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ABSTRACT A comparison between the development of cognitive science in France and the USA enables us to analyze some national differences linked to specific connections between the scientific, military, economic and political worlds. The influence of new practices and tools developed during World War II and the Cold War appears to be of crucial importance in understanding the development of this new field, as well as that of cybernetics, computer science, artificial intelligence and molecular biology. This paper can be considered as a study in how the differing contexts in France and the USA shaped the history of the construction of cognitive science in each of these two countries. In spite of various differences, some common aspects may be pointed out: in both cases, computer experts and psychologists using a computational modelling approach were those first engaged in the construction of cognitive science. If in France neuroscience-oriented cognitive science research was stronger than in the USA, it seems that the artificial intelligence orientation is also of growing importance in France.

The Emergence of Cognitive Science in France:

A Comparison with the USA

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During the past 20 years, the development of cognitive science has been quite impressive. In this field, the number of scientists, books, seminars, degrees and courses seems to increase daily, but it is very difficult to understand exactly what 'cognitive science' is. This ambiguous term is used by a wide variety of people from different disciplines who aspire to analyze the processes involved in the formation and exploitation of knowledge. Researchers in cognitive science explain that they are interested in studying the mechanisms of the mind: describing, explaining and simulating cognitive functions such as memory, language, learning, reasoning and perception. This interest leads them to propose different theories of the mind.

Defined as 'The Mind's New Science',[1] cognitive science is invested with both strong and vague components, susceptible to multiple appropriations and, because of this, in a state of perpetual redefinition. The recent use of the term 'cognitive' seems to be characterized, on the one hand, by an association of various disciplines, such as artificial intelligence, psychology, neuroscience, linguistics, philosophy and anthropology and, on the other hand, by the use of mathematical expressions to represent cognitive functions. A particular conception of 'psychism' is expressed, the

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basic hypothesis being that 'thinking' is 'processing information'. The multi- or inter-disciplinarity claimed by researchers in cognitive science is not easy to grasp: according to their basic discipline, each person who participates in the development of the domain produces a different discourse corresponding to competing choices. For example, the rhetoric of neuroscientists differs from that of computer experts because of their own training and interests. Some maintain that the study of brain functioning is crucial for the understanding of the cognitive processes,[2] whereas others believe that a functional characterization of cognition can be made independently of the study of the brain.[3] Neuroscientists search for the neurophysiological mechanisms that underlie cognitive functions by identifying molecules and neuronal structures involved in these functions. Computer experts try to obtain intelligent behaviour from a machine or, more precisely, what would be deemed intelligent if it were produced by a human being. This goal is shared by researchers on 'artificial intelligence'. A set of metaphors (machine/organism/man) participates both in constructing the field and in establishing contacts with the political world. The influence of new practices, ideas and tools elaborated during World War II and the Cold War appears to be of crucial importance for understanding how the production of more and more sophisticated machines, capable of assuming intellectual tasks, became an objective, and how this objective was linked to the development of theories of the mind.

Books devoted to the history of cognitive science in the USA refer to the origin of cybernetics and artificial intelligence,[4] but how did these fields develop in France? The aim of this paper is to answer this question, and to compare the emergence of cognitive science in France and the USA.

Psychologists and researchers in artificial intelligence were the first to be interested in building up a new profession around the term 'cognitive'. The professions generated by the construction of this field are not easy to define. Andrew Abbott's theories on the system of professions help us to orient our research toward the study of work, jurisdiction and competition.[5] Indeed, each profession is bound to a set of tasks by ties of jurisdiction, which represent more or less exclusive claims. The subjective qualities of a task are constructed by the profession currently 'holding the jurisdiction' over the task. In their cultural aspect, such jurisdiction claims create these subjective qualities by reference to three kinds of claims: how to classify a problem; how to reason about it; and how to take action on it. In summary, the academic knowledge system of a profession generally accomplishes three tasks: legitimation, research and instruction. The system model described by Abbott recognizes the interdependence of professional development, and emphasizes that the internal structure of professions is one among many determinants. It stresses the fact that external social forces affect professions through many mechanisms, and that tasks are continually changing.

In this paper I analyze the evolution of cognitive science by focusing on the claims of researchers, the interrelations between disciplines, and on the internal and external forces bearing on the system. I have particularly investigated the economic and political context. Because abstract knowledge is the foundation of an effective definition of professions, I have studied how such knowledge is used to annex new areas and to define them as the property of these researchers. Abbott gives an important example:

> Practitioners of artificial intelligence argue that all professional inference follows a certain form, which can be generated by a suitable programmed machine. This is in some sense the ultimate abstraction, reducing all professional inference to one form and all jurisdiction to a single unit.[6]

This type of abstraction allows researchers in artificial intelligence to study cognitive functions, and to propose theories of the mind. Even if cognitive science cannot be assimilated to artificial intelligence because researchers from other disciplines want to participate in this domain, the construction of cognitive science functions to increase the influence and prestige of artificial intelligence. To check this assumption, and to compare the construction of cognitive science in France and the USA, I used a multiform approach.

The paper will be articulated around five points. First of all, I asked who were initially engaged in the construction of this field, and why. A discrepancy of 20 years was evident between the first use of the term 'cognitive' in France and the USA, and so I studied the mechanisms involved in this gap. Like an archaeologist who sees the more recent period first and then goes back to the past, I chose to begin in the 1980s, and then to go back to World War II. For each part of this paper I examined the more recent period first because the use of the term 'cognitive' is recent. I have chosen this approach so as to avoid the methodological trap of a chronological approach which would consider 'cognitive science' as 'given'. Thus, I could show how the history of mathematics during and after the war, and the evolution of cybernetics, computer science and artificial intelligence, all appeared crucially important for understanding this 20-year discrepancy.

Second, I studied intellectual, cultural, political and economic influences of the *Groupe des Dix*, a group composed of scientists and politicians who met between 1969 and 1976. The functioning of this group, and its consequences for the institutional development of cognitive science, enabled me to understand how French cultural resistance was progressively eroded.

Third, because French professional life is often overshadowed by the state, it was important to analyze the institutional history of cognitive science. Studying the institutional process allowed me to identify the types of interrelation and competition between disciplines, and to determine the weight of economic pressures on the orientation of the field towards artificial intelligence.

Fourth, I detailed the abstract knowledge produced by researchers in cognitive science, so as to address the way in which theories and representations have been formulated, and to define the kinds of practice that support such theories, and the main directions pursued by scientists who participated in the construction of cognitive science.

Finally, I addressed the more general question of the construction of a contemporary scientific field by comparing it to the construction of molecular biology. Two types of rhetoric are expressed during the construction of a new scientific field: an emphasis on extreme specialization, or a claim to universality and global vision. The second rhetoric may be an aspect of the first, but with a different emphasis that favours 'fuzziness', so as to extend the power of the domain. Cognitive science belongs to the second type of construction. Two strategies of legitimation may be described. First, the fact that it is difficult to define cognitive science makes 'fuzziness' more important in the field, with its heterogeneous participants. The claim to universality and unified science reminds one of the rhetoric surrounding 'cybernetics'. The effective strategy is not to erect barriers between 'inside' and 'outside', but to make the 'inside' and the 'outside' converge.[7] A new model of scientific organization is proposed, mediated by a universal language and a computational modelling approach. Second, the importance of applied research and links with industry and the military facilitates support for the new field.

This study of the construction of a new scientific field examines the dynamics of different alliances and numerous false starts before the field is stabilized, and focuses on the creation of frameworks delimiting the boundaries of legitimacy. These frameworks are composed of a set of discourses, rules, heuristic principles, representations, models and practices, and an analysis of these frameworks is interesting because it helps us understand how the field's legitimation is negotiated, and how a new conception of Human Nature is developed. I was particularly interested in analyzing the speeches, books, images and work produced by the most active participants in the construction of cognitive science, so as to understand what kind of ideologies they develop, in what sort of cultural environment they live, what arguments they use, how their practices interact with their conceptions, and how their work opens up markets and corresponds to economic claims.

This analysis gave me the opportunity to enter into a world in which information and logic are more important than energy or matter, and living beings are transformed into an abstraction. Cybernetics and artificial intelligence play a crucial rôle in the establishment of this new vision of the world. Because the researchers in these fields built new machines which could operate faster than their human controllers, they were able to interest military and industrial bodies; thus funding was easy to obtain. Researchers in artificial intelligence were able to train more and more students, and convince them of the importance of building machines which could take the place of human beings. They adopted the tools produced by cyberneticians, but chose a different orientation: for them, studying the functioning of the brain was of no use in producing 'intelligent' machines.

The French Attempt to Construct Cognitive Science

In France, the term 'cognitive science' has been used since 1981: the first association of cognitive science, *Association pour la Recherche Cognitive* (ARC), was founded at this time, and was essentially made up of researchers in computer science. Why were computer experts particularly interested in the construction of cognitive science, and why was there a difference of 20 years between the first use of this term in France and in the USA? In 1960, the term 'cognitive' appeared for the first time in the title of an American institutional centre, the Center for Cognitive Studies, founded at Harvard University by two psychologists, Jerome Bruner and George Miller.[8] They wanted to liberate psychology from its behaviourist yoke. To behaviourists, psychology was the study of observable behaviour through measurable and reproducible experiments; they studied responses to stimuli and did not care about internal mental states, considering the mind to be a 'black box'. Miller was interested in mental mechanisms involved in the use of language, and sought a computerized model of a glossary. He considered knowledge to be the manipulation of symbols, and perceived the computer as a good model for the human mind; he wanted to introduce more formal rigour in the social sciences, and tried to integrate computer science and elements of logic and mathematics into his work. His method of research consisted in modelling and formalizing in a language as close as possible to formal logic. This method was also used by members of the French ARC.

In the late 1970s, before the creation of the ARC, a group of French computer experts, psychologists and linguists met on several occasions to develop a theoretical computer science oriented towards the understanding of natural language.[9] Experts in artificial intelligence were faced with the problem of developing computer programs capable of 'understanding' natural language. For them, the goal was to obtain intelligent behaviour from the machine, and they considered the most significant cognitive process to be textual understanding. Financed by the *Institut de Recherche en Informatique et Automatique* (IRIA),[10] these meetings aimed to develop a simulation of expert cognitive activity, already much in use on the other side of the Atlantic. Language understanding, automatic recognition, and acquisition of knowledge by computers were topics discussed in 1977 and 1979. In May 1977, the first meeting, entitled 'Understanding', aimed to 'introduce the interdisciplinary domain of studies on understanding and contribute to the rise of original research in France'.[11] The participants were mainly researchers in computer science (Daniel Kayser, Mario Borillo, Jacques Pitrat, Jean-Pierre Desclès, André Lentin) and psychologists (Jean-François Le Ny, François Bresson, Georges Noizet, Jean-François Richard). Kayser suggested a collaboration with psychologists who were faced with the same problems, but who had a different approach.

Borillo suggested that they use linguistics for theoretical support for automatic treatments of language. In September 1979, the second meeting was devoted to the representation of knowledge and reasoning in the social sciences.[12] The problem was to automate intellectual functions, such as knowledge representation and reasoning.

