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Remarks on the foundations of cybernetics and cognitive science

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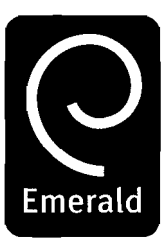

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Keywords *Communication, Cybernetics, Systems theory*

Abstract *The paper states that cybernetics has failed to live up to its dream as an interdisciplinary field unifying all the phenomena within the vast space of animals and machines. It reminds the reader of the cybernetic dream, the related aspirations in the fields of cognitive science and social theory and the overall aim of the unity of science movement. It briefly argues that ignoring communication and adopting continuous systems as its class of systems for theory construction (CSTC) was bound to lead cybernetics to the abandonment of its dream and points out that cognitive science may well be heading the same way. A proposed conception of communication that is both rich enough to be used as a unifying theoretical construct and general enough to cut across all disciplines studying "communication". On that basis some major implications are outlined. The paper concludes with a brief note on the impact of our conception of communication on the structure of human society.*

1. Introduction

Despite its successes and impact on a host of other disciplines, cybernetics failed to live up to its dream as an interdisciplinary field unifying all the phenomena within the vast space of animals and machines. The reason, I submit, was twofold. First, it ignored one of its two fundamental concepts, namely, communication. Second, it adopted an inadequate class of systems for theory construction (CSTC).

Cognitive science adopted the interdisciplinary nature of cybernetics and brought in a major new CSTC, programming systems. Unfortunately, it kept ignoring communication and the added CSTC, although appropriate for relatively simple phenomena within the space of intelligent systems, it is inadequate for the complex part of that space.

Section 2 reminds us of the cybernetic dream, the related aspirations in the fields of cognitive science and social theory and the overall aim of the unity of science movement; we briefly argue that ignoring communication and adopting continuous systems as its CSTC was bound to lead cybernetics to the abandonment of its dream; and we point out that cognitive science may well be heading the same way. Section 3 proposes a conception of communication that is both rich enough to be used as a unifying theoretical construct and general enough to cut across all disciplines studying "communication". On that basis some major implications are outlined. Finally, we conclude with a brief note on the impact of our conception of communication on the structure of human society.

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2. Domains of investigations and CSTC

Scientific disciplines never die (except if all scientists do). They are transformed, absorbed, merged, renamed, or go through a combination of these processes. I submit that cybernetics has been transformed to a much less attractive discipline because it has abandoned its characteristic dream. An historical perspective concerning the status[1] and nature of cybernetics will make this point clear.

Let us start with the claim of some commentators that cybernetics is in essence dead. This may indeed be seen as a (too) strong a way to express our point of dream abandonment. The strongest such claim has been put forward by Arbib (1987) in a section heading entitled: "Cybernetics Defined and Dissolved". A more balanced viewpoint was expressed by Eden (1983, p. 439):

> The notions of cybernetics have permeated many disciplines ... Having been integrated into them, cybernetics has performed the function for which it was proposed.

Although the first part of the quote is true, the second is not. Eden might have had in mind the wide use of concepts like feedback in a great variety of disciplines, but that is far from the original motivation or dream that brought together the pioneers of cybernetics. The motivation was what may be truly termed interdisciplinarity in the study of a certain area of inquiry, namely, a two-way communication among any disciplines exploring the same object of investigation. In such areas, as Wiener remarked:

> ... every single notion receives a separate name from each group, and in [such areas] important work has been triplicated or quadruplicated, while still other important work is delayed by the unavailability in one field of results that may have already become classical in the next field (Wiener, 1961, p. 2).

Interdisciplinarity is strongly related, but distinct from integration or unification. The second aspect of the dream of the pioneers of cybernetics belongs to the long history of the quest for the unity of science movement. In Wiener's words:

> We had dreamed for years of an institution of independent scientists, working together in one of these backwoods of science, not as subordinates of some great executive officer, but joined by the desire, indeed by the spiritual necessity, *to understand the region as a whole,* [emphasis added] and to lend one another the strength of that understanding (Wiener, 1961, p. 3).

A recent expression for *the need* of unification is Newell's call for unified theories of cognition and Baldwin's case for a unifying social theory[2]. A most recent argument for the synthesis of all human knowledge and an attempt to that end is Wilson's (1998) *Consilience*[3]. The oldest primitive expression of that belief goes back to the legendary Greek philosopher of the sixth century BC: Thales of Miletus.

