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Information, Data, and Knowledge in the Cognitive System of the Observer

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Abstract

Purpose: In line with the cognitive viewpoint on the phenomenon of information, the constructivist tradition based on Maturana and Varela's theory of knowing and some aspects of Shannon's theory of communication, , the purpose of this paper is to shed more light on the role of information, data, and knowledge in the cognitive system (domain) of the observer.

Design/methodology/approach: In addition to the literature review, a proposed description of the communication and knowledge acquisition processes within the observer's cognitive system/domain is elaborated.

Findings: The paper recognizes communication and knowledge acquisition as separate processes based on two roles of information within the observer's cognitive system which are emphasized. The first role is connected with the appropriate communication aspects of Shannon's theory related to encoding cognitive entities in the cognitive domain as data representations for calculating their *informativeness*. The second role involves establishing relations between cognitive entities encoded as data representations through the knowledge acquisition process in the observer's cognitive domain.

Originality/value: In this way, according to the cognitive viewpoint, communication and knowledge acquisition processes are recognized as important aspects of the cognitive process as a whole. In line with such a theoretical approach, the paper seeks to provide an extension of Shannon's original idea, intending to involve the observer's knowledge structure as an important framework for the deepening of information theory.

1. Introduction

This paper is intended to describe and clarify the role of information, data, and knowledge within the cognitive process in the cognitive system (domain) of observers as defined by Maturana and Varela's (1980) approach, according to a cognitive viewpoint [1]. It should be mentioned here, that the cognitive viewpoint in information science (Belkin, 1990) is based on ‘any processing of information, whether perceptual or symbolic (...) mediated by a system of categories or concepts which, for the information-processing device, are a model of his world’ (De May, 1977, pp. xvi-xvii). While information, data, and knowledge are involved in this description, the cognitive process also involves certain aspects of the communication (Shannon and Weaver, 1963) and knowledge acquisition processes.

Following the Shannon's notion from his initial communication theory, Maturana and Varela state that information in communication process appears only as observer's "...degree of uncertainty in his behaviour within a domain of alternatives defined by him, hence the notion of information only applies within his cognitive domain" (Maturana and Varela 1980, p. 54). If the information is recognized with a 'degree of uncertainty', then the data is recognized as ‘alternatives defined by [the observer himself]’. Since the word 'data' in the literature is mostly used in an objective manner, the data that appear within the cognitive domain of the observer we call 'data representations'. We use 'data representations', hence, to refer to specific 'cognitive entities', always in some way 'encoded' to represent each perceived 'difference' by the observer [2]. In that specific sense, 'encoded' could correspond to the term 'constructed' (Bosancic and Matijevic, 2019). This, therefore, allows us to use mainly constructivist concepts and methods to describe the role of information, data, and knowledge in the cognitive domain of the observer.

Hence, the paper's first section presents the main components of Maturana and Varela's 'theory of knowing,' a cognitive and autopoietic system. Some aspects of Shannon's communication theory regarding information are considered in the section entitled “Information in a Context of Communication Theory by Shannon and Weaver.” The following chapter outlines a short overview of the knowledge acquisition process. Finally, a description of the cognitive process in the observer's cognitive system, based on terms of information, data, and knowledge, is presented.

2. Cognitive viewpoint on the phenomenon of information

The cognitive viewpoint in LIS, also known as the cognitive turn, had many prominent advocates (De May, 1977; Brookes, 1977, 1980; Belkin, 1980, 1984; Ingwersen, 1982; Wilson, 1984). It was a direct consequence of the development of cognitive science during the 1960s and 1970s. The most important aspect of the cognitive viewpoint in LIS "[...] is that information is mediated by a potential recipient's state of knowledge" (Cornellius, 2002, p. 406).

However, starting in the 1990s, the cognitive viewpoint in LIS was widely criticized. Many researchers became sceptical about the cognitive viewpoint because its theoretical approach marginalized the role of culture and society (for example, in Hjørland, 2013). Moreover, Buckland and Florian held that the cognitive model (as a system's model of the user) must be supplemented by the conceptual model (as a user's model of the system), as long as "[...] 'conceptual' denotes knowledge and 'cognitive' denotes learning" (Buckland & Florian, 1991, p. 642). In his paper ‘Death of the user: Reconceptualizing subjects, objects, and their relations’, Ronald E. Day criticized one of the most prominent cognitive models of all—Belkin's Anomalous States of Knowledge (ASK) model—from the philosophical perspective of French philosopher Jacques Lacan. According to Day, the concept of 'need' in the ASK model "[...] does not belong to a subject's cognitive state, but rather, it belongs to the condition of the subject in a symbolic order" (Day, 2011, p. 82). In other words, the concepts of 'need' and 'information' denote nothing 'cognitive' within themselves, but rather, something symbolic. Namely, as long as "[...] the term 'information' refers not to a real entity [...], what is 'information' are those things that we term 'information'" (Day, 2011, p. 84).

Belkin (1978), however, believed that individuals were not troubled by a definition of information, but rather by a concept. A definition indicates what a phenomenon is, while a concept is a way of seeing or interpreting a phenomenon or situation. For Belkin, cognitive models are images "[...] that the components of the system have of one another and of themselves" (Belkin, 1984, p. 111).

