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Trans-Disciplinary Communication: Context and Semantics

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ABSTRACT

Science is split into subject-oriented disciplines that are grounded on varying shades of the scientific method. Being a social activity, communication lays at the creative core of the science-building process of facts and explanations. To communicate means, in its most seminal sense, to bring something in common between distinct parts or to transfer something from one part to another. This 'commonality,' or what lays in common to the parts, can occur not just among persons but also among persons and nature or persons and non-human things. This article starts discussing communication at the human scale from the very beginning, widening the scope from its inner kernel in individuals towards social interactions in the scientific community. The perspectives, concepts, and guidelines unveiled by this exercise are applied in the article's text itself.

Keywords: Scientific Disciplines, Dialogues, Understanding, Semantics, Contexts, Trans-disciplinary Communication.

1. INTRODUCTION

Science, née natural philosophy, is *homo sapiens* effort to understand and explain Nature and its variegated phenomena, an activity plenty of psychological nuances concerning both objectives [1]. Being an offspring of philosophy, science is an intellectual activity in its core and relies strongly on (many sorts of) logic and dialectical discussions. However, it carries in its innermost center the need to interact and dialogue with Nature. This requirement singularizes it from philosophy. Forecasting and problem solving are ancillary activities to the scientific process, serving mainly to reassure us about our understanding of Nature. Our inabilities in predicting weather or in inferring the consequences of social actions mean simply that we fall short, widely short indeed, from understanding the underlying phenomena. The failures depend only minimally on the unavailability of (observation) tools and solution gadgets.

Notwithstanding, Nature is a rich and succulent subject, with the potential of satisfying every palate. It deploys simple phenomena, like moving around (falling stones, water flows, growth, traffic, or heat), as well as awfully and utterly complex phenomena, like (global) economies, landscapes, weather, human society, environment, or human-human and human-nature interactions. It generously also deploys a variety of phenomena in-between, like molecular re-organization (chemistry and biochemistry), life and its continuity, human spontaneous (uncontrolled and not planned) behavior and ingenuity, and so on, that help us to gradually understand complex behavior.

For the moment, two things are worth remarking in this overwhelming kaleidoscope. In general, complex phenomena depend on simpler ones—molecular re-organization depends on movement, life depends on biochemistry, and economies on society's re-organization and human behavior (e.g., preferences, production, consumption), to cite a few. Second, there are many ways of looking into Nature and to sort natural phenomena into hierarchically constructed classes, as well as, of enrolling mutual interdependencies among classes. Their description beyond these simple statements lays, nevertheless, outside the scope of this essay (see [2] for an example of phenomenon-classes).

To tame this unbounded maze of infinities, human ingenuity designed a way of investigating the many facets of Nature, that distribute the effort among several people, under several perspectives, centering though on the scientific method to keep all these efforts (loosely) coupled. Science is in this way a collective human enterprise transforming the unknown into known descriptions approximating the largely unknown Nature. The scientific method enables and supports this workflow. Consequently, despite being collective, it subdivides itself into (scientific) disciplines by abstracting interdependencies and sharpening the method for the resulting specific class of phenomena. Therefore, we must acknowledge that the description in the first paragraph results from the way science evolved and the current point of view that our training as scientists imposes upon us, rather than from any intrinsic characteristic of Nature.

Dialectical discussions entail conversations and communication pervades the scientific enterprise. This article looks forward throwing some light on the scientific process by inspecting and studying its most pervasive feature — communication. Communication is in itself a phenomenon. I start from the very beginning, trying to dissect how the meaning of words are 'constructed' and the communicative interactions among persons with the same culture and professional background occur, identifying key elements and what is transferred between communicants. This discussion promotes the introduction of useful concepts and terminology, leading to a better understanding of communication that, as will be seen, may be based on whichever means are available: in written, in sounds, in

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frequencies, in pictures, in visual elements, or in gestures and attitudes composing a hidden body language. Thenceforth, I use these tools to address more elaborate aspects of communication in science, sharpening them as needed. To make viable this humble study, emotional and other psychological states, that do indeed affect any communicative process, will not be considered, and only minimally alluded to.

This text is also an essay in trans-disciplinary communication. I have made efforts to apply the unveilings reported and the ideas proposed to the article's writing itself. Metaphors and analogies are grounded on images and referents available in principle to all.