This quest for the combination of inter-disciplinarity and unification is what I call the cybernetic dream (or viewpoint). Unfortunately, Wiener appears to have neglected[4] its development. His emphasis was rather on the expansion of the field. As he wrote in his preface to the second edition of *Cybernetics*:

> If a new scientific subject has real vitality, the center of interest in it must and should shift in the course of years (Wiener 1961, p. 7).

He then went on to present an expansion of the then range of cybernetics by discussing learning, self-reproducing machines, and self-organising systems.

Field expansion is necessary for a young field, but inadequate. A discipline is characterised by its domain of investigation and the class of systems used to develop theories for that domain[5]. As a result, apart from expanding to address all the phenomena within its domain a discipline also needs re-organisation and more significantly, conceptual rigor, depth, richness, and above all, unification. Consider where physics would have been without the series of unifications it has undergone.

And I do not for a minute adopt a physics-based model here for the social sciences and the humanities. Quite the contrary as it will be seen below. Still unification is necessary for any scientific advance. The difference lies in what CSTC is to be adopted.

Cybernetics has, unfortunately, neglected its own dream. The adopted CSTC, continuous systems, was inadequate for the realisation of the cybernetic dream although very successful for a range of application-oriented problems. Cognitive science, although has not abandoned unification, it is viewing it through severely restricting lenses thus rendering it stunted/sickly and consequently, ineffective. The next paragraphs briefly argue for the necessity of certain notions and the inadequacy of the current major CSTCs in attempting to develop a unified theory of intelligent systems.

The two fundamental notions of cybernetics are control and communication. Cognitive science, the study of intelligent systems, is a subset of cybernetics. Interestingly, neither of these two disciplines has developed a unified theory[6] of its subject matter that incorporates communication. In particular, cybernetics[7] has never developed a unified theory of control and communication in the animal and the machine. Within cognitive science several candidate, unified theories of cognition have been proposed (see Newell, 1990 for an excellent review and the most elaborate proposal to date). Communication is glaringly missing from all of them! Gelepithis (2002) has taken the processes of communication and understanding as central notions in the development of a unified theory of intelligent systems, but so far the scope of his axiomatic theory is quite limited.

As already remarked, the most outstanding neglect within the foundations of both cybernetics and cognitive science concerns the notion of communication. In contrast, if one constrains the domain of intelligent systems to that of organisations and human society then one sees that the study of "communication" occupies central importance and in the special case of critical social theory, plays the role of a fundamental tool. Equally interesting is the CSTC mainly employed in the social sciences and humanities, human language, a tool looked down by the so-called hard sciences. I think this is a major mistake. Figure 1 shows the class of systems employed in theory construction in the three nested domains of cybernetics, cognitive science and organisations and human society and the role of "communication" in each one of these classes.

Considering carefully Figure 1, the reader can easily verify the lack of a unified conceptual framework or methodological approach ranging across the various disciplines – e.g. cybernetics, cognitive science, sociology, political science – studying the depicted domains of investigation. Given that the notion of "communication" is of fundamental importance to all of the above disciplines, we propose that it needs to be sufficiently clarified so that it can be used as an explanatory theoretical construct across all the disciplines studying the space of animals and machines. In other words, "communication" should be added to the system of explanatory concepts for the study of intelligent systems and their organisations.

In addition, a richer, more comprehensive CSTC[8] needs to be adopted across those disciplines. The following points summarily present our argument for such a class. First, a theory concerning the foundations of social science and based on the notion of communicative action has been developed (Habermas 1981/1984/1987). Second, human language is a much more comprehensive system than any mathematical system. Third, cybernetics and cognitive science each specifies a much more complex domain

