SEMANTICS
AND COGNITIVE RESEARCH

François RASTIER

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Semantics and cognitive research

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INTRODUCTION

1. The state of cognitive research has evolved considerably over the five year period during which this book was written. In France, as elsewhere in Europe, cognitive research has been institutionalized to a considerable extent in research and in teaching programs as well. Indeed a good number of researchers, in order to obtain funding, have found themselves obliged to claim some allegiance to its dominant themes and orientations.

Despite this rapid progress our initial goal has not changed: to explore what cognitive research can bring to the social sciences, especially to linguistics, and to evaluate cognitive research from the point of view of linguistics. This double perspective has enabled us to organize a vast subject matter, touching upon a number of disciplines, in such a way as to present the most important themes without necessarily offering an exhaustive treatment of everything that is at stake.

The relations between the various disciplines engaged in cognitive research have also evolved over the last five years. The rise of the connectionist problematic (cf. chap. II) has been marked by a strong interaction with the neurosciences and with network physics. Indeed these disciplines have made decisive progress. Within the neurosciences, these advances are partially due to progress in biochemistry on the one hand and in cerebral imagery on the other. In network physics, progress has been made by the application of statistical mechanics[1] and in physics by the development of spin glass theory.

These fields of enquiry are evolving very rapidly and could well lead to important discoveries. Gérard Toulouse for example has elaborated a rather promising parallel: just as classical mechanics, developed in order to replace human and animal force, gave rise unexpectedly to quantum mechanics, so too might network physics, developed in order to assist human intelligence[2], lead to theoretical upheavals of the same magnitude.

2. Semantics itself however is not directly affected by these developments. Our aim requires us to remain within this fine layer of Being that is the symbolic (cf. *infra*, chap. I, 3 and the epilogue). It is by recognizing the relative autonomy of the symbolic that we are able to separate words from things and describe the specificity of speech and of languages without becoming embroiled in reductionist enterprises which would situate linguistics within a psychology, a biology, or even a physics[3].

Within the symbolic sphere, linguistics neighbors with psychology as well as that branch of AI which processes linguistic symbols. This is why we propose to devote the last

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[1] For an introduction see Mézard and Nadal (1990), Meunier (1990).

[2] Connectionnist networks of course serve the objectives of Artificial Intelligence (henceforth AI).

[3] A case in point is René Thom's *semiophysics* as developed by J. Petitot (1989, p. 218): "considered as the mathematical science of natural languages, theoretical linguistics is a natural science, more a physics than a logic". The expression *natural languages* that Petitot uses does not obliterate their cultural nature.

two sections to these sciences even if we also permit ourselves incursions into other disciplines.

3. The concept of interdisciplinarity that we are going to put forth differs from one discipline to the next. In the case of a technology such as AI, we will attempt to study firstly how its characteristic formalizations and procedures can be used in semantics, and secondly, what semantics can contribute to the automatic language processin. In the case of sciences such as psychology and neurology we will investigate the correlates of semantic phenomena that might serve to corroborate or impair our hypotheses, without necessarily expecting our findings to validate or dismiss them. Whatever may be said of fusional conceptions of interdisciplinarity, no science can in itself validate another, since even if they share the same empirical object (such as linguistics, psycholinguistics, and neurolinguistics), they do not have the same epistemological objectives and presuppositions.

There may be some interest in evoking the image of a kind of free trade between the sciences if only their borders touched. But these borders are constantly modified by scientific practice and in such a way that contact between neighboring disciplines is not necessarily made since each discipline defines its object in a particular way and circumscribes for it a distinct level of reality. Two sciences can occupy the same terrain--or, in Husserlian terms, describe the same layer of Being--but not the same domain. Transdisciplinary theoretical formulations are in the best of cases regional ontologies or in any event philosophies and not sciences.

In short, the first section of this work will concern epistemology in order to deal with a number of convergent questions:

(i) Cognitive research is interdisciplinary; what are the forms of this interdisciplinarity ?

(ii) Cognitive research takes knowledge as its object, one of the traditional objects of philosophy. Can a gnoseology be scientific?

(iii) What is the role of language in knowledge ? Does this question, incidentally, concern linguistics ?

(iv) Since the problem of meaning has long preoccupied philosophy, and to a considerable extent still does, what conditions are necessary in order for semantics to constitute itself as a scientific discipline ?

4. Answering these questions requires first of all some reflection on the evolution of cognitive research. In order to understand this evolution, one has to evaluate recent advances in the field in light of the various problematics that have contributed to them and in relation to those problematics that this same research has rendered outdated. This understanding cannot be limited to an examination of research conducted throughout the 80s, nor even to the half century during which modern cognitivism developed, since in many respects, cognitive research today is pursuing, or challenging, an ancient philosophic tradition.

We will consequently make frequent reference to the history of ideas. Certainly the history of linguistic semantics is still brief and cognitive research is possibly even younger since it willingly claims not to have any history at all or at least pretends to have inaugurated a new era in research. In our view it is profitable to situate the questions this research evokes in a historical perspective. As well, the history of the sciences, far from

limiting itself to intra-theoretical matters, also takes into account sociological factors and ideological perspectives that we will refer to and discuss when need be.

Aside from epistemology we will avoid incursions into general philosophy, although we have aptly presented philosophy as the first of the cognitive disciplines. We will also be perhaps unjustly reserved in our discussion about the philosophy that developed suddenly from cognitive research and which is known generally as the *Philosophy of Mind* : often perspicacious and speculative, but lacking a reflexive dimension, this philosophy, which frequently details experiences of free thought (*Gedankenexperiment*), has inherited more than a few of analytical philosophy's peccadilloes. As a consequence we are resigned to make only a few allusions to it.

5. Even with these restrictions in mind our subject matter remains large and diverse. We propose to organize it along two lines.

First of all, we do not propose to treat the entire field of cognitive research in an exhaustive nor even an equitable manner. And we will not attempt to rival the fine introductions that have already expounded on the disciplines under discussion[4]. We prefer to select and focus on specific themes that have an explanatory value in order to investigate the complex relations between linguistic semantics and related disciplines, an approach that we feel conforms to our concept of interdisciplinarity.

Beyond this, the choice and treatment of these themes illustrate four parallel theses that inform this entire study and that we hope will unify it as a whole.

(i) Linguistics (and the semantics which is a part of it) is a descriptive and partially predictive discipline. This characteristic depends on the nature of its object[5]. As with all the social sciences, linguistics can surely avail itself of mathematics and logic but it cannot aim to be axiomatic (no more so than the physical and natural sciences). Contemporary endeavors in this direction have lead to a proliferation, interesting no doubt, of partial models but without being able to satisfy the often repeated need for a unified descriptive theory[6].

(ii) If one agrees with the preceeding remarks, it follows that an empirical rationalism is the philosophic position best suited to the linguist's theoretical activity[7]. It is a position that best enables the linguist to confront and treat the diversity of factors inherent in any cultural situation or context, linguistic exchanges themselves being the primary example. In the case of dogmatic rationalism, its enviable desire for the absolute has impelled it to seek, if not to impose, the most diverse archetypes and universals. Ultra-nominalism by contrast, which alone in our opinion has permitted semantics to emancipate itself from metaphysics, leads us nevertheless to see in its approach only methodological universals, simple inventions on the part of theoreticians who reify them and who thereafter content themselves with their discovery. Our scepticism is perhaps more sympathetic with the

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[4] As for the automatic treatment of language, see Sabah (1989-90) for the AI point of view; see Caron (1989) for the psycholinguistic perspective.

[5] Grammar, a discipline as ancient as writing itself, has always been descriptive. The historical and comparative grammar that late eighteenth century German scholars named *Linguistik* was certainly not a spontaneous invention on their part. It is the beneficiary of a long tradition of linguistic thought, even if its object of knowledge continues to be shared to the present day.

[6] For a discussion of related propositions bearing upon semantics, see Rastier 1987 a and 1989 a and b.

[7] See Auroux 1989, and Rastier 1989 b.

empirical tradition that has always stressed the tentative and relative character of knowledge (whereas dogmatic rationalism holds mathematical truths as paragon--and by extension analytical truths as well that in fact are tautologies--and concludes that it can uncover absolute truths on the basis of their epistemologically necessary character).

(iii) It might well be possible to uncover a natural foundation (in the brain, then in genetic codes) for linguistic regularities, but the scientific problem and interest rest no less-- or no more--with the unity of languages and their semantics than with their diversity. Aside from this one has to consider the immense diversity of those empirical objects known as texts, and doubt that they can ever be reduced to universals.

Furthermore, the linguistic and non-linguistic context (especially in semantics) is, insofar as it figures as the interpretant, constitutive of the "message". One has to concur at least that, in a global as well as more immanent sense, the text is determined and marked by the context in a multitude of ways. In short, linguistic performance consists of a continual adaptation to a variety of situations whose parameters betray any facile and handy calculations[8]. Such calculation is inevitably frustrated by a falculty of adaptation (i.e., selection of gender, of tone, etc.) that in fact belongs to linguistic competence or is so indissociable from it that one could not imaginably produce any "pure" linguistic act which is free from its influence[9].

By bearing this faculty of adaptation in mind we are placing ourselves in a decidedly ecological perspective (in Gibson's sense) moreso than in a logical one. A growing number of researchers engaged in cognitive research, notably in ergonomics and in anthropology (disciplines for which context is not a simple variable), have argued for and adopted this very perspective[10].

(iv) The phylogenesis of languages, together with their attendant significations, does not prevent them from being considered as historical formations (just as social phylogenesis does not annul the historicity of societies). This point in fact permits the integration of a historical linguistics in order to go beyond it in the form of a panchronic linguistics.

6. Scientific research in this century has been marked by a general *fundamentalism* of which classical cognitivism is just one expression. As examples of this trend one would have to cite Russell and Whitehead's *Principia Mathematica* and Hilbert's *Foundations of Geometry,* in the field of mathematics In physics, one could refer to the Unified Field Theory. These fundamentalist movements in the hard sciences have quite possibly influenced other disciplines.

Whatever the case may be, if we consider the life sciences one notices for example a remarkable expansion of the field of molecular biology and the relative discrediting of cladistics and for ongoing efforts in the area of what remains the unfinished repertory of the

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[8] Montague deserves credit for having invented the notion of *index* in order to account for this very fact. The term refers to a sequence of variables such as *place, time, speaker, listener, deictic moves, possible worlds* . D. Lewis and Stalnaker have enlarged this list. Of course it is not sufficient to be able to recognize the existence of these variables in order to produce and witness their effects...

[9] Especially in the case of linguistics.

[10] For an anthropological perspective, see Suchman (1987); for the implications of Suchman's theory, see Visetti (1989). This perspective has no necessary link with pragmatics since there exists such a thing as universalist pragmatics; in a similar sense, one could mention the ethnocentrism of Grice, and of researchers like Sperber and Wilson who follow him and who write : "All human beings live in the same physical world" (1989, p. 64).

species[11]. One might even attribute this particular evolution to economic factors: a molecule can be patented. One also has to remember that the number of living species is diminishing rapidly.

