information E furnishes. Besides equation (12), the German philosopher describes information in words as a twofold category:

(1) Information is only that which is understood.
(2) Information is only that which generates information.

Weizsäcker stresses that a biological structure is something that can be known (definition 1), while at the same time the whole organism is the product of genetic information (definition 2).

The notions of *novelty* and *confirmation* embody the pragmatic information theory; notably, the maximum of pragmatic information is assigned to a message that transfers an optimum mixture of novelty and confirmation to the receiver. Conversely, a redundant message that basically confirms the prior knowledge of a receiver will not cause any change. Weizsäcker warns that a message completely unrelated to any prior knowledge of the receiver is *novel* but will also not change any structure or behaviour simply because it will not be understood. The pragmatic information of this message is null.

The anthropological definition by Bateson

Gregory Bateson (1973) takes inspiration from his background in various human sciences and concludes:

Information is a difference that makes a difference.

Bateson observes that an individual perceives reality through his or her senses which detect differences in stimuli, and in turn influence individual cognition. When a sensory message to the brain is constantly repeated, the sensitivity weakens and finally is suppressed; namely, *there is not information when there are not differences*. Lack of contrast does not make people informed and the receptors are capable of reporting news to the brain only when something changes.

Bateson observes that any item of information triggers a feedback process. The brain processes sensorial data which provokes internal reactions even if there is no apparent sign. Factually the decision to react or not to react is an internal state of the individual after a stimulus.

Bateson feels the need to specify the notion of difference that is central to his definition and notes that any object is characterized by a high number of special features that are the *differences* typical of that object. It is precisely because of this infinitude that a system, as such, cannot enter into a communication or a mental process. Systems normally *select* and *filter out* a limited number of differences of the intended object; notably, *information is an abstract entity*, the outcome of mental filtering. As an example, the 'object hammer' is material with several peculiar attributes; 'information hammer' is abstract since it has the reduced set of attributes accepted by the individual's mind.

Bateson (1980) stresses the contrast between the world as seen from the perspective of physical sciences, where the effects are caused by concrete causes, and the world of communication, where the effects are brought about by differences. Bateson emphasizes the separation between the world physically explained, which he calls *pleroma* after the Swiss psychiatrist Carl Gustav Jung, and the world created by the human mind that he calls *creatura*. He does not put a distinction between Nature and mind but rather between two separated modes of explanation.

The autopoietic definition by Maturana and Varela

Humberto R. Maturana (1970) outlined a set of principles originally intended to address issues of biology and cognition. Later Maturana – with the aid of Francisco Varela, his student – developed interesting theoretical implications for (among other things) epistemology, linguistics and sociology. It is necessary to provide some background first because of the innovative profile of this theory where novel ideas about information have been put forward (Maturana and Varela 1980, 1992).

Maturana began scrutinizing sensorial perception, and sense illusions convinced him that the human faculty of perception is absolutely unreliable. Things are not as we see them, and Maturana reached the extreme conclusions: the scientific method postulates the objective knowledge of the physical reality and proceeds on the basis of this unproved axiom. Scientists search for the objective knowledge even if this knowledge turns out to be illusory.

Maturana and Varela examine closely the context which stimulates the neuronal activities and note how these activities are determined by the individual's biological structure which is unique. *Thus knowledge is not the representation of the world out there, but is the construction of a personal world through the living processes* which operate at the biological level and the psychological level as well. Maturana and Varela deny the conventional distinction amongst being, knowing and acting; instead they say, "All doing is knowing, and all knowing is doing" inside the *autopoietic system*. Basically, an autopoietic system can be defined as a network of processes that is able to create, transform and destruct its own components. Biological beings are modelled as autopoietic systems because, for example, the human body keeps alive all its organs by itself and even creates its own cognition. An autopoietic system is the opposite of an *allopoietic system*, such as a car factory, which uses raw materials and produces a car that is something other than the factory.

Maturana and Varela say that living systems are cognitive systems and living is a process of cognition. Cognition is the sum of all interactions of the living organism in its operational domain. Cognition is not a special property of higher nervous systems but takes place even without a nervous system. Cognition is a biological phenomenon.

The validation of knowledge is the maintenance of a successful system whereas *false knowledge* will lead to the destruction of the autopoietic process. To illustrate this, Maturana uses the example of the amoeba engulfing a protozoan. The amoeba is able to capture a protozoan thanks to the internal correlation between its sensory and motor surfaces. Maturana says that in more complex organisms the process of sensorimotor coordination is much the same. This is quite different from the idea of a message or instruction that is being acted upon; instead, it is an internal correlation that is being maintained. Thus, cognition cannot be viewed as information processing; *cognition comes into existence from the internal coherence of the autopoietic system rather than from the internal representation of something*. Thus for Maturana and Varela:

Information does not exist.

What we usually call 'information' is a matter of internal construction rather than external instruction, hence, there cannot be such a thing as information transfer. The model transmitter/channel/receiver is nonsensical. Maturana and Varela see the tem 'information' as a flawed explanatory device for analysing the phenomenology of living systems. More specifically, they criticize the school of thought which assumes that the adaptation of organisms to achieve closer consonance with the external reality is to be evaluated from the perspective that "their organization represents the environment in which they live", and that "through evolution they have accumulated information about it". Maturana and Varela deny that the sense organs can gather correct information about the world; in preference, they attribute the capacity for functional discrimination to the organism's structure. Maturana and Varela even *reject any internal manipulation of information or signals, as the cognitivist viewpoint would have us believe*.
The Chilean authors develop an organizational and structural description of living systems which does not require recourse to a conventional notion of information. In particular, they explicitly negate the notion of information processing. This would mean that such inputs or outputs are part of the definition of the biological system, as in the case of computers or other appliances that have been engineered. The authors write "The nervous system, however, has not been designed by anyone. (...) The nervous system does not 'pick up information' from the environment, as we often hear. (...) The popular metaphor of calling the brain an 'information-processing device' is not only ambiguous but patently wrong." Maturana and Varela make a landmark attempt to integrate biology, cognition and epistemology into a single science, reversing the dualism fact/value and observer/observed. The autopoietic theory of information could be defined as the *negationist theory of information* and appears extremely intriguing for this reason.