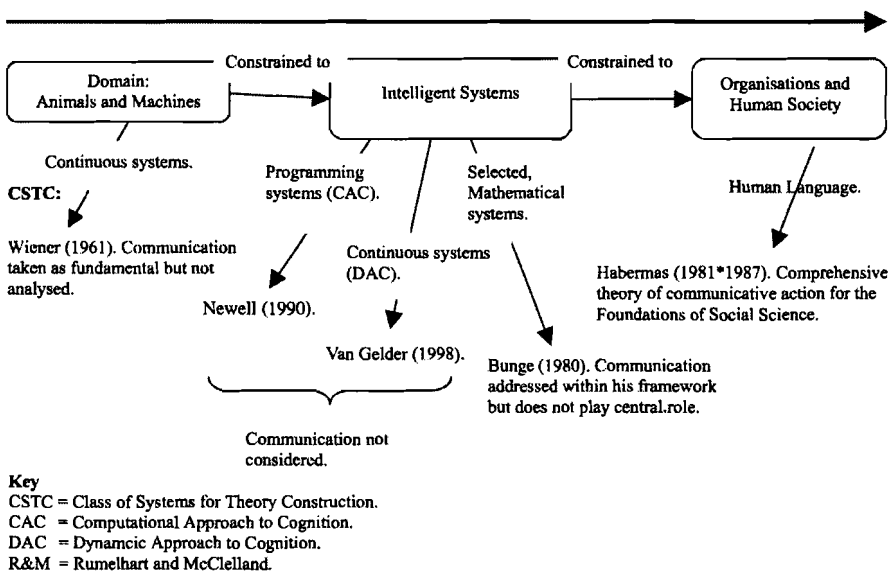

Figure 1.
Domains of investigation, classes of systems used in theory-construction, and the role of "communication" within each one of them

than it was initially thought of and subsequently, a much richer class of systems for a comprehensive, unified theory of either field is required than that of continuous or programming systems. Human language is our best available such class.

Furthermore, cybernetics – including second-order cybernetics – has been institutionally marginalised. Of course, there are conferences on cybernetics or conferences including cybernetics in their title, but the fact remains that academically it has been marginalised. Its name, or part of it (cyber), is mainly used for commercial purposes, and whenever it is used for academic objectives they are remotely related to the cybernetic dream/viewpoint. Still, I believe that its revival may just be possible. One proposal is for a concerted effort by all true cyberneticians to promote the study of our domain (animals and machines) as the melting pot of science, technology, social sciences and the humanities. That would require true interdisciplinarity and integration and would lead the scientists concerned to focus their attention to the really key issues of our society. The required critical mass is available, but it is dispersed. It would also require us to take a closer look at complementary foundations, develop alternative ones, and adopt CSTCs that will be much more widely ranging.

On the other hand, cognitive science is institutionally ubiquitous, but suffers from increasing fragmentation due to expansion, increasing specialisation, and lack of genuine interdisciplinarity let alone unification[9]. As a result, cognitive science is in danger of:

(1) being appropriated by its dominant computational paradigm[10]; or

(2) essentially split into its constituent disciplines.

The first warning signs are with us already (Bechtel and Graham 1998; Wilson and Keil 1999). If unification does not soon produce fruit, the centrifugal forces of increasing specialisation will break up cognitive science as they did with cybernetics.

"Communication" is of fundamental significance to unification, but it is far from being adequate just on its own. A host of other notions are also required (Gelepithis, 2004).

In a nutshell:

(1) no discipline aspiring to be the scientific study of intelligent systems can ignore communication except to its detriment and, possibly, eventual demise;

(2) I suggest that, the proper CSTC for such a discipline – call it whatever – is human language.

The aim of the next section is to propose a conception of communication that is both rich enough to be used as a unifying theoretical construct and general enough to cut across all disciplines studying "communication".

3. The nature of communication

> The book *[On Human Communication]* was first written as an attempt to make a case for the study of human communication as an academic subject. That case still stands, though the nature of such a study is still far from crystal clear (Cherry, 1978/1980).

Twenty-five years later Cherry's remark is still true. Actually, the situation is worse because both number of different senses of "communication" and number of disciplines studying "communication" has been increased. The aim of this section is threefold. First, we illustrate the ambiguity with which "communication" is being used in a number of disciplines. Second, we briefly counter a potential argument concerning the presumed lack of objective characteristics of communication. Finally, we present a conception of communication that clarifies its nature, it is applicable across the range of animals and machines, and is rich enough to be used as an explanatory theoretical construct in disciplines like cybernetics, cognitive science, sociology and political science.

The literature on "communication" is extremely varied, and multidisciplinary. It ranges from the mathematical theory of signal transmission (Shannon and Weaver, 1949) to intercultural communication (Hall and Whyte 1966), from non-verbal communication (Harrison 1973), to public opinion (Allen 1995), from Habermas's (1981) magnum opus *Theorie des Kommunicativen Handelns*, to skirmishes on communication systems like the press (Thompson 1995). Mattelart and Mattelart (1995/1998) state 11 disciplines involved with its study: philosophy, history, cybernetics, geography, psychology, biology, sociology, ethnology, economics, political science, and the cognitive sciences! Nevertheless, the nature of "communication" was never pinned down in a convincing and generally accepted way and is primarily used as an orienting term rather than as an explanatory theoretical tool.