Even the diversity that characterizes our own species is undergoing a comparable evolution: one just has to think of the growing uniformization of social and cultural practices patterned on an increasingly limited number of models, and the disappearance each year of a condiderable number of languages and dialects.

Fundamental research is certainly a desirable thing. Fundamentalism however evidently favors theoretical reductionism (which, unlike methodological reductionism, is without justification). Finally, it reflects and even anticipates a world whose qualitative richness is being diluted.

Yet the real challenge for the sciences (and especially for the social sciences) has to begin with not being satisfied with the notion of the "universal"--which is precisely where Aristotelian thinking would have them situated--but instead seeking to account for diversity.

7. Of all the branches of linguistics, semantics is without a doubt the one where the problem of diversity is the most crucial and the least easily discerned. Broadly speaking linguists have general or universal semantic theories, but there exists no semantics specific to particular languages, much less particular discourses or genres. Nevertheless whoever has done translations has had to content himself with less than equivalent terms. And whoever has engaged in text analysis cannot but be struck by the unpredictable and indefinite variability of semantic relations within specific contexts.

We have adopted a semantic approach that we consider to be the most sensitive to diversity: differential semantics (cf. chap. III). Developed within the Saussurian tradition, differential semantics has integrated some aspects of the componential semantics[12] current during the 60s but has gone beyond it in our view precisely by challenging its pretensions to universalism[13], in the aim of being better able to account for contextual and textual complexity.

Yet within the range of problematics that semantics encompasses this last has surely received the least attention by the cognitive sciences, even though recent debates about the *subsymbolic* have situated a number of its themes, for example contextual variation and the non-compositionality of meaning, at the level of mental representations.

This paradoxical situation will enable us to establish a link with previous debates and to formulate questions that are not ordinarily raised in this domain. Most importantly, our interest will be to discuss the reduction of the semantic to the mental, as well as the relations between linguistic signifieds and concepts on the one hand and mental images on the other. By introducing or maintaining these fundamental distinctions we will be able to define the relative autonomy of the symbolic. This endeavor exceeds the confines of semantics strictly speaking and interests semiotics as a whole.

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[11] An idea that is summarized perfectly by a maxim attributed to Jacques Monod : "What is true for bacteria is true for elephants".

[12] This expression is a partial misnomer: componential semantics has never been "unified". On the contrary, it relects all the contradictions between the competing problematics of the period.

[13] The debate was largely focused on the status of semantic features. Doubt was cast on many common assumptions concerning their nature, in particular whether they were few in number, whether they constituted minimal or indivisible units, and of course, whether they were universals (see Rastier, 1987 a, chap. I).

Semiotics appears to be the privileged domain where the interaction between cognitive research and linguistics as a social science is most clearly played out. Indeed this relationship may well characterize the future of the social sciences as a whole and also of cognitive research itself.

We will also be led in several places to formulate a number of critiques concerning the postulates of orthodox cognitivism, and even those of cognitive research more generally, particularly in respect to their triple neglect of languages, of concrete situations of interaction and in the end of cultures. This neglect has not permitted these disciplines to free themselves from metaphysical traditions.

In effect we are placing ourselves in a different and sometimes distanced perspective : we have adopted the point of view of a semiotics of cultures (and here the semantics of languages plays a pivotal role) that has yet to be constituted as an autonomous discipline and indeed remains to be developed. In both their practical and theoretical forms, its basic constituents still remain disparate in most of the social sciences. In order to sketch its parameters, one would have to return to anthropology and the works of Lévi-Strauss and Marshall Sahlins, to the works of Cassirer in philosophy, to the comparative mythology of Dumézil and Charachidzé, in history to the works of Carlo Ginsburg, of Panofsky, Saxl, and Gombrich in iconology, to Segre in philology, and to the semiotic research of Lotman and Uspensky.

For the moment we will content ourselves with mentioning that cognitive research as a whole would doubtless profit from a greater consideration of cultural factors, even if only to enable it to better account for the specificities of human cognition; and also that a semiotics of cultures should approach the notion of the *human mind* with prudence. Consequently, our wish is to initiate a debate between cognitive research and a semiotics of cultures, not in order to open a polemic but in the aim of strengthening the relations between the two disciplines. Our conclusions about the anatomical substrata of cultures tend precisely in this direction. In the end, it is really a question of coming to terms with the oppositions between nature and culture, acquired and innate, precisely in order to overcome them. It should be clear that this excludes hasty classifications, quarrels between different "schools", and sophomoric conflicts between paradigms. We must proceed in the spirit of research, in the hope of extending the circle of our ignorance.

Chapter I

COGNITIVE RESEARCH

1. SOME PRELIMINARIES

a) Does there exist *a* cognitive science ? This is the impression left by a few American sources (the journal *Cognitive Science*, the title of Gardner's work: *The Mind's New Science*, 1985). Or additionaly, by this definition of the *science of cognition* (Le Moigne, 1986 b : 239): "a disciplinary field defined (since 1977) as autonomous by virtue of its object and by its mode of constitution and involving the study of cognitive processes in general, natural or artificial; it is also characterized by the interaction of a certain number of disciplines aiming to understand cognitive processes (disciplines not only in the "hard" sciences but the "soft" sciences as well) : computational and computer sciences, logic, linguistics, psycholinguistics, cognitive psychology, neuropsychology and the neurosciences, social psychologies [sic], communication sciences, socio-anthropology, economics, systemics, epistemology. Cognition, the act of knowing, is defined by the entire range, natural or artificial, of observable cognitive processes. Cognition cannot be reduced to knowledge (the latter representing the resulting product of a cognitive process)". This ambiguous definition calls for several remarks and clarifications.

(i) An interdisciplinary field should not be confused with a science. The recent history of the social sciences would suggest that their progress has been hampered by their adherence to what may be termed a *fusional conception* of interdisciplinarity. Indeed the entire history of the sciences demonstrates that they evolve more by fission and differentiation than by fusion. And in the end we would be better off to avoid this rather lax use of the word *science*; we believe it is more prudent, and accurate, to use the expression *cognitive research* which comprises all the disciplines studying cognition.

(ii) The list of disciplines mentioned by Le Moigne is to say the least heterogeneous and raises a number of questions concerning their interrelations. Are systemics and epistemology sciences or branches of philosophy ? What is the cognitive function of economics ? Does linguistics not belong to the communication sciences?

(iii) The insistence on *natural and artificial* cognition, frequent enough in the context of cognitive research, often leads to the supposition that animate beings and machines might be able to think and understand in a comparable way. This postulate, said to be *functionalist*, has been called to play a foundational role: it is the only position that is thought capable of establishing any unity within an interdisciplinary field. As such it presupposes what is in fact a maximalist conception of simulation : what goes on in an animate being, and within the machine that simulates it, are said to belong to the same order of reality.

b) If there does not exist *a* single cognitive science, let us turn our attention to *the* cognitive sciences. In the list just cited, does there exist a cognitive science in the sense of taking cognition to be its specific and exclusive object? No such case exists. Cognition remains an object that no science has yet been able to dispossess of its usual philosophic framework. We need first of all to specify what the cognitive character of those central

disciplines most often cited (computer science, cognitive psychology, linguistics) actually consists of.

The cognitive aspects (in Le Moigne's broad sense) of *computer science* concern only one of its associated technologies, namely Artificial Intelligence[14]. Cognitive psychology is a branch of psychology and not an autonomous discipline. In practice it does not study all aspects of cognition (for example the neurological level is beyond its scope).

Before considering under what conditions *linguistics* might be placed on the list of the cognitive sciences we must first consider the role of language in cognition.

2. THE GEOGRAPHY OF COGNITIVE RESEARCH

Geography, one could say, determines history. We can begin by showing how the relationships between those disciplines that are usually included under the heading of cognitive research are represented today. The study sponsored by the Sloan foundation in 1978 on the state of art proposed the following diagram :


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_____ : strong interdisciplinary link
---------- : weak interdisciplinary link
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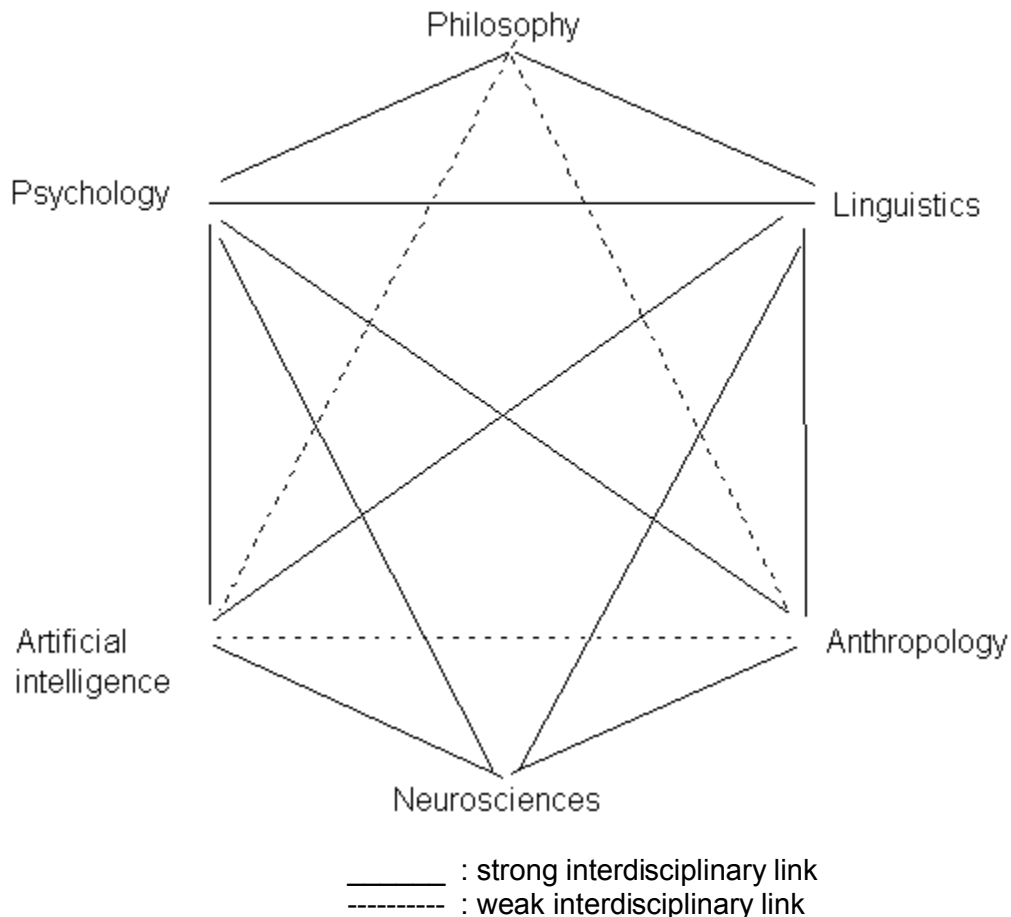
Diagram 1

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[14] AI is after all not just one technology among others. The theoretical ambitions of its founders, just as the philosophical debates which surround AI today, attribute a unique place to it, distinct from others disciplines.