The cognitive definition by Brookes

Bertram C. Brookes (1980) believes a direct link is placed between information and knowledge since information alters the receiver's knowledge, placing this idea at the centre of his construction:

Information is that which modifies a knowledge structure.

Brookes recognizes that *knowledge is a structure*, or better is a linked structure of concepts, and claims that *information is the dynamic part of such a structure*. He argues that the theoretical pursuit of information science should be "the cognitive interactions between users and the public knowledge systems" and formalizes this idea using the mathematical language. Specifically, he introduces the so-called *'fundamental equation of information science'*

$$K(S) + \Delta I = K(S + \Delta S). \tag{13}$$

This expression states that a person's existing knowledge structure $K(S)$ is changed to the new modified structure $K(S + \Delta S)$ by the information ΔI, and ΔS indicates the effect of the modification. The dynamic influence of ΔI on the knowledge structure $K(S)$ causes this structure to be different; that is to say, knowledge changes the human mind in some way with the input of information. The same information ΔI may have different effects on different knowledge structures. Existing private knowledge is transformed under the action of various changes ΔI that are continually selected and integrated. It may be said that Brookes provides the most abstract formal specification of the interaction of data, information and knowledge.
Because thinkers see a mathematical equation as a reductive expression of reality, Brookes points out that (13) should be viewed as a representation of more complex insights, and appends extended annotations on the concepts of knowledge and information.

The common-sense definition by Derr

Richard Derr (1985) does not study the term 'information' in literature but rather examines ordinary discourse and conversational utterances. He analyses sentences of this type: "Do you have information about the whereabouts of John Smith?" and "The same information can be found in the newspaper". From the analysis of common discourses, Derr derives the most common properties of information as follows:

(1) Information is a representation.
(2) The representation is abstract.
(3) The representation is meaningful.

(4) The representation consists of determinations which have been made.
(5) The determinations have been made of certain objects.

Derr argues that – on the basis of these five sufficient conditions for information phenomena – four derivative properties of information can be identified as well. In usual conversation, information turns out to be:

- *Communicable*;
- *Informing*;
- *Empowering*, i.e. one can make decisions on the basis of information;
- *Quantitative*, i.e. information varies in amount.

Starting from this premise, Derr arrives to the following definition:

Information is an abstract, meaningful representation of determinations made of objects.

For Derr, information has the capacity to inform rather than being that which informs. Information is an objective phenomenon existing independent of whether or not it produces an effect on a receiver. Derr describes an abstract phenomenology in which information is *a record of resolved uncertainty* that is making a determination, and *determination* is a judgement of what is the case.

The systemic definition by Luhmann

Niklas Luhmann is a German sociologist and philosopher who produced an impressive amount of works whose language is not easy to read and decipher. In the information domain, Luhmann (1990) assumes systems are autopoietic and makes a distinction among *social, psychic* and *biological* systems. The generic system S is defined by a boundary between itself and its environment. The boundary divides S from a complex and rather chaotic exterior. The interior of the system is thus a zone of reduced complexity for Luhmann. The environment interferes with the life of S not through input/output mechanisms but through perturbation, noise, disturbance and even irritation. Social and psychic systems transform the solicitations into information and a guide for decision-making. Hence, *information is a purely inner property of systems*, as Luhmann writes, "Information is an internal change of system state, a self-produced aspect of communicative events and not something that exists in the environment of the system that has to be exploited for adaptive or similar purposes". To Luhmann, information does not exist in the world but only inside the system which brings about information through a selective process:

Information is selection from a known and unknown repertoire of possibilities provoked by the environment.

The system cannot freely create information as its own product; S can but transform external perturbation into information. Luhmann relates this concept to communication and meaning which become three interrelated notions in his theory.

He claims psychic systems think and social systems communicate while communication consists of accepting something and rejecting something else; and consciousness is manoeuvred by communication into a situation of forced selection. He notes that both psychic systems and social systems are closed systems but the former are constituted on the basis of self-referential relations of *consciousness* and the latter on the basis of self-referential relations of *communication*.

Meaning is exclusive to psychic and social systems whereas it is absent in biological systems. According to Luhmann, "systems develop a special way to deal with [external] complexity, i.e. introducing a representation of the complexity of the world into the system. I call this representation of complexity 'meaning'". The function of meaning is to provide access to all possible topics of communication.

The organizational definition by Stonier

Tom Stonier (1990)(1992) aims to unify the concept of information in the physical, biological and human domains. He starts from the idea that information is a fundamental constituent of the physical world; it looks like basic physical quantities such as energy and entropy. Because of its physical essence, Stonier concludes, "Information exists". Namely, information does not rely on human thinking. Information is independent of whether any form of intelligence can perceive it or not. Stonier reaches this conclusion since he sees a divide between information and meaning; the two are independent and one can handle meaningless messages.

Information may convey meaning if and only if it has been processed by somebody or something. Information is the raw material modelled by information processes which create significant texts, music, images, etc. In fact, when we try to define information, we almost always relate it to some sort of system (e.g. DNA, computer, human speech, etc.) and for Stonier researchers should examine *information systems* and *information processing systems*, not merely information per se. He asserts:

Information is the capacity to organize a system or
to maintain it in an organized state.

The effect of information on organized systems turns out to be powerful since an organized system becomes well structured as a result of adding more information to it. If one looks at the evolution of technology, for example, one finds many inventions that become increasingly more efficient by later improvements added on. The same holds true for biological evolution and for the evolution of human languages, among other things.