Besides other aspects of the cognitive viewpoint in LIS, mainly focused on Information Retrieval (IR), we remain exclusively interested in the cognitive viewpoint on the phenomenon of information in LIS. In our opinion, such an approach is thoroughly presented in Brookes' papers (Brookes, 1975a, 1975b, 1977, 1980). Regarding the cognitive approach to the notion of information, Brookes developed what he would call 'the fundamental equation of information science', which has been widely discussed in the literature (Belkin, 1990; Todd, 1999; Bawden, 2011). The equation states that "the knowledge structure K [S] is changed to the new modified structure K [S + ΔS] by the information ΔI, the ΔS indicating the effect of the modification" or "K [S] + ΔI = K [S + ΔS]" (Brookes, 1980, p. 131). At the same time, he admitted that the equation at this level was not operable in a practical sense (Brookes, 1980). Furthermore, the interpretation of this 'fundamental equation', which Belkin called Brookes' 'fundamental cognitive equation' (Belkin, 1990, p. 15), "[...] is the basic research task of information science" (Brookes, 1975a, p. 117), and it "[...] will take a long time" (Brookes, 1975b, p. 48) to elaborate all of its elements. Still, this equation is "[...] regarded as a foundation of the cognitive paradigm in information science**"** (Bawden, 2011, p. 101).

What is important, Brookes' paper considers the phenomenon of information in the context - not of the dataset from which it originated (Shannon & Weaver, 1949), but in the context of the recipient's knowledge structure.

Despite the fact that Brookes' equation is understood as a pseudo-mathematical expression, even by Brookes himself, Capurro and Hjørland widely criticized the equation because of its non-operational character. "The tendency to use and define terms in order to impress other people has been called persuasive definition. The definition provided by Brookes (1977) [...] seems to us to serve only such a persuasive function" (Capurro & Hjørland, 2003, p. 349). On the other hand, Cornelius stated that this equation "[...] has remained operational as a general consideration" (Cornelius, 2002, p. 407).

Similar efforts were made by philosopher Dretske. For Dretske, information precisely pours into the recipient's knowledge structure as a flow, after which it becomes the content of new, true, meaningful and understandable knowledge (Dretske, 1981). Consequently,

Dretske also emphasized that information which an individual receives "[...] is relative to what he or she already knows" (Dretske, 1981, p. 86). That is why "[...] information is something that makes learning possible, as something that is required for knowledge" (Dretske, 1981, p. 82). In Brookes' own words, "[...] whatever 'goes' in depends on what is already 'there'" (Brookes, 1974, p. 148).
As we can see, the cognitive viewpoint can be realized as an instance of constructivist thought, which Talja et al. (2005) called cognitive constructivism, which differs from social constructivism and constructionism. According to social constructivism, social practices and interactions with others play a significant role in the construction of our world, which, in turn, became a starting point for the aforementioned critique of the cognitive viewpoint. On the other hand, in line with constructivism, constructionism does not hold that we acquire any knowledge of reality itself; but, contrary to constructivism, a constructionist viewpoint holds that "[...] knowledge is a modelling process which shapes and edits reality to make it intelligible" (Floridi, 2019, p. 49). While constructivism thoroughly describes what is observed, or 'how the world is', constructionism "[...] neither describes nor prescribes how the world is, but inscribes it" (Floridi, 2019, p. 30). The further distinction between constructivism and constructionism will be elaborated in the fifth chapter, where we discuss how information (or data representation) acquire their meaning.

3. To Know Something Facilitates Survival

In addition to Piaget's (1954) cognitive learning theory, many researchers (Glasersfeld, 1995; Cornelius, 2002; Capurro and Hjorland, 2003) agree that work conducted by the Chilean biologists Humberto Maturana and Francisco Varela (1980) can also be used as the foundation for the constructivist viewpoint and, on that basis, for the cognitive viewpoint. Accordingly, we briefly introduce the key concepts of their work - the autopoietic and cognitive systems of the observer first. In the following chapters then we will see how the communication and knowledge acquisition process in general take play within.

In a short, an autopoietic system is a network of processes that can regenerate themselves by producing the components that reproduce those processes (Maturana and Varela, 1980). Equally, those processes constitute such a system "...as a concrete unity in the space" (Varela, 1979, p. 13), whose boundaries are determined by the system itself. At the same time, this boundary "...remain[s] open to the flow of matter and energy through it" (Bourgine and Stewart, p. 329) [3]. The term *autopoiesis*, which the authors have introduced in the literature, in a general sense, means the capacity of a biological unit to regenerate itself and determine its own boundaries (Maturana and Varela, 1980).

On the other side, a cognitive system is a system with an established subset of possible interactions within the system (i.e., internal interactions) as well as with the environment (i.e., external interactions) (Maturana and Varela, 1980). At the same time, the observer lives in a domain of descriptions and through his rich representations of interactions with the environment (triggered by perturbations), he can increase the complexity of his cognitive domain. Together, the cognitive and autopoietic systems form the basis of living organisms.