2. COMMUNICATION: MESSAGE AND MESSAGING

All communications embody the *transfer* of something. It can be of heat, matter, or movement, of feelings or emotions, of moods, enthusiasm, or depression, of fluids as in communicating ponds and rivers, of raw materials or goods in the productive arena, etc. Transfers may occur, though, that cannot be easily associated with communication, for instance, those coming from any kind of physical or verbal aggression. Nevertheless, for transfers to occur between two material or immaterial things they need to be in contact. Contact can result from spatial proximity, as when ponds are side by side or humans meet face-to-face in social gatherings being able to touch each other, or it implies the existence of a connecting channel, as when two rivers or oceans are brought in contact by a canal from one to the other, or when two persons talk over a telephone line or the internet all over the world. Either way, a *communication channel* must exist for *transfers* to occur.

Notwithstanding, communication between humans seems to be always symbolic, particularly when our brains explicitly mediate the transfer, which is the rule, but also when brain intervention is less conspicuous, as when we dance together (cheek to cheek) or play soccer. In science, communication and transfers relate almost always to information, knowledge, or the allure of understanding and discovering nature. The two later motifs add yet another dimension to communication, beyond channels and transfers, that shall be addressed in the sequel. Moreover, the raw scientific stuff is made of ideas, ideals, representations, observation, argumentation, and the like. All of them immaterial things that need a representation to be handled and referred to. For this very reason communications in any scientific field or scientific explanation employ symbolic tokens as transportation vehicles organized in the form *signals* or *messages;* the difference between the two being that signals come from anywhere and have no underlying intention, while messages come from potential interlocutors and are intended to communicate something. Scientific *messages* or *signals* may be arrangements of symbolic tokens, which can be visual, auditive, scent, or any other *signal* perceivable by our localized or diffuse senses, or by apparatuses designed to augment human senses. They can also be collections of *signaling processes* interpretable into a message, like in hidden body language.

To summarize, when our brain intervenes, *transfers* in communications employ arrangements of symbolic tokens in the form of, *signals* or *messages*, that travel over communication *channels*, conveying what is to be transferred from one 'place' to another, from *sender* to *receiver* in the case of messages.

3. COMMUNICATION: IMPRINT AND IMPRITING

The communication elements hereto identified—signals, messages, channels, and transfers—are collective in the sense of requiring more than one person or thing to make sense. The next ones are individual-centered and will be inspected, with no loss of objectivity or generality, with the help of children learning about words. Furthermore, the initial focus shall be on a simple message: "eat." Granted that embryos are constantly being nurtured through the placenta; we can safely assume that it never thought about "eating." Even if it could sense this word echoing thru its mother body, it would have nothing to attach to because there is no contrast, no change, that allows it to distinguish "eat" from "no eat," for instance. We can also safely skip the breast-feeding period, for it is difficult to imagine a mother saying, 'come and eat,' or similar things, while accommodating a child at her breast. Scents and smelling are what is just needed. I shall also assume that, biologically, all brains and minds are alike and provide the same possibilities and potentialities to all human beings[2] without exception.

Children are fantastic learning machines. Moreover, they seem to have nothing to hinder their learning. Their attention is always on and their energy seems unbounded. Most children understand what is said to them much earlier than they can pronounce any sound recognizable as a word. What happens when a child is learning what the sound "eat" means? That is, when it learns how is this sound employed by other people. How is this sound inserted and recorded in their minds? Being the brain and the mind adaptable organizations, eager for new tokens and associations, with what in the brain-mind complex will this incoming new sound "eat" be associated with and how does it become related to other portions of knowledge in the brain-mind complex?

Of course, children will associate this word with sitting at a table or on the womb of their tender and having an awfully awkward object forced into their mouth upon which there are things that may appeal to them or not, tasting good or not that good. Is that all? Well, this is certainly the most conspicuous part of the noticeable sensations and tend also to be the most vivid ones. Remember though, that a child has all his attention on and has potentially nothing blocking or narrowing its attentiveness. Therefore, the child is concomitantly sensing scents, vibrations, tensions, warmth, colors, sounds, affection or coldness in its tender, and many other signals. It also perceives signals not so close by, like street sounds, music, people working around, light entering through windows, air humidity, and an infinity of other stimuli. By a hypothesis needed to define in-formation [3], all these stimuli are temporarily *imprinted* in brains or any part of an organization that receives and processes sensorial signals. This process generates *signatures* for each signal in the form of a dynamic process over the organization, like the electro-chemical currents over the brain. Signatures that stabilize form physiological organizations called *perceptions* that are, so to speak, (internal and private) representations of stimuli. The plethora of signatures flooded over the child while eating

[2] This does not preclude, though, the existence of innate (genetically inherited or womb-acquired) preferences and abilities.

aggregate through stronger or weaker associations into organized collections of perceptions. Part of these associations are made consciously, but the majority may be not.