Stonier argues that the universe is organized into a *hierarchy of information levels* and identifies the self-organizing information processing systems as the "physical roots of intelligence". He sees information as a basic property of the universe because of this notion.

Stonier even explores the possibility that information, like light, may ultimately exist in particle form, which he proposes to call *infons* in analogy to electrons and other elementary particles. Infons, however, do not possess mass or energy and cannot be detected in a traditional physics experiment. Infons manifest their effect as they change the system organization.

The general definition by Klir

George J. Klir (1991) introduced a research programme under the name *generalized information theory* (GIT), whose objective was to study *information-based uncertainty* and *uncertainty-based information* in all their manifestations. Klir assumes uncertainty as a manifestation of some information deficiency and in consequence:

Information is conceived as the capacity to reduce uncertainty.

He formalizes this interpretation using the following simplified expression

$$I = U2 – U1. \qquad (14)$$

Where information I equals the difference between the final uncertainty U2 and the initial uncertainty U1 when U2 is lower than the initial uncertainty. Klir specifies the quantity I introduced in (14) and described in the following terms

$$I(A_S|S,Q) = U(A_E|E,Q) – U(A_S|S,Q). \qquad (15)$$

Where Q denotes a given question; A_S is the generic system answer and A_E is the specific answer obtained after the physical experiment E that improves our knowledge and reduces the uncertainty about Q. Namely, one has the initial amount of uncertainty $U(A_S|S,Q)$ and reaches $U(A_E|E,Q)$ after the event E.

Klir is aware that the restricted notion of uncertainty-based information does not cover the full scope of the concept of information. For example, GIT does not fully capture our common-sense conception of information in human communication and cognition.

Klir (2006) prefers to focus on the problems associated with systems. He notes that the scientific knowledge is organized, by and large, in terms of systems of various types. In each system, information has the effect of determining unknown states of some variables on the basis of known states of other variables.

GIT started as an attempt to include classic measures on information and uncertainty – Hartley and Shannon, for instance – while now it offers a steadily growing inventory of distinct theories. Each uncertainty theory recognized within GIT is characterized by a particular formalized language (classical or fuzzy) and a generalized measure of some particular type (additive or non-additive); thus GIT makes an attempt to include more expressive formalized languages based on fuzzy logic and more expressive non-additive measures of various types.

The physical definition by Levitin

Lev B. Levitin presented his first ideas before the Second World War. Later he notices that Shannon developed a rather abstract study which gives the impression that the laws of transmission and information processing are not physical. Levitin (1992a)(1992b) regrets that the notion of information seemed to be something apart from the world out there. After the works of Brillouin (1964), who explored the profound relationship between energy and information, Levitin plans to fund his information theory as a branch of physics.

Levitin considers the transmission system in terms of thermodynamic equilibrium and notes that the choice of a determinate signal absorbs energy and deviates the system from its thermal equilibrium state. He calculates the amount of entropy associated with this system change. Levitin assumes that the ensemble of physical signals a_1, a_2, a_3, . . . a_n have respective probabilities p_1, p_2, p_3, . . . p_n. The generic signal a_i brings the system S to the macro-state A_i which includes a set of m micro-states with probabilities w_{ik}. Levitin calculates the Shannon entropy H_i for the macro-state A_i

$$H_i = -\sum_k^m w_{ik} \ln(w_{ik}). \tag{16}$$

Then he qualifies the average entropy of the states under the action of the signals a_1, a_2, a_3, . . . a_n in this way

$$\bar{H}_a = \sum_i^n p_i H_i. \tag{17}$$

The physical system S assumes the macro-state A under the action of the signal a and its entropy is

$$H = -\sum_k^m w_k \ln(w_k). \tag{18}$$

Levitin establishes the entropy defect principle that measures the deviation of a physical system from its thermodynamic equilibrium state and formalizes the concept of information in this way

$$I = H - \bar{H}_a. \tag{19}$$

In words:

The amount of information obtained by the physical system S *is equal to its entropy defect.*

This result established for classic physics has been generalized and applied to quantum mechanics (Levitin 1992b). In summary, the informational properties of real systems are described in purely physical terms.

The quantum definition by Lyre

First, Werner Heisenberg had explained the key role of symmetries for all processes in the phase spaces of physics and his student Carl Friedrich von Weizsäcker [just mentioned as the author of the pragmatic interpretation of information] advanced this idea to describe symmetry as the basic property in nature. More specifically, the Abstract Quantum Theory (TQA) by Weizsäcker reconstructs physics in terms of yes/no alternatives, called *ur*-alternatives or simply *ur* (from the German prefix 'Ur': original) and establishes a connection between quantum structures and the structure of the universe. He presents the *ur* as the fundamental and simplest element from which, in principle, any physical object can be built. The universe is not yet matter nor space nor time, but just binary alternatives. TQA is a programme to understand the unity of physics and is based on the simplest structural distinction that can be made in empirical science.
Holger Lyre (1995)(1998), professor of theoretical philosophy at the University of Magdeburg, proceeds with TQA and develops 'a quantum theory of information' with binary alternatives representing the information content of a yes/no decision or one bit of quantum theoretic potential information. An *ur* is formally represented by a two-dimensional Hilbert space C^2

$$|u_r\rangle \in C^2, \qquad r = 1,2. \tag{20}$$

In this sense

An ur-alternative is an information atom.