It is important to highlight the fact that an organism, as a self-organizing system, must survive perturbations from the environment (Maturana and Varela, 1980). This means that the phrases "to survive" and "to know something" correspond very closely to each other. The difference between those phrases only arises through expanding the cognitive domain of an observer. On the other hand, as Brier noted, the cognitive system "[...] does not 'pick up information' from its surroundings; rather, it 'brings forth a world'" (Brier, 2008, p. 88). In that manner, we are interested in answering the following question: what is the role of information and data with regard to the hypothetical 'cognitive entities' in the cognitive process in a cognitive domain?

Therefore, in this paper, we first look at the theory expounded in Claude E. Shannon's *A Mathematical Theory of Communication* (1948) that broadly introduced the term of information in scientific discourse. Although the meaning from Shannon's theory was exempted, we claim that his theory offered some theoretical insights related to the concept of information that is of paramount importance.

4. Information in a Context of Communication Theory by Shannon and Weaver

As we know, a well-formed communication theory was completed in papers by Claude Elwood Shannon in the middle of the 20th century [4]. The two aspects of Shannon's theory are important in the context of this paper. We will list them without consideration of their implications for technical implementation (which was Shannon's main intent): the necessity of encoding signals/symbols (or 'what is being transmitted' in a communication process) and *informativeness* (or 'amount of information') of signals/symbols depending on the probability of their appearance in a communication process.

According to Shannon, the communication process must always be encoded in some way. For example, if we want to convey a simple message (or say something) to our interlocutor, then, first, we must encode this message, for example, using the symbols of the English alphabet. Nevertheless, to do this operation, somewhat paradoxically, we must know *a priori* what can but *will not be said* in our conversation. For example, suppose that our message to an interlocutor is "Salt, please!". In that case, in order for the message to be informative to him, the interlocutor must be aware of all other possibilities; for example, we did not mention *pepper* or *sugar* or any other name from the appropriate domain or predefined set of possible condiments in a given context. In other words, the encoding process must involve a system that can encode all possible messages in communication. Thence, information becomes the property of encoding signals/symbols, representing the measure of its novelty or *informativeness*, which is possible to compute in a quantitative manner.

Another aspect of Shannon's theory involves calculating the probability of encoded signals/symbols based on the appearances of the signals/symbols, which precede them. A simple example borrowed from semiotician Winfried Nöth illustrates this nature of information. One may say, "Give me, please, *s*...". In this sentence, the letter *s* has no meaning; however, it does have *information value*, as the letter indicates only words that begin with the letter *s*. Thus, other words such as *car* or *flour* are excluded from consideration. Though the sentence has no meaning, it does have information. If two more letters are added to the letter *s*, for example, the letters *al*, the word *sal* is produced, which still has no meaning but has a much higher information value because there are only a few words that have that root. Essentially, *sal* has much more information than *s*. Finally, if the letter *t* is added, the word *salt* is produced, which does have meaning. However, in this case, the letter *t* has only little information because it was expected (Nöth, 2004, p. 169). As shown in the provided example, according to Shannon (1948), the meaning of information in the transmission process is irrelevant. In other words, what is important regarding the information is its *informativeness*—or the measure of newer, more certain (as much as possible) and unexpected content. In this context, information, and its main property—*informativeness*—are synonyms.

5. The Knowledge Acquisition Process on a Trail of the Cognitive Viewpoint

Knowledge acquisition as a topic was originally a subject of philosophical study, specifically in the branch of epistemology. However, since the 1950s, the knowledge acquisition process has become a subject of interest in the wider area of artificial intelligence (AI). In Library and Information Science (LIS), an explanation of the knowledge acquisition process is indivisible from the terms of data, information and knowledge. Understanding the relationships among these terms resulted in the development of a certain model often mentioned in LIS literature called the DIKW model or DIKW hierarchy (Data-Information-Knowledge-Wisdom [DIKW]) (Ackoff, 1989; Rowley, 2007) [5]. What is important in the context of this paper is that the DIKW hierarchy symbolically implies the knowledge acquisition process as a whole. Anyway, the DIKW model was widely criticized in the literature because of its general (Zins, 2007), logical (Frické, 2009), epistemological (Ma, 2012) and symbolical (Bosancic, 2016) assumptions. In other words, the sustainability of the DIKW model in its current form has become questionable.

Recently, in the literature, at the conceptual-metaphorical level, a new dynamic model of the DIKW hierarchy called the DIKW tree or 'tree of knowledge', has been proposed (Bosancic, 2016). The corpus of human (and not only human) knowledge is represented by a "tree of knowledge" that grows by virtue of two sources. One stems from the 'data ground' and is represented by the 'information sap' (the flow of information) and the other, the 'meaning sap', was created as a consequence of 'mind sun rays' above the 'tree of knowledge' (a former layer of wisdom) which symbolizes a men's faculty for abstract thought. Although symbolic in character, this image makes information visible, which is not the case with the ordinary experience, making the role of information in the knowledge acquisition process more understandable. Information is recognized as a cognitive construction because it appears within the 'tree of knowledge' as an invisible 'communication tool' between a "predefined set of data" and existing knowledge structure within a cognitive system (Bosancic, 2016).

According to W. Hofkirchner, information is a relation "...by which, from the perspective of a self-organizing system..., a spontaneous build-up of order corresponds to a perturbation in the environment" (Hofkirchner, 2014, p. 58). In other words, "...information mediates the interaction of the system with its environment" (Hofkirchner, 2014, p. 58). Hence, in the context of the knowledge acquisition process, information can be considered a relational property of 'things' that leads to the growth or reduction of knowledge. In information science, as we mentioned, B.C. Brookes (1980) first pointed out this plain statement through his 'fundamental equation of information science'. In the next chapter, finally, we describe how this claim can be implemented within observer's cognitive domain.