The following examples illustrate some of the many different senses it has been perceived or defined within the last 40 years.

(1) In more than numerous studies, "communication" is taken for granted in one of its two meanings[11] and on that basis, subclasses of communication phenomena are defined and studied, practices examined, or connections between disciplines considered. For example, Benowitz *et al.* (1984/1985) on the communication of affect on the basis of paralinguistic cues; Sass (1984/1985) on communication patterns as revealing factors in the etiology of schizophrenia; Scott (1996) on the institutional practices that may lead to a special case of communication failure

("inadvertent pathologies"). Murray (1998) on the connections between literacy and cybernetics.

(2) "a relationship between two or more active persons, entered into [it] with the aid of shared signs" (Schramm, 1973)[12].

(3) As "the social mediation of information" (Roberts, 1973).

(4) "communication" identified with interaction (Katz and Danet, 1973)!

(5) "communication" as "any exchange of messages between human beings" (Runcan, 1985).

(6) As perilously close to propaganda[13] "When I intend to communicate, I intend to produce [emphasis added] understanding. But understanding will consist in the grasp of my meaning" (Searle, 1999/2000, p. 145).

(7) Schirato and Yell (2000, p. 1) provide the following definitions: "Communication can be understood as the practice of producing meanings, and the ways in which systems of meaning are negotiated by participants in a culture. Culture can be understood as the totality of communication practices and systems of meaning". Finally, as Adler and Rodman (2000, p. 2) remark in their seventh edition of *Understanding Human Communication*, no single universally accepted usage of "communication" exists. They go on to provide still another conception: "communication refers to the process of human beings responding to the symbolic behavior of other persons".

The breadth and imprecision of the notion of communication leaves one with a dilemma: either "communication" to go on being used as an orienting device for thinkers and researchers (like for instance, the notion of social control) or to be developed into an explanatory tool (like for instance, the notion of gravity or plate tectonics). In the latter case, we have to ask ourselves: are there any characteristics of "communication" that cut across all of its different nuances of meaning and can they be combined in a way that captures the nature of communication? I believe there is.

Before proceeding with the task of providing a first preliminary account of the nature of communication, we have to address a potential objection. "Communication", as opposed to gravity, is a socially constructed notion rather than an objective reality and therefore, any attempt to provide an objective account of it is doomed to failure. This objection sounds powerful, but misses an important point. Both "gravity" and "communication" are humanly constructed concepts and both refer to some external phenomena (see our conception of communication below). Their only difference is that "gravity" has a generally accepted meaning within the earth-based physicists, whereas "communication" does not have one within the community of scientists using this notion. I am of course fully aware that the viewpoint just expressed will be immediately subjected to a double attack. Both by those postulating the existence of characteristically social "facts" (à la Durkheim) and those postulating "meanings" as the key methodological approach of sociology (à la Weber). This debate in sociology is reflected in the systems and interpretive perspectives in communication studies (Monge, 1977; Putnam, 1983). It is time that an effort is made to offer a conception of communication that could be used as a major explanatory tool in all disciplines (e.g. cognitive science, cybernetics, social sciences) concerned with the correspondingly-related phenomena. In other words, an effort towards bridging the

objective-subjective divide. The next few paragraphs summarise the key difference between our conception and the one characterising the relevant literature, and outline the elements of such an alternative conception of communication.

Despite its huge literature, work on the nature of communication or serious analyses of it are few and far[14] between. The two most important treatises are those of Cherry, 1978/1980, (still the best overall survey of human communication) and Habermas's (1981/1987) theory of communicative action. Still, both of these substantial works along with a number of other significant contributions, (Adler and Rodman, 2000; Grice, 1989; Mead, 1934/1962; Ogden and Richards, 1923/1956; Rogers 1983/1986; Sperber and Wilson, 1986), have failed, or have not attempted, to provide a clear, unequivocal, and all encompassing (applicable to animals, machines, or extraterrestrials) definition of communication.

Based on the general agreement in the literature that "communication" involves a kind of an exchange, relationship, symbolic response, sharing, (system of) meanings, or even "understanding", Gelepithis provided a general axiomatic definition of communication (see Gelepithis, 1984 for the overall framework and detailed argument, Gelepithis, 1991 for a summary and its implications for human-computer/robot interaction; Gelepithis, 1997 for its implications for Information Science and Information Systems Design). I introduce the definitions of communication and understanding and proceed with stating their major implications which is as follows.