Quantum theory should be regarded as a general theory of information and *quantization* has to be understood as the forming of concepts or semantic levels which are necessary for the existence of information in general. According to this, structural and kinetic information is an intrinsic component of the universe, independent of whether or not any form of intelligence can perceive it. Physical objects are reduced or even 'made out of' information.
Lyre relates his interpretation to present-day technology. Quantum items of information are represented in terms of their Hilbert state spaces, and the quantum states correspond to empirically decidable alternatives, nowadays called quantum bits or qubits. *Urs*, therefore, are nothing but qubits. Ongoing efforts to develop the quantum computer demonstrate that Lyre's work is not just an ethereal idea.

The independent definition by Losee

Robert M. Losee (1997) points out how some studies on information cover narrow areas of interest, and he searches for a definition of information which can cross different fields and theoretical disciplines. He puts the notion of *process* or *function*, which can be seen in a domain-independent way, at the centre of his theory and links the definition of information to this process:

Information may be understood as the value attached or instantiated to a characteristic or variable returned by a function or produced by a process.

Losee uses the term '*value*' in reference to a variable's *attribute* or *characteristic*, and not to economic value unless economics is explicitly mentioned. Information consists of the values within the process outcome, and this view has the consequence of allowing different kinds of processes to be informational. From Losee's perspective, the processes range from simple mathematical functions to complex human actions. All processes produce information: physical processes and processes commonly understood as non-physical, describable and indescribable processes. Losee invites us to consider a common process such as cooking. The inspection of the final product provides information about the process used as well as about the ingredients. Information is always informative about something and Losee completes his definition this way: the returned value is informative about the input to the process and/or about the process itself. Losee notes how processes have more or less broad effects; thus, he establishes a hierarchy in the process of classification. In particular, he finds this hierarchical model in human communication:

Knowledge > Phrase > Phoneme

These stacked processes provide satisfactory links between physical processes and high-level mental functions discussed by psychologists and philosophers.

The social definition by Goguen

Joseph Goguen (1997) has developed a conception of socially embedded information and provides the ensuing definition:

An item of information is an interpretation of a configuration of signs for which members of some social group are accountable.

The social theory of information claims that meaning is an ongoing achievement of some social group. The interpretation of signs requires a certain broad effort which takes place in some particular context, including a particular time, place and group. Information can only be fully understood within its context, but the relationships between information and the context may be more or less strong. In general, information cannot be fully context sensitive nor fully context insensitive, and Goguen describes a continuum of the character of information from *wet* to *dry*. For example, the processes of abstraction and formalization – such as mathematical reasoning – are attempts to take information out of any context. Information is *dry* but by way of compensation is widely applicable.

About the accountability, Goguen remarks that members are held accountable for certain actions by their social groups. The elaboration of a language is universally recognized as socially significant by all the people. Goguen argues that information has the following properties:

- ***Situated*:** Information can only be fully understood in relation to the specific and concrete situation in which it actually occurs.
- ***Local*:** The interpretations of information are constructed in some particular context.
- ***Emergent:*** Information cannot be understood at the level of the individual since it has a social value.
- ***Contingent:*** The interpretation of information depends on the current situation.
- ***Embodied*:** Information is tied to bodies in special physical situations.
- ***Vague*:** Information is only elaborated to the degree that it is useful to do so; the rest is left grounded in tacit knowledge.
- ***Open*:** Information must remain open to revision in the light of further analyses and further events.

This theory places people at the centre of its view, so it may be said Goguen humanizes and de-technologizes the concept of information.

The purpose-oriented definition by Janich

The majority of biologists is inclined to accept the leading role of information in biological processes, but Peter Janich (1998, 2006), a German philosopher, wonders: Is information a natural or at least a material phenomenon residing in organisms and objects, or is it conversely a cultural product of human (or human-like) actions?

Janich rejects the first hypothesis and argues that the use of the concept of information in the natural sciences is a redundant description of the concept of causality. Then he develops a theory of information that he relates to purpose-oriented human actions. Janich formulates two principles to begin his construction:

(1) It is necessary to place the description of actions apart from the execution of actions.
(2) It is necessary to apply a methodical order in rational human activities to acquire success.

Janich holds that the definition of information has to comply with both principles, especially the second has a noteworthy role. Janich looks at the human communication with its pragmatic purpose of organizing collaborative actions and concludes:

Information is a predicate that qualifies human communication.

Information is indifferent to the roles of speaker and listener who may be reversed. Because communication is subjected to correctness, it is also subjected to validation in order to achieve the final success. Janich describes the three levels of information this way:

a. *Syntactic*: Information is transported and basically is carrier-bound.
b. *Semantic*: Information is the result of perception and conception; validation is relevant.
c. *Pragmatic*: Information is the mean to orientate people toward the success.

The German author relates the syntactic, semantic and pragmatic features of information to the information technology (IT), the information system and the information society. He also discusses the reproduction of human actions on the basis of anthropomorphic artificial devices.

The cybersemiotic definition of Brier

Soren Brier places the concept of information inside a comprehensive view of the world. He has conducted a broad study, so we have to introduce Brier's terminology.

In the 1950s, Heinz von Foerster (1979) conducted a critical review of the cybernetic theory of Wiener. He warns that the observer does not contemplate the object from outside without influencing it but is irrevocably a part of what he is studying. He introduces the "subject-oriented approach to science" which contrasts the "object-oriented approach to science." Foerster marked the distinction between *first*- and the *second-order cybernetics*, which may be concisely defined as the *cybernetics of observed systems* and the *cybernetics of observing systems*, respectively.

Soren Brier (1999, 2008) labels his construct *cybersemiotics* as long as it connects two major and very different paradigms:

- The second-order cybernetics and autopoietic approach.
- The Peircean triadic evolutionary semiotic approach to meaning.

Brier intends to create a transdisciplinary frame in terms of dynamic and contextually adaptive relationships between the signs, the objects and the interpreter. Cybersemiotics is a combination of four principal forms of knowledge each of which offers only a partial view:

Physics is explained as originating in energy and matter.
Biology is conceived of as emerging from the development of life processes.
Social culture is seen as founded on the development of meanings in languages and practical habits.
Consciousness is interpreted as deriving from the development of the individual's inner life.