Naturally this harmonious "cognitive hexagon" posed more problems than it resolved. However, in commenting on the diagram, the authors evoked a widespread opinion : "What has brought the field into existence is a common research objective: to discover the representational and computational capacities of the mind and their structural and functional representation in the brain" (1978: 8, according to Gardner, 1985: 36).

Le Moigne has outlined a newer version, more detailed and considerably different from the hexagon of diagram 1 (cf. 1986a: 51).

    (a) Cybernetics
    (b) Neurolinguistics
    (c) Neuropsychology
    (d) Computational linguistics
    (e) Psycholinguistics
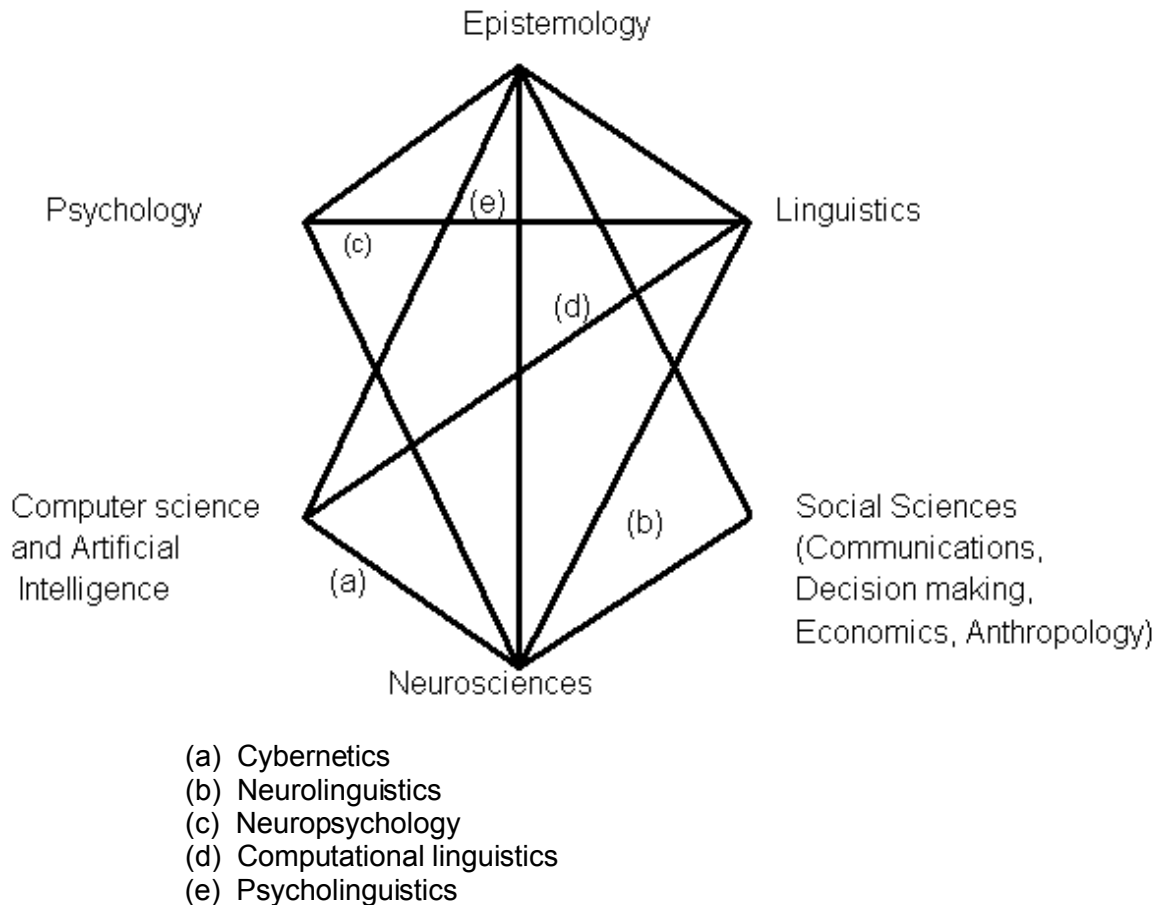
Diagram 2

Diagram 2 calls for the following observations.
(i) *Epistemology* has "replaced" philosophy, a move that does not better establish its scientific status. Whatever the case, epistemology is situated at a different level than the other disciplines.
(ii) Whereas socio-linguistics (not represented here) should be situated under the heading of linguistics, *psycho-linguistics* is situated within psychology.
(iii) Lastly and most significantly, linguistics is not counted among the social sciences. This is a most telling omission.

These hexagons aside, it might be useful to present a prism of our own design acknowleging of course that no diagram can fully represent the complexity of such a field of research. It is intended to illustrate current interdisciplinary relationships independently of what these disciplines might or should be.
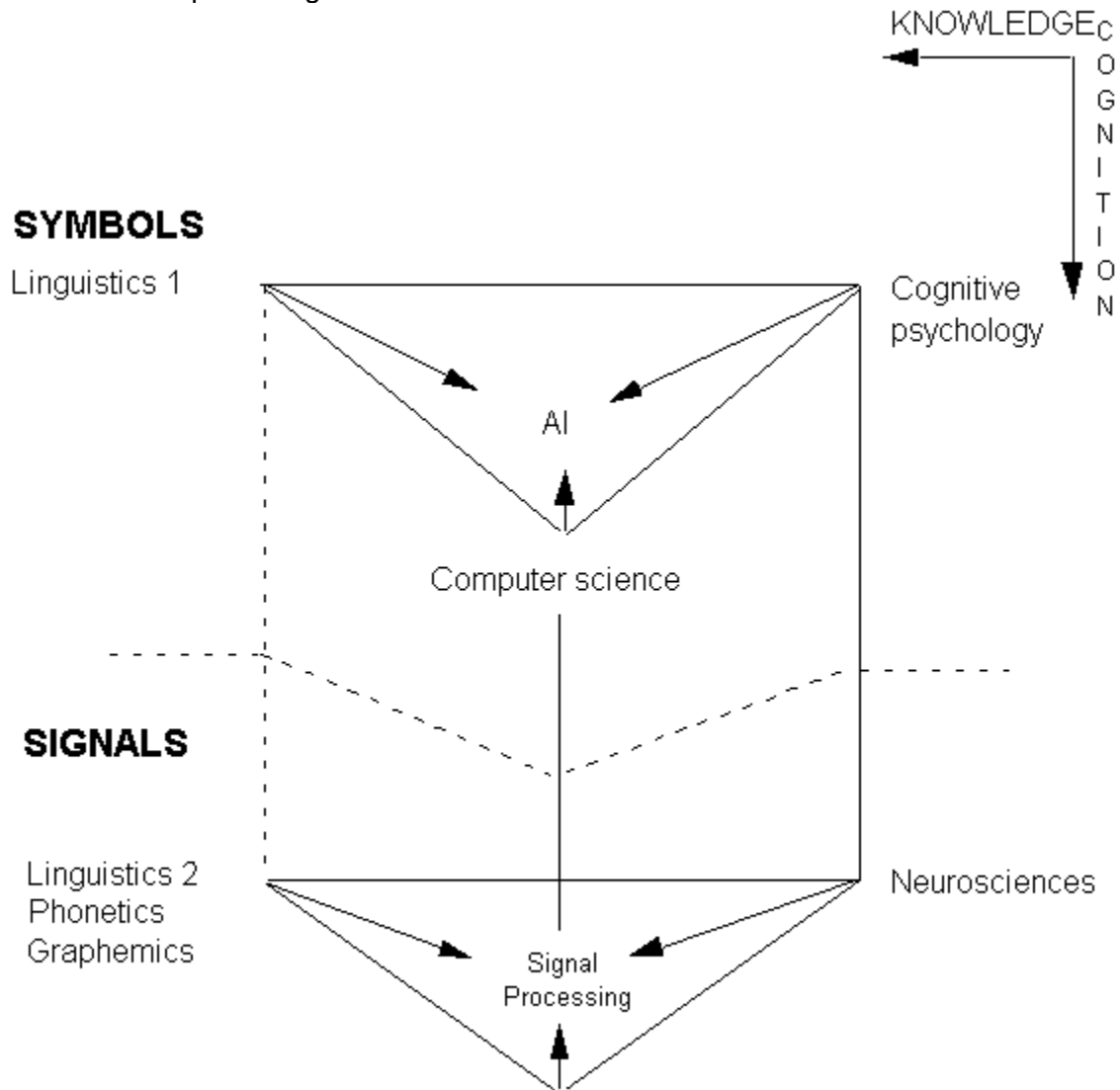
Diagram 3

The following clarifications are in order:

(1) The area covered by signals and symbols is distinguished by means of a semiotic opposition : a *symbol* (a linguistic sign for example) is a unit composed of a signifier and a signified; a *signal* is a physical entity that can be interpreted but to which no specific signified can be associated. In linguistics, the symbolic level constitutes the first articulation

of language; the level of signals constitutes the second articulation[15]. This distinction may serve to clarify somewhat the rivalry which opposes the dominant paradigms in cognitive research today (cf. *infra* § 5) : cognitivism shows a predilection for the processing of symbols; connectionism conversely still has difficulty analyzing symbols and has been more successful in the automatic perception of signals[16]. Whatever the case, linguistics encompasses both these levels: the symbolic and the "subsymbolic". The relations between symbolic entities supposedly constitute knowledge. It is within this space that representations are situated as well as the reasoning processes which operate on these representations; situated within this space as well is the problem of the representation of knowledge. The process that leads from signals to symbols is a cognitive one : it is in this sense that cognition is of interest to linguistics

2) AI presents all the characteristics of a technology. This is the principal reason why computer science, cognitive psychology and linguistics are able assist in the realization of its projects. The processing and analysis of signals seems to occupy an analagous position within the space delineated below the symbolic.

3) Several sub-disciplines involved with language could be situated on our diagram.

a) Psycholinguistics, a branch of psychology.

b) Linguistic-assisted computer science, a branch of linguistics, uses computer technology in order to carry out its research.

c) Computational linguistics, a branch of computer science, uses linguistics in order to carry out its research. This relation is not a direct one and is established within the framework of AI.

d) Neurolinguistics, a branch of the neurosciences, studies linguistic activity.

e) Phonetics and graphemics are interested in the neurophysiology of perception[17].