One of those who participated in these meetings was Gérard Courtieux, a computer expert interested in the creation of systems of computer-assisted design; he concluded the final meeting with remarks on computer science and ideologies.[13] He stressed the difficulties encountered when modelling the behaviour of human beings, and tried to think about the underlying ideological motivations leading to these attempts to rationalize and computerize organizations and society in general. He suggested some elements of such an analysis: the over-evaluation of the tool (the computer); experts' positivism; the absence of theoretical reflections; the deficiency of interdisciplinary communication; the disengagement from politics; the atomized society; the dream of communication between individuals and social groups; the Western endeavour to rationalize; and the American model. He quoted a text by Haroun Jamous and Pierre Grémion, published in 1978:

> The power of the myth of the computer and of the political and economic organizations which develop and favour it, the influence and the increasing persuasive capacity of the expert, the go-between, who tries to enhance his ascendancy, the fascination for the instrument, the prestige that it bestows, the excessive interest in problems of information . . . all these elements may produce a depoliticization of problems, and avoid fundamental political questions . . .[14]

This type of transformation was called the 'computer escape' ('*fuite informatique*') or 'computerization instead of policy'.[15] The idea was that the tool overshadowed the political questions and social choices.

The First Steps toward Artificial Intelligence

At the very outset, artificial intelligence was defined as a confrontation between machines and men. The first steps, in 1956 in the USA, were characterized by the development of computational models, and computer programs designed to produce 'intelligent machines'; this involved the use of high-level programming languages to provide models of various aspects of intelligent activity.[16] The heuristic approach was chosen to resolve any problems, from theorem demonstration to the conception of artificial vision. John McCarthy, Marvin Minsky and Allen Newell, all mathematicians, and Herbert Simon, an economist, played a pre-eminent rôle in the construction of artificial intelligence in America. McCarthy wanted to explore the idea of a finite automaton as an intelligent agent. In 1956, he participated in the Symposium on Information Theory at MIT, with Simon, Newell, the linguist Noam Chomsky and the psychologist George Miller. The same year, the 'Dartmouth Meeting' was held – considered to be the inaugural meeting of artificial intelligence.[17] Mathematicians, psychologists, engineers and economists met in Dartmouth; all agreed that the computer is a good instrument with which to understand intelligence, and that all the features of intelligence can be formally described for simulation by a digital computer. McCarthy proposed calling this new project 'artificial intelligence'; in 1957, he became the first director of the artificial intelligence laboratory at MIT.[18] The success in obtaining funding for this type of research is explained by the fact that studying human–machine interaction, artificial vision and automatic translation interested the US Army at the time of the Cold War. ARPA (the Advanced Research Projects Agency) disbursed important funds for artificial intelligence, and this led to a concentration of resources, enriching the main centres controlled by the pioneers in this field. Most of the funding came from that source.[19]

The presupposition expressed by McCarthy, Minsky, Newell and Simon, that any knowledge could be solely approached in terms of logic, was severely criticized, and gave rise to many discussions.[20] Nevertheless, the project of artificial intelligence – simulating cognitive processes through computers – became the basis of cognitive science. Instead of being absorbed by the established areas of linguistics, psychology, neuroscience and philosophy, artificial intelligence succeeded in generalizing a computational modelling approach now prevalent in cognitive science.

At the Origin of the Differences between France and the USA: The French Mathematicians' Rejection of Logic and Applied Mathematics

During the two meetings in France in 1977 and 1979, the term 'cognitive science' was not yet used, but the participating computer scientists and psychologists began to structure the cognitive science association (ARC) that they eventually founded in 1981. In 1982, at the ARC's first conference, they tried to set up the field of cognitive science.[21] Their ambition was to go back to the main topics of philosophy and treat them with the tools of computer science. However, they lacked influence and did not succeed in obtaining sufficient funds for any important developments in this area. Computer science and artificial intelligence were not considered 'noble' sciences, and computer experts were regarded as technicians.[22] They had less power than some neurobiologists during the same time, even if computer science was considered a national priority by the French government.

If, in the USA, American computer scientists also suffered feelings of inferiority *vis-à-vis* other disciplines,[23] the importance of technology and a pragmatic conception of science constituted propitious grounds for building cognitive science around computer engineering. This was not the case in France, where cybernetics and artificial intelligence have different institutional and intellectual histories. Multiple factors are at the origin of these differences. One is that French mathematicians from the Bourbaki group rejected logic and applied mathematics before, during and after World War II.[24]

It was very hard to develop logic in France for at least two reasons. The first contingent reason includes the untimely death of logicians such as Jean Nicod (1893–1924) and Jacques Herbrand (1908–1931), and philosophers interested in logic such as Jean Cavaillès (1903–1944) and Albert Lautman (1908–1944). The second reason is linked to the fact that Gödel's theorem (1931) bridled the formalist programme, and the Bourbaki group, composed of young and ambitious mathematicians, was hostile to logic.[25] During a meeting in 1934, six young French mathematicians gathered in a Paris café decided to write, collectively, a textbook on analysis because they were dissatisfied with the mathematics teaching they had received, and did not want to use the old textbooks for their students.[26] A few months later, in 1935, they formed 'Bourbaki'. On the basis of the notion of structures, they would construct the foundation of all mathematics with the help of the axiomatic method. Eight booklets were published, essentially devoted to aspects of algebra and topology.[27] If, at the beginning of the 20th century, the theory of functions constituted the main line of French mathematics, after World War II the Bourbaki 'choice' was pre-eminent. From 1950 to 1965, the predominant ideology was embodied by Bourbaki.[28] It succeeded in imposing its conceptions when its founders reached positions of influence. Logic and applied mathematics were disregarded. Only 'pure' mathematics was respectable, and mathematicians were opposed to exchanges with other disciplines and to any direct participation of mathematicians in technological applications.[29] Such mathematical conceptions were poles apart from cybernetics. The contempt of French mathematicians for cybernetics helps us to understand why, if in the USA the cyberneticians included some of the most famous mathematicians, in France the supporters of cybernetics were mainly physicians and scientific journalists.[30]

A Comparison between American and French Cybernetics

As articles, ideas and tools elaborated by cyberneticians are often used by researchers in artificial intelligence or cognitive science, it seems important to analyze this influence. Cybernetics appeared in the mid-1940s in the context of World War II as the result of several meetings between researchers from different disciplines, in particular mathematicians (Norbert Wiener, John von Neumann), neurophysiologists (Warren McCulloch, Arturo Rosenblueth) and electrical engineers (Julian Bigelow).[31] Typical military problems gave rise to cybernetics:[32] together with Julian Bigelow, Norbert Wiener studied mathematical aspects of the guidance and control of anti-aircraft fire, working on the design of control equipment for anti-aircraft guns. They had to conceive an anti-aircraft predictor able not only to locate a plane in order to intercept it, but also to anticipate the pilot's strategy. They came to the conclusion that any solution to this problem was determined by what the servomechanism specialists called 'feedback'.

Feedback was defined as an alteration of input by output. Information was considered as the crucial variable: the information transmitted to the control mechanism makes the difference between the state to be reached and the existing state. The mechanism acts to reduce the difference between the two states.[33]

In order to understand the pilot's strategy better, Wiener contacted neurophysiologists and psychologists. The collaboration of Rosenblueth, Wiener and Bigelow was followed in 1943 by the publication of an article in which the authors described their new representation of control systems, comparing physiological homeostasis, servomechanisms and behavioural processes.[34] Nervous system troubles were compared to mechanical malfunctions, purposeful systems were distinguished from non-purposeful systems, and the purposeful ones were then subdivided into feedback (teleological) and non-feedback (non-teleological) systems. In an effort to erase the distinction between humans and machines, Wiener and his colleagues rehabilitated the terms 'purpose' and 'teleology' by bringing them under the aegis of a 'uniform behavioristic analysis'.[35] Teleology was defined as the study of purposeful conduct that was equally applicable to living organisms and machines.

A paper by Warren McCulloch and Walter Pitts, published in 1943,[36] is also an important reference for researchers in cognitive science. It was often discussed during the Macy Conferences (1946–53), a series of conferences sponsored by the Macy Foundation and organized by cyberneticians.[37] McCulloch and Pitts constructed a mathematical model of neuronal networks based on Carnap's logical calculus and Alan Turing's work on theoretical machines. They considered that 'because of the "all-or-none" character of nervous activity, neural events and the relations among them can be treated by means of propositional logic'.[38] All logical choices were condensed into statements of 'yes' or 'no', and the question of brain functioning was reduced to a logical and physical problem that an engineer could solve. McCulloch and Pitts introduced the idea that logic could be considered as the appropriate discipline to understand brain functioning. The engineers' point of view gained ground: nervous system disorders were compared to mechanical malfunctions;[39] neurons were considered as apparatuses exhibiting two states, either active or inactive;[40] human/machine analogies and metaphors became more frequent; logic and modelization became crucial; any problem was translated in terms of communication and control. When Norbert Wiener published his popular *Cybernetics* in 1948, it became a cult subject for a large audience.[41] Cyberneticians wanted to produce a theory that could be equally applied to animate and inanimate, and to humans and machines. They saw in the principle of feedback the basic mechanism common to different organizational levels. The logico-mathematical formalism was introduced in brain science, and the notion of information treatment was generalized. Information was seen as a measure of organization and control and used in a technical sense without its semantic value, resulting in the erasure of its meaning.[42]

Cybernetics shows multiform aspects, but if we consider the computer engineering route for framing the history of cybernetics, the beginning of computers and the production of new kinds of machines cannot be dissociated from this history. After mechanical and energy-producing machines, machines using and transforming information were conceived: machines resolving mathematical or logical problems, and 'teleological machines' able to pursue goals such as recognizing letters, playing a game of chess and translating languages. All these machines were considered as automata, achieving more or less complex operations without human intervention. In the USA, cybernetics, which emphasized automatism, was closely linked to the military domain. This is exemplified in Wiener's work, as well as in von Neumann's project.[43]

The development of computers was central to von Neumann's strategic and technological objectives. In 1944, he joined the ENIAC Project (Electronic Numerical Integrator and Computer) and formally defined the first machine to incorporate an internal stored program, the EDVAC (Electronic Discrete Variable Automatic Computer).[44] In 1948, von Neumann conceived a general and logical theory of automata.[45] He made detailed comparisons between computing machines and living organisms: machines, like organisms, could use raw materials from their surroundings and transform them into complex and specific matter that made up their parts. Thus a reproducing machine had to be endowed with the ability to transform pieces of matter into machine parts, and to organize them into a new machine. The von Neumann machine possessed a 'nervous system' to provide logical control, body 'muscles' and a genetic 'tail', transmission cells carrying messages from control centres.[46] All these metaphors were borrowed from biology.

At the same time as von Neumann designed machines for military goals, he conceived, with other cyberneticians, a theory of the mind. Indeed, cybernetics was characterized by a will to describe phenomena of mind and behaviour through conceptions derived from the mathematical and physical sciences. Jean-Pierre Dupuy has described cybernetics as 'a physicalistic attempt to conquer the sciences of the mind which provided formal means to think about the category of process without subject'.[47] A mechanistic conception of the mind was proposed: the brain was compared to a computer and the living being to a self-regulated machine. Brain and mind were both machines, McCulloch reasoned; Wiener considered the method for studying organisms and machines to be similar. From the importance attributed to information and its exchange emerged a new vision of the world dominated by the culture of physicists, who search for universal laws, of mathematician-logicians, who think in terms of formalization and modelization, and of engineers, who look for efficiency.