The *Semiotic Star* is a fine visual model that represents cybersemiotics as a crossroad among the four knowledge traditions. Brier conceives his theory as an ontological and epistemological framework for a universal information science in which:

Information is a kind of formal cause working through pattern-fitting.

Brier does not add information on top of a traditional mechanistic frame, or inside a physical frame improved by complex or random dynamics. He devises a hierarchy of different levels across which information processes and meaning can develop. He describes the multifold evolution of information through four levels or planes:

(1) The first is the physical level including human dynamics. This is the level of efficient causation dominated by classic mechanics and also by the will of the mind.
(2) This is the level of objective information, where the formal causation manifests itself clearly. This level is influenced by the complexity and also by the organization of involved elements.
(3) On the third level, life is self-organized and semiotic interactions become prominent. Brier relates this status of information to the Luhmann model in which organizationally closed systems working separately make communication possible.
(4) Finally, human self-consciousness emerges through syntactic language games, and with that come rationality, logical thinking and creative inferences. Intelligence is closely connected to conscious finality.

Brier does not develop a theory of information in the usual sense. He openly claims that “information in biological systems is not simple objective data but has to be interpreted in a situated context” (Brier 2013). For Brier, a monolithic concept of information is not enough, and describes more or less explicit manifestations of information and semiotic meaning at the various levels of the world where information is part of the development of living intelligence.

The activity-based definition by Karpatschof

Benny Karpatschof’s (2000) main purpose is to assess his ‘Activity Theory’ as a comprehensive framework for the anthropological sciences. The roots of this theory trace back to Hegel, Marx and two Russian psychologists, Vygotsky and Leontiev.

Human activity is defined as a *mediated form of activity* in that human actions have several kinds of *mediators* that are tools, instruments, co-operators and also signs. The use of the signs refers to the so-called *release mechanism*, a process that can draw on an amount of potential energy. The release mechanism lets this energy out in specific ways, whenever triggered by a signal fulfilling the specifications of the release mechanism. The signal that prompts the mechanism is the *indirect cause* of the resulting reaction, and the process of the release mechanism is *the direct cause*. The latter is a high-energy reaction, the former a low-energy entity. Karpatschof places the notion of information inside this context and provides the follow definition:

Information is the quality of a certain signal in relation to a certain release mechanism.

Information consists of signal emission and reaction between different entities; hence, information lies at the core of the cybernetic self-regulating system.

The release mechanism has a double function since it reinforces the signal and directs the reaction by defining the functional value of the signal in the pre-designed system. Signals and release mechanisms may be of any kind and Karpatschof’s theoretical model covers a variety of situations. If information concerns the satisfaction of veracity constraints, the model will be linked to the knowledge problem or, generally, to semantic issues. If the requirements are of an aesthetic nature, the model will be related to the problem of artistic information. Analogously, it could also be adjusted to problems of biological adaptability, social coexistence and so forth.

For Karpatschof, information should be placed *above* the classic categories of physics; that is to say, information is neither directly reducible to these categories nor is a radically different category of a different nature from mass and energy. Factually, information is the causal result of existing physical components and processes; it is an emergent result of such physical entities.

The biological definition by Jablonka

Eva Jablonka (2002) intends to justify information stemming from various sources. She comments on information transmitted in different types of inheritance systems – including biological, cultural and technical – and puts forward a list of requirements that identify a common denominator among informational phenomena of different types, such as telegraphic messages, DNA codes and computer programs. The common attributes of these phenomena are as follows:

(1) A special type of reaction occurs between a receiver and the source, affecting the potential or actual actions of the receiver.
(2) The receiver response leads to a complex, regulated chain of events that depend on the organization of the source rather than on its energy, content or chemical constitution.
(3) The reaction to the source draws a response that is beneficial over evolutionary time.
(4) The variation in the form of the source leads to a corresponding variation in the form of the response.

On the basis of these premises, Jablonka provides the following definition:

A source becomes an informational input when an interpreting receiver
can react to the form of the source in a functional manner.

Namely, a source can be said to convey information when a receiving entity reacts to this source in a special way. In the Jablonka terminology, the words *source* and *form of the source* resemble the term *signified* as used in semiotics.

In Jablonka’s view, the reaction of the receiver to the source has to be such that the reaction can *actually* or *potentially* change the state of the receiver. There must be a consistent relation between the variations of the source and the corresponding changes in the receiver. Jablonka specifies that the reaction to information is not rigid as in the execution of a software program but is free in a certain way. She emphasizes the prominent role of the receiver’s interpretative capabilities in evolutionary terms. To illustrate, the source S – for instance an allele, alarm call, cloudy sky, etc. – carries information about the system state E of the receiver and this fulfils an interpretation process that usually ends by adapting itself to E.

The term *functional* is used in Jablonka’s frame to mean the consistent causal role that a part plays within a *man-designed system* or *natural-selection-designed system*, a role that usually contributes to the goal-oriented behaviour of this system.

The mathematical definition by Kåhre

The Danish engineer Jan Kåhre (2002) assumes that a receiver gets information through a channel or medium. For instance, a reader examines the article B about the event A, and Kåhre gives shape to 'information B about A' in this way

$$\text{inf}(B@A). \tag{21}$$

Kåhre holds that information can be measured in different units, from bits to dollars. He argues that any measure is acceptable and uses various statistical methods, including the Shannon entropy, to calculate inf(B@A). For Kåhre, there is not a single rule to calculate information about something.