Strictly speaking, these sub-disciplines do not have the status of intermediary disciplines, developing along side the other disciplines. They owe their scientific status (their object, their methodology, their principles of validation) to the disciplines from which they derive[18].

Note : So as not to encumber our diagram we have not represented on it a number of disciplines mentioned by the authors already cited.

(i) Epistemology, which is a philosophic discipline, has no privileged relation to cognitive research.

(ii) Philosophy's approach to cognition is typically speculative (whereas cognitive research wants to make of cognition a science and so unseat philosophy's traditional claim on the problem[19]).

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[15] On the double articulation of language, see Martinet, *Eléments de linguistique générale*, Paris, Armand Colin, 1960, pp. 17-19. Signals can be grouped systematically in order to form symbolic signifiers (the signals of the Morse code are a perfect example).

[16] The "sub-symbolic level" that Smolensky (1988) associates with connectionism seems to correspond in part with that of signals.

[17] We leave it up to the reader to situate the sub-disciplines that do not have a direct relationship with linguistics (neuropsychology, psychophysiology, etc.)

[18] "Interdisciplinary" disciplines that are developed within their borders do not exist; one cannot simply form a discipline with hyphens (psych-socio-something). One question remains open however : can a particular relation that exists between disciplines itself take root and become a new discipline--one that would have a *new* object ?

[19] In this connection we should distinguish the scientific experiments carried out in psychology from the so-called *Gedankenexperimente* conducted in neuroscience by people such as Searle and

(iii) Logic serves as a kind of master paradigm for a number of the discplines mentioned but cannot be precisely situated.

(iv) Cybernetics and systemics have yet to demonstrate themselves as sciences.

(v)   Finally, the links established up until now between anthropology, economics and cognitive research have been very tenuous.

In fact, what needs to be made more precise is the status of all the social sciences in relation to cognitive research. The case of linguistics, which is the only social science among the central disciplines that study cognition, should be particularly enlightening in this regard.

3. The Historiography of Cognitive Research

Up until now cognitive research has occasioned very little historiographical reflection. In fact,very little work has been devoted to retracing its history : one book length study (Gardner, 1985) and a handful of articles. As interesting as these studies may be, they are not the product of specialists in the History of Ideas and overall reflect a largely desultory historiographical practice . This has not been construed as a weakness since the scientific community that is engaged in cognitive research tends to live in the present if not in the future and has been generally satisfied with a sketch of recent orientations and developments and in effect is not unlikely to deem historical research as gratuitous erudition. Researchers are interested quite rightly in results and the moment a theory is judged outdated one simply forgets about it[20].

3.1 *The birth of a problematic*

There is a consensus that the contemporary origins of cognitive research can be situated between 1935 and 1950. Let us recall three decisive steps.

(i) In the summer of 1935 the young mathematician Alan Turing finds an answer to the problem of decision advanced by Hilbert in 1928. Turing's article, *On Computable Numbers, with an Appplication to the Entscheidungsproblem*, appeared in 1936. These numbers could be calculated by a machine capable of scanning and writing symbols on an infinite tape that is divided into squares, each of which is either blank or has printed on it one of a finite number of symbols; the machine can then read these symbols as an instruction to alter the condition of the scanned square, move the tape or change to another square. Turing concluded that is was now possible to construct a calculating machine.

(ii) In 1937, C. Shannon, a student at MIT, proposes to represent "the Boolean laws of thought" by means of electronic circuitry; the conclusions of his thesis were published the following year in an article entitled *A symbolic analysis of relays and switching circuits*. The idea that the laws of logic can be identified with the laws of thought is as old as Logic itself; Boole's aim of formulating the laws of thought is declared in the title of his major work *An investigation of the laws of thought on which mathematical theories of logic and probability are founded* (1854). The idea of using a machine to represent Boolean calculations was not new : Charles Babbage had formulated a similar proposal during the

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Dennett.

[20] Didn't Marvin Minsky say : "A dynamic science doesn't fret over its past--it charges forward" (in response to F. Fogelman-Soulié, cited in Dupuy, 1985:10) ? One easily detects this modern amnesia in the bibliographies : only the last two numbers of any given year are mentioned. It thus appears unimaginable that works from previous centuries could be cited. In linguistics--where theories are not really "falsifiable"-- theories that are merely out of style are quickly declared outdated or obsolete.

same period. Turing and Shannon's discoveries were materialized during the war with the construction of the first computers.

(iii) In 1943 the neurophysiologist and psychiatrist Warren McCulloch coauthored an article with the young mathematician W. Pitts entitled *A Logical Calculus of the Ideas Immanent in Nervous Activity*. In it they defined *formal neurons* (constituted by elementary dual state electronic circuits) organized into *networks* capable of producing Boolean calculations and able to reproduce–so the authors thought--the activity of the brain.

Why are these three texts still cited ? The answer is that they outline a problematic that remains current to this day. Of course cognitive research has been involved in innumerable theoretical debates over the last fifty years but these debates have always revolved around the same problematic upon which the paradigms that divide researchers today still depend. The following diagram represents the major poles of this problematic :

STRUCTURE
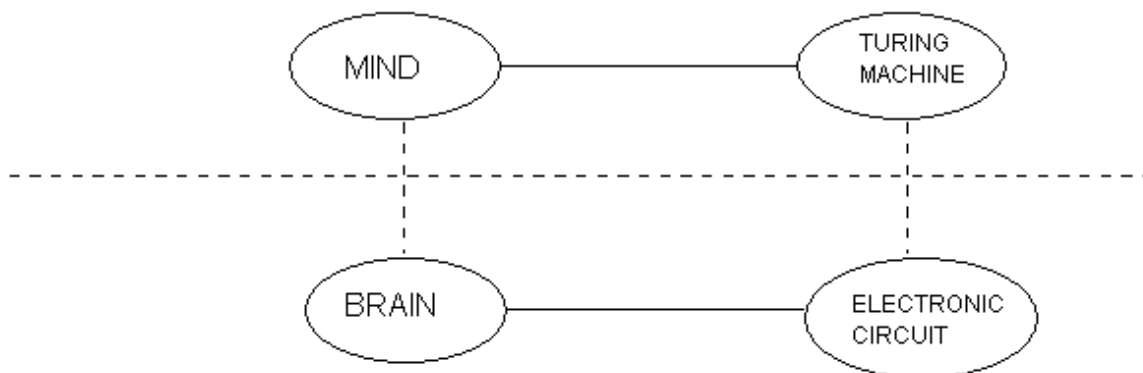
ARCHITECTURE

Diagram 4

(i) The *mind* is equated with rational thought, and rational thought is confined to logical thinking; the logic in question is identified with Boolean logic. According to this restricted rationalism the laws of thought are reduced to the principles of identity, non-contradiction and of the excluded middle.

(ii) The *Turing machine* is a "theoretical" abstract automaton defined independently of any material implementation. Its unlimited tape reveals only a string of either empty squares or squares marked by a slash.

(iii) The activity of the *electronic circuits* (relays and switching circuits) is restricted to a combination of two fundamental states: either the current is transmitted or it is not.

(iv) The activity of the *brain* is limited to a single consideration: only neurons are treated and again in terms of "all or nothing" (there is or is not a neural discharge).

Note : The upper area of this diagram corresponds to symbols; the lower area corresponds to signals.

It appears to us that the four entities represented in this diagram are based on relations between two (and only two) fundamental states which permit the following homologation :

1. Thought (logical)	*true*	*false*
2. Turing machine	slash	*blank*
3. Electronic circuit	*transmission of current*	*non-transmission of current*
4. Brain	*activation*	*inhibition*

The problematic we have just outlined is obviously of a philosophic nature. It appears to exhibit a materialist character to the extent that the distinction between mind and brain is reduced to the point of disappearing[21]. But its dominant characteristic is mechanistic : if the operations of the mind and/or brain can be reproduced by means of a machine it is because these entities are themselves natural machines or at the very least because there is nothing essential separating the biologic from the artificial.

This thesis subtends the cybernetic project. In 1943, Rosenblueth, Wiener and Bigelow proposed a description of messages that was uniform to the extent that it did not differentiate between means of transmission be they electronic, mechanical or via the nervous system. Wiener published his rather confusing study in 1948 under the title *Cybernetics, or Control and Communication in the Animal and the Machine.* The brain was considered an adequate model for machines. In *Design for a Brain* (1952 : v), Ashby declared : "My aim is simply to copy the living brain".

The fabrication of the first computers during the Second World War resulted in a simplification of the problematic that we schematized above : electronic circuits enabled the construction of a Turing machine. The design chosen was said to be that of *von Neumann* and called a *stored program machine* [22].

The creation of the first computers inaugurated a new, less speculative, phase for cognitive research by providing it with a new capacity for experimentation. In fact, experimentation supposes a relation to empirical reality that engages only a methodologically derived fraction of the object to be described. However for lack of a defined object it is really a question here of *simulation* : cognitive research is based on the desire to simulate mental and/or cerebral processes in the computer (as far as these processes are understood)

If this link were not legitimate why then would we have agreed on the 1940's as the founding years for cognitive research ? Indeed the computer figures as the single most decisive factor. In fact it is in relation to the computer that one is able to distinguish the founders (like Turing, Shannon, Wiener, von Neumann) from the precursors such as Babbage and Lovelace: the machines of the former group were operative while those of the latter group were not[23].

Since this inaugural period in cognitive science the major interest has been focused around three poles : the computer, the mind and the brain. Each of these poles is associated to an attendant discipline, respectively, computer science, logic, and neurophysiology. Linguistics (and psychology as well) has in fact been excluded from this primordial tripartition.

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[21] Consider the title of a paper presented by McCulloch at the Hixon symposium (September 1948) : "Why the Mind is in the Head".

[22] One only begins to see competing design projects beginning in the early 1980s.

[23] In the area of cognitive reserach the only projects that tended to hold anyone's attention for long were those capable of a computer implementation.
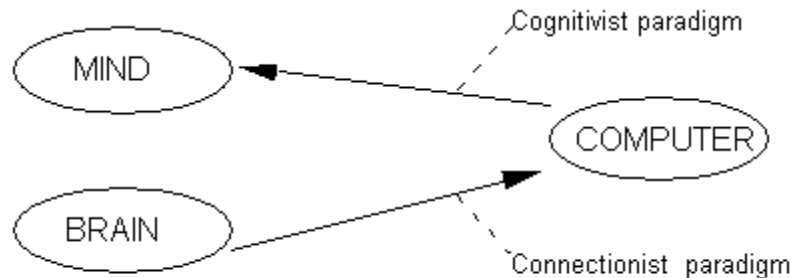
Diagram 5

These three poles are paired into two distinct and interrelated paradigms.

The first privileges the relations between the mind and the computer; this alliance was the foundation of classical AI and of its philosophical correlate that we could call *orthodox cognitivism* [24] (represented today most notably by Chomsky, Fodor, Pylyshyn).