The next time the child "eats," a portion of the perceived sensations may be quite different from the already imprinted ones while another portion, related for instance to the sitting and the mouth experiences, may be very similar or analogous. The similar ones reinforce the imprinted perceptions as well as their associations provoking incremental adaptations in the organization of perceptions in the brain/mind. Collaterally, this organized aggregate is also reinforced as a whole, gradually stabilizing. The dissimilar ones or those that do not associate well tend to fade-out, although some of them may still remain in the brain in association to "eat." These *stranger-perceptions* keep some 'openness' in the organization maintaining in it a propensity to change, to further adapt. This, or a homologous, process occurs as long as the child repeats the "eat" process. Gradually, the perceptions-organization that the act of eating evokes enter a stasis-state from the organizational standpoint, eventually achieving stability but remaining somewhat fluid and open to change, for instance, in aspect and flavor signatures related to the food itself that change from one "eat" experience to the next. This collection of perceptions is what the child will *mean* for "eat" from that point on. The 'size' of this conglomeration of perceptions depends on the number of spices, scents, tasting-expositions, and other stimuli the child is subjected to during the period it takes the "eat" *knowledge-singleton* to attain stability. The length of the stabilizing period is itself affected by the richness of "eat" experiences. Of course, incremental adaptations in this specific knowledge-singleton pervades the whole life of any human-being since no one will forget to eat.

In summary, *perception* is a never-ending (biological) process centered on sensorial stimuli. The conglomerate of sensation-perceptions attached to a signal or message is its *meaning*. The perception process builds a *knowledge-singleton* in the brain-mind complex, which contains also long-lasting *stranger perceptions* that induce flexibility and adaptability in the singleton.

4. COMMUNICATION: CONTEXT

This or a similar process occurs for each word, concept, thing, felling, procedure, experience, et cetera, the child goes through, for each of the many chunks of knowledge we learn during our lives. Each knowledge-singleton eventually becomes associated with other elements of similar kind, for instance, the "eat" singleton with "being hungry" one or the singleton registering music being heard while eating, and so on. Certain associations 'strike back,' as when a music provokes the desire to eat definite things. The more we learn, the more this maze of perception-organizations grows. Eventually, a new message or signal being perceived has an astronomical number of possible manners to associate with other portions of this knowledge-singletons maze. Notwithstanding, there may exist in the maze preferences to where to bind as well as regions that become inaccessible under certain mutable conditions. Moreover, some associations may be or may turn out to be stronger or weaker than others.

The collection of all knowledge-singletons we have access to, together with all their associations, form the (knowledge) *context* in which a person is immersed. The context is then the (organized) collection of things, memories, experiences (conscious or not) that allows a message to be understood, acquiring *meaning* while being imprinted in the brain-mind complex. Unsurprisingly, the more associations a knowledge-singleton has the more stable it becomes. It becomes also more and more difficult to change its insertion loci, how it is inserted in the memory, as well as, to adapt its meaning; unless the brain-mind complex where it belongs is trained to keep its perceptions, its knowledge-singletons, and their associations swift, fuzzy, and flexible, along with its childish eagerness in creating new associations [4].

Clearly, associations induce a notion of distance between knowledge-singletons: eating is closer to being hungry than to starving, that requires being hungry for a long while to intrude itself in any context. Moreover, an individual may be reasonably fed and never reach the point of starving, despite the concept being part of his context. We may thus question about what portions of the context are easily accessible when the child learns about "eat." The portion of the context that is easily accessible while learning, discussing, or experimenting something, will be called *active context*, or *immediate,* or still *illuminated* context. It varies swiftly and often widely, due to changes in the collection of stimuli occurring at any given situation.

To appreciate the importance of this concept, let us consider a child whose parents have different native languages, English and French for instance, and who commute between England and France, subjecting the child alternatively to both cultures. It will then learn about "eat" while in England and about "manger" while in France. It is likely that the active context, the informational organization that is immediately accessible to the child will not be the same in the two situations.