6. A Description of the Cognitive Process in the Observer's Cognitive System Based on Terms of Information, Data, and Knowledge

6.1. The Principle of Undifferentiated Coding

How does the cognitive process play a part within the cognitive domain of the observer, if we decide to use the terms information, data and knowledge in its description? What role does information (and data) play in those processes? Accordingly, our starting point in the following discussion is a particular perturbation of the environment, and our ending point is the appropriate part of the knowledge structure with a certain meaning related to such perturbation.

According to the constructivist viewpoint, the first step to find the answer to these questions lays in the principle of undifferentiated coding, which originates from German physiologist Johannes P. Müller (Foerster, 1981; Segal 2001). The principle simply states that instead of the stimulatory agent, the nervous system of the cognizing agent produces sensations from the environment's perturbations. Moreover, "The signals transmitted through the peripheral nerves to the brain code information only about *the intensity of the stimulus*, not its cause." (Segal, 2001, p. 18). As Glasersfeld pointed out "...signals sent to the brain by neurons in your finger tips or toes... or in the retina of your eye, are qualitatively all the same." (Glasersfeld, 1995, p. 115). It follows that causes of the same 'intensity of stimulus' could be entirely different (Glasersfeld, 1995). At the same time, both an organism and the environment in their mutual interaction, which Maturana and Varela called "structural coupling", "undergo transformations" (Varela and Maturana, 1998, p. 102) [6]. Although "the sensors change through physical interactions" (Maturana and Varela, 1980, p. 13), the signals could only be some type of subsequent consequence of environment perturbation; they could not be any sort of "physical representation" of environment perturbation. Furthermore, more detailed explanations of this process can be found in papers on cybernetics by W. Ross Ashby.

6.2. Cybernetics' Explanation of the Principle of Undifferentiated Coding

W. R. Ashby (1956, 1958) has shown what possibly happens on the boundary of the autopoietic system of a self-organizing system when perturbation occurs (Figure 1). Accordingly, he carefully used constructed sets to explain how an organism would respond and survive in its environment. These sets include a set of disturbances (D) (perturbations of environments), a set of responses (R) (of cognizing agents), a set of possible outcomes (Z), and finally, a set of values (E), which is related to an organism's "...'essential variables' — those fundamental variables that must be kept within certain 'physiological' limits if the organism is to survive" (Ashby, 1956, p. 2). First, a set D of disturbances can be met by a set R of responses. It is important to highlight that those interactions may occur only at the physical level. Based on the process of 'single-valued mapping' between those sets, one may construct a set of possible outcomes (Z). Regarding Müller's work, these outcomes may relate to signals from the nervous system, which represent 'the intensity of stimulus'. Furthermore, according to Ashby, "... a further mapping of the set Z of outcomes into a set E of values" occurs; E values are values with a certain meaning (Ashby, 1958, p. 2)

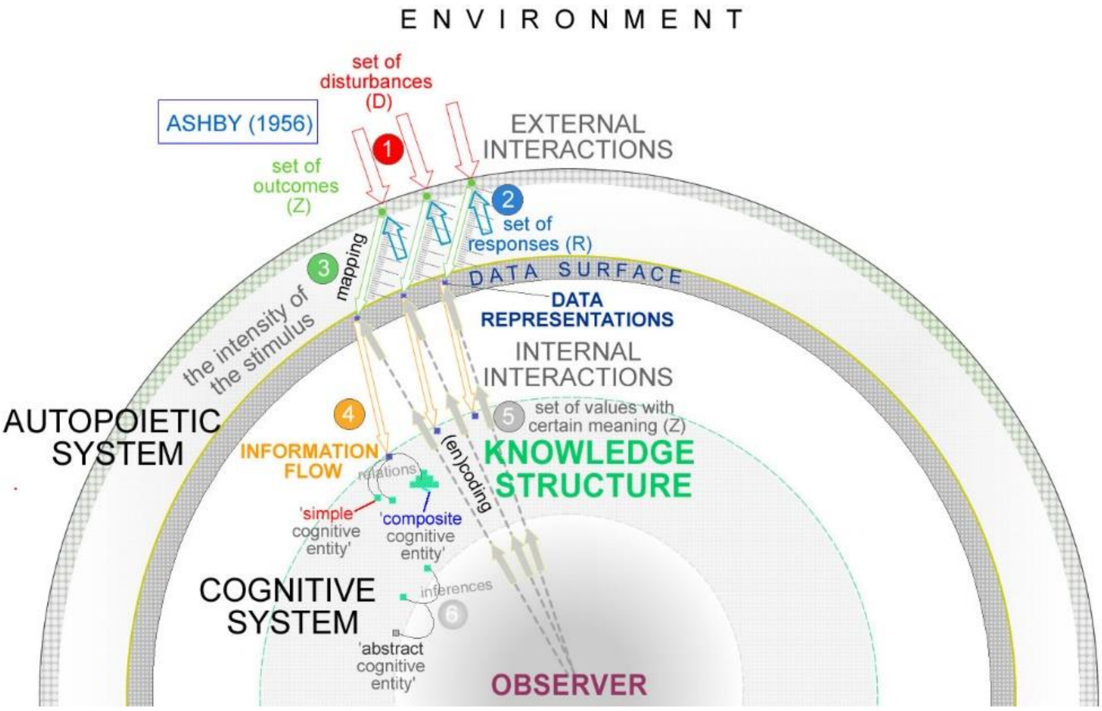

Figure 1: Data, information, and knowledge in the context of autopoietic and cognitive systems.