Definition of communication:

E_1 communicates with E_2 on a topic S if and only if:

(1) E_1 understands S; Symbol: $U(E_1\ S)$;

(2) E_2 understands S; Symbol: $U(E_2\ S)$;

(3) $U(E_1\ S)$ is presentable to and understood by E_2; and

(4) $U(E_2\ S)$ is presentable to and understood by E_1.

Definition of understanding[15]:

An entity E has understood something, S, if and only if, E can present S in terms of a system of its own primitives (i.e. self-explainable notions).

Before proceeding with the implications of our conception let me remark that our definitions specify classes of events that are objectively available, namely, the systems of primitives involved in each and every completed process of communication.

Implication-1: the process of understanding is an invariant.

First, *the process of understanding* as defined above is independent of any entity capable of understanding. Naturally, one should keep in mind that we talk of the process of understanding and not of its end result. That does depend on the specific entity capable of understanding. Second, *the process of understanding* is independent of time. Of course, this is not to say that the actual process does not take time; only that however long it may take its defining characteristics remain invariant.

These two features of understanding: time independence and applicability throughout the evolving space of understanding entities makes understanding an invariant of that space. In particular, of course, the process of *human* understanding is a human cognitive invariant[16].

Implication-2: understanding and communication are extremely complex processes.

Despite their simple definitions, understanding and communication are extremely complex processes. The following few paragraphs intend to illustrate key aspects of

this complexity. First, since understanding involves primitives, it – and therefore, communication – involves meaning. Second, without going into details[17] we note that the meaning of something depends on its context, the entity for which that something is meaningful, and the time of that conception. Let us summarily see some of the major complications that primitives and context bring in.

First, one's own primitives may refer to any idea, expression, belief or whatever someone may use to think. Second, primitives are of two kinds: linguistic and non-linguistic. It follows that such primitives may be either formal or informal. Usually, they are informal. Primitives may also be implicitly referred to. It is obvious that what may be a primitive for one person may not be a primitive for another. Even more to the point, what may be a primitive for one may be a complex idea for another. For example, "water" was a primitive for my grandmother, but it is not a primitive for those knowing that "water" is really H_2O.

It follows that since one's understanding depends on *one's* own primitives, it may well vary very significantly from person to person depending on the system of primitives reached by each person on a particular topic by a certain time. Also, since one's primitives may change with time, one's understanding may change as well. Compare, for example, a toddler's primitives with those of a quantum physicist with respect to the notion of electricity (for a discussion see Gelepithis, 1995). In summary, one's understanding depends both on time and one's primitives. Or, more accurately, it depends on one's own primitives, which in turn depend on time.

Context is extremely important and varied[18]. We have, for example, emotional, social, non-verbal, and shared knowledge context. Contexts not only affect the interpretation of a linguistic or non-linguistic situation; they also provide their own primitives. For instance, non-verbal primitives associated with postures, gestures, and facial expressions. As an illustration, in the case of social primitives, culture provides illuminating instances. Consider the host-guest relationship. In India and Hellas for instance, when a potential host invites a potential guest with an expression like "come at any time", she expects such an invitation to be taken literally. Interestingly, if the recipient is an outsider from, say, the Anglo-Saxon culture such an invitation will definitely not be taken literally but simply interpreted as a kind of friendly invitation.

Implication-3: human knowledge[19] (both individual and collective) is the end result of the communication and understanding processes.

Nearly all theories of knowledge are based on the notion of belief and differ only on how they justify this presumably basic notion. A worthy exception is Newell's (1990) conception that is based on his notion of intelligence. Our theory[20] differs fundamentally (Gelepithis, 1989). Its basic building blocks are:

(1) the notion of meaning;

(2) the process of understanding; and

(3) the process of communication.

As a first approximation, individual knowledge is the end result of the understanding process; and collective knowledge of a community is the end result of all communication processes among the members of that community. Although extremely interestings a discussion of collective human knowledge would take us far beyond the scope of this paper. We shall, therefore, briefly comment on the former only.

Through successive applications of the process of understanding over a period of time – quite often on the same topic – an entity (human, machine, or extraterrestrial) accumulates *individual* knowledge. Specifically:

Definition of individual knowledge:

Knowledge of entity E at time t is the system of understandings that E has reached by that time.