The sounds, scents, textures, tastes, colors, warmth, and hidden language signals coming from the "eat" or "manger" experiences as well as those from the surroundings are different in both countries, not to say the food itself. In particular, the signatures activated by more diffuse environmental signals coming to the child are substantially different, depending on where the child happens to be. Hence, there is a high chance that the messages "eat" and "manger" will be associated to substantially different contexts. Does any portion of each context remain common in them? What happens if the child always sits at a table while experiencing 'eat' and on its tender's womb while experimenting 'manger?' What may happen then if the child is subjected to the message "manger" while in England?

In summary, *context* is a maze of life-long constructed 'individual-centered' perception-organizations (also knowledge-singleton organizations) reflecting all its innate and acquired knowledge. It grows cumulatively and modifies as a consequence of individual experiences and preferences. It depends on cultural factors and on individual actions and choices. The *active context* is a portion of this *context* that becomes stimulated by a set of signals present in and around the individual at any given moment. It is the portion of the context that is 'ready to use.'

5. MULTI- AND TRANS- DISCIPLINARY COMMUNICATION

We may also question about portions of the context that do not result from direct experiences but from knowledge acquired from

others. This section collaterally addresses this important point, that is nuclear to learning and creating knowledge collectively.
Due to the wealth of signals and stimuli involved in the construction of contexts and their will-be parts, a process modulated moreover by preferences and personal moods, it is rather unlike that even two twin-brothers in the same family, subject to the very same experiences, develop exactly the same context for the signal ‘eat,’ or any other message they learn. For instance, while hearing ‘eat,’ one twin may become eager for a cold meal while the other for a warm one, despite their twin-brotherhood almost certainly has subjected both to the same experiences. On the other way around, family members do communicate pretty well with each other, and the twins’ mother may even know which is coming for the cold or the warm meal even if the twins look absolutely identical.

Let us qualify the perceptions, signals, and messages underlying this kind of (guess-prone) communication as *empathic*, since they provide an intimate glimpse into choices, preferences, and desires of other people. Apparently, though, the trick supporting empathic communication is a general feature of biological entities, present at all scales, that enable the perception of change, dynamics, and propensities of things. In theoretical biology, this feature is called *anticipation* [5] [6]. Anticipation provides the means for living entities to build representations for stimuli affecting other entities concomitantly with the reactions the other entities have to the same stimuli. Using the hypotheses sustaining the definition of in-formation [3], we may say that the twins, having eaten together their whole short lives, create different signatures for “eat” within their heads: one for his own perceptions and reactions, and another for his sibling’s reaction to apparently very similar stimuli.

As far as it goes, it looks possible for brains to create empathic representations for every person or thing in its nearby environment. Representations of this kind are created instinctively and appear to be a very basic feature of human brain-mind complexes. Anticipation can also be observed in cells, or even sub-cellular organizations. However, the swiftness and clarity in constructing them show signs of being strongly influenced (both agonistically and antagonistically) by emotional bonds, granted that it is easier to build them for people emotionally closer to us, even when we are not exactly fond of them. Creating *empathic representations* also seems to require a relaxed mind, since it is easier to build them during childhood, when little to no restrictions, nor criticisms, nor impositions, are present to impair this process. The construction of empathic perceptions appears also to occur more swiftly when we are playing and behaving in a childish state of mind, with no obligations, goals, or tensions whatsoever.

To adapt this understanding to disciplinary communities, let us first consider the communication between (two) persons. Let us also remark that the possibility, willingness, and patience to redo whatever needs to be re-done dampens tension and can overcome most hindrances to the process of building empathic perceptions, by bringing people closer to a childish state of mind. Disciplines are a particular kind of cultural milieu and people trained within a given scientific discipline share a considerable amount of contextual knowledge and of observation protocols, particularly when it concerns the meaning of basic elements of the disciplinary thinking, like terms, words, the nature and limits of concepts, perceiving-procedures, and so on. In spite of that, discrepancies in how a signal or stimuli is understood may occur due to personal experiences, taste, interest, and feedback from things in one’s environment, given that persons differ, and the disciplinary training can occur in different schools, places, and cultures. Additionally, there are, sometimes, slight but important differences in the methods and procedures used when training a person in scientific matters by distinct academic centers, a good omen.

Nevertheless, discrepancies of meaning, interpretation, and perspective between persons with the same culture can be overcome by means of simple, almost instinctive, hand in glove dialogues. Good to note that this goes hand in hand with the building of empathic representations within a family, where often not even spoken dialogues are necessary; the communication needed to form empathic representations remaining subliminal. Notwithstanding, emotional bonds outside family like ambiences grow weaker being even neglected or inhibited. Hence, dialogues turn out to be mandatory to create emphatic representations and handle discrepancies and misunderstanding in groups and communities with weaker bounds, by inducing for instance a kind of knowledge-discrepancy tolerance.