In France, even among physicians and journalists interested in cybernetics, the discourses differed from those produced in the USA. French people were aware of the importance of the new calculators, but they did not appreciate machine anthropomorphism. For example, Albert Ducrocq,[48] a science journalist who constructed an 'electronic fox' during the 1950s, had reservations about the American advertising for the brain calculators:

> It seems that in the beginning there was an unfortunate mistake in principle, because cyberneticians expressed their ambition to demonstrate that the human brain is only an improved mechanism. It would have been better, and more consistent with the spirit of science, to ask the question in these terms: among the functions of the human brain, which of them could be compared to servo-mechanisms?[49]

Whereas Ducrocq explained that 'It is impossible to talk about personality for these machines since the robot is deprived of consciousness',[50] in England, Grey Walter's 'electronic turtles' were described in anthropomorphic terms,[51] and American cyberneticians compared the brain to an electronic calculator.

The mathematician who represented cybernetics in France, Louis Couffignal, was a mechanic-mathematician, and his interests and conceptions differed from those of American cyberneticians. The options chosen by Couffignal did not favour the creation of an electronic calculator. He actually thought that the stored-program architecture was a historical dead-end in the evolution of computing machines. In 1946, the CNRS (*Centre National de la Recherche Scientifique*) founded the *Institut Blaise Pascal* to stimulate research into calculators and create a centre of computation. In 1947, Couffignal, considered as the French specialist in binary algebra, was made director of a CNRS project to construct a great calculator, but he never succeeded in bringing it about.[52] Whereas the first electronic calculators were built in the universities of the USA, England, Germany and Italy before the 1950s, no calculator was constructed in French universities at the same time.[53] Companies such as SEA (Society of Electronics and Automatism) undertook to build computers. Researchers in French universities were not interested in constructing machines, since for them it was not research: they thought that companies should construct machines for researchers. This conception of research was based on a division of work between researchers in the university and industrialists. Couffignal, who was an applied mathematician concerned with technology, entrusted a small company with the construction of a calculator. Unlike von Neumann, he had no personal experience in developing electronic machines.

The meaning of cybernetics was indeed different for Couffignal and for Wiener or von Neumann. Even if, during World War II, a comparable cross-disciplinary curiosity had gathered Couffignal, the mathematician, with the neurophysiologist Louis Lapicque, the relationship between them did not resemble that of Wiener and Rosenblueth. Lapicque wanted to apply the concepts of physics and mathematics to the understanding of the nervous system, and not to the construction of a machine. In 1942, on the initiative of Louis Lapicque, neurophysiologists and mathematicians met together to study the functions of the brain,[54] like American cyberneticians.

Lapicque was opposed to the idea of chemical transmission for nerve impulse. He was a fierce proponent of a solely electrical transmission, and defined a strength–duration curve over time, the 'chronaxie'. It provided a coherent way of describing the excitability of many different types of tissues through the examination of the duration of these curves. Chronaxie was used to measure the effect on the nerves of various agents such as drugs and temperature, and to follow the evolution of degeneration or regeneration processes. By developing a measurement which took a threshold ('rheobase') sufficient to fire the nerve, the chronaxie (which Lapicque explained as 'time-value'), by definition, was an intensity double the rheobase. Using small electrodes of silver to stimulate, one produced what Lapicque termed an 'invariable chronaxie', which meant that the curves of excitability were identical in shape for a muscle and its nerve.[55]

Using the electrical analogy of the nervous system, Lapicque's theory was more than a simple time-duration measurement. It was a grand theory of the nervous system which inspired a great deal of research in France and throughout Europe. From 1903 to 1938, Lapicque had enormous influence, and his theory of chronaxie generated hundreds of papers on the subject. This theory emphasized that only the physical form of the nerve impulse accounts for the nerve transmission. Lapicque had a global vision of the nervous system. Studying the conditions of nerve impulse, he aimed to discover a mechanism of nerve harmony. The functioning of the 'nerve machine' was founded on the law of isochronism (invariable chronaxie) but, in England, the Cambridge School disagreed with this law, since it found that muscle chronaxie changed as a function of electrode diameter. In 1932, W.H. Rushton, a young British neurophysiologist from the Cambridge School, attacked the theory, questioning the significance of chronaxie and, after the war, even Lapicque avoided references to his theory, which was replaced by the new concepts of measurement of action potentials and chemical transmission. Now, the period of chronaxie is described as 'a shameful period of French science'.[56]

In 1952, Couffignal compared the structure of the cerebellum to the diode memories of the Blaise Pascal Institute machine, but his conclusion was:

> The studies we pursued with Louis Lapicque were unsuccessful. The analysis led us to understand that our analogical reasonings failed because these analogies were structural.[57]

The same association of mathematicians and neurophysiologists did not produce the same results in France and the USA. The objective was different. Whereas American cyberneticians used the knowledge of neurophysiologists and psychologists to design new machines, French researchers wanted to use the concepts of mathematics and physics to understand the functioning of the nervous system. They used structural instead of functional analogies. For Lapicque, the nervous system was an electrical machine and he wanted to demonstrate that nerve transmission was only electrical in nature. These differences, and especially the difficulties encountered in France in constructing calculators, had important consequences for the development there of computer science, and therefore for the history of artificial intelligence and cognitive science.

The Development of Computer Science and Artificial Intelligence in France

The French conceptions of mathematics, Couffignal's personality, the misunderstanding between the spheres of universities and industry, and the difficulties encountered in building an efficient industrial ensemble,[58] explain the difficulties in producing calculators in France. With a few exceptions, such as René de Possel (1905–74) and Jean Kuntzmann (1912–92), very few French mathematicians were interested in computation and computers. Jean Kuntzmann played a pioneer rôle in the development of computer science in Grenoble. The interactions between Grenoble University and local industries, and the existence of an engineering school, the *Institut Polytechnique de Grenoble*, stimulated the development of applied mathematics and computation. As early as 1945, Kuntzmann began to teach these disciplines that were not appreciated by other French mathematicians. A computation laboratory was created in 1951, and a cooperative programme with industry and aeronautics services enabled it to obtain funds. In 1957, Kuntzmann initiated the French Association of Calculus (AFCAL) and in 1958, the publication of the review *Chiffres*. In 1960, l'ENSIMAG, a prestigious school for engineering in computer science and applied mathematics, was created in Grenoble, as well as a Centre for the study of automatic translation.[59]

René de Possel was a member of Bourbaki but, in 1941, he left this group and became a Professor of Numerical Analysis at the University of Algiers. In 1957, Jean Coulomb, director of CNRS, asked him to replace Couffignal at the head of the *Institut Blaise Pascal*. De Possel acquired powerful computers, and led the development of teaching of computer science and research in new directions, such as artificial intelligence.[60] De Possel was particularly interested in optical character recognition. Just as the US Army provided funds for research in automatic translation (Russian/American), the French military financed automatic translation (Russian/French).[61] The beginning of computer science in France coincided with the emergence of laboratories in numeric computation, and the use of applied mathematics. Among factors that slowed down this development were the low prestige of the applied sciences, the domination of Bourbaki, and the rivalry between disciplines inside the university. However, engineers needed applied mathematics, and the association between universities and engineering schools in some regions favoured the emergence of computer science in France.[62]

A restricted but very active professional milieu was established around the first calculators. It created associations, reviews and organized meetings. The term '*informatique*' (used for computer science and technology) was created in 1962, and gradually replaced the usual terms 'electronics' and 'automation'. Social and political recognition of this field appeared with the *Plan Calcul* (1966–75) and when masters' degrees were created in French universities in 1967.[63] Daniel Kayser, one of the founders of the ARC, submitted one of the first successful theses in computer science. Two organizations contributed to the development of computer science: the DGRST (*Délégation Générale à la Recherche Scientifique et Technique*), founded in 1959, and the AFCAL association, founded in 1957, which became AFCET (*Association Française pour la Cybernétique Economique et Technique*) in 1968.[64]

Between 1957 and 1970, the advent of the second and third generations of computers led to a marked increase in the market directed towards management applications. It was the period of great programmes (nuclear, space, aeronautics), and the USA took the lead on the world market. European countries perceived this situation as dangerous and regarded computer science as a tool for American domination.[65] Beginning in 1963, European countries reacted against this supremacy, but had a considerable distance to make up. In 1963, in France, the DGRST designated computer science as a priority, and created the concerted action 'Electronic Calculators', dedicated to the financing of joint projects in computer design, programming and use. This soon became a national industrial policy. In 1966, the *Plan Calcul* was created, a great technological programme of the Fifth Republic,[66] conceived for the protection of the French computer industry.

The idea of '*informatique*' as a science took shape between 1965 and 1968. Teachers in computer science fought to establish their field as a reputable science. They tried to secure their students' futures. In fact the latter were not considered as mathematicians, and found it difficult to obtain positions of employment.[67] At the beginning of the 1970s, computer science progressively gained autonomy in relation to other disciplines. More and more laboratories were created within, or in association with, the CNRS. The professional milieu was very active and organized many meetings and conferences. The IRIA, founded in 1966,[68] organized 150 meetings and four international conferences between 1967 and 1969.[69] IRIA and AFCET were involved in the financing and organization of many meetings and congresses related to the problems linked to cybernetics, computer science and artificial intelligence. These organizations constituted meeting places for industrialists, researchers and officials; pressure groups; and producers and disseminators of information. The topics embraced pattern recognition, the understanding of language, knowledge representation, the formalization of reasoning, the development of robotics, and computer-assisted teaching. Two options were sometimes distinguished: 'informatique pratique' and 'informatique théorique'. Researchers in artificial intelligence included themselves in the second option.

In the 1960s, the term 'artificial intelligence' was not often used in France. Research projects in this field were carried out, but this provocative expression was treated with reserve. The archives of the French Ministry of Research contain a document about pattern recognition, dated February 1969, which uses the term.[70] At the same period, in the *Bulletin de la recherche scientifique et technique*, artificial intelligence was defined as . . .

> . . . a field aiming to endow computers with faculties considered as specific to human beings. Two directions gave rise to this new branch of computer science: the study of processes leading to the mechanization of intellectual faculties; the research on models explaining the functioning of the brain and the organs of perception. The problem of pattern recognition is dependent on the first tendency.[71]

Examples of applications of this type of research were listed: optical character recognition, recognition of electroencephalograms, automatic diagnosis, classifying of letters, aerial photography, synthesis and analysis of speaking, and submarine recognition. Precise short-term results were produced by this type of research, and led to the creation of new markets. In October 1978, during a press conference, Pierre Aigrain, who had been the president of the Electronic Committee of the DGRST in the 1960s (the committee that had created the concerted action 'Electronic Calculators'), explained the importance of the interests linked to the 'information revolution':

> The Americans were in fact the first to control computer science and to associate vast technical means with telecommunications. They invested considerable resources in these new ways of treating scientific and technical information in order to achieve economic and commercial domination.[72]

Pierre Aigrain noted a French deficiency in this domain and the necessity of changing this situation, because the American monopoly had 'unacceptable consequences' in the political, economic and scientific fields. Some government initiatives tried to stimulate the development of computer science in France. While in some universities researchers wanted to participate in this action, until the 1980s computer science was neglected by top schools like the *Polytechniques*.[73] Computer experts were considered as technicians for computation centres. Computer science was reduced to a calculation service for other disciplines. The French reserve with regard to computer science and artificial intelligence recalls its rejection of cybernetics. Reservations were expressed with regard to the brain/computer comparison and the consideration of living beings as machines.