Let us use the symbol $K_{e,t}$ to refer to E's individual knowledge at time t (equivalently, E's knowledge system at time t)[21].

$$K_{e,t} = U_{e,t}(\text{i.e. the } \textit{system} \text{ of understandings of E at time } t).$$

$$U_{e.t} = \otimes_{s \in S} U_{e,t}(S)$$

where S is the space of anything that is being, has been, or may be investigated by an entity e.

$$U_{e,t}(s) = \Pi_{e,t}(\text{i.e. the } \textit{system} \text{ of primitives of E at time } t).$$

$$\Pi_{e,t} = \otimes^{\pi} i, C_j$$

where: $i \in N$; C denotes the context within which something stands as a primitive $\pi; j = 1, \ldots, n$.

It should be noticed that none of the $\otimes$ operations are as yet defined. Furthermore, and most importantly, my exclusive reason for using this mathematical notation is to stress and focus attention to the extremely complex processes that both "the system of understandings" and "the system of primitives" requires for their development. Actually, I very much doubt that a complete specification of the $U_{e,t}$ and $\Pi_{e,t}$ systems can ever be achieved. Having said that, I do believe that some progress towards the elucidation of the characteristic properties and processes of both these systems – in psychological and neuro-physiological terms will occur in due time.

Implication-4: the processes of understanding and communication are the primary processes shaping the structure of the human mind.

We have five reasons for the proposed centrality. First, understanding is a prerequisite for human communication that, in turn, is at the very basis of the existence of the human society. Second, there are multiple levels of understanding corresponding to multiple levels of primitives-based descriptions. This multiplicity of descriptions is structured (by virtue of being primitives-based) and therefore, the associated knowledge is structured (see Implication-3 above). Third, the systematic and structured characteristics of understanding makes it a prime tool in the acquisition and (re)-structuring of knowledge and consequently of the shaping of an entity's mental structures. Fourth, the very close relation between understanding and explanation, the fact that they constitute necessary elements of human reasoning, and their role in shaping the cognitive structures of both learners and tutors (Gelepithis and Goodfellow 1992). Finally, since primitives may, equally well, be either formal or informal, understanding bridges the formal-informal interface.

I would like to propose that the processes of communication and understanding are the central processes shaping the structure of the mind of an intelligent entity (animal, machine, or extraterrestrial). This I call the communication-understanding principle.

4. Concluding remarks: communication and human society

> With the collapse of the rationalist ideology of continuous, linear progress, communication has taken over and flaunts itself as the parameter par excellence of the evolution of humanity in an historical period when it is desperately seeking a meaning for its future (Mattelart and Mattelart, 1995/1998, p. 155).

The outmost significance of communication for human society is acknowledged without exception. But this acknowledgement is based on a sense of communication that is either extremely weak or inadequately deep; essentially, an interaction or at most a sharing of meanings.

The conception of communication outlined in the previous section is both deeper and much more demanding in its realisation. The question is can people be convinced (not persuaded) that such a conception can only lead to a better society?

My thesis can be summarily described as follows: adopting the communication-understanding principle will eventually lead to a fundamentally inquisitive and critical mind and therefore, to a less effective propaganda (e.g. political persuasion) by the power elites. I think that such a development is a good enough *basis towards* a better society. The next paragraph indicates a couple of features that can contribute to the creation of a better society and which may be seen following from the adoption of the communication-understanding principle.

Since communication and understanding shape the structure of human mind, the kind of future society depends fundamentally on whether the deep or superficial conception of communication will eventually prevail. Consider, for instance, the following two remarks by T. H. Huxley, and Albert Einstein, respectively:

> "Some experience of popular lecturing had convinced me that the necessity of making things plain to uninstructed people was one of the very best means of clearing up the obscure corners of one's own mind" (T. H. Huxley, as quoted in Gregory and Miller, 1998, p. 83-84).

> "Restricting the body of knowledge to a small group deadens the philosophical spirit and leads to spiritual poverty" (Albert Einstein, as quoted in Gregory and Miller, 1998, p. 83-84).

Huxley's point presupposes the kind of communication I advocate and which necessarily leads to the widest possible clarification of one's own mind through restructuring on the basis of convincing new primitive systems that need to be taken into account. Einstein's point essentially refers to the richer gnostic (e.g. cognitive, spiritual) development that follows the synthesis of scientific knowledge and public primitive systems. Both results are highly desirable features of a society, I submit. Both are mostly absent, in a society of weak communication and maximum propaganda like the one, currently, characterising most of the western world.