What can be said if the two communicants are trained in different disciplines? In this case, we cannot escape a deep plunge into the epistemological roots of the disciplines involved to venture answering this question. Some disciplines are ‘close’ to each other while others are apparently ‘distant.’ For instance, physics and inorganic chemistry are ‘closer’ to each other than are physics and biology or physics and population dynamics. The main subject of physics is the motion of ‘immutable things’ that interact whenever in contact, while chemistry deals with reorganization of molecules from distinct substances and thus with ‘mutable things.’ To a certain extend motion goes well into chemistry, where we need to shake, stir, or heat substances to promote uniform contact and interaction. But terms like position or velocity are rarely used. Motion enters chemistry through terms like energy, enthalpy, reaction rate, and the like. There are additionally terms, like chemical affinity, that result from molecular organization and not from motion, bringing into stage terms strange to physics like reaction rate, acidity, configuration, and valency.

Biological phenomena ground on (bio-)chemical interactions. However, motion, velocity, and position are not generally considered in biologists’ explanations, nor stirring or shaking by the way, even if this is done in lab-protocols. The importance of signaling in biological phenomena bring to the stage yet other concepts that are not present in either physics or chemistry. Moreover, terms commonly used in both disciplines do not necessarily have exactly the same context, like ‘eat’ and ‘manger' for the twins.

The other way around, there are terms occurring in many disciplines that retain the same or very similar global meaning and contexts, like force, system, organization, action, induction, and so on. Other terms have very similar intentional meaning at more aggregate levels but come from underlying phenomena that cannot be matched or even brought into analogy. The term ‘friction’ refers to something that hinder dynamics or change, dispersing energy and loosing time, it doesn’t matter whether occurring in physics, information dissemination, or social dynamics. Yet, these ‘frictions’ are caused by rather distinct phenomena in all these occurrences; namely, electro-magnetic interactions, noise, lack of attention, or semantic mismatch and chaos-inducing actions which can barely be brought into relation with one another.

Establishing communication between scientists from different disciplinary backgrounds demands from both sides to create empathic representations for the fundamental terms involved in the communication, in such a way that one can have a good picture of what the other is saying and how it uses the term like children do, without the imperative of fully grasping and adopting the meaning and context belonging to other communicants into his own world.

Summarizing, each scientific discipline has its own set of basic thought-elements that stem out of their subjects of study and pervade the phenomenological class determined by it. Some of these terms may occur in both or several disciplines, eventually with slight distinctions in meaning. In some cases, the same word may represent rather distinct phenomena, or their effect, but retain a common and similar understanding from an encompassing stand. The ability of creating *empathic perceptions* is mandatory for acknowledging these subtleties and understand other disciplines' contexts while preserving the integrity of one's own.

6. CONCLUSIONS

Besides the exposed above about under-determinacy of meaning in person-to-person (non-disciplinary) communication, biology teaches us that the same organization (molecular complexes, organelles, and cells, for instance) may have different functions depending on where it is located within its environment and on how it inserts itself in its immediate surroundings [7] and that they may respond differently to the same signal. Moreover, it is clear that the brain informed by stimuli being received may block or weaken associations that are not likely to be needed, to save energy or for any other physiological reason. (Most of us have the experience of being hard to recall impressions not stimulated for a long time.) Thus, we may say from the standpoint of the extended JG Miller scale for living individuals [8] [9] that communication as described above is biological signaling and function 'upgraded' or 'elevated' to more sophisticated organization-levels. This approach allows for considering in its framework communication and dialogues not only between single individuals but also between collective ones, like groups, teams, boards, institutions, communities, as well as any cross-combination of them.

Of course, one may, in a simplistic approach, investigate communication reporting only to the all-encompassing context; a single accretive entity consisting of everything learned and experienced up to the moment of the exchange by whoever is communicating. Notwithstanding, this will put us back to where we started and make the handling of different and subtle meanings of messages or of different functions of the same communication context much harder. The idea of context explored in this article aims to help us to understand the communication of scientific matters, especially when the referents suggested by messages are fluid, fuzzy, or underdetermined, and need thus to be kept as flexible as possible.