France/USA Comparison, and a Focus on Operations Research

If we consider that cognitive science derived from cybernetics and artificial intelligence, we can better understand the differences between France and the USA, and especially the lapse of 20 years between the creation of the first Center of Cognitive Studies at Harvard and the first Association of

Cognitive Science in France. Because of the contempt of French mathematicians for cybernetics, delays in the production of French computers and the use of these tools, the difficulties encountered by researchers in computer science in getting their discipline accepted as a science and not as a technique, and the French reservations with regard to the comparison between men and machines and the excessive language of the American pioneers of artificial intelligence, the simulation of cognitive faculties by computer had a bad reputation in France. The myth of thinking machines was rejected.

The conception of research deepened the gap. Designing computers and promoting the development of computer science were not considered to be 'research'.[74] The culture of mathematicians after World War II exercised an important influence. Whereas American mathematicians were encouraged to participate in the war effort during World War II, French mathematicians were not. Some of them were prisoners who directed their work towards objectives that could not be applied or used by the enemy.[75] After the war, the absence in France of a military and industrial complex (in contrast to America, where its development was directed toward technological warfare) constitutes an important factor for understanding the different developments of cybernetics, computer science and artificial intelligence in these two countries.

World War II altered the character of science in a fundamental and irreversible way. In the USA, the importance of the contribution to the war effort of engineers and scientists, particularly mathematicians and physicists, changed the relationship between scientists and the state. From the mid-1940s to the mid-1950s, a close relationship was developed between scientists and the military. World War II also initiated a revolution in management science. Operations research and its methods were partly responsible for initiating these changes. The objective was to increase efficiency and effectiveness. The first American groups were formed in 1942, and one of these groups included John von Neumann, who brought 'game theory' into operations research. The mixed-team aspect of the groups and the interdisciplinary nature of the effort was to become a distinguishing characteristic of both operations research and systems engineering. Operations research was predominantly an Anglo-American phenomenon.[76]

As Ted Porter observes,[77] the notion of 'objectivity' has prestige mainly as a substitute for trust, and logic and objectivity are most readily expressed by the language of numbers, quantification and mathematics. Whereas logic and applied mathematics (in particular cryptography) provided concepts and tools for launching computer science, these matters were neglected in France. Computers have been powerful tools for computation and applied mathematics. Thus the development of computer science and applied mathematics were tightly linked. Because of the low prestige of applied mathematics in the academic milieu and the rivalry between disciplines, it was only by the end of the 1960s that the French school of applied mathematics began to emerge. During the 1950s and

1960s, French universities succeeded in developing computer science through associations with schools of engineering interested in applied mathematics.[78]

Between 1960 and 1970, American researchers in artificial intelligence (AI) obtained important funds from the military but, after a critical report on automatic translation (the Pierce Report), this funding decreased.[79] More funds came from industry, and the priority shifted to the creation of new markets. Moreover attacks on the foundations of AI came from MIT, one of the major centres of AI research, and from Joseph Weizenbaum,[80] a man who had made an early major contribution to the field. Because of these many criticisms, the status of researchers in AI weakened; they needed to gain respectability in the academic context. Provocative theses became less frequent, and different discourses were produced according to the interlocutors. At that period cognitive science began to develop. The definition of this field was sufficiently vague not to trigger such attacks. As 'operations research' was a term covering a whole range of already known activities, studied and applied under other names, cognitive science picked up different lines of research already followed by other fields, in particular topics covered by the AI rubric. The remarkable fluidity of the definition of operations research, and the lack of precision of its boundaries, are also applied to cognitive science.

The study of the history of cybernetics, computer science and artificial intelligence in France reveals the existence of cultural resistances to these fields but, even if it took a long time, the ideas and tools produced were gradually accepted. Attempts by some scientists and politicians to promote the new technologies played a rôle in this acceptance. To understand how the French contempt for cybernetics, computer science and artificial intelligence gradually disappeared, I studied the *Groupe des Dix*, a group made up of scientists and politicians which met between 1969 and 1976. This informal structure, which favoured exchanges between scientists and politicians, appeared as a first step towards the institutionalization of cognitive science in France.

The *Groupe des Dix* and the Political and Economic Context (1969–85)

The aim of this study is not to stress the scientific and political importance of the *Groupe des Dix*, but to illustrate a series of connections between science and politics during the 1970s which succeeded in creating propitious ground for the development of cognitive science.

The four founders of the *Groupe des Dix* were Robert Buron, a politician interested in productivity and automation; Jacques Robin, a physician and director of a pharmaceutical company; Edgar Morin, a sociologist; and Henri Laborit, a biologist. They wanted to bring together scientists and politicians so as to help politicians make more 'rational' decisions and avoid the 'magical aspect of the political decision'.[81] The group organized meetings and discussed cybernetics, artificial intelligence, information theory, the functioning of the brain and the behaviour of human beings and societies.[82] From its creation in 1969, Jacques Sauvan also participated in these meetings. A long time before, Laborit and Sauvan, who were both physicians, had been attracted by cybernetics and, when the International Association of Cybernetics was founded in 1956, they participated in conferences organized in Namur. Sauvan was employed by the *Société Nationale d'Etude et de Construction de Moteurs d'Avion* (SNECMA) to design autonomous machines able to function without human help.

These pioneers had many aims. For Robert Buron, the essential task of politicians was 'to help to change the world through objective knowledge'.[83] Henri Laborit, who believed that 'scientific elements were removed from all value judgments', said:

> Politics being a human activity, Man being a living organism, why should a biologist, who is essentially interested in the things of life, not have a point of view on the political thing? Man being a living organism who thinks, who is conscious of his existence, why shouldn't the biologist, especially if he is professionally interested in the study of the cerebral mechanisms of consciousness, be useful to political action?[84]

Edgar Morin saw the importance of the life sciences for ensuring mankind's enlightenment in society. For him 'the social sciences establish the great problems of human development but cannot resolve them'.[85] Jacques Robin was the most enthusiastic:

> Biology and the other life sciences now have enough means to be applied to the study of man, his evolution and Society, as well as to the study of man's environment.[86]

The founders of the *Groupe des Dix* wanted to elaborate a theory of the organization of society founded on a better use of knowledge, and believed that the group could participate in the construction of a fair society.

In February 1969, a first meeting with ten people was organized in Jacques Robin's apartment. Others members joined later, particularly Joël de Rosnay, scientific popularizer, and Henri Atlan, a biophysicist. The group had socialist inclinations: Jacques Attali, Michel Rocard and Jacques Delors participated in some of the meetings.[87] Attali was often present and took notes. All the members of the *Groupe des Dix* were very interested in cybernetics: they liked to use its metaphors and analogies, and they often compared biological organization and social structures. Cybernetics reinforced their dream of a global, unified science because one of its aims was to discover universal mechanisms that could be applied to different areas: biology, society, science, economics, politics. Cybernetics helped them conceive of a cooperative, self-regulated society, the ideal image of a classless society based on a rationalization of choices and objective decision-making processes. A member of the *Groupe des Dix*, Jean-François

Boissel, an engineer, was an out-and-out cybernetician. For him, hierarchy would disappear with . . .

> . . . the perfect expression of organization and continuous, complete information: given a system . . . when the goal has been chosen . . . everything or almost everything is determined if we look for the optimal way. Then we need only information. Decision-making becomes a collective activity. No need for a leader. Each member of a company would become a leader, but as everybody would be a leader, there would be no more leaders. This new point of view seems to go with the flow of socialist development throughout the world.

For Boissel, the fusion of science and politics could be achieved through cybernetics, defined as 'the search for an optimal solution in order to obtain a functioning system, whatever the system (machine, human organism or society)'.[88] In these systems, one element was considered to be essential: information.

Members of the *Groupe des Dix* tried to apply cybernetic concepts to society and politics. Twenty years earlier, members of the Macy Conferences had been tempted by this option. Lawrence Frank, a researcher in social sciences and vice-president of the Josiah Macy Foundation, was stirred by the belief that 20th-century social sciences would be able to liberate us from old superstitions. For him, as well as for Margaret Mead and Gregory Bateson, human nature was not fixed but adaptable and changeable. Based on this view of human nature, some of the theoretical concepts provided by cybernetics seemed suitable for modelling people and cultures. Frank's pragmatic faith in the merits of social science expertise took for granted the right and ability of experts to guide the people for their own good,[89] a presumption shared by some members of the *Groupe des Dix*.

Founded within the context of the social and political crisis of May 1968,[90] the *Groupe des Dix* tried to imagine a new society in which science would be a tool to overcome social crisis and ensure efficient social management. Many books written by members of the *Groupe* propounded the idea that the aim of science and technology was to improve the human condition. Beyond this activity, a few members of the *Groupe* succeeded in implementing an important project: the creation of CESTA (*Centre d'Etude des Systèmes et Technologies Avancées*), which aimed at the circulation and promotion of new technologies. Since it organized the first cognitive science national congress, originating government action, CESTA was linked to the development of cognitive science in France. An analysis of the history and the achievements of this *Centre* allowed me to bring to light some political and economic aspects of the construction of cognitive science in France.

In 1981, when François Mitterrand became President of the French Republic, Jacques Attali became one of his advisers and proposed the foundation of CESTA. Influenced by the meetings of the *Groupe des Dix* and aware of the importance of the computing revolution, Attali wanted to create a centre for forecasting and aiding decision-making processes. At that time, the Japanese were planning to implement the fifth generation of computers, called 'intelligent computers', which were supposed to make decisions.[91] In 1982, CESTA was founded with the help of several members of the *Groupe*. At the same time a research laboratory was created, the LDR (*Laboratoire de dynamique des réseaux*), which was engaged in the mathematical modelling of biological systems.[92] In this laboratory, Françoise Fogelman, a computer scientist, used artificial neural networks for the first time in France.[93] Another structure was also created, the CREA (*Centre de Recherche en Epistémologie et Autonomie*), a social science centre affiliated to l'Ecole Polytechnique and directed by Jean-Pierre Dupuy, a philosopher.[94] Both the LDR and the CREA were interested in mathematical modelling and the epistemological status of self-organizing and complex models. In the same way that MIT was the American centre where the abstract knowledge of cognitive science was elaborated, from the 1980s the CREA was the French centre where this knowledge was propagated. The philosophy of language, the links betweeen philosophy and psychology, and the development of cognitive science especially interested the CREA members.