Imagine that you touched the table you are sitting at with your finger. In this case, sensations of 'hardness' represent the outcomes of the interaction between the table and our finger. We should not say that the table is 'hard' rather that we have experienced the sensation of 'hardness'. This apparent 'pedantry' in a discourse is the main characteristic of constructivist thought and reveals the very essence of constructivism. What we receive from the 'outer world' is not a reflection of the 'subject' or some kind of 'tangible' force that the 'subject' has transmitted to us but an electrochemical impulse, which only represents the consequence of the encounter of our 'body parts' (like a finger) with the objects of our everyday experience (such as a table) [7].

Thus, there are only electrochemical representations (in the form of signals) of the results of the 'physical interactions' between an autopoietic system and its environment—and not a representation of the environmental perturbation in any sense. Anyway, it seems that Ashby's papers lack a detailed description of the second process—the process of "...further mapping of the set Z of outcomes into a set E of values" (Ashby, 1958, p. 2). In other words, how can we imply (or derive) the 'values with certain meaning' from electrochemical signals? Hence, this is a point in our consideration where data and information may come to play.

6.3. The Role of Information and Data in an Observer's Cognitive Domain

6.3.1. From simple cognitive entities to data representations

Based on the considerations presented in the previous chapter, electrochemical signals, taken from the principle of undifferentiated coding, could be considered the basis (and starting point) of the observer's rich 'cognitive representation' of the 'outer world' (including realist and constructivist perspectives). The smallest parts of the observer's 'cognitive representation', which Maturana called 'simple unities' (Maturana and Varela, 1980, p. xix), we call the 'simple cognitive entities'. Without addressing the nature of the connection between electrochemical signals and simple cognitive entities, we may still ask how we are able to 'observe' anything within the cognitive domain of the observer. If we take into consideration the philosopher Immanuel Kant, we may get an answer in what he suggested: it lies in a specific 'pre-encoding' process that is carried out by space and time itself. In Kant's words, space and time represent the necessary conditions (or forms) of our perceptions and sensations *a priori* (Kant, 1998). In other words, on a primitive level, observing the space itself makes it possible, even in a literal sense, 'to make a space' for all simple cognitive entities; at the same time, time itself makes it possible 'to set' cognitive entities 'in time'. We believe they do this in the form of the particular 'cognitive spatial-time grid' in the cognitive domain of the observer [8].

On this basis, the simple cognitive entities can accumulate around each other (by space) or one after the other (by time). The 'letter' of such encoding system is the relative position of the simple cognitive entities in the cognitive spatial-time grid of the observer. In the same time, the observer's cognitive spatial-time grid immediately allows the establishment of 'pure relations' between the simple cognitive entities (Maturana and Varela, 1980, p. 13); for example, one may say that one simple cognitive entity is *next to* the other or one *follows* the other and so on. The establishment of the 'pure relations' between the simple data representations, finally, leads us to form the knowledge structure of the cognitive domain at a primitive level.

To become data these simple cognitive entities must be encoded in some way. Thus, an appropriate encoding system always lies behind the creation of any dataset. However, as we have already seen, the simple cognitive entities are already encoded by the 'undifferentiated coding system'. The 'undifferentiated coding system' includes a type of quantitative scale, which runs, for example, from 'very weak' to 'very strong'; it is expected that all such 'values' of 'intensities of stimulus' may take place on that scale. It that sense, what we call 'data representations' are appropriately encoded simple cognitive entities located in the cognitive spatial-time grid of the observer. If the observer, in any sense, through 'pure relations' notices any orderliness in the encoded simple cognitive entities or data representations that appear, s/he may perceive the 'existence' of an appropriate 'composite cognitive entity' or 'composite data representation' (which Maturana called 'composite unit'). 'Composite cognitive entity' may refer to the macroscopic object of our common experience.

6.3.2. Informativeness of Data Representations Within the Communication Process

The next time s/he observes the same 'composite data representation', a certain aspect of Shannon's theory as previously explained comes into play. As shown in Nöth's example, we may simply replace the letters of the English alphabet with the data representations. After that, we will be able to calculate the probability of one data representation depending on the previous one in the context of an appropriate 'recognizable string', which represents the particular 'composite data representation' already presented in the cognitive domain. Furthermore, in Shannon's sense, in a particular context we may measure which data representation must be more informative than the others and so on. For example, a macroscopic object such a table may serve as a 'composite cognitive entity' in a cognitive domain. In such a case, by the calculation only a few simple data representations we may be certain deal with just a certain 'composite cognitive entity, which represents the table at a macroscopic level. In other words, if we in our common experience see only a part of a table, we are able to derive the 'existence' of the entire table.