Contexts are meant to be fluid concepts that depend not just on who communicate but also on the domain of what is being communicated as well as other factors relevant to a given communication. Nonetheless, contexts need also to acknowledge what and how interlocutors presently are by taking into account everything learned during their lifetime, to properly highlight brain intervention in the process. The dual concept formed by contexts and active contexts is introduced exactly to address fluidity, stimuli variability, and communicator dependence, as well as other key-factors in a communication that vary from one communication-event to another. Active contexts are mutable parts of the less mutable communicant-centered context that grows continually and encompasses everything learned. This stand was said above to be a simplistic approach. However, in the case of living communicants, it is convenient rather than simplistic, because living entities evolve and learn themselves implying that the communicant-centered context changes constantly on its own, as a living entity, and cannot be manipulated as a tool to investigate communications. The same stimuli may induce distinct *active contexts* in the same individual at different moments, as a result of context re-organization.

The formalisms and theories provided by the diverse disciplines supporting the communication-picture being here advanced (see section 8), particularly the JG Miller characterization of living systems [10], the generalization of 'systems' and 'Shannon's information' brought forth by the organization/in-formation perspective [3], and the re-writing of Miller's conclusions in terms of organizations and in-formation, imply that the picture for communication introduced is valid at all the living scales pinpointed by JG Miller, granted that we can find how the key concepts enrolled above instantiate at each level of his scale. That is, we need to see how signals, messages, meaning, transfers, channels, brains, etc. instantiate at each level in this scale: sub-cellular, inter-cellular, tissue, organ, group, teams, larger groups, populations, societies, and so on. This rises daunting questions like: "what are *collective contexts* and *collective active contexts*?", "how concepts (should) form in multidisciplinary teams?", "how are *empathic perceptions* instantiated in groups?" (i.e., "how groups anticipate?"), "how can people be trained to naturally maintain independent thinking while thinking collectively?", and so on, questions that urgently need to be addressed in multi-disciplinary research instalments.

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I am perfectly aware that some assertions above still require experimental verification, despite being natural guesses. As conjectures, though, they are indeed adequate to present the concepts here introduced and to explain their meaning and use. Furthermore, questions in the text are not mere stylistic artefacts and are meant to provoke thinking, completing the text on an individual basis.

To make this essay a real experiment I shall need the help of my readers. I will be forever indebted to those of you who willingly spend a slice of your precious time to feedback me about which portions of the text were difficult or easy to understand.

I hereby declare no conflict of interest. I am just pursuing knowledge and understanding.

8. REVISITATION

Social dynamics have been usually studied considering individuals organized as populations or networks where some phenomenon moves around from individual to individual. These studies employ various modes of statistical analysis and abide to statistical premises [11]. Although hosting agents and emerging properties, they do not accommodate dialogues, argumentation, and individual change. The present work aims at later niche of the social dynamics' universe, being thus closer to social psychology [12].

The learning and communication picture sketched in this text stems from the personal observation of my children (a couple) and my students while learning, and from the crossing of a wealth of proficient thinking avenues molded under an integrated perspective rooted in general systems theory [13] [14] [15]. Previously, references and justifications were kept to a minimum for the sake of simplicity as well as argument clarity, fluidity, and sequence. The picture proposed and these thinking avenues are notwithstanding based on decades long of documented prime quality research. For those who are not at easy with the scientifically humble arguments provided before or for those who want to dig deeper into these charming waters, this section provides further references, arguments, and discussion, aiming to disentangle them to the best of my abilities. Everyone else is welcome to skip it.

Out of the multitude of excelling work supporting investigations about trans-disciplinary communication and the previous picture, we may list the following. To be fair, some ideas and concepts molding the propositions in this text cannot be traced to definite sources and stem diffusively from years-long work centered around a person or main group. In this case, the name of the person or group is enrolled, eventually with a couple of citations pointing to the more important literature. Anyway, references are no better than indicative.

Investigations about sensorial perceptions, brain capabilities, mind functioning, and brain-mind delineation date back to at least the middle of last century when the counterpoint between biological and electronic brains had made these subjects highly fashionable [16]. Furthermore, communication is more needed and conspicuous in groups and other social systems. Therefore, our supportive research falls into three encompassing and intertwining collateral lanes: the psychological-philosophical-epistemological, the physico-biological-mathematical, and the social-linguistic-humanistic. After the 1970s, computer science, whenever looking forward to model brain-mind behavior, in total or in part, provided important and non-trivial insights into memory and the more "hardwired" aspects of brain-mind behavior. The indications provided below are far from being exhaustive and are centered on readings of mine, without being constrained by it. Moreover, it will be clear that many references provided touch more than one of the above lanes, if not all the three. This is due to the integrative nature of the subject under investigation. In the last 15 to 20 years, with the settling of the neurocognitive sciences, psychology and AI included, as well as the hard-to-believe advances of in-vivo brain-observation methods and technology, the number of writings that can really improve knowledge about communication exploded but lost a great deal of its former integrative ethos.