While the CREA group participated in the elaboration of the abstract knowledge of cognitive science in France, the director of CESTA, sociologist Yves Stourdzé, tried to promote the development of new technologies in France. Stourdzé and his team actively participated in the organization of the Versailles Summit in June 1982. At this meeting of the industrialized countries, François Mitterrand suggested dedicating a day to science and technology, to encourage international, technological and scientific cooperation. Following this meeting, a 'Technology, Growth, Employment' group was created including Canada, France, Germany, Italy, the United Kingdom and the USA. Yves Stourdzé was appointed its General Secretary. In January 1983, the group proposed 18 projects in a cooperative initiative involving companies specializing in microelectronics, computers, robots, new energy sources and materials.[95]

Two months later, Ronald Reagan proposed the Strategic Defense Initiative, or 'Star Wars'. Pointing to the USSR as the enemy, he asked scientists to participate in the development of a protection system against nuclear ballistic missiles. He invited the other nations to collaborate with the USA to improve robotics, electronics, artificial intelligence, telecommunications, lasers and biotechnology. Irritated by what he considered as an American injunction to participate in Star Wars, François Mitterrand asked CESTA to propose a topic for an European joint project in civilian research. The work of Yves Stourdzé and his team from 1982 to 1985 resulted in the creation of Eureka (European Research Coordination Agency), an agency established to encourage companies to join the world of new technologies.[96]

In this context, early in 1985, Yves Stourdzé decided to support the organization of the first important congress in cognitive science,[97] called '*Cognitiva 85*: from artificial intelligence to biosciences'. CESTA, in collaboration with ARC and AFCET, succeeded in organizing this important congress in June 1985. The programme committee chairman was Jacques-Louis Lions, the president of INRIA from 1980 to 1983. Many researchers in computer science were present, but very few neurobiologists, such as Jean-Pierre Changeux, were invited. The explicit objective was to bring together diverse experts so as to understand better the functioning of mind, memory, language, learning and perception, and to model and simulate cognitive processes. All problems, from pattern recognition to knowledge representation, were approached through artificial intelligence. No classical neurophysiological work was submitted. In the session devoted to neurophysiology, models of mental states, expert systems for diagnosis, biological modelling, and spatial-ability training using computer games were presented. Other topics included image processing, man–machine communication, robotics, expert systems, language understanding and memory models. On the first day, Allen Newell, a pioneer in artificial intelligence, gave the inaugural talk.[98] During this meeting the construction of cognitive science was clearly centred on artificial intelligence and computer expertise, and members of ARC and AFCET were pre-eminent. After the congress, the popularity and funding of cognitive science increased.

Just before the organization of *Cognitiva 85*, CESTA began to be troubled by political rivalries. At this period Laurent Fabius was Prime Minister (1984–86). Although he belonged to the same party, he did not appreciate Jacques Attali. Considered as Attali's creation, CESTA was attacked. In 1984, the Audit Office was called upon, and its report (delivered in 1985) concluded there had been 'severe anomalies' in CESTA's financial administration.[99] At the same time, the responsibilities of the Eureka project were entrusted, not to Yves Stourdzé, but to the military engineer Yves Sillard, a close collaborator of the Research Minister, Hubert Curien. Moreover, Stourdzé learned he had severe health problems; in December 1986, he died, aged 39 years.

In March 1986, the French parliamentary election gave the right a slight margin of victory: it was the beginning of the 'cohabitation' experience, with a President on the left and a parliamentary majority on the right. Jacques Chirac was Prime Minister. Hostility against CESTA was amplified because of the right wing's resentment. Indeed, CESTA was created after the closure of the Auguste Comte Institute, founded in 1978 by Valéry Giscard d'Estaing. Conceived for an advanced training of a limited group, essentially polytechnicians, this Institute was closed in 1987. CESTA took its place, but with another perspective: it fitted into the image-making policy of the Mitterrand government. It was conceived to shape decision-making, training, forecasting and, essentially, to foster technological choices. Yves Stourdzé was central to this last function. His death, and the many attacks against CESTA by both left and right politicians, led to the dissolution of CESTA in November 1987.[100] However, the dynamic impulse communicated by Yves Stourdzé allowed cognitive science to enter a process of institutionalization.

Institutional Aspects: After a First Step in the Direction of the Neurosciences, Computer Experts Gained Influence (1984–95)

In 1984, CNRS became interested in the emergence of cognitive science. Pierre Papon, its director, asked Dominique Wolton, a sociologist, to write a report on the communication sciences and cognitive science. Later on, several reports were commissioned by the CNRS and the Ministry of Research, to investigate how to use funding to develop cognitive science in France. An analysis of these reports,[101] written between 1984 and 1995, enabled me to follow the institutional development of cognitive science in France. The institutionalization process of this domain is quite different from that observed in the USA. Before dedicating public funds to cognitive science, a large number of reports were requested. This explains the delay in setting up institutional structures. The multiplicity of reports reveals the inefficiency of the authorities when faced with a problem, but also indicates how difficult it is to define a field that includes antagonistic interests. The different reports reveal a clash of interests between those who wanted to structure cognitive science around the study of the brain (neurobiologists) and those who wanted this field to be centred on computing.

The first action taken by CNRS was based on the American definition of cognitive science, because computer science, psychology and linguistics were defined as the core of the field. Dominique Wolton, who wrote the first report, specialized in sociological studies of problems of communication. The report's aim was to stimulate the 'interdisciplinary field of communication' by encouraging research in three directions; neurosciences, cognitive science and social sciences. But in fact, this report seemed to be an attempt to join together 'human and social sciences', on the one hand, and 'engineering sciences', on the other.[102] Wolton identified collaboration between psychologists, linguists and computer experts as essential. He considered the ARC association crucial. In an appendix to this report, Gérard Sabah, a computer expert and president of ARC, defined cognitive science as the result of 'three epistemological revolutions in psychology, linguistics and computer science'. Artificial intelligence was described as central, and 'the aim was to construct computer models of knowledge'. The other disciplines were considered as 'tools' for computer science. Neuroscience was not mentioned by Sabah, and Wolton evoked the rivalry between neuroscience and cognitive science. He blamed neuroscience for considering itself to be the core of the cognitive sciences 'in the name of an analytical and fundamentalist approach'. In fact, if the development of cognitive science took shape around the study of the brain, the social sciences would probably be discarded, whereas a preferential relationship could be woven between computer experts and researchers in social sciences who work on problems of communication (multimedia, image treatment, man/machine interactions, and the like).

If the first report followed the American direction of cognitive science, neurobiology was favoured in 1989 when Jean-Pierre Changeux, a neurobiologist, was commissioned by the Ministry of Research to manage the programme on *Cognisciences*. The most famous French neurobiologist, Changeux is a molecular biologist. He entered the Pasteur Institute in 1959, and worked in Jacques Monod's laboratory with François Jacob. After a study of regulatory enzymes, Changeux became interested in allosteric proteins and cellular control systems.[103] In 1965, Monod, Wyman and Changeux published their research on the allosteric model.[104] In this model, the regulation of cell metabolism relies on the control of enzyme activity. Allosteric properties are a biochemical alternative to the regulatory model of gene action.

Interested in the functioning of the brain, Changeux chose to apply the allosteric model to a neurotransmitter, the acetylcholine receptor. In his 1983 book,[105] Changeux detailed a neuronal theory of thought, establishing a causal relation between structure and function. He described the neuronal membrane as an arithmetic calculator, and suggested the translation of human behaviour in terms of neuronal activities. Changeux was director of a CNRS laboratory devoted to molecular neurobiology at the Pasteur Institute, and Professor at the *Collège de France*; he was thus a powerful member of the scientific community. Widely known in the media, he was regarded as an expert, and a good scientific popularizer. Owing to the success of molecular biology during the 1960s, and his contacts with influential people, Changeux gained trust, responsibility, power, and a multiplicity of positions, which allowed him to influence the direction of cognitive science. He was the president of the scientific committee in charge of the report for the Ministry of Research. No computer science expert was on this committee. The report reflected his conceptions: 'The final goal is the scientific knowledge of the organization and functioning of the brain and especially the most elevated human faculties'.[106] The rôle of computer science was minimized and the ARC association was not mentioned.

However, in 1995, an important change seems to have occurred because, for the first time, a computer expert, Jean-Gabriel Ganascia, was appointed director of the unified programme on the *Sciences de la Cognition*, which included the CNRS, the Ministry of Research, the CEA (*Commissariat à l'Energie Atomique*), the INRIA and, since 1996, the INRETS (*Institut National de Recherche sur les Transports et leur Sécurité*). Since technological transfer and practical applications were more and more in demand, computer experts were in a good position to give precise examples of industrial development (editing, video games, electronic components, robotics, telecommunications, and so on). Ganascia's project seems to have been an attempt to rehabilitate applied research and the status of the engineer. Industrial applications were put forward. Neurobiology was not mentioned. The new system of alliances involved computer experts and industrialists. As in the USA, the field of cognitive science is now centred on computing technologies. Student training in cognitive science confirms this direction: logician-computer experts are moulded with basic notions of psychology, philosophy, linguistics and biology, so as to increase their domain of efficiency, and allow them to apply the same approach – formalization, modelling and simulation of all problems in all domains.[107]

Jean-Gabriel Ganascia is a member of the ARC, and in 1996 published a popular book on cognitive science.[108] Almost all of the members of the ARC actively participated in directing cognitive science towards artificial intelligence. Daniel Kayser, one of the founders of ARC, is now working in a computer science laboratory at the University of Paris-Nord: he is trying to produce a program capable of processing reports written after road accidents, without human intervention. Mario Borillo, another founder of ARC, is also a computer expert: he has participated in a number of conferences in cognitive science, and works at the Institute of Computer Science Research in Toulouse. This institute has many links with aeronautics and aeronautical companies (Matra, Aerospatiale, Airbus, CNES); it has carried out research on the coding of representations in spatio-temporal tasks, mental space representations, and 'performance mistakes'. The links between industry and the military are important. A clear tendency towards applied research echoes the requirements of the government. Indeed, a desire for greater state control and research planning was made clear with the *Consultation Nationale sur les Grands Objectifs de la Recherche Scientifique* launched by François Fillon in 1994. A closer relationship between public laboratories and private companies was strongly recommended, and more and more researchers tend to choose short-term projects, as they find it easier to obtain funding. As funds become scarce for research with no short-term applications, or in fields not considered as high priority, most researchers adapt themselves to the demand.

This analysis of the institutional development of cognitive science shows interrelations with the economic and political spheres. Now, if we turn to recognition in the academic arena, we must examine and understand the theoretical framework of cognitive science.

The Abstract Knowledge of Cognitive Science: The Generalization of a Computational Modelling Approach (1960s–90s)

The study of abstract knowledge produced by researchers in cognitive science is of crucial importance for understanding how old problems are defined in a new way. The theoretical framework elaborated by American researchers was used and popularized in France by the CREA, and by some researchers in artificial intelligence. We saw that Jerome Bruner and George Miller defined knowledge as the manipulation of symbols, and perceived the computer as a good model for the human mind. In 1975, Jerry Fodor, psychologist, philosopher, and researcher in computer science, suggested a model for the functioning of the mind which summarized the favourite theories of cognitivists during the 1960s and 1970s.[109] Thought was seen in terms of an automaton processing input and producing output; the internal state of this system corresponded to our mental states and mental representations. This computational theory of mind and behaviour, and the related notions of persons as 'information-processing systems', was advocated by Fodor, who suggested the existence of a language of thought involving a programmed mind, like a computer.[110]

According to Howard Gardner,[111] psychology and computer science are at the central core of cognitive science, and these two fields are linked, via information techniques, and by cognitivist treatment of knowledge as symbol manipulation. The cognitivist hypothesis, which assumes that cognition is a computation of mental representations, considers that there is an informational equivalence between living beings and machines. From this assumption arose a kind of functionalism, based on material independence and formal equivalence. For these functionalists, it is not the material support but the function that is important. Zenon Pylyshyn, director of the Cognitive Science Center of the University of Western Ontario, considered functionalism as the basic theory unifying the domain,[112] but this assumption is not accepted by all researchers in cognitive science.