The opposing paradigm privileges the relations between the brain and the computer. The latter is supposed to mimic the operations of the former by means of programs and even in its very design. In this paradigm, which today is called *connectionism*, the brain is the dominant pole (cf. *infra*, chap. II).

3.2 *Periodization*

It is generally agreed that following the heroic period of the Founders of cognitive research and of the construction of the first computers (1937-1945) at least three other relatively distinct periods can be identified.

(i) *Cybernetics* [25] (1946-1954) recruited all kinds of theories of communication and of information, as well as theories of regulation in natural and artificial systems. On the institutional level, cybernetics found an audience in the United States during the ten Macy conferences (1946-1954), as well as the Hixon symposium (1948). In 1949, the *Ratio Club* was founded in England. The following year saw the formation in Paris of the *Cercle d'études cybernétiques*. The term *cybernetics* is no longer used except in some quarters of the neurosciences but its theoretical interests have to some extent been prolonged by systemics.

(ii) Apart from systemics, the cybernetic project was in part carrried on within AI-- which rendered it, according to some, out-of-date if not totally invalid. During a seminar at Dartmouth (summer, 1956) Marvin Minsky presented a paper later published under the title *Steps towards an Artificial Intelligence* [26]; A. Newell and H. Simon gave a demonstration of the first supposedly intelligent program called LT (for *Logic Theorist*) capable of an automatic demonstration of various theorems.

The research in AI that was carried out during this early period (when the relations with cybernetics were more evident) appeared to be informed by three main concerns : to become less speculative and more concrete by devoting itself to the writing of programs--

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[24] This term being inspired by an expression of Dennett's (*high-church computationalism*).

[25] A term no doubt coined by N. Wiener and the title of his work *Cybernetics* (1948).

[26] The authorship of this slogan is contested but it is probably attributable to John McCarthy who created LISP (AI's first programming language) and who founded AI laboratories at MIT (1957) and at Stanford (1963).

programs that were thought capable of solving theoretical problems; to attempt to study the manipulation of symbols in a greater number of contexts, and not simply with respect to numerical calculation; to extend the capacities of computers, especially through the creation of programming languages.

In France, the first French-language article to invoke AI was published in 1962. In 1966 its author, Jacques Pitrat, defended the first thesis in AI ever undertaken in France and the following year he founded the first research group in the domain.

(iii) The first published occurence of the term "*cognitive science* " seems to date from 1975 (as the subtitle of a collection of papers edited by D. Bobrow and A. Collins[27]: *Studies in Cognitive Science*). Two years later a number of computer scientists (R. Shank among them), linguists and psychologists started up the journal *Cognitive Science.* In 1978 a report bearing the same title was sponsored and published by the Sloan Foundation. In 1979 the Cognitive Science Association held its first meeting with considerable fanfare. The *Association pour la Recherche Cognitive* was created in France in 1981 principally on the initiative of D. Kayser, J.-F. Le Ny, and A. Lentin.

It almost seems a customary pleasure to salute scientific revolutions once every five years. Initially the promotion of a science of cognition simply reflected an increasing interest for research into Artificial Intelligence, which remains the privileged domain and focus of collaboration for the many disciplines engaged in cognitive research. Doubtless the expression *Cognitive Science* , along with *Artificial Intelligence*, should be understood as a federating slogan. Some would say : what difference does it make if it's a slogan as long as it *is* federating.

(iv) These last years have seen a renewed debate within cognitive research between cognitivism and connectionism. The substance of this debate will be discusssed further on (cf. *infra* § 5); suffice it to say that orthodox cognitivism has defended the postulates of classical AI, whereas these have been the object of criticism from philosophers belonging to the connectionist school.

The proponents of these two paradigms are opposed at every level; as a consequence we are led to stipulate the existence of two divergent histories. The connectionists have attempted to rehabilitate cybernetics, which apparently had been unjustly occluded by the development of AI. As J.-P. Dupuy has written: "There is a deeper justice. We have seen AI and the cognitive sciences tire out in recent years, only to give birth to a new branch, duly baptized 'neo-connectionism' which is nothing other than a reformulation of good old cybernetics[28] " (1985: 14).

By contrast, the so-called orthodox cognitivists have quite deliberately bypassed cybernetics. George Miller for example has claimed that "cognitive science" was born on September 11 1956 during an MIT symposium on information theory.

These historiographical differences *per se* are secondary to our interests and we will not dwell on them; as well, even an accurate periodization cannot pretend to be an history.

2. Nevertheless what we have just outlined should enable us to see more clearly how language has become progressively one of the centres of interest for cognitive research.

Language was largely ignored during the period of cybernetic research; computer scientists effectively limited themselves to numerical calculations. Of course some linguists such as Roman Jakobson--perennial avant-gardist--participated during the Macy

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[27] With respect to its basic principles, it's not new--as witnessed by the opposition between Turing and McCulloch in the 1940s.
[28] See also P. Livet, 1985.

conferences and in effect Jakobson labored with the usual ingenuity in the hopes of linking the mathematical theory of information to linguistic communication. But, alas, in vain[29].

While not being "linguistics" , language was nevertheless the central focus of an article published by Turing in 1950 : *Computing Machinery and Intelligence*. In order to answer the question, "are machines capable of thinking?", Turing devised a game of imitation, a type of verbal test generally known as the *Turing test*, according to which the capacity for thought will be recognized in any machine that has learned to imitate a human dialogue perfectly (cf. infra, chap. VI).

As an outcome of research in AI, linguistics began to assume an increasingly important role in cognitive research during the decade from 1955 to 1965. This is so not only because "Chomskyism" occupied a dominant position during the period (his work represents, in the strictest sense, the first cognitivist linguistic theory), but is also due to the formation of two sub-disciplines associated with linguistics.

The first of these is computational linguistics which is a branch of computer science that specializes in the automatic processing of language. Its three principle domains include the analysis and synthesis of speech, the man-machine dialogue and automatic translation[30].

The second is psycholinguistics whose first aim was to use experimental methods to test the validity of linguistic theories but which later extended its field of investigation to include all psychological forms related to the acquisition, use, and loss of language.

Over the last ten years the debates within cognitive research have been polarized around the question of language. And while these debates sometimes misconstrue or mishandle linguistics, they have become of increasing interest to linguists.

In this connection it is perhaps superfluous to recall the famous Piaget-Chomsky debate which ended up legitimizing Chomsky and Fodor's cognitivist theses about language[31]. Thirteen years later it is still on the field of language that the cognitivists have chosen to mount their offensive against connectionism (cf. Fodor and Pylyshyn, 1988, versus McClelland and Rumelhart, 1986).

3. We need to withdraw for a moment from the historiographies as we can mesure them currently in cognitive research. These paradigms rival each other of course but nonetheless remain implicitly in agreement on three essential points with which we do not entirely concur.

(i) That there exists a cognitive science and that linguistics constitutes ones of its parts. Yet, as we have already stated, cognitive research is a multidisciplinary field. Surely linguistics participates in it--to an extent yet to be determined--but naturally maintains its own autonomy as well as its own specific history.

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[29] See his article "Linguistique et théorie de la communication". Jakobson writes that for Norbert Wiener there exists "no fundamental opposition between the problems which engineers encounter with regard to communication and those encountered by philologists" and he goes on to remark that there exist striking similarities and convergences between recent work in linguistic analysis and the approach to language that is characterized by communication theory (1963: 87).

[30] The first system designed for the automatic treatment of speech dates from 1952 (capable of recognizing ten count nouns uttered by a single speaker). The first dialogue system dates from 1960 (it responded to questions about baseball scores).

[31] See Massimo Piatelli-Palminari, éd., 1979.

(ii) The foundations of cognitive science go back to the 1940's[32]. Yet research into cognition has at the very least been secular--certainly as far as the sciences are concerned; and from a philosophical perspective enquiries into cognition are ancient. The historical privilege granted to the 1940's is only justified if we select the computer as the tutelary figure of all research into cognition.

(iii) A somewhat hasty historiography of cognitive research has granted an exhorbitant status to Chomsky, other linguistic theories being relegated to the rank of precursors (the case of the neo-grammarians according to Gardner[33]), if not to the distant background (American "structuralist" linguistics). Gardner summarizes a general opinion in commenting that : "In a nontrivial sense, the history of modern linguistics *is* the history of Chomsky's ideas and of the diverse reactions to them on the part of the community" (1985 : 185). This privilege is explained when we recognize that Chomskyism is explicitly and entirely situated within the field of cognitive research. Yet it is not justified since linguistics is only concerned with certain aspects of cognitive research.

Together with the preceding remarks we should also include three distinct trends, each with its own history, that continue to this day within cognitive research.

(i) The relations between linguistics and psychology were formed during the middle of the last century. In linguistics one would have to mention the contribution of Steinthal, in particular his work *Grammatik, Logik und Psychologie* [34] (1855). In contemporary psychology one would have to recall the work of Vygotsky and above all the work of Bühler whose *Sprachtheorie* remains an unequalled synthesis[35].

(ii) The relations between linguistics and the neurosciences go back to the end of the last century. (i.e., most notably to the work of Wernicke and of Lichtheim).

(iii) Finally, the links between linguistics and AI were established throughout the 1950s.

In short the relations between linguistics and these three disciplines or groups of disciplines have contributed to the establishment of a problematic for cognitive research.

4. The Postulates of Cognitive Research

Let us turn our attention to what has contributed to this particular imbrication even if it requires us to restrict our focus to the so-called "central" disciplines. It seems to us that cognitive research is based on two postulates of a philosophic nature which it hopes to transform into scientific theses.

1. The traditional dualism between mind and brain should be restricted perhaps even to the point of disappearing. In other words the mind and the brain would belong to the same "layer of Being" or level of reality. This monistic postulate appears to be materialist[36].

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[32] See for example Arbib, Conklin, Hill, 1987, chap. I : *The Cybernetic roots of Cognitive Science.*

[33] "In the 1860s and 1870s, in a manner paralleing the Chomskian circle a century later, a group of young rebels called the *Junggrammatiker* (or neo-grammarians) attempted to put the situation in order " (1985:197).

[34] According to Erwin Esper, Steinthal did linguistics the service of replacing logic with psychology (cf. *Mentalism and Objectivism in Linguistics,* New York, American Elsevier, 1968).

[35] Interdisciplinary encounters do not date back to yesterday! Consider the famous special issue of the *Journal de psychologie* (1933).

[36] We will see however that orthodox cognitivism maintains certain forms of dualism.

Note : This idea has of course been accused of being reductionist (most notably in the criticisms directed at the idea of *Neuronal Man*). Yet reductionism has less to do with maintaining this postulate than with being satisfied with it. If matter thinks, then it *is* : the major problem--one that this first postulate leaves in the dark--remains the relations between the mind and the rest of the body. As well, the facile and hasty parallels often drawn between the mind and the computer are generally based on a complete neglect of the body : while the research concerns representations, reasoning processes, etc., it too often neglects the fundamental problem of perception.