Accordingly, what we suggest in the context of a cognitive system as a whole is a model in which the data representations as encoded simple cognitive entities stand on a particular 'data surface'—the place on the boundary of the cognitive system, which represents the 'reception point' for all signals and which the observer receives through the nervous system (Figure 1). If we want to establish an appropriate 'information flow' of selected data representations to 'another point' of the cognitive domain where data representations can become the 'values of certain meaning'—or appropriate parts of the cognitive domain, which we call 'knowledge structure'—Ashby's principle of requisite variety should also be taken into account [9].

6.3.3. From data representations to knowledge structure

In a general sense, establishing relations between data representations, as a sort of information processing, represents the ability of the cognitive domain to build its own knowledge structure with a certain meaning. Von Foerster also states that information is a relative concept that assumes meaning only when related to the cognitive structure of the observer (von Foerster, 2003) [10].

However, it is still unclear how information (or selected data representations) can become 'values with certain meaning' or Ashby's "set E of values" (Ashby 1956, 1958)? As we said earlier, the aim of an observer's cognition process is to survive perturbations from the environment (Maturana and Varela, 1980). In other words, the cognition process is not a meaningless process; it has its 'primitive meaning values' *a priori*. Ashby quotes that 'good' and 'bad' may serve as certain 'primitive meaning values'. In that sense, one data representation can be met by the value 'good' and another data representation by the value 'bad' and so on. Moreover, it is easy to imagine that all other 'meaning values' could be derived from them, including the 'pleasure' and 'pain' as well as 'will survive' and 'will not survive' and so on [11].

An alternative approach proposed by Floridi suggests a "theologically free" or "primitive meaning values free" theory of meaning that he called action-based semantics (or *praxical* semantics). Floridi contends that there is no need for primitive meaning values for solving the Symbol Grounding Problem (SGP), which asks how data acquire their meaning. (Floridi, 2011). In his "*praxical* semantic," Floridi shows how data can obtain their meaning in a manner similar to that presented in this paper, by considering the interactions between artificial agents (observers) and their environment. We do not hereby unpack meaning itself, but leave the comparison of these opposing approaches to theory of meaning for further research [12].

Whether based on a 'primitive meaning values' or 'primitive meaning values free' theory of meaning, our goal is to illustrate that meaning arises from establishing relations among the selected data representations in a particular context in the knowledge structure of a cognitive domain.

6.3.4. Informativeness of Data Representations Within Knowledge Acquisition Process

In the context of knowledge acquisition process, it is obvious that the amount of information or informativeness of such data representations depends on a number of relations, which particular data representations are able to establish with existing data representations within the knowledge structure. More established relations means that particular data representation is more informative for the knowledge structure of observer [13]. In other words, we may say that the informativeness of a certain data representation is proportional to the total number of relations that it can be able to establish with existing data representations in the knowledge structure [14]. This is acceptable while each subsequent data representation is forced to establish a larger number of spatial (geometric) and temporal relations with existing data representations of those which precede it. This rule applies to both 'simple' and 'composite cognitive entities'; on the other side, it only regards the spatial-temporal relations.

6.4. About the expanding of cognitive encoding systems

As noted previously, the ability to expand cognitive encoding systems is one of the main indicators of the expansion of the observer's cognitive domain. In our opinion, one way to expand the cognitive encoding system of the observer is by establishing more and more sophisticated relations between selected data representations. In that sense, those relations can be used as the source of new 'values' for the expanding encoding system. For example, if one electrochemical signal in the form of simple cognitive entities causes pain to the observer, and another one pleasure, we are able to give a certain meaning to particular simple cognitive entities by mapping them with 'primitive meaning values'. We may say the simple cognitive entity that caused the pain is 'bad', and the other one, which caused the pleasure, is 'good'. According to the radical constructivist viewpoint, only the meaning connected to our survival allows us to distinguish 'things', nothing else. In addition, that also means that assigning meaning to one simple cognitive entity is able to create precisely one 'value' of an emerging encoding system. When the next simple cognitive entity comes into the cognitive domain, depending on its signal strength, it could assign the meaning of 'less bad' or 'more bad' due to the ability to cause sensations like 'less painful' or 'more painful', and so on. In other words, there is no other functionality of the cognition system as a whole except to ensure the survival of the autopoietic system. The consequence is that the developing simple cognitive entities would no longer have to compare with 'primitive meaning values'. They could compare with any emerging 'meaning values' as the 'values' of the expanding cognitive encoding system.

6.5. Logical reasoning in a function of the knowledge acquisition process

Among establishing relations between encoded information as well as deriving the appropriate meanings from those relations, there is another function of the observer's cognitive domain in the knowledge acquisition process, which is '...to draw inferences from this description' (von Foerster, 2003, p. 251) or from relations between the cognitive entities. As already mentioned, through logical reasoning, or inferences, the observer could postulate the 'existence' of a macroscopic entity such as a 'table', if s/he observed the same particular composite cognitive entity for a long time. Thus, the observer her/himself never directly experiences any macroscopic entities; logical reasoning only derives the 'existence' of those entities. The same applies to any abstract term ('abstract entity' in the Figure 1), property or relation that appear within a cognitive domain [15]. In that case, it can be assumed that abstract logical reasoning is nothing else than the observer's capability to establish 'relation of relations' among the components of a knowledge structure.