Notes

1. For a very informative and thought provoking discussion on the various relations in the cluster disciplines and specialties that come under the heading "studies of information" see Machlup (1983) and Machlup and Mansfield (1983). For a clearly structured argument that cybernetics constitutes part of systems theory see Mattessich (1983).
2. It is interesting to note that both Baldwin (1986) and Newell (1990, 1992) argue for unification and propose models (Meadian theory and Soar, respectively) as approximations of, or candidates for, such unification. The key difference between the two is that the latter but not

the former model aspires to a unified theory that would span all levels from the biological to the social. An early advocate of the idea of a unified theory of sociology based on functionalism was Parsons (1937).

3. A politically biased, but still interesting, informative, and thought provoking viewpoint on the integration of science is that of Chepikov (1978).
4. Quite probably though, such an interdisciplinary and integrating approach was too tall in order to be followed within the emerging profit and performance culture of the United States in the 1950s and 1960s.
5. I do not use the term methodology because of its imprecision and ambiguity. Nevertheless, if the reader wishes to think of methodology as the class of systems employed in theory construction that would be welcome by me. This conception follows closely that of Newell (1983).
6. Following Newell (1990), I perceive a theory as a body of knowledge enabling an appropriate user to draw explanations and predictions about its subject matter and to control the existing and design new systems within its boundaries. A unified theory of a domain X is a theory ranging over the whole gamut of phenomena characterising X.
7. I do include second-order cybernetics within cybernetics. Although an argument for this position is beyond the scope of this paper, making a little point I cannot resist. Physics has undergone at least four major revolutions from Aristotle to Galileo to Newton to Einstein. If physicists had adopted a similar viewpoint we would have been to at least a fourth order Physics by now. The issues that this little point raise go to the very heart of the nature of science but as we said however important they are far beyond the scope of this paper. See Glanville (1998) for an interesting personal account of the gestation of second-order cybernetics and a sound albeit rather unexpectedly made point supporting my view (ibid., p. 90).
8. An approach illustrating this point may be seen in Gelepithis (2002).
9. For a recent debate of the issues involved see Anderson and Lebiere (2004) and Gelepithis (2004).
10. It should be noted that the computational paradigm is an integrating conception, but grossly inadequate in terms of its scope.
11. (a) To make (opinions, feelings, information, etc.) known or understood by others; and (b) to share or exchange opinions, feelings, information, etc. (Longman, 1987).
12. It should be noted that perceived in this way, "communication" gives rise to numerous further splits of interest. As Schramm remarks: such a relationship is very complex and due to the lack of "general theoretical insights, researchers have typically worked on parts of the relationship".
13. As Searle himself remarks: "Notice that this analysis is independent of the question of whether I am telling the truth or lying, ... even if I am lying, by saying something and meaning what I say, I am committed to the truth of what I say. So, I can have a commitment to the truth even if in fact I believe that what I say is false" (ibid. p. 146).
14. It is worth noting that three readers, spanning six decades of research in communication contain not a single article on the nature of it (Pool *et al.* 1973; Smith, 1966; Vaina and Hintikka, 1984/1985).
15. For a comprehensive, critical review of both analytic and hermeneutic schools of thought on human understanding as well as the theories of Pask (1976) and Ziff (1972) that do not neatly fall in either of the two schools and approaches within them the reader is referred to Gelepithis (1986).
16. For a review of Herbert Simon's view on cognitive invariants see Gelepithis (1992).

17. For a survey of the various theories of meaning and discussion of a radical new theory see Gelepithis (1988, 1989).
18. For the significance of context in the generalised case of meaning and a theoretical model of the latter see Gelepithis (1989).
19. The debate on the nature of "knowledge" is far from settled and it is well beyond the scope of this paper to review the relevant literature and provide an analysis. Implication-3 is just a statement of our thesis concerning human knowledge along with some associated remarks. For a philosophical and AI perspective on "knowledge" the reader is referred to Newell (1990) and Pollock (1986), respectively.
20. For some major consequences see Gelepithis and Parillon (2002).
21. Obviously, $K_{e,t}$ is a subsystem of E's semantic system at time t (symbol $S_{e,t}$) where, $S_{e,t}$ is the system of all meanings that E has acquired, or has produced, by that time.

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