2. Man can simulate mental processes by artificial means. This second postulate--the very words *Artificial Intelligence* summarize the ambiguities in it--has been interpreted in many ways.

(i) A minimalist interpretation limits itself to simulating output without seeking to reproduce the operations which generate these output. In the case of a man-machine dialogue (cf, *infra*, chap. VI) this approach can lead to echolalic systems, the archetype of which remains Weizebaum's ELIZA; it could also lead to more elaborate systems capable of manipulating semantic representations, without the form or the treatment of these representations being necessarily analogous to those of the human mind (i.e., Winograd's SHLRDU).

(ii) More ambitiously, one might conjecture that in order to produce comparable output one would have to be able to simulate the mental operations which produce them--at least as far as these mental processes are understood. This is the reason why computer scientists turn toward psychologists, even neuropsychologists, in order to validate their hypotheses. Of course they can attempt to improve the performance of their systems on the basis of what they know about mental operations without at all pretending to be able to reproduce these operations.

(iii) Arising from the last point is the maximalist interpretation of cognitive research's second postulate: in order to simulate cerebral functioning as faithfully as possible, one has to be able to treat information by means of networks of formal neurons. This is the principle behind connectionist models[37]. The basic idea being that it is possible to reconstruct networks of formal neurons by the use of specific programs run on even a classical computer design. In order to go beyong this, it is thought that other systems are needed : more sophisticated machines (designed for massive "parallel treatments"), or entirely new computer designs. Even the simulation of cerebral matter itself has been imagined, following the model of the simulation of output in the form of simple verbal syntagms.

As the preceding points show, there are three principal ways in which the notion of simulation can be understood, each representing an increasing degree of fidelity in the representation of mental operations : the first degree of fidelity presumes that the cooperation between computer science and linguistics is sufficient, in the second degree, the collaboration beween linguistics and computer science becomes necessary, and in the third degree, one is obliged to collaborate with the neurosciences.

3. Though not the object of much discussion, a third postulate is generally accepted and could be characterized as "gnoseological"; according to it, knowledge is a symbolic representation of a given reality . If one agrees with Descartes that thought consists of operations on such representations, and with Hobbes that reasoning, the superior form of thought, can be reduced to a calculation, then a machine that operates on symbols should

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[37] See Feldman and Ballard (1982), Cottrell and Small (1984), Waltz and Pollack (1985), Béroule (1985), Smolensky (1988); for an introduction, see Jodouin, 1990.

be capable of reasoning on the basis of certain knowledge data[38]. This hypothesis underlies the comparisons which hold that the brain and the computer are two material systems capable of performing calculations on symbolic representations[39].

This third postulate subtends the project of simulation which finds its expression in the maximalist version of cognitivism--as much in AI as in cognitive psychology-- both sciences projecting that the true functioning of the brain will be known once it can be simulated by means of symbol processing machines. In the domain of linguistics, this hypothesis would imply that one will come to understand language and human linguistic faculties only if one arrives at being able to automatically produce and enumerate every grammatical phrase in every known (or even possible[40]) language.

Of course we are aware that such a succinct presentation as this is bound to raise a number of questions of an epistemological nature. We will examine two of these possible questions without trying to treat either of them exhaustively.

1) The notion of *knowledge* of course plays a central role in cognitive research. Yet, even if theories of knowledge abound in the history of philosophy, it seems that cognitive research makes very broad use of this notion without endeavoring to clearly specify its scientific status. For example, in AI and in cognitive psychology there is frequent use of *semantic networks* in order to represent knowledge. However the "concepts" defined by these networks are simply linguistic contents, and it is imprudent to assimilate meaning and knowledge without first enquiring into their relations. Let us at least agree that these relations are neither simple nor unmediated (cf. *infra*, chap. IV).

In short, up until now cognitive research has organized itself on the basis of what remains largely an implicit gnoseology.

2) The organization and regulation of relations between disciplines within cognitive research requires other precisions. In the first place the status of these disciplines is unequal. We can probably agree that computer science, cognitive psychology, linguistics and the neurosciences merit being designated as sciences, each for a number of reasons. This is not the case for AI. Thinking of AI as a science would inevitably lead us to perpetuate an error that today is almost banal : namely the belief that a given program application capable of operating in the form of an AI system is in itself sufficient reason for *validating* the theoretical conceptions which contributed to making the system operational in the first place. However, that a given concept is technically *operational* does not necessarily make it *operative* within the theory that created it. Maintaining this confusion will not allow cognitive research to overcome the *technicism* for which engineers today are unjustly credited[41].

The notion of *interdiscipline*, which Newell recently advanced in order to characterize AI, very much suits this open-armed technology; but it should not be extended to cognitive research in its entirety. Experience has shown that the *inter* -, *trans* -, or *meta* -disciplines

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[38] "Reason is nothing but reckoning", *Leviathan*, 1651.

[39] In AI, this is what the notion of intelligence is generally reduced to.

[40] And hence Chomsky's initial ambitions will have been fulfilled.

[41] For example, a simple and efficient system of cabalistic interpretation is entirely conceivable and it might operate by the permutation of letters or by the calculation of numerical values, which are mysteriously attached to them. It remains true that the necessity of introducing and working with computers has led many disciplines to become more rigorous in their research. The capacity to transform a problem into a program can have a significant heuristic value. Of course, one should not conclude that only programmable problems are pertinent.

are really just philosophies that dare not declare themselves as such and it is for precisely this reason they are inferior to the traditional philosophies.

5. THE TWO PARADIGMS

> *"Paradigm clashes" , as everyone who goes to cocktail parties knows, are diffuse confrontations of world views.*
>
> Jerry Fodor

1. The postulates that we have just outlined are fundamental to the extent that they are shared by both rival paradigms, so-called orthodox cognitivism and connectionism[42].

However these labels are themselves misleading : cognitivism never really constituted itself as an orthodoxy, although Fodor and Pylyshyn (1988) portrayed themselves as champions of the *classical* point of view; yet very often fundamentalists create an orthodoxy in order to confirm their leadership and perpetuate their own way of thinking. Connectionism on the other hand does not represent a new paradigm, one whose vocation would be to supplant its predecessor. In fact the two paradigms have rivaled each other since the nineteen forties, each in turn profiting from the other's difficulties.

It is possible to associate these two paradigms to two different philosophies (analytical philosophy and phenomenology), as well as to two implicit ontologies (one favoring the discrete, the other priveleging the continuous), even to two distinct poetics (one sustained by the metaphor of the computer, the other by the metaphor of the brain). Recalling these divisions may be useful but it is also necessarily tendentious : firstly, there are strong divisions within each camp; moreover, up until now a certain confusion has dominated the debates concerning not only argumentation but also the various theoretical references summoned by each paradigm.

A precision is in order here : by *cognitivism* we mean orthodox cognitivism and particularly the "MIT school" the most prominent representatives of which remain Chomsky in linguistics and Fodor in cognitive linguistics. We should add that in formulating our criticisms of cognitivism it is not our intention to condemn AI as such.

2. As far as the cognitivist paradigm is concerned, cognitive research appears to have a common object : knowledge. This object is not however of the same nature as the object of a particular science. Its specificity is more that of a recurrent theme : (i) Cognitive psychology is principally interested in the analysis and treatment of reasoning, in inferences based on knowledge, and in the storage and retrieval of knowledge; (ii) AI focuses on the problem of *knowledge representation* ; (iii) linguistics attempts to propose models that will enable these tasks to be realized.

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[42] According to Anglo Saxon epistemology, the term *paradigm* designates a scientific problematic. In defining the notion of paradigm in five different ways, Kuhn introduced a term that has become a popular reference and we will not try to diminish its utility. Is it licit today to speak of two paradigms ? The informed reader will judge that the idea is not altogether erroneous. According to a number of people there are two opposing paradigms : See Andler, 1986, Winograd and Flores, 1986, McClelland and Rumelhart, 1986, Fodor and Pylyshyn, 1988.

Within the cognitivist paradigm, *knowledge* is a process of representation conceived in terms of symbolic translation :

(i) The world is composed of things and of states of affairs.

(ii) Knowledge is the symbolic representation of these things and states of affairs.

(iii) One of the principal tasks of AI, linguistics and psychology is to elaborate and construct symbolic representations of knowledge itself in such a way as to be able to analyze and operate on these representations.

This paradigm puts into place what could be called a *translationist* conception of meaning : the meaning of a symbol is equivalent to its translation into other symbols[43], or more precisely, what it has in common with its translation. One might object with this by contending that the representation of an object by means of a symbol, and the representation of a symbol by means of another symbol have nothing in common[44]. This difference is nevertheless often neglected, as if the objects of this world were themselves symbols : in cognitivism's implicit ontology these two entities share many characteristics such as discreteness and uniqueness or self-identity.

Furthermore, thought itself is assimilated to a language. Hence the thesis that a mental representation is a series of symbols deriving from a mental language and describable as a kind of formal language. This postulation was necessary in order to allow thought to be integrated into the idea of a superimposition of symbolic representations that translate each other successively. Thus the image of the knowledge process that emerges from this is that of a *transduction*, or even of a *compilation* ; these terms signifying the "translation" of a series of symbols into other series of symbols, and more precisely, of superior order languages to lower order languages. In this sense, knowing would consist of transforming objects into "bits".

As far as linguistics is specifically concerned, this theoretical program entails two major consequences : (i) linguistic meaning is in the final analysis denotative meaning : linguistic symbols designate objects of the real world; (ii) the job of linguistics consists of being able to represent the symbols of natural languages by means of symbols created by formal languages (an endeavor that would open the possibility of computer applications).

3. Insofar as a general characterization is possible, the connectionist paradigm is organized around the problem of cognition conceived as the formation, learning and retrieval of knowledge. More broadly, the term *cognitive* is not limited to the study of so-called superior mental activity--in man this activity culminating in language and in the creation of languages generally--but encompasses the vast field of complex interactions between an organism and its environment. It is by virtue of this extension that cognitive research has opened itself to the neurosciences. Even the notion of knowledge finds itself extended :

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[43] Jakobson, with his usual eclecticism, defines this particular conception as *semiotic* and in so doing unduly assimilates information (which computer science deals with) with "semantic information" (which linguistics deals with) : "The semantic definition of the meaning of a symbol as being its translation into other symbols finds a useful application in the linguistic study of translation; in approaching semantic information in this way, we meet up with Shannon's proposal of defining information as 'what remains unchanged after all the reversible operations of encoding and translation, in short, as the equivalent form of all these translations " (1963, p. 97).

[44] All the more so since the signified cannot be said to represent objects. Their relationship to objects is far more complex, and is mediated by the representations to which these signifieds are associated.

(i) Knowledge is no longer defined as an agglomerate of representations. In other words, the mimetic theory of representation is rejected.