He discusses the properties of information with respect to the receiver since his theory revolves around the idea that a receiver is *ideal* if no intermediary reduces its performance. Let R be an ideal receiver, who gets the message B about the event A. Then suppose that the channel C is sandwiched between B and R, with the output C that is the input to R. The system B-C-R cannot provide a better outcome than B-R alone, because R is already an ideal receiver. The *principle of diminishing information* holds that the information that C gives about A to the ideal receiver R cannot be greater than the information B gives about A

$$\text{inf}(C@A) \leq \text{inf}(B@A). \tag{22}$$

This means that compared to direct reception, an intermediary channel can only decrease the amount of information. Kåhre sustains this law by two independent arguments: one derived from the Bar-Hillel ideal receiver, the other based on Shannon's noisy channel. Kåhre concludes that any measure of information is acceptable if it does not violate the law of diminishing information which is the necessary and sufficient condition for a mathematical function to be accepted as an information measure.

The general definition by Burgin

Mark Burgin (2003) aims at establishing an exhaustive theory and states beforehand a system of ontological and sociological principles. He introduces his theory through some *axiological principles* that explain the multiple values of information. The first principle lays the foundations of this construction:

The measure of information **I** *for a system* **R** *is some measure of changes caused by* **I** *in* **R.**

Thus, Burgin continues using this triple

$$(\mathbf{C}, \mathbf{I}, \mathbf{R}). \tag{23}$$

Where **C** is the vehicle of **I.** Another axiological principle holds that according to time orientation, there are three temporal types of measures of information: *potential* or *perspective, existential* or *synchronic*, and *actual* or *retrospective*. There are three structural types of measures of information: *external, intermediate*, and *internal*; and three constructive types of measures of information: *abstract, realistic*, and *experiential*. Hence, information does not appear as an absolute and univocal quantity.

Burgin (2009) pursues the purpose of establishing a comprehensive theory and holds that the evolution of information science should resemble the evolution of geometry. As the latter improved through a variety of studies and research, so the former can progress on the basis of his global frame – called the *general theory of information* (GTI) – that progressively advances step by step.

Burgin makes efforts to systematize the various theories and tends to show that GTI has very broad coverage and every other information theory is a reduced form of GTI.

The philosophical definition by Floridi

The early philosophical ideas about information may be found in the works of Sanders Peirce and other thinkers, but the *philosophy of information* (PI) has grown considerably under the influence of Luciano Floridi. He begins with two main remarks. On one side, he points to the crisis at the heart of contemporary philosophy and concludes that it can only be solved by looking at innovative areas of reflection which are more foundational than the traditional categories of knowledge and existence. On the other side, he is convinced of the 'prismatic nature' of information that can be exhaustively treated only

through the philosophical approach. The author presents PI as a completely new development with a capacity to revolutionize philosophy per se. Floridi (2004) poses eighteen questions about the concept of information, with the first query directly related to the present survey: What is information?
Floridi answers that the principal use of the word 'information' is in terms of semantic content that is functional to epistemic purposes, and he concludes:

Semantic information is well-formed, meaningful and veridical data.

This concept encapsulates truth, exactly as the concept of knowledge does; hence, *misinformation* or *disinformation* is not an inferior kind of information, it just is not information. Floridi relates the dynamics of information to:

- The constitution and modelling of information environments, including their systemic properties, forms of interaction, internal developments, applications, etc..
- The information life cycles which consist of various stages and functional activities through which information can pass, from its initial occurrence to its final utilization and possible disappearance.
- Computation, both in the Turing-machine sense of algorithmic processing, and in the wider sense of information processing.

Floridi believes that a unified theory of information would be of interest to many but does not hide his sceptical understanding. The author's position is different from those – labelled as *reductionists* – who support the feasibility of a unified theory general enough to capture all major kinds information and also sufficiently specific to discriminate between conceptual nuances. Reductionists attempt to show that all kinds of information are ultimately reducible conceptually, genetically or genealogically to some basic elements. Floridi holds that reductionist strategies are unlikely to succeed even if he adds that it is worth trying to find a unified theory of information and philosophy has a role to play in attempting to construct such a theory.
Concluding, Floridi (2011) leads to a novel metaphysical framework in which our understanding of the ultimate nature of reality shifts from a materialist one to an informational one. In this new world, called *infosphere*, all entities, be they natural or artificial, are analysed as informational entities.

The sociological definition by Garfinkel

Harold Garfinkel is known as the founder of *ethnomethodology*, a perspective within sociology which focuses on the way people make sense of their normal actions. It studies the tacit organization of everyday activities that elude formal prescriptions and reports. People are seen as rational actors who make sense of and function in society.
Garfinkel examines the state of the art of information theory in an unpublished report, and some decades later he expands his viewpoint with the help of a collaborator in (Garfinkel and Warfield 2008). He argues that a community is entirely dependent on the informal methods of achieving and displaying knowledge and that information is something which stems from social interactions. Garfinkel's book introduces the definition of information by illustrating a chess-like game. The various situations occurring during the game and the active roles of players are used to demonstrate how information rises from the combination of social circumstances. Garfinkel believes that "information is constituted – not just interpreted – or symbolically represented and exchanged but actually constituted as information by the social (cooperatively ordered) aspects of the situated social orders in which it occurs". These social orders, he argues, are created in the routine practices of people as they go about their daily lives. Something is information for a specific individual in a specific context insofar as it is acted upon by that individual in that context. Garfinkel puts forward the *situated interpretation* of information:

Information is constructed by situation.

Information only exists in and through the ways in which it is constituted and apprehended cooperatively in social events. Information is actually constituted by the ordered mechanisms of a social environment. Garfinkel's theory of information is consistent with his overall approach to communication, interaction and the pervasive achieved orderliness of social life in general. He pays special attention to redundant information which reduces the disorder inherent to an organization in that disorder underlies order. For Garfinkel irregularity underlies a pattern and he posits meaning as order instead of relationships between ideas and symbols.