Along the social lane, we find near-decomposability and the sciences of the artificial [17], the characterization of living systems [10] [18], investigations on socio-linguistic interactions [15] [19] [20], as well as, integrative socio-economic perspectives [21], education, and ecological-economy. Centered on this lane but overflowing into other areas that may go even beyond these three lanes, I note the influence of many portions Noam Chomsky's work, particularly [22], and the multi-disciplinary thinking of Edgar Morin.

Along the psychological-philosophical-epistemological lane, there are several studies and approaches to understand the mind-brain or mind-body dichotomy, encompassing altogether intelligence and learning that clearly influenced the context approach above [23] [24] [25] [26] [4] [27] [28] [29] [30] [31] [32]. Along this lane, there is also the *system thinking* approach [18] [14] [15] with many other nuances and more problem-directed authoring. These achievements not only are investigative tools but also lay the integrative tunes of the present article, as do biosemiotics and C. S. Pierce ideas.

Along the lane closer to STEM-biology disciplines, it is pretty more difficult to separate work addressing models meant for life phenomena [5] [6] [14] [18] [3] from those that are not [33] [34] [35] [6], work aiming at artificial life and robotics [36] [37] [38] from those which focus primarily in the (formal) development of an underlying theory for the living [18] [3] [6] [39].

Computer science is a mathematical science really close to mental processes, logic, and meta-mathematics, borrowing many ideas and even a few techniques from them. Thus, its contribution to the subject of this text is indeed pervasive, starting short in the wake of Alan Turing's work on the decision problem [40]. Furthermore, the areas akin to (the science of) programming, an activity that encompasses planning and other brain-mind abilities, and those related to computational essays trying to mimic memory, language, and similar brain activity are of special relevance to this essay [41] [42] [43] [44] [45].

9. BIBLIOGRAPHY

[1] K. J. W. Craik, The Nature of Explanation, London: Cambridge University Press, 1943.

[2] M. Vieira Kritz, "Boundaries, interactions and environmental systems," Noviembre 2010. [Online]. Available: http://www.cimec.org.ar/ojs/index.php/mc/article/viewFile/3183/3110. [Accessed December 2023].

[3] M. Vieira Kritz, "From Systems to Organisations," *Systems,* vol. 5, no. 1, p. 23, March 2017.

[4] Douglas Hofstadter and the Fluid Analogies Research Group, Fluid Concepts and Creative Analogies: Computer Models of the Fundamental Mechanisms of Thought, New York, NY: Basic Books, 1995.

[5] R. Rosen, Anticipatory Systems, New York, NY: Pergamon Press, 1985.

[6] R. Rosen, Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life, New York, NY: Columbia University Press, 1991.

[7] J. Shrager, "The fiction of function," *Bioinformatics,* vol. 19, no. 15, p. 1934–1936, 2003.

[8] M. Vieira Kritz, "Scientific Milieu, Multi-Disciplinary Science and Creativity," *Journal of Systemics, Cybernetics and Informatics,* vol. 20, no. 5, pp. 1-16, 2022.

[9] M. Vieira Kritz, "Trans-disciplinary communication and multi-disciplinary research," in *Proceedings of the 27th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2023)*, Winter Garden, FL, 2023.

[10] J. G. Miller, Living Systems, N. York, NY: McGraw-Hill Book Co., Inc., 1978.

[11] C. Garcia-Diaz, "Review of "Serge Galam's Sociophysics: a physicist's modelling of psycho-political phenomena, Springer-Verlag, Berlin, 2012"," *Journal of Artificial Societies and Social Simulations,* vol. 16, no. 2, March 2013.

[12] M. Sherif and C. W. Sherif, Social psychology, N.York, NY and Tokio: Harper & Row and John Weatherhill, Inc., 1969.

[13] K. Boulding, "General Systems as a Point of View," in *Views of General Systems Theory*, New York, NY, 1964.

[14] G. M. Weinberg, An Introduction to General Systems Thinking, N. York, NY: Dorset House Publishing, 2001 (1st ed. 1975).

[15] N. Luhmann, Introduction to Systems Theory, Polity, 2012.