Finally, an earlier mentioned Ashby's sentence can be interpreted in the following way: the outcomes, which belong to the set Z, are data representations (or the cognitive entities after being embedded in the knowledge structure) encoded in some way. The "further mapping" is the process of knowledge acquisition, and "set E values" are the units of knowledge structure with a certain meaning. It is important to highlight that a knowledge structure, to be properly constructed, must be able to receive at least two types of 'information flow': the first 'information flow' is only used within the communication context of an already developed cognitive domain, and the second one is only able to change the knowledge structure of a cognitive domain. Furthermore, the appropriate established relations among 'arrived' information build the meaning of the knowledge structure.

6.6. The Communication & Knowledge Acquisition Process as a Closed Loop Cognitive Processes

However, considering the cognitive process as a whole, the constructivists insist that perturbation must always be able to cause a reaction. In that reacting, the observer's autopoietic system becomes the source of perturbation for the autopoietic system that caused the original perturbation (Maturana and Varela, 1980). Particularly, as a such closed loop process, the cognitive process enables learning and surviving. A rabbit will run away ('as requisite variety') from the wolf (which can be seen as the perturbation) immediately after it recognizes the wolf as a bad composite cognitive entity in its knowledge structure. In the context of this paper, the reacting on the perturbation by implementing the appropriate action can verify the achieved knowledge. However, the reaction of the observer's autopoietic system has no more information. The nervous system's signals are going to muscles not to inform something or someone but to cause a physical-chemical reaction. Therefore, it seems the reaction, as an aspect of the cognitive process, is not so important within the context of the knowledge acquisition process as it is to applying the achieved knowledge.

7. Conclusion

This paper is intended to provide a description of the cognitive process in the observer's cognitive system, with a focus on clarifying the role of information, data, and knowledge in the cognitive system (domain) of the observer as defined by Maturana and Varela’s (1980) approach. On this basis, communication and knowledge acquisition processes are recognized as important aspects of the observer's cognitive process as a whole.

In accordance with the above, in the cognitive system of an observer, we found two types of 'information flow'. One relates to the appropriate communication aspects of Shannon's theory in the cognitive process pertaining to encoding cognitive entities in a cognitive domain into data representations for calculating their *informativeness*. The second type of information flow is changing the knowledge structure of the observer by establishing the appropriate relations between the cognitive entities observed as data representations within the cognitive domain. In other words, one approach to understanding information is to understand it as a phenomenon, which refers to the observer's degree of uncertainty in her/his interactions with composite cognitive entities defined by her/him in her/his cognitive domain (Maturana and Varela, 1980, p. 54); and another is to consider information as something that enables the growth or reduction of knowledge (Brookes, 1980).

In a metaphorical sense, one can recognize information as a 'vehicle' of data representations that drives through the cognitive system of the observer on the 'data surface' – 'knowledge structure' route. Beyond that metaphorical interpretation, the information is recognized as the relational property of encoded cognitive entities or data representations, which reflect its ability to establish as many relations as possible in the knowledge structure of the observer. Thus, one may notice that this kind of 'cognitive information' is slightly distinguished even from the concept of *informativeness* (or measure of novelty), while we could imagine a very new data representation that is unable to establish any relation in the existing knowledge structure. That is the reason why we, in line with an exposed theoretical approach, advocate an extension of Shannon's original idea, with the intention of involving the observer's background knowledge as an important framework for deepening the grounds of information theory.

Notes

[1] For that matter, it is important to highlight we are not using the neuroscientist terminology and discussing the communication and knowledge acquisition processes as special instances of cognitive processes from their point of view, which includes phrases such as primitive visual area (V1) or neuronal wiring. At the same time, we know much more about the transmission of signals thanks to Shannon’s communication theory; thus, we are using the phrase 'constructed' or 'cognitive entities' to mark the representations that the

signals (by the neural networks) are carrying out. Those 'constructed' or 'cognitive entities' on the appropriate conceptual level are mostly data for us. Therefore, we are open to any contributions from cognitive scientists to find the appropriate cognitive mechanism, described by their terminology, which will fit to the one—information *per se*—proposed by this paper.

[2] As shown in "What is information? Towards a theory of information as objective and veridical" by Mingers and Standing (2018), *differences* are good starting points for creating any information theory. Contrary to this paper, the authors are considering the differences as 'physical differences,' which can be used to trace an objective information theory. The differences have been taken "as a mark or token of the event" in a physical manner. Hence, information for the authors is nothing other than "the relationship between a token, sign or message and the event(s) that caused it" (Minger and Standing, 2017, p. 6).

[3] It is relatively difficult to distinguish cognitive and autopoietic systems. Principally, a cognitive system is a closed system with a predefined domain of interactions while the autopoietic system refers to the closed network of processes that reproduce themselves as a separate unity in space and physically stay open to the environment. Living systems are cognitive and autopoietic systems at the same time even though it is not necessary that an autopoietic system be a cognitive system and *vice versa*. Paul Bourgine and John Stewart conclude that "...all living systems lie within the intersection between autopoietic systems and cognitive systems" (Bourgin and Stewart, 2004, p. 341).