(ii) Not all knowledge is necessarily accessible or conscious. The brain cannot be limited to the cortex, nor can the nervous system be restricted to the brain.

(iii) All knowledge is not *a fortiori* conceptual. Hence the frequent evocations of a "sub-conceptual level".

(iv) As an extension of the last point, knowledge is not considered *a fortiori* to be of a necessarily symbolic nature. Following Smolensky's impetus there will be a return to the notion of a "sub-symbolic level". In any case the cognitive sciences, including linguistics, cannot limit themselves to the description of operations on symbols.

Whereas the marked interest of orthodox cognitivism is for the study of reasoning and for rule-governed operations on symbols, connectionism tends more specifically towards the problem of perception (biological or artificial[45]). It consequently grants a very important role to *context* (in the non-linguistic sense of the term), which encompasses spatial, temporal, even intentional dimensions; every perception of a phenomenon is considered closely dependent on its environment. Perception also depends on temporal factors and in fact evolves with time; it is also motivated by some aim (an organism's drives, the intentions of an individual, or the aims of a given program)[46].

With connectionism the relations between the disciplines are also modified : the neurosciences gain considerably in stature to the detriment of computer science. As well, there have been considerable upheavals in certain disciplines, notably in AI : machines are no longer programmed, they are "conditioned"; and rather than writing rules, one specifies the relations between "formal neurons"; results are not obtained (or at least series of symbols interpreted as results), instead one identifies stable or temporary activations of certain parts within a given network.

Finally, connectionism's implicit ontology is more accurately portrayed on the model of physics rather than logic : an object is not considered to be a discrete entity bearing a unique identity but instead a singularity situated within a continuous space and capable of infinite variation.

4. Implicit ontologies seek the support of explicit philosophies. Orthodox cogntivism has inherited much from logico-positivist philosophy, notably from Russell, Carnap, and the first Wittgenstein. And if descendance is not always claimed outright it is because logico-positivist philosophy represents for orthodox cognitivism something like "common sense" -- that which goes without saying; for example, the simplistic conception of representation that we described above finds its source in Wittgenstein's *Tractatus* .

The relations between this philosophy and orthodox cognitivism are close and no doubt necessary. First of all, it provided the theoretical conditions necessary for the design and development of computers, which dominate the cognitivist imaginary. Secondly, logico-positivist philosophy, and orthodox cognitivism following it, propose formal languages as a kind of symbolic ideal--a fact that is not without consequences for subsequent cognitivist conceptions of language.

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[45] This is clear from the fact that the first tends to reduce perception to reasoning and the second tends to reduce reasoning to the recognition of forms.

[46] All this escapes of course the logicist strain of thought introduced by orthodox cognitivism; and within so-called classical AI, it is precisely the most ardent adversaries of logicism who have created or developed those concepts designed in the aim of accommodating the role played by context (linguistic or not) : *preferences* for Wilks, *plans* or *scripts* for Schank.

In contrast the partisans of connectionism embraced certain strains of phenomenology[47] in order to combat cognitivism on the philosophic front. In this way they followed H. Dreyfus's lead in his radical critique of AI, and beyond that, of logical positivism. But the combat between these two philosophies has lost the intensity and lustre of the interwar period. It is somewhat pitiful to see how Winograd and Flores (1986) seek to use in due scholarly manner extracts from *Sein und Zeit* with the intention of *creating* a new computer *design*, however commendable the effort may be in theory. Invoking Heidegger in the hopes of being able to improve a technology is to commit a rather disconcerting act of misinterpretation.

Unfortunately our enemies' enemies are not always our friends. Heideggerian phenomenology is anti-technological, whereas connectionism remains above all a mean of computer implementation. Moreover, whereas the connectionists find support in physics (cf. Smolensky's theory of harmony), Heideggerian phenomenology by principle refuses to treat the physical *universe* , the brain included of course : at the very most it treats the human *world* (that is to say, the world as far as experience gives it meaning). Finally, as far as physics is concerned, technology is situated squarely on the side of *being*, whereas phenomenology organizes itself around the question of *Being* .

In short whereas orthodox cognitivism shares close ties with logical positivism, connectionism cannot lay just philosophic claim to Heideggerian phenomenology nor Husserlian phenomenology for that matter. In effect while the transcendental subject remains the central focus of the latter philosophy, the connectionist model calls into question the classical philosophic conception of the subject (and thus transcendental philosophy[48]).

5. These two rival paradigms have developed around two contrasting metaphors. For cognitivism, the computer remains the metaphorical centerpiece. This poetics of the computer is very clearly illustrated by cognitive psychology : "individuals are supposed to *treat* information in *real time*, *in sequence* or *in parallel*; *effectuate* a text once it is *compiled*; *stock* information in different memories (virtual memory, buffer memory, simple registers, etc.) [...] ; all this with the help of a *supervisor* who allocates resources to *specialized* processors" (Denhière and Poitrenaud, 1985, p. 4). Naturally, the orthodox cognitivists are avant-garde in this respect (cf. Fodor, *The Modularity of Mind*, 1983) and the literature on AI is not to be outdone : cf. *Thinking Computers* (Raphael, 1976), *Cognitive Computers* (Schank, 1983), *Machines who Think* (McCorduck, 1979).

The theoretical stakes are considerable since it is a question of reducing cognition to a series of automatic operations carried out on symbols, and following from this, of reducing cognitive research to computer science, the former being construed merely as a theoretical aspect or extension of the latter. In this sense Winograd writes : "The design of computational systems also has a theoretical side, which is often called *cognitive science*. The same concepts of program and data that serve as a framework for building and undrestanding computer programs can be applied to the understanding of any system carrying out processes that can be understood as the rule-governed manipulation of symbols" (1983 : 2).

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[47] So-called existential philosophy (Heidegger), even existentialist (Merleau-Ponty).

[48] Dreyfus uses Heidegger and Husserl indifferently in order to attack AI, despite Heidegger's radical critique of Husserl's theory of the transcendental subject (which is precisely what leads him to reduce phenomenology to a philosophy of Being).

The adherents of this paradigm conceive of the mind in the image of computer programs thus enabling a correspondance to be established between the modularity of computer systems and the supposed modularity of the mind (cf. Fodor[49], 1983). The modular conception of language that has been promulgated by Chomskyism and which is accepted as common sense in AI, needs to be reevaluated from the following point of view: if linguistic components are separate and follow each other sequentially, is it not because the "mental organ" of language is conceived according to metaphors of the computer rather than neurological facts ?

Even more revealing is Fodor's affirmation that "The only psychological models of cognitive processes that seem even remotely plausible represent such processes as computational" (1975: 27; cf. also 1987). Such conceptions are not rare in cognitive research and will naturally have an effect on any consequent conception of language. Thus Desclés for example who has assimilated a discourse to a program (capable of applications) and proposed that its interpretation is conditioned by a *compilation* [50].

Note : Andler also writes : "AI's thesis is double : first of all a computer is potentially intelligent and secondly, the human mind (defined as the "organ of intelligence") is--if its seen from the right angle--a material and automatic symbolic system, that is to say, more or less a computer. We should specify that this utterance is far more precise, and thus more risky but at the same time more promising, than the ancient proposition according to which the brain is a machine" (1986 : 46).

However, the affirmation, even if it is implicit, that the brain functions like a computer does not appear to us to hold any promise for furthering research. Aside from the fact that the hypothesis runs counter to basic facts, it also supposes as resolved what has yet to be proven[51]... The fact that human intelligence has been able to delegate some of its tasks to computers does not justify any analogy concerning their common functionning, much less their structure.

Let us recall that the structure and functionning of present-day computers designed for general usage are basically the result of choices made in the forties and based on the aims (essentially military) and technological constraints of the period. Even von Neumann himself wanted to see the development of systems other than those to which his name was lent--systems it would not have been any less gratuitous to compare to the human brain.

A classical computer is essentially composed of a single arithmetical and logical unit (A.L.U) working in sequential fashion, and of a separate memory, entities whose operations are dependent on programs and data. Recent progress in aphasiology, and above all in cerebral imagery, has led researchers to revise what was thouhgt to be known about the localization of cerebral functions, especially in relation to the activity of the cortex; one can not precisely situate in the brain *the* memory, nor anything that would correspond to an A.L.U.

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[49] And since "computation presupposes a medium of computation: a representational system" (*ibid.*), he concludes that there exists a language of thought that despite appearances has no definable relation to actual languages. Its role, in relation to the brain, is to be a language-machine for the computer.

[50] "*A linguistic discourse appears as a program capable of specific applications*, which is constructed by an enunciator and addressed to a hearer. The latter must call upon a compilation program whose function it is to construct cognitive representations of the immediate discourse, and this with the help of intermediary (metalinguistic) representations" (1987, p. 34).

[51] As if man had conceived the computer in his own image and as if the computer reflected this image perfectly. This specular effect is clear in the case of robots. And robotics, not preoccupied by the myths of science fiction, has progressed by opting for solutions that are decidedly non-anthropomorphic.

Neurons have reaction times superior to the millisecond whereas existing circuits are capable of processing data about one million times faster. On the other hand, because complex transformations can be obtained in fewer than a hundred milliseconds we can say that they are obtained in fewer than a hundred units of time. By contrast, simulation programs in AI typically require millions of time units. Thus, relatively speaking, the brain achieves results rapidly although the information itself is propagated slowly. The computer on the other hand is capable of treating information rapidly but it has to treat it for a long time in order to achieve, grosso modo, comparable results. Lastly and most importantly, the distinction between program and material(even relativized by *firmware*) does not apply to the human brain which conceives its strategies in a uniquely autonomous manner, and we might even venture to say, conceives its own programs.

To this computational reductionism, connectionists have answered by adopting a neural metaphor. For example, Rumelhart, Hinton and McClelland assert their poetics very clearly : " We wish to replace the "computer metaphor" as a model of mind by the "brain metaphor" as a model of mind" (McClelland and Rumelhart, 1986 : 75). In fact, in AI the connectionist vocabulary abounds with terms borrowed from neurophysiology, such as *activation*, *inhibition*, *formal neurons*, etc. As a consequence of the admirable simplicity of connectionist systems the metaphor of the brain finds itself considerably weakened : the focus on neurons–"wired" cells par excellence--entails a neglect of glial cells which are more numerous and entirely functional; there is also a total neglect of the hormonal brain whose activity cannot in any way be reduced to the simple propagation of electrical signals. In short, the image of the brain that is presented is basically an outdated caricature.

Here again connectionism appears as cognitivism's complicit opposite : its practioners[52] refuse, if only through their choice of metaphors, to admit the practical and theoretical autonomy of the computational approach since what they seek is an experimental validation of their philosophic presuppositions by means of computer implementation.

The history of the sciences is teeming with metaphors : if nothing else they serve to stimulate theoretical innovations; they also contribute to uncovering just what is at stake ideologically. What is important is never to consider them satisfactory, that is to say, as capable of legitimizing theories *per se* [53].