Cognitivism and functionalism are linked to analytical philosophy by a common fascination with formalization. Heir to logical positivism, analytical philosophy is interested in formalizing language, so as to reach a logical understanding of thought. The analytical task lies in transcribing a statement into more 'appropriate' terms, a sort of translation within the same language. A regard for formalism leads us to replace scientific objects with syntactic constructions. For cognitivists and functionalists, the brain is compared to a computer and the mind to a program functioning as a system of symbol manipulation. Daniel Dennett, an American philosopher who directs the Center for Cognitive Studies at Tufts University, adopts what he calls a 'top–down' strategy which 'begins with a more abstract decomposition of the highest levels of psychological organization, and hopes to analyze these into more and more detailed smaller systems or processes until finally one arrives at elements familiar to the biologists'.[113] He compares consciousness to the activity of a virtual machine that has taken root in the brain.[114] A new conceptual universe is proposed which produces new metaphors and new images, often inspired by science-fiction; it expresses a new way of conceiving life. The vocabulary used by biologists is entirely redefined: a chromosome becomes a chain of bits,[115] a neuron or a cell an apparatus sculpted from the ultra-tiny quantum transistors. CREA members in France participated in the translation of Dennett's books and in the popularization of his ideas. Cognitive science defined by Dennett looks like a project for the redefinition of categories such as knowledge, intelligence, consciousness, mind and life. It has established a new frame of thought in which mathematical language and computers appear as the most relevant tools for understanding cognitive processes.

Cognitivism is not the only theoretical framework for cognitive science. Since the 1980s, connectionism has gained influence. Inspired by the model described by Warren McCulloch and Walter Pitts in 1943, connectionism takes neural networks as its model. The method consists in building a cognitive system from components connected to each other in just the same way that neurophysiologists describe the architecture of the brain. The idea is that human thought solves problems not by a series of logical deductions but by virtue of complex interactions between micro-units of information.

Research on neural networks was enhanced by Frank Rosenblatt in 1958, when he came up with the 'perceptron', a model of visual perception.[116] This network was arranged in layers of formal neurons. The activity of the retina was simulated by input 'neurons', whereas output 'neurons' classified the features recognized by the system. 'Neurons' from the hidden layer realized an intermediate calculus. Only separable linear functions can be achieved by this architecture. This limitation was stressed by Marvin Minsky and Seymour Papert, who criticized this rival approach to cognitivism in 1969.[117] The pioneers of artificial intelligence disapproved of neural-net theory propagated by cyberneticians. The criticisms were highly elaborated from a mathematical point of view, and came from influential scientists. The neural-net approach was largely rejected for ten years. However, throughout the 1970s, some researchers continued working on neural networks, and this method regained favour from the 1980s, when control of the development of artificial intelligence by an 'élite' was weakened. Dramatic decreases in computing costs brought about a 'democratization' in access to computing resources.[118] As mentioned earlier, Françoise Fogeman, a French computer scientist working in the LDR, was engaged in research on neural networks in the early 1980s.

Whereas computation is sequentially performed in a cognitivist model, it is conducted in parallel without central control as a result of local interactions in a connectionist model. As with cognitivism, connectionism provides a computational modelling approach, but it is better understood by neurophysiologists who find it more suitable for simulating cognitive functions. Connectionists, therefore, are often closer to neuroscientists.

For the philosopher Patricia Churchland, one of the major figures of an American group known as the eliminativists, cognitive science cannot exist without a neuronal theory of mind.[119] Neurophysiology is central to this conception, and psychology and functionalism are criticized. In 1975, Churchland began to adopt these positions in disputes with Fodor, who argued that an understanding of brain functioning was useless for understanding the functioning of the mind. She was convinced that the psychological level was not relevant to a study of the mind, and propounded eliminativist reductionism, which means the reduction of mental states to biological phenomena. This group competes with the cognitivists and disapproves of functionalist positions. It uses the method of neural networks to simulate cognitive functions.

Other currents of thoughts are proposed by researchers who are inspired by phenomenology and its central concept of intentionality. They describe the links between consciousness and phenomena in terms of intentionality, and take perception to be the most representative form of knowledge. A French proponent of this approach is Francisco Varela, a neurophysiologist from the CREA group. He suggests that observer and observed phenomenon define one other; his idea is that cognitive structures emerge from sensory-motor schema, allowing action to be guided by perception.[120]

In spite of this diversity, the most powerful cognitive scientists are still the functionalists, and it is important to analyze their political strategies and rhetorics. The next section addresses this point through a comparison with another major contemporary field: molecular biology.

The Construction of a Contemporary Scientific Field: A Comparison with Molecular Biology

When cognitivists examined the language of biology, they were attracted by the problems posed by biologists but felt an aversion to the biological techniques and methods used, just like physicists at the beginning of molecular biology.[121] Their aim was to redefine problems in terms that would enable them to use their methods and know-how. The cognitivists' objective was to impose an approach originating from their own discipline, and to force biology to be treated by the techniques and tools of cognitive science. Biology was seen as a territory to be conquered. In the 1950s, a number of geneticists and biochemists began to redefine organisms as cybernetic systems, and to rewrite their accounts in terms of information:

> DNA carries the 'genetic information' (or program), and genes 'produce their effects' by providing the 'instructions' for protein synthesis. DNA makes RNA, RNA makes proteins, and proteins make us.[122]

Cognitive science also moved from material and energetic representations of life to informational ones. Molecular biology appeared as a first step in rewriting biology as an information science. After reading Wiener's cybernetics, a few molecular biologists and geneticists found in this new way of looking at life some unifying principles and a powerful interpretative framework. They concluded that genes form the basic element of control within the organism's integrated control systems.[123] Molecular biology initiated a new way of seeing and speaking about organisms (a description of a human being in terms of molecules), and cognitive science a new way of seeing and speaking about the mind. Both used a mechanistic vision in which the human being is compared to a machine, but in one case the machine is made of molecules and, in the other, the material support does not matter, only the function is taken into account.

The rhetoric used by the pioneers of cognitive science, artificial intelligence and molecular biology exhibited the same tendencies. When Francis Crick gave a lecture to the British Society of Experimental Biology in 1957,[124] he expressed, for the first time, the idea that protein folding was a spontaneous process, and that the final configuration was only a function of the order of amino acids. He suggested that the specificity of a nucleic acid was based only on the sequence of its bases, and he formulated what he called the 'central dogma': information can go from a nucleic acid to a nucleic acid and from a nucleic acid to a protein, but never from a protein to a protein, or from a protein to a nucleic acid. As Evelyn Fox Keller notes:

> The crucial point of the central dogma is its insistence on unidirectional causality, its repudiation of the possibility of a substantive influence on genes, either from their external or from their intra- or inter-cellular environment.[125]

The pioneers of artificial intelligence postulated that a human being functions as a universal system of symbol manipulation, and that any knowledge can be explicitly formulated. Mind was considered as a system composed of binary elements of information following formal rules. In 1957, Allen Newell and Herbert Simon claimed that within the next ten years, a computer would be a world chess champion, would discover and prove new mathematical theorems, would write music exhibiting obvious aesthetic qualities, and almost all psychological theories would come in the shape of computer programs.[126] They postulated that human behaviour was managed by programs organized by a system of elementary processes of information treatment,[127] justifying their postulate in terms of a basic methodological principle, the principle of economy: all information processed by the human mind is of the same type as information processed by computer, because this hypothesis is the simplest, and therefore the most economical.[128] As for molecular biologists, simplicity was the 'new credo'.[129]

If the pioneers of molecular biology have played a rôle in reducing the specific properties of living beings to physics and chemistry, the pioneers of cognitive science reduced the mind to a kind of computation, and thus to mathematics and logic – but also to computer science, which allows simulations – the aim being the computing simulation of cognitive functions. If Erwin Schrödinger's book, *What is Life?*,[130] looks like a transfer of new concepts from physics to biology, a physicist's appropriation of heredity mechanisms, books written by the pioneers of cognitive science look like a transfer of concepts from logic and computer science to biology, the appropriation of cognitive processes by mathematicians, logicians and computer experts. Molecular biologists favour a new way of perceiving a living being as a store house and transmitter of information. Researchers in cognitive science use the same reasoning to consider living beings as a set of functions, and functions as information processing, but they have added a new component: functionalists assimilate artificial organisms to living beings, as cyberneticians once did.

In spite of their many common features, molecular biology and cognitive science offer opposing visions of life and competing sets of metaphors. In the one case, everything is reduced to molecules and, in the other, to logic and words. In the late 1980s, Francis Crick pointed out the rivalry between the two conceptions. When he 'decided that the move to the Salk Institute was an ideal opportunity to become closely interested in the workings of the brain', he discovered 'a new subject that called itself cognitive science':

> Some people define cognitive science as studies that take no account of such things as nerve cells. In cognitive science the usual procedure is to isolate some psychological phenomenon, make a theoretical model of the postulated mental processes, and then test the model, by computer simulation, to make sure it works as its author thought it would. If it fits at least some of the psychological facts it is then thought to be a useful model. The fact that it is rather unlikely to be the correct one seems to disturb nobody.

Crick's prejudices were exactly the opposite of the functionalists': 'If you want to understand function, study structure'.[131] Crick was particularly interested in the mammalian visual system, and when he met Patricia Churchland in 1984 at the University of California, San Diego, he appreciated her point of view, because she was interested in molecular and cell biology as he was; but the positions adopted by Churchland are not dominant in the field of cognitive science. The first direction to be followed by researchers in cognitive science was that of cognitivism, which describes cognition as computation, and many studies were devoted to the formalization of language. The influence of logical positivism and analytical philosophy is significant. An attraction towards the study of language, formalization, axioms and postulates, reveals the pervasiveness of this philosophy, focused on the understanding of the meaning of statements. In the 1920s, with the 'Vienna Circle',[132] logical positivism was codified, and Rudolph Carnap was the first to achieve Bertrand Russell's wish to use as a base for physics the method Russell used as a base for mathematics.[133] Even if Carnap was blamed by Quine for confusing problems of logic with those of translation, and signs with objects, this direction was followed by those who have now created cognitive science.

The elaboration of simple schemes and models which reduce the complexity of biological phenomena has contributed to the success of molecular biology. In the same way, simple models which seem to favour a better understanding of cognitive processes are attractive to cognitive scientists. They use an *a priori* method – namely, to construct simplified mathematical models and to try to find general solutions to them. These models look obvious to them because they correspond to the world image reflected by the mass media: in the late 20th century, the computer dominates our imagination; every day, the computer model is exemplified. The 'information revolution' is described as the advent of a new world, and its revolutionary dynamics is attributed, not to the creative power of humans, but to the tool. Communication is considered as essential, even if this communication is without meaning and not correlated with a social object. Just as molecular biology succeeded in imposing a new vision explaining the functioning of living beings in terms of information, memory, code, message and regulation by feedback, functionalists try to assimilate cognitive functions to computer performances, thus eliminating differences between image and object, natural and artificial, virtuality and reality.