[4] Namely, this theory was the result of a relatively long period of efforts in telecommunication engineering. First, Nyquist (1924), and then Hartley (1928) on the trail of Nyquist's paper, calculate some sort of measure of the amount of information that transmits through the telecommunication channel. Shannon's theory seeks to determine the best way to improve the efficiency of information transmission through the telecommunication channels. In his classified report, "A Mathematical Theory of Cryptography" (1945), Shannon uses, for the first time, the term "information theory" (Gleick, 2011). However, in 1948, he published "A Mathematical Theory of Communication", a paper in which he poses his own theory of communication. A year later, the same paper was published again, but this time, it was presented together with a paper written by Shannon's colleague, Waren Weaver, who suggested that Shannon's mathematical communication model could apply to all sciences and be used as a general communication model (Shannon and Weaver, 1963).

[5] In addition to the terms of data, information and knowledge, the term 'wisdom' also found its place within the DIKW model/hierarchy. Overall, in the literature about the DIKW hierarchy (Ackoff 1989, Rowley 2007), data is a symbol or signal in the transmission process or the product of observation. Information is processing data, a message or even 'data with meaning'; knowledge encompasses cognition, recognition and capacity for acting, or 'information with meaning'; and wisdom is understood as some kind of 'accumulated knowledge', or 'the ability to increase effectiveness', etc.

[6] In that sense, Brier added: "The 'picture' of the environment is constructed through a society of observers making structural couplings to the environment and to one another through languaging" (Brier, 2008, p. 89). At the same time, as Maturana claimed, "[...] outside language no thing exists" (Maturana, 1988, p. 80). We noticed that this attitude reflects the theories of poststructuralist thinkers who, like Maturana, emphasised that there is nothing outside of language and that everything starts from the middle (Derrida, 1997). From this perspective, the concepts of scientific discourse are mostly created by ourselves, and it is an illusion that pure observation of the outer world generates these concepts (Foucault, 1978). Lacan (1988) stated that the 'real' stands outside language, and it is impossible to integrate it in any symbolic order; however, the 'real' can be differentiated from 'reality', which is only a 'theoretical construct'. All that means that only "[...] through languaging and social practice, we bring forth our worlds" (Brier, 2008, p. 180).

[7] Anyway, this example applies only in an already developed cognitive domain in which the 'observed electrochemical signals' can be mapped to existing values with meanings such as 'hardness'.

[8] In addition to the 'space-time' and 'undifferentiated' encoding systems, it is easy to imagine other encoding systems based on the ability of our senses to produce their 'values'. Colours, sounds, or even shapes may also be easily identified as certain cognitive entities encoded by the 'values' of an appropriate 'cognitive encoding system' in the cognitive domain. In that sense, expanding observers' cognitive domains (Maturana and Varela, 1980) corresponds with expanding their cognitive encoding systems. If we want to enable knowledge growth, from a data perspective, we do not need more information; what we need is the possibility to expand our cognitive encoding systems. However, we will not present a deeper explanation of this process, which involves the association of each particular data representation with a certain wavelength of colour/sound or position in space and time to create the appearance of an appropriate macroscopic object.

[9] According to Ashby's requisite variety, the amount of information triggered from the 'data surface' must be enough to allow an organism to survive against perturbation. This means that if just one 'single data representation' is enough to make sure that the organism will survive, the established 'information flow' will consist from only that 'simple data representation' (Ashby, 1958).

[10] "Hence, a measure of the number of events... which constitute a cognitive unit ...or of the probabilities... of their occurrence—is again the "amount of information"... received by an observer upon perceiving the occurrence of one of these events" (Von Foerster 2003: 187).

[11] For example, in a primary context of the survival of an organism, the 'very strong' 'intensity of stimulus' may mean a death threat and a 'very weak' 'intensity of stimulus' may indicate something harmless in principle. At the same time, the 'very strong' value could also mean a 'bad' or a 'pain', and the 'very weak' value could mean a 'good' or a 'pleasure', and so on.

[12] There is a general impression that Floridi in his book *The Philosophy of information* handles the same problem as this one in this paper. He deals with it using his terminology from the Theory of Strong Semantic Information (TSSI) (Floridi, 2011). Where he talks about meaningful data or semantic information, for our purposes we recognize the description of components of the *ready-made* knowledge structure of the observer.

[13] Furthermore, it cannot be said that each new cognitive entity outside the 'spatial-time grid' will be more informative than the previous one. If the entity is unable to achieve any relations with other existing cognitive entities, we may say this entity is not informative within the context of the knowledge acquisition process. For example, if a strange person is not recognized as a member of a particular family by its members, he is unable to establish any family relations with the members of that family. However, in the context of establishing the 'pure relations' in the 'spatial-time grid', each subsequent 'simple data representation' is more informative than the previous one.

[14] For example, the total number of possible unary relations into 'spatial-time grid' can be calculated according to a predetermined mathematical pattern: $R_n = n\,(n+1)\,/\,2 - n$, where R_n is the number of possible unary relations between existing data representations, and n the total number of data representations within the knowledge structure. This formula is derived from the formula for calculating triangular numbers: $x_n = n(n+1)/2$.

[15] For example, the cognitive entities, which always establish the same relation, may become the members of the appropriate class. In that manner, this class is derived from abstract terms. Further consideration will lead us to the topic of ontology and knowledge bases, which are mostly considered in computer and information science.

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