The unified definition by Hofkirchner

Hofkirchner (2009, 2013) notices the factual dissemination of 'information' which appears astonishing worldwide whereas the proper and comprehensive definition of information is missing. The author's evident intent is to fill this gap with an exhaustive construction which he calls *Unified Theory of Information* (UTI). UTI is about self-organizing systems, from the most primitive physical system to social systems, which for themselves (in the case of *cognition*) or in interaction with other self-organizing systems (in the case of *communication*) or as part of higher-level self-organizing systems (in the case of *cooperation*), generate and make use of information. The areas of cognition, communication and cooperation also involve devices like the Turing machine that contributes to information generation not by organizing itself – this is impossible for artefacts – but by being instrumental to the overarching social self-organization. Hofkirchner means to include in his model all the varieties of the information concept; for example, *structural information*, free information and *actual information* are merely the manifestations of a single unified concept. From this perspective:

Information is the super-concept which incorporates all the different manifestations of this item regardless of the realm in which they appear.

Hofkirchner holds that information is closely related to a number of similar concepts. The choice of one out of them is rather a terminological issue, and even the way they are related is often rather arbitrary. What matters for the author is the extensive usage of the *super-concept*, that is to say, what it embraces and the network of relations. According to the philosophical classification, information concepts are stuck between materialism and idealism. UTI means to unify various perspectives developed in philosophy and in scientific domains. He sees on the one hand materialism, idealism, dualism, hard science, soft science, natural and engineering sciences, while on the other hand the arts and humanities.

The communicative definition by Budd

John Budd (2011) observes that some popular theories on information do not provide us with an exact procedure for determining whether something is or is not an instance of information. The initial assumption of Budd toward a new definition is that information "cannot be defined unless within the context of meaning and truth". He goes on with a discussion on reference and meaning and puts forward this statement:

Information is meaningful communicative action that aims at truth claims and conditions.

Information involves communicative actions that can be evaluated by a population as meaningful or not worthy of trust or belief. Meaning is not limited to pure semantics but includes context and history within evaluation. Budd is oriented to accepting a broad use of the term 'meaning'. For Budd, information is even true or false since it warrants the communicative action, which includes no deliberate deception or omission. In conclusion, information is meaningful, communicative and truth-directed.

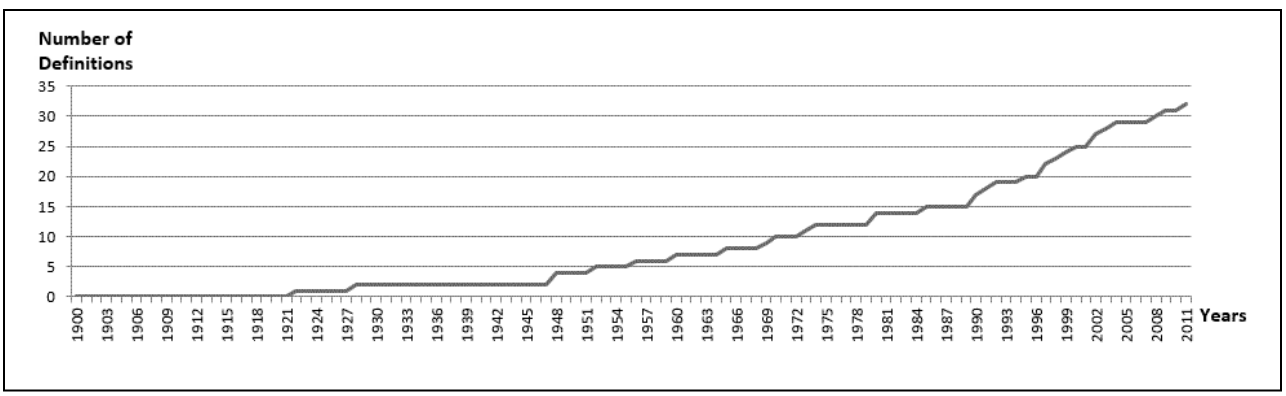

Figure 1 – Distribution of the information theories

4. A statistical distribution

Guidelines **A), B)** and **C)** were applied to configure this inquiry to the scientific method, and as a consequence we have obtained an unbiased sample that yields further results.

Table 1 shows the publication years of the theories that we divide into four intervals:

1. (1900–1940) there are two definitions.
2. (1941–1960) there are five definitions.
3. (1961–1980) there are seven definitions.
4. (1981–2011) we count eighteen new definitions.

The time distribution (Figure 1) shows how the number of theoretical inquiries concerning the concept of information remained modest during the first six decades (1900-1960) and became ever greater in the subsequent five decades (1961-2011). The number of interpretations increased from seven to twenty-five between these two periods. Now we recall the milestones in the IT history:

a. (1900–1940): Modern data processing began in 1890 with the *tabulating machine* patented by Hollerith. Numerous electromechanical calculators and telecommunications lines were installed in Western countries.
b. (1941–1960): In the early 1940s the first *programmable computers* were built and installed prevalently in universities.
c. (1961–1980): In the 1960s *general-purpose computers* began to achieve considerable success in companies, businesses and organizations.
d. (1981–2011): From the 1980s onward, the use of *personal computers* and the *Interne*t increased all over the world.

We can relate the interpretations of information 1, 2,,..4 to the advance of technology a, b,...d, and note how original theoretical proposals follow the most successful digital solutions. It could be said that these commercial waves stirred thinkers to devise new ideas; thinkers seem to have reacted to the most significant leaps forward in computing.

5. Discussion and conclusion

This study starts with the observation that reviewers often level the variety of opinions concerning the concept of information and so we decided to conduct an inquiry into the creativity of the theoretical contributions in the information literature.