Conclusion

This study shows that both in France and the USA the first scientists engaged in the construction of cognitive science were computer experts and psychologists using a computational modelling approach. Some of the protagonists in the new field of computer science, using the tools for formalization they drew from their training in mathematics and engineering, developed artificial intelligence (for those primarily engaged in military projects to improve machines or human/machine interfaces) and cognitive science (for those working in more traditional academic arenas and entrenched in psychological discourse). Neurobiologists began to invest in the construction of the new field of cognitive science 15 years later. Cognitive scientists' claim to study the functioning of the mind by using a computational modelling approach and their functionalist positions provoked the neurobiologists.

For neuroscientists and molecular biologists, cognitive functions cannot be understood without studying brain functioning and the molecules involved in neurophysiological mechanisms. Many critics of this point of view emphasize that human behaviour cannot be described purely in terms of the sequences of organic transformations involved in its production.[134] For researchers into artificial intelligence, cognitive functions are compared to mathematical models, the subject is defined as a unit of functions, and its functions described as information processing. A topic is chosen – knowledge, the mind, or life – and a definition is provided in such a way that the best possible approach to deal with the problem is the one used by logicians and computer experts. This phenomenon tends to increase the social recognition of computing. When it was on its own, computing was considered a technique that could be used in different domains.[135] Integrated into cognitive science, computing became, with artificial intelligence, a *force majeure* which tried to impose the logic of its researchers on its other partners. Artificial intelligence is concerned with constructing devices that can perform complex tasks rapidly and efficiently. As Jeff Coulter says:

> The problem with the proponents of the computational approach to cognition is not their blind faith in technological progress, but their conviction that such progress in computer science alone illuminates the domain of the mental and the material in the study of man.[136]

In an attempt to theorize biology, the proponents of the computational approach to cognition regard formalization and modelization as the final step in what they consider to be 'scientific'. They argue that the computer provides a new technology that covers all of knowledge, and that cognitive science is the abstract representation of that technology.

In spite of common features, this comparison between the development of cognitive science in France and the USA has revealed clear differences in the institutional process. First, the attempt to define and construct a new scientific field only began in France in the 1980s, whereas, in the USA, the first Center of Cognitive Studies was founded in 1960. Second, in the mid-1980s, a French neurobiologist succeeded in orienting cognitive science toward the study of the brain. However, with the establishment of a professional milieu by computer experts, and a political claim for technological transfer and practical applications, cognitive science in France began to follow the orientations of artificial intelligence as it had developed in the USA.

Andrew Abbott's theories on the system of professions allowed me to examine the effects of both internal and external forces on the construction of cognitive science. Among external forces, politics and economic choices play a significant rôle in structuring the field, as the study of the French case illustrates. When politicians became aware that cognitive science could be built around information technologies, which were considered crucial, funding was made readily available. Even if, at the end of the 1980s, a neurobiologist thought he had succeeded in directing research toward the study of the brain, the pressure of international competition led to a concentration on artificial intelligence. A strong correlation is observed between the impact of political and economic pressures and the orientation of science. Conversely, science strongly influences ways of life. Science and technology are integrated in a political strategy and play a prominent rôle in national and international choices. Science and politics seem to be linked through the function of science in resolving problems and creating new markets.

Heir to game theory, cognitive science favours an approach which redefines an object through computer simulation. Is this a revolution, as its protagonists like to claim? Not in the sense used by Thomas Kuhn.[137] It is not a crisis caused by an anomaly, but a fight for the prescription of an approach and a new conception of the world: the important thing is not to discover the mechanisms of nature but to invent nature.[138] If molecular biology has succeeded in imposing a new way of conceiving life, cognitive science seems to be pursuing the same goal in seeing the human individual and the living organism in terms of information exchange, but with a supplementary element: artificial organisms are considered as living beings.

This study of the construction of a new domain has enabled us to analyze some changes in the scientific field since World War II. The influence of cybernetics is significant, as well as the emergence of new rivalries and alliances: just as molecular biologists competed with embryologists after the war,[139] researchers in cognitive science competed with neurobiologists and molecular biologists, while new alliances were formed between computer experts and certain researchers in the social sciences. The goals of science and the position of a researcher are continually being redefined.

Cognitive science, defined as the mind's new science, can be adapted for different purposes. According to their training, practice, and their discipline, researchers involved in the construction of cognitive science define the field in different ways. While they elaborate theories of the mind they define an image of the society they are trying to construct.

Archives

During my study, I consulted the following archives:-

ANF Archives Nationales Françaises (Direction des Archives de France: 60 rue des Francs-Bourgeois, 75141 Paris Cedex 03), including:

- CNRS Archives (Centre des Archives Contemporaines: 2, rue des Archives, Fontainebleau 77300), versement 800284:
  – articles 129 & 141–49; liste des colloques Rockefeller, cybernétique, les machines à calculer (colloque de 1951).

- *Délégation Générale à la Recherche Scientifique et Technique* (DGRST) Archives (Mission Archives Nationales-Recherche: 1 rue Descartes, 75231 Paris Cedex 5), versement 770321 (1960s):
  – fonds RE 130/6, RE 130/12, RE 130/19, RE 130/20 (*Informatique*)
  – RE 130/26 (*Calculateurs*)
  – RE 130/10, RE 130/11, RE 130/32 (*Electronique*)
  – RE 160/22 (*Sommet de Versailles*)

- CESTA Archives (address as for DGRST Archives):
  – RE 292 (*service de publications*)
  – RE 295 (*fonds Feldmann*)
  – RE 297 (*création et dissolution du CESTA*)
  – RE 558 (*préhistoire du CESTA, rapports de Rosnay*)

AGD Archives of the *Groupe des Dix* (Jacques Robin, *Transversales Science Culture*, 21 boulevard de Grenelle, 75015 Paris):
  – Numéro 1 d'*Objectif* 72 (May 1967)
  – Plaquette de présentation d'*Objectif* 72 (1968)
  – Convention Nationale d'*Objectif* 72: 'Sciences de la Vie, Sciences de l'Homme et Politique' (December 1968): Robert Buron, Jacques Robin, Henri Laborit, Edgar Morin (No. 18, supplément Convention Nationale d'*Objectif* 72, December 1968)
  – Séminaire à Chantilly (14–15 February 1970)
  – 'La Science, la Politique et l'Homme', Jack Baillet (September 1970)
  – 'Manifeste pour une Pensée Politique de Fondement Scientifique' (1970)
  – Jean-François Boissel's text, 'Cybernetics and Hierarchy' (7 September 1970)
  – UNESCO meeting, 'Vers la Dépropriation' (19 February 1971)
  – Joël de Rosnay's text: *Vers une Société en Temps Réel* (1 April 1971)
  – *Cahiers des Dix: Vers la Dépropriation?* (March 1972)

- Proceedings of the meeting, *L'Homme et la Société de l'An 2000*, Hénin-Beaumont (22 April 1972)
- *Cahiers des Dix*, 'Agressivité, Violence et Politique' (September 1972)
- Jacques Robin's text for preparing the meeting of the Club of Rome: 'En cette Fin du Néolithique, un Projet pour l'Espèce Humaine: la Société Informationnelle' (22 November 1972)
- Meeting with the Club of Rome: 'La Croissance Économique' (22 November 1972)
- Bulletin spécial du journal municipal *Laval Demain* (1973)
- 'A la Chasse à l'Alibi', Jack Baillet (May 1973)
- 'A propos de la Notion de "Malaise" ', Jacques Attali (16 January 1974)
- 'A propos de l'Équilibre en Biologie Moléculaire', Joël de Rosnay (16 January 1974)
- Letters (1969–76)
- *Science/Culture* letters (1985–89)

INRIA Archives of the *Institut National de Recherche en Informatique et en Automatique* (INRIA) (INRIA Rocquencourt, Domaine de Voluceau B.P., 10578 153 Le Chesnay Cedex):

- Séminaires IRIA, Journées du Travail: 'La Compréhension (acquisition, représentation et utilisation des connaissances)', Arc-et-Senans, 17–18 May 1977 (U508)
- Colloque de Saint Maximin: 'Représentation des Connaissances et Raisonnement dans les Sciences de l'Homme', September 1979 (V543)
- Proceedings of the ARC colloquia, 1982–95 (JJ)

Interviews

I conducted more than 50 interviews during my research, with: members of ARC (computer experts, psychologists and linguists); members of CREA; personalities who were commissioned to write reports on Cognitive Science; neuroscientists; members of the *Groupe des Dix* and/or CESTA; cyberneticians; cognitive scientists; and students in cognitive science. The details (names, places and dates) are as follows.

Members of ARC

Daniel Kayser, Villetaneuse, University Paris XIII, 17 June 1994
Mario Borillo, Paris, 4 June 1996
Jean-Pierre Desclès, Paris, 9, 17 May 1995
Jean-François Le Ny, Antony, 4 April 1996
Jacques Mehler, Paris, 4 May 1994
Serge Nicolas, Paris, 1 September 1994
Michèle Kail, Paris, 16 November 1995

Members of CREA

Jean-Pierre Dupuy, Paris, 20 July 1995
Dan Sperber, Paris, 10 November 1995
Joëlle Proust, Paris, 11 April 1994
John Stewart, Paris, 5 May 1994, 30 September 1994
Francisco Varela, Paris, 10 May, 1994

Reports

Alain Berthoz, Collège de France, Paris, 18 May 1994
Jean-Pierre Changeux, Institut Pasteur, Paris, 1994

Michel Imbert, Louvain-la-Neuve, Belgium, 11 April 1995
André Holley, Paris, 3 March 1995
Jean-Gabriel Ganascia, Paris, 4 May 1995

Members of Groupe des Dix

Henri Atlan, Paris, 10 April 1995
Jacques Attali, Paris, 6 July 1995
Jacques Baillet, Paris, 28 August 1995 & 13 September 1995
Jean-François Boissel, Paris, 17 November 1995
Joël de Rosnay, Paris, 13 March 1995
Alain Laurent, Paris, 28 August 1995 & 26 September 1995
Edgar Morin, Paris, 26 June 1995
René Passet, Paris, 7 April 1995, 8 May 1996, 4 & 17 June 1996
Annie Robin, Paris, 30 January 1996
Jacques Robin, Paris, 10 & 24 August 1995, 21 & 28 September 1995, 5 & 18 October 1995, 8 November 1995, 4 & 11 January 1996, 6 March 1996, 4 & 16 April 1996 & 14 May 1996
Michel Rocard, Paris, 25 July 1995
Jacques Sauvan, Paris, 24 July 1995 & 2 September 1995
Michel Serres, Vincennes, 26 January 1996

Members of CESTA

Eric Barchechath, Paris, 18 June 1996
Annie Battle, Paris, 6 September 1995
Pierre Chavance, Paris, 28 March 1996
Michel Feldmann, Paris, 9 May 1996
Jean-Paul Karsenty, Paris, 15 April 1996 & 13 May 1996

Others

Pierre Aigrain, Paris, 11 July 1995
André Danzin, Paris, 20 October 1995
Jean-Marc Devaud, Isère, 24 March 1994
Pierre de Latil, Paris, 3 July 1995 & 7 September 1995
Jean-Claude Pagès, Paris, 20 October 1995
François Raymond, Paris, 9 August 1995
Michel Rodriguez, Isère, 23 March 1994
Robert Vallée, Paris, 26 September 1995, 21 November 1995 & 22 January 1996

Notes

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1. Howard Gardner, *The Mind's New Science: A History of the Cognitive Revolution* (New York: Basic Books, 1985).
2. See Patricia Churchland, *Neurophilosophy: Towards a Unified Science of the Mind-Brain* (Cambridge, MA: MIT Press, 1986); Paul Churchland, *The Engine of Reason, the Seat of the Soul* (Cambridge, MA: MIT Press, 1995).
3. See Zenon Pylyshyn, *Computation and Cognition: Toward a Foundation for Cognitive Science* (Cambridge, MA: MIT Press, 1984); John Haugeland, *Artificial Intelligence:*

The Very Idea (Cambridge, MA: MIT Press, 1985); Philip N. Johnson-Laird, *The Computer and the Mind* (Cambridge, MA: Harvard University Press, 1988).