The cognitivist metaphor *mind --->computer* and the connectionist metaphor *computer --->brain* can be read together so long as one is ready to concede that matter thinks, and secondly, that the breach between mind and brain should be closed. What then of the reciprocal comparison *brain <--->computer* ? This metaphor reveals the secret complicity between the two paradigms, the single difference being that cognitivism wants to think of the brain in the image of the computer and connectionism the computer in the image of the brain[54].

6. The origin of this "complicity" can be traced to the extention of the notion of *information* that presided over the development of cybernetics. In rendering hommage to cybernetics, J.-P. Dupuy summarizes perfectly its fundamental analogism : "in a certain

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[52] With some brilliant exceptions, such as Smolensky (1988), who has demonstrated why connectionist models cannot be said to be neural.

[53] Despite Winston : "Computer metaphors aid thinking. Work with computers has led to a rich new language for talking about how to do things and how to describe things. Metaphorical and analogical use of the concepts involved enables more powerful thinking about thinking" (1977, p. 3)

[54] This is why connectionists like Feldman and Ballard judged them to be "dramatically different" (1982, p. 205). But where is the drama? And why not acknowledge that are strictly incomparable?

sense, yet to be discovered, there is communication between the neurons of neural man just as there is communication between members of the same society, or further that "information" circulates within a computer just as it does between man and computer, or why not, just as it might be able to circulate, in perhaps the not too distant future, within a society of machines[55]" (1985 : 9-10). One is led to concede, as Andler does, that at the very most there are two sorts of *information* : "To our knowledge there are two varieties: the biological and the artificial" (Andler, 1986 : 21).

The two cognitive paradigms are thus confronted with the same dilemma. Either the foundational concept of *information* becomes a rather vague notion designating all forms of communication, and even more broadly, of interaction (even at the biological level), in which case cognitive research risks meeting the sad fate of a certain semiotics (when it left the domain of signs in order to venture onto the terrain of the "genetic code", and even chemistry itself), or the concept of *information* manages to conserve its technical content (in opposition to *redundance*) and so remain pertinent for electromechanical receptors with a calculable capacity. Information conceived in the second case can only be described using the language of mathematical physics. Yet as Andler justly remarks, "what could possibly justify the supposition that the type of information that a given organism chooses to exchange with its environment can also be viewed as a *mathematically rule-governed* configuration of energy exchanges ?" (1986 : 65); and moreover, of *discrete* quanta of energy whose frequency can be calculated ? These notions hardly concur with the actual state of knowledge in biology.

This concept of information, which both paradigms share, is at the basis of their common *functionalism*. Putnam (1975a) defined the notion of functionalism[56] by considering that AI was on the way to realizing its basic projects. Hence machines could find themselves invested with "intelligent functions" and be capable of thinking. Because the real identity between men and machines was deemed not to reside in the *hardware* , Putnam turned his attention to the *software* : all beings capable of intelligence, i.e. machines, men, even Martians, should be capable of performing the same sorts of *programs* [57]. In this sense functionalism provided the possibility of finding a novel solution to the problem of the relations between mind and body.

The notion of functionalism was for a time remarkably popular doubtless because it permitted researchers to give a theoretical formulation to AI's presuppositions. And of course orthodox cognitivism claimed stake in it, most notably in the work of Pylyshyn and Fodor (once a student of Putnam). Partly because they shared the objectives of classical AI, and only differ from it by the means of simulation adopted, the connectionists were never able to criticize functionalism in a convincing way.

Functionalism, although Fodor refrains from it, evidently reformulates a traditional dualism. Transposed onto the philosophic plane, the distinction between *soft* and *hard* repeats the separation of mind and matter, not in a general way but under several kinds of

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[55] This "program" is not yet outdated since, according to Dupuy, it was an important part of the "transversal structure of the Centre National de la Recherche Scientifique (CNRS) whose mandate was to promote the "communication sciences" ".

[56] Not to be confused with functionalism in the sense used by W. James.

[57] He neglects animals--as always in these kinds of debates. Why should the sea slug be refused the computational metaphor (the aplisia dear to the neurosciences) ? Doubtless because it is deprived of intelligent behavior, in the restricted sense of the term, that is to say, reason. Yet, traditionally, reason is one of the soul's attributes. As for the mental states of machines, the reader will be grateful if nothing more is said.

opposition between form and substance (or material substratum[58]). In effect, the "intelligent functions" that are invoked have to do with rational actions or behavior, but the rational is identified with the formal[59].

Functionalism is consequently a kind of formalism[60], that is to say, one of the branches of idealism. Refusing Aristotle's elegant solution of claiming form immanent to substance, the cognitivists maintain a dualism which goes back to the Platonic tradition. The novelty however has to do with the fact that Reason, pure form, transcends the opposition between the natural and the artificial.

Saint Thomas of Aquinas affirmed that "The rational soul is the form of man" (*Summa Theologica* I, 1, 9). Professing a kind of godless scholastic, the orthodox cognitivists have pared the soul down to a single attribute, reason, and affirm that the "intelligent functions" are, considered from the point of view of their formal rationality, common to both man and computers. In short, reason is their common ground and not merely the exclusive asset of man[61].

The duality between form and substance is homologated to other dualities : the mind and the body on the one hand, the symbolic and the physical on the other (particularly in Fodor and Pylyshyn). From these cleavages appear one of orthodox cognitivism's aporias : the dualism that it sanctions bars any correspondance between the symbolic[62] and the physical. Hence Fodor's claim of "methodological solipsism" and Pylyshyn's observation of an irreducible rift between the cognitive (internal) and the physical (external) (cf. 1984 : 166-167). He sees quite justly in this rift an "extremely serious problem". Cognitivism has really no means of verifying whether or not mental representations are adequate to what they are supposed to represent (whereas knowledge is classically defined as *adaequatio rei et intellectus*). It thus finds itself without any criterion of truth, and the associated solipsism signifies the inevitable outcome of its idealistic dualism. Correlatively, the language of standard physics that cognitivism uses to describe the world is incapable of describing what is salient for a given subject, nor is it able to resolve the problem of pertinence (in the broad sense of the term).

It was in the hope of solving some of these difficulties that certain connectionists (cf. Smolensky, 1988) proposed the idea of a *subsymbolic level* that is supposed to play a

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[58] The separation between form and substance is a recurrent theme in Platonic philosophy (for example, Ficino defined heaven as "a self-sufficient form without substance"). This separation certainly had an influence on the Christian tradition for which pure forms were thought to be forms of celestial Intelligence.

[59] This very common reduction is a threat to the social sciences : obliged in practice and in theory to profess a rational discourse they find themselves called upon to produce formal calculations--lest they lose their funding.

[60] Visetti remarks that "in a sense, every science is 'functionalist'. It is an inevitable outcome of any formal approach [...] that seeks to discover the essence of things by way of an objectively articulated characterization. There are thus strong chances that the resulting characterization applies to a category of natural or artificial beings, even ideal ones, much vaster than the one that undertook the study" (1990: 209). But not all science uses a formal approach. As well, how does one manage to secure the descriptive adequacy of a science to its object if the formal approach leads the researcher to exceed the object ? What for example would be the value of a grammar of the Tamang language that would also describe mbay (an African language) or ancient Gascon ?

[61] Form in the sense of Aquinas takes the attributes of being into account and notably what is peculiar to it (here it is reaon).

[62] By *symbolic* we mean not the linguistic but rather the mental states such as they are formulated in a mental language.

mediating role between the symbolic and the physical on the one hand, and the symbolic and the biologic on the other. The orthodox cognitivists aptly retorted that the subsymbolic was but an avatar of the symbolic. Without going into the details of the debate, suffice it to say that these problems have yet to receive satisfactory solutions largely because the connectionists adhere to a functionalism that is indissociable from AI's program and consequently they have not been able to elaborate an alternative to orthodox cognitivism's theory of signification.

This theory of signification rearticulates what is in fact a traditional dualism. For Plato and for Aristotle (at least as he has been interpreted by neo-platonic philosophers such as Porphyrus, Ammonius and Boethius), the sign--or at least what we will agree to call by that name--finds itself split : on one side is the signifier, belonging to the material order; on the other side is the concept which belongs to the irreducible order of the mind. The Church Fathers--and Doctors--most notably Origen and Saint Augustine, reinforced this separation by means of the Paulinian opposition between the letter and the mind, the former being of course of a material nature[63].

This ancient division is rearticulated by the cognitivists in three different but complementary ways : (i) by the separation between sign (i.e. signifier) and concept ; (ii) by the separation of semantics and syntax, syntax being understood as the organization of signifiers and semantics being construed, in a mentalist perspective, as the interpretation (in the logical sense) of these signifiers by means of concepts ; (iii) lastly, since concepts are themselves organized in a mental language, the division between "exterior" language and mental language simply transposes the division between signifier and concept to a higher level. We will examine this in greater detail in chapter 3.

7. Far from being a branch of poetics or philosophy, computer science does not work on metaphors but on the structure and form of data structures. In the end the confrontation between the two paradigms can be reduced to two competing modes of data or information processing (implying differences in means of implementation, and soon, in design types and architecture [64]).

In the preface to the most recent edition (1988 : viii) of their celebrated *Perceptrons* (1969), Minsky and Papert propose the following list of oppositions :

symbolic	*connectionist*
logical	*analogical*
serial	*parallel*
discrete	*continuous*
localized	*distributed*
hierarchical	*heterarchical*
left-brained	*right-brained*

As long as we agree to return the cerebral hemispheres to their rightful place, this list portays well enough the principal differences between the two kinds of treatment[65].

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[63] For a more ample discussion see Rastier, 1987 a, chap. VIII. See as well Origen *On the Principles,* I, 1, 1-2: "Without a doubt the *letter* designates corporeal realities, the *mind* intelllectual ones that we also call spiritual".

[64] Connectionist systems are still implemented on machines that were conceived for other types of application.

[65] With one reservation : although frequently used by connectionists (i.e., Waltz and Pollack, 1985; McClelland and Rumelhart, 1986), the term *parallelism* needs to be clarified because it designates

A sociology of the fields of computer science and AI is no sooner evoked than practical concerns are invoked : connectionism will not have firmly established itself until it is capable of demonstrating a superior efficiency in a wide range of applications. It seems that the gains will likely be made in the domain of automatic perception[66]. Of course one will have to envisage and promote a greater sharing of tasks : for example, it is difficult to imagine an invasion of connectionist calculators onto the consumer market ; and not only a sharing but a peaceful cohabitation that the squabbles between paradigms have only made more difficult.

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an advanced form of sequentiality. Far from escaping algorithmics, parallelism constitutes the end of the end.

[66] It is at least in this area that investment is heaviest, particularly in military programs engaged in refining computerized target recognition systems.