Excluded works

In retrospect, exclusion rules *#3* and *#4* caused significant number of cancellations. A first group to be excluded consisted of authors who places the concept of information in between a semiotic frame, thereby disregarding the rule of centrality such as Shreider (1965) who locates his work midway between logical and linguistic semantics; Doede Nauta (1970) who aims at providing a general semiotic framework; and Jonathan Furner (2014) who constructs a theory of meaning. Other rejected semiotic works include (Langefors 1966), (Barwise and Seligman 1998), (Queiroz et al 2008) and (Pérez-Amat 2009). A second group to be excluded was that of authors who sought to import, reuse or extend the fashionable construct of Shannon, thus not complying with the dissimilarity rule. For example, Jacob Marschak (1971) imports the ideas of Shannon into the economic territory and Cherry Colin (1957) into psychology; Fred Dretske (1981) presents a theory of knowledge and a philosophy of mind importing the ideas of the communication theory; and Marcin J. Schroeder (2004) attempts to calculate information by subtracting two entropies. A third group of excluded theorists were those who imitate or relaunch existing concepts thus failing to conform with the dissimilarity rule such as Buckland (1991) and Bates (2005) who, like Stonier, seek to reconcile the physical world with information, and provide notions that echo Stonier's concept. Madden (2004) in a way evokes the model of the 'image' present in Mazur and also Jens-Erik Mai (2013) develops a qualitative study of information. Chernavsky (2004) reuses the theory of Kharkevich. Finally, as a consequence of rule #1 the works published after the year 2011, the time limit of our sampling frame, have been scratched e.g. (Boell and Cecez-Kecmanovic 2015), (Mckinney et al 2012) etc.

Weak and strong points of the present inquiry

Guidelines **A), B)** and **C)** meet objectives **1** and **2**, but present some residual shortcomings in terms of the impossibility of ensuring that all relevant theories have been detected by means of a mechanical tool. In addition, one cannot exclude the possibility of a little personal influence affecting the interpretation of the search engine answers.

The method adopted here has the purpose of preparing an agile report about the information domain which does not seek to simplify or change things as they actually are. All the authors have been examined with the same attention. We cite an example case to illustrate the advantage of the present approach over contemporary surveys. Maturana and Varela (1980) negate the existence of information as an autonomous entity and reviewers tend to overlook this viewpoint that seems to be designed to discredit the quest for information; instead the present report lists even the most paradoxical constructs of information.

Wide variety of interpretations

We have relinquished any personal views, comparisons, understanding and interpretations; only at the close we append remarks and comments.

This paper at times pinpoints the conceptual links emerging from amongst the constructs. For example, Brier takes up the concept of autopoiesis while Luhmann generalizes it from biology into the social systems theory. However, it is the differences among the theories that appear much more relevant. The faithful recording of the definitions brings evidence of the great distance among the authors who not only disagree on the nature of the problem, but even on several essential aspects. This empirical research presents so many blatant discrepancies that we must necessarily confine ourselves to concise citations.

Where a group of authors means to create a comprehensive frame, e.g. Burgin, Hofkirchner and Klir; others focus on narrow fields; for example, Hartley and Kolmogorov relate information to technology, Lyre and Levitin to physics. Certain constructs stem from professional fields; for example, biology inspires Jablonka, electrical communication Hartley. Brier develops a frame so wide that it could be catalogued as a philosophy, whereas Power proposes a very concise system of equations. Mazur describes the qualities of information and not its size; whereas around half of the contributions centres on mathematical statements that nonetheless differ in mathematical terms or even in significance. For example, Shannon and Levitin assume entropy to measure information but this function has quite different meanings in the two contexts. Floridi is convinced of the intellectual width of the information concept whereas Derr holds that common sense should determine our view of information. Even when a theme attracts the attention of diverse authors, they may yet arrive to distinct conclusions. For example, Goguen, Bateson, Brier, Brookes, Budd and Garfinkel focus on human knowledge and communication, but all develop original and independent constructs. Striking contradictions emerge in some crucial passages. Wiener rejects the idea that information is physical, while Stonier sees information as being as much a part of the physical universe as energy and matter are. Shannon holds that semantics is irrelevant, while Carnap and others study the meaning of information. For the former, information is inversely proportional to probability, while for Wiener it is directly proportional to probability: the one is simply the negative of the other.

In summary, the present inquiry brings evidence that what divides the theories of information is more than what unite them. So many incomparable definitions appear to support the 'Capurro trilemma,' which negates the possibility of a unified conceptualization (Capurro et al 1997), but we mean to go in another direction.

What idea of information have they in mind?

Even though these theoretical proposals exhibit very different profiles, we observe how they share a common trait.

The authors depict information from a variety of viewpoints. They take inspiration from biology, electrical transmission, mass media and even everyday life, but ignore the perspective of computer practitioner such electric engineers, software developers and so forth. Nobody wonders: What idea of information do those who invent so astonishing digital solutions have in mind?

'Shannon's theory' is not the correct answer since his entropy is very rarely used in the working environment (Denning 2000). The remaining equations are normally ignored by the practitioners who set up hardware and software systems, thus there is an apparent gap between thinkers and technicians who operate in the same territory and who ought to share basic topics and targets. The time distribution (Figure 1) shows how the proposed theories follow the advance of the computer technology around the world and makes theorists' widespread lack of concern for the thoughts of practitioners all the more surprising. The information age is what motivates these authors, who nevertheless pay no attention to the architects of that age. The former seek to contribute to the revolution that is currently reshaping human reality, but inexplicably ignore the perspective of the latter who started that revolution and continue to advance it. The inattention of theorists has consequences not in the abstract but in the real environment, where information technology has advanced immensely but the conceptualization of information has fallen into stagnation. In our opinion, the viewpoints of IT experts could open up new possibilities for theoretical research in the information domain, an argument that the recent paper (Rocchi 2016) goes into in depth.

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