[16] B. V. Bowden, Faster than Thought, London, UK: Sir Isaac Pitman & Sons Ltd., 1953.

[17] H. A. Simon, The Sciences of the Artificial, Cambridge, MA: The MIT Press, 1996.

[18] L. von Bertalanffy, General Systems Theory, London: Allen Lane, The Penguin Press, 1971.

[19] L. L. Cavalli-Sforza, Genes, peoples and languages, North Point Pr, 2000.

[20] E. H. Lenneberg, Biological Foundations of Language, Malabar, FL: Robert E. Krieger Publ. Co., 1984.

[21] P. Samuelson and W. D. Nordhaus, Economics, Boston: McGraw-Hill Co., 2005.

[22] A. N. Chomsky, Language and mind, Harcourt Brace Jovanovich, Inc., 1972.

[23] W. Ross Ashby, Design for a brain : the origin of adaptative behaviour, London, UK: Martino Fine Books, 1960 (2014 reprint).

[24] W. Ross Ashby, An Introduction to Cybernetics, London, UK: Chapman \& Hall, 1957.

[25] J. Piaget, Biologie et connaissance: essai sur les relations entre les régulations organiques et le processus cognitives, Paris: Éditions Gallimard, 1967.

[26] J. Piaget, L'équilibration des Structures Cognitives --- Problème Central du Dévelopment, Paris: Presses Universitaires de France, 1975.

[27] H. R. Maturana and F. J. Varela, The Tree of Knowledge: The Biological Roots of Human Understanding, Boston, MA: Shambala Publication, Inc., 1998.

[28] S. Papert, Mindstorms:children, computers and powerful ideas, New York, NY: Basic Books, Inc., 1980.

[29] G. Bateson, Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology, Chicago: University of Chicago Press, 1972.

[30] A. M. Turing, "Computing machinery and intelligence," *Mind,* vol. LIX, no. 236, 1950.

[31] M. L. Minsky, The society of mind, New York, NY: Simon & Schuster, 1986.

[32] F. J. Varela, E. Thompson and E. Rosch, The Embodied Mind: Cognitive science and human experience, Cambridge, MA: MIT Press, 1991.

[33] W. Weaver and C. E. Shannon, The Mathematical Theory of Communication, Urbana: University of Illinois Press, 1949, rev. ed. 1998.

[34] N. Wiener, Cybernetics, or control and communication in the animal and the machine, Cambridge, MA : MIT Press, 1961.

[35] J. von Neumann, The Computer and the Brain, New Haven: Yale University Press, 1958.

[36] C. Emmeche, "The Computational Notion Of Life," *Theoria – Segunda Epoca,* vol. 9, no. 21, p. 1–30, 1994.

[37] C. G. Langton, "Special Issue on Highlights of the AlifeIV Conference," *Artificial life,* vol. 1, no. 4, p. iii–vi, 1994.

[38] M. Luz Cárdenas, J.-C. Letelier, C. Gutiérrez, A. Cornish-Bowden and J. Soto-Andrade, "Closure to efficient causation, computability and artificial life," *Journal of Theoretical Biology,* vol. 263, no. 1, p. 79–92, 2010.

[39] M. D. Mesarović, Ed., System Theory and Biology, New York, NY: Springer-Verlag, 1968.

[40] A. M. Turing, "On computable numbers, with an application to the Entscheidungsproblem," *Proceedings of the London Mathematical Society,* vol. 42, p. 230–265, 1936.

[41] T. Kohonen, Content-Addressable Memories, Berlin: Springer-Verlag, 1987 (1980).

[42] T. Kohonen, Self-organization and Associative Memory, Berlin, Heidelberg, New York: Springer-Verlag, 1088.

[43] Rumelhart, David E., McClelland, James L., and the PDP Research Group, Parallel distributed processing: explorations in the microstructure of cognition, vol. 2, Cambridge, MA: MIT Press, 1986.

[44] M. L. Minsky and S. Papert, Perceptrons: expanded edition, Cambridge, MA: MIT Press, 1988.

[45] S. P. Franklin, Artificial Minds, Cambridge, MA: MIT Press, 1995.

[46] F. J. Varela and P. Bourgine, Toward a Practice of Autonomous Systems. Proceedings of the First European Conference on Artificial Life, Cambridge, MA; London, UK: MIT Press, 1992.

[47] M. Vieira Kritz, *Issues of Multidisciplinary Sciences,* Petrópolis, RJ: https://www.researchgate.net/profile/Mauricio_Kritz, 2007.