4. See Gardner, op. cit. note 1, Part I, Chapter 6; also Jean-Pierre Dupuy, *Aux origines des sciences cognitives* (Paris: La Découverte, 1994), Chapter 2.
5. Andrew Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago, IL: The University of Chicago Press, 1988).
6. Ibid., 102.
7. Geof Bowker, 'How to be Universal: Some Cybernetic Strategies, 1943–70', *Social Studies of Science*, Vol. 23, No. 1 (February 1993), 107–27.
8. For more details, see Gardner, op. cit. note 1, Part I, Chapter 3.
9. Interviews with four members of this group: Daniel Kayser, researcher in computer science (17 June 1994); Jean-Pierre Desclès, mathematician-linguist (17 May 1995); Jean-François Le Ny, psychologist (4 April 1996); Mario Borillo, researcher in computer science (4 June 1996).
10. IRIA was created in 1967 to stimulate the development of computer science, and to encourage exchanges between researchers and industrialists. In 1982, IRIA became INRIA (*Institut National de la Recherche en Informatique et Automatique*).
11. *La Compréhension (acquisition, représentation et utilisation des connaissances)*, Arc-et-Senans, May 1977 [INRIA U508].
12. *Representation des Connaissances et Raisonnement dans les Sciences de l'Homme*, Saint Maximin, September 1979 [INRIA V543].
13. INRIA V543, Gérard Courtieux, 'Informatique et idéologies', 571–78.
14. Haroun Jamous and Pierre Grémion, *L'ordinateur au pouvoir* (Paris: Seuil, 1978), quoted in Courtieux, op. cit. note 13, 577:

    > La puissance du mythe informatique et des organisations économico-politiques qui le développent et le favorisent, l'ascendant et les possibilités de persuasion toujours croissants d'une profession d'intermédiaires qui cherche à croître et à élargir son emprise, la fascination de l'instrument, le prestige qu'il confère, l'intérêt excessif porté aux problèmes de données et d'information . . . la conjonction de tout cela peut conduire à dépolitiser les problèmes et les enjeux, à esquiver les questions politiques fondamentales. . .

15. Courtieux, op. cit. note 13, 577.
16. See Pamela McCorduck, *Machines Who Think* (San Francisco, CA: Freeman, 1979); James Fleck, 'Development and Establishment in Artificial Intelligence', in Norbert Elias, Herminio Martins and Richard Whitley (eds), *Scientific Establishments and Hierarchies, Sociology of the Sciences Yearbook*, No. 6 (Dordrecht: Reidel, 1982), 169–217, at 170.
17. Gardner, op. cit. note 1, Part II, Chapter 6; McCorduck, op. cit. note 16, Chapter 5.
18. McCorduck, op. cit. note 16, 216.
19. Ibid., 110; see also Jon Guice, 'Controversy and the State: Lord ARPA and Intelligent Computing', *Social Studies of Science*, Vol. 28, No. 1 (February 1998), 103–38.
20. Hubert L. Dreyfus, *Alchemy and Artificial Intelligence* (Santa Monica, CA: The RAND Corporation, Paper P-3244, December 1965) and *What Computers Can't Do: The Limits of Artificial Intelligence* (New York: Harper & Row, 1972); Joseph Weizenbaum, *Computer Power and Human Reason: From Judgement to Calculation* (San Francisco, CA: Freeman, 1976).
21. *Domaine et objectifs de la recherche cognitive*, the first colloquium in cognitive science organized by the ARC, Pont-à-Mousson, April 1982 [INRIA JJ].
22. Interviews with French researchers in computer science: Daniel Kayser (17 June 1994), Jean-Gabriel Ganascia (4 May 1995), Mario Borillo (4 June 1996).
23. Stuart Shapiro, 'Boundaries and Quandaries: Establishing a Professional Context for Information Technology', *Information Technology & People*, Vol. 7, No. 1 (Winter 1994), 48–68.
24. See Martin Andler, 'Les mathématiques à l'Ecole normale supérieure au XXe siècle: une esquisse', in *Ecole normale supérieure: le livre du bicentenaire*, directed by Jean-

François Sirinelli (Paris: Presses Universitaires de France, 1994), 351–404; Amy Dahan Dalmedico, 'L'essor des mathématiques appliquées aux Etats-Unis: l'impact de la seconde guerre mondiale', *Revue d'histoire des mathématiques*, Vol. 2 (1996), 149–213.

25. Andler, op. cit. note 24, 376, 384–85.
26. These French mathematicians were Henri Cartan, Claude Chevalley, Jean Delsarte, Jean Dieudonné, René de Possel and André Weil. See Liliane Beaulieu, *Bourbaki: Une histoire du groupe de mathématiciens français et de ses travaux (1934–1944)* (unpublished PhD thesis, History of Sciences Department, Université de Montréal, 1989).
27. Nicolas Bourbaki, *Eléments de mathématique* (Paris: Hermann, 1936). See David Aubin, 'The Withering Immortality of Nicolas Bourbaki: A Cultural Connector at the Confluence of Mathematics, Structuralism, and the Oulipo in France', *Science in Context*, Vol. 10, No. 2 (Summer 1997), 297–342.
28. Andler, op. cit. note 24, 376.
29. André Weil, 'L'avenir des mathématiques', in François Le Lionnais (ed.), *Les Grands Courants de la Pensée Mathématique* (Paris: Cahiers du Sud, 1948, new edn 1986), 307–20.
30. Jacques Sauvan, Paul Cossa, Henri Gastaut and Ernest Huant were physicians who propagated and, sometimes, criticized ideas of cyberneticians in the medical milieu. Albert Ducrocq and Pierre de Latil were scientific journalists, popularizers of cybernetics. Only a few French physicists (Louis de Broglie), mathematicians (Louis Couffignal, Georges Guilbaud, Robert Vallée) and philosophers (Pierre Ducassé, Raymond Ruyer) were interested in cybernetics. In fact, physicists were essentially interested in the information theory.
31. See Steve Joshua Heims, *John Von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death* (Cambridge, MA: MIT Press, 1980), Chapter 9, and Heims, *Constructing a Social Science for Postwar America: The Cybernetics Group, 1946–1953* (Cambridge, MA: MIT Press, 1991), Chapter 2. See also Dupuy, op. cit. note 4, Chapter 2.
32. See Peter Galison, 'The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision', *Critical Inquiry*, Vol. 21 (1994), 228–66.
33. Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine* (Paris: Hermann; New York: John Wiley, 1948), Chapter 4; Warren McCulloch, 'Summary of the Points of Agreement Reached in the Previous Nine Conferences on Cybernetics', Appendix I in Heinz von Foerster, Margaret Mead and H. Lukas Teuber (eds), *Cybernetics: Transactions of the Tenth Macy Conference* (Princeton, NJ, April 1953) (New York: Corlies, Macy & Co., 1955), 69–80.
34. Arturo Rosenblueth, Norbert Wiener and Julian Bigelow, 'Behavior, Purpose and Teleology', *Philosophy of Science*, Vol. 10, No. 1 (January 1943), 18–24.
35. This remark is quoted in Galison, op. cit. note 32, 245.
36. Warren McCulloch and Walter Pitts, 'Logical Calculus of the Ideas Immanent in Nervous Activity', *Bulletin of Mathematical Biophysics*, Vol. 5 (1943), 115–33.
37. See Heims (1991), op. cit. note 31, 41; Dupuy, op. cit. note 4, 41.
38. McCulloch & Pitts, op. cit. note 36, 115.
39. Rosenblueth, Wiener & Bigelow, op. cit. note 34.
40. McCulloch & Pitts, op. cit. note 36, 117.
41. Wiener (1948), op. cit. note 33; Bowker, op. cit. note 7, 108.
42. Lily E. Kay, 'Cybernetics, Information, Life: The Emergence of Scriptural Representations of Heredity', *Configurations*, Vol. 5, No. 1 (Winter 1997), 23–91.
43. See Heims (1980), op. cit. note 31, Chapters 9 & 11.
44. Ibid., 182. See also Kay, op. cit. note 42, 62, and Eloína Peláez, 'The Stored-Program Computer: Two Conceptions', *Social Studies of Science*, Vol. 29, No. 3 (June 1999), 359–89.
45. John von Neumann, 'The General and Logical Theory of Automata', in Lloyd A. Jeffress (ed.), *Hixon Symposium: Cerebral Mechanisms in Behavior* (New York: John Wiley; London: Chapman & Hall, 1948), 1–31.

46. See Kay, op. cit. note 42, 73.
47. Dupuy, op. cit. note 4, 170.
48. Albert Ducrocq was a 'middle-man', a cultural intermediary. As he built machines, he was considered a scientist by the general public and the press. Since 1953, he has managed the French Society of Electronics and Cybernetics, which realized prototypes for industry within the framework of an automation policy.
49. Albert Ducrocq, *Appareils et cerveaux électroniques* (Paris: Hachette, 1952), 135–36:

> Il semble qu'une regrettable erreur de principe ait été commise à l'origine, les premiers cybernéticiens ayant proclamé à peu près officiellement leur but final d'arriver à démontrer que le cerveau humain est seulement un mécanisme très perfectionné. Il aurait été préférable et, en même temps, plus conforme à l'esprit scientifique, de poser le problème en ces termes: parmi les fonctions du cerveau humain, lesquelles relèvent de purs servo-mécanismes?

50. Ibid., 150.
51. W. Grey Walter, *The Living Brain* (London: Gerald Duckworth, 1953), French translation, *Le Cerveau Humain* (Neuchatel, Switzerland: Delachaux & Niestle, 1954), 90–96.
52. See Girolamo Ramunni, 'Louis Couffignal (1902–1966): Informatics Pioneer in France?', *Annals of the History of Computing*, Vol. 11, No. 4 (1989), 247–55 ; Ramunni, 'La non construction du premier calculateur électronique au CNRS', *Cahiers pour l'histoire du CNRS* (1989), Vol. 4, 113–42; and Pierre-Eric Mounier-Kuhn, 'L'Institut Blaise Pascal du CNRS (1946–1969)', *De Bourbaki à la machine à lire, Journée d'hommage à René de Possel (1905–1974)* (Paris: Publications de l'Institut Blaise Pascal, November 1994), 15–29.
53. See Pierre-Eric Mounier-Kuhn, 'L'enseignement supérieur, la recherche mathématique et la construction de calculateurs en France (1920–1970)', paper delivered at a colloquium (Metz, December 1995), in Françoise Birck and André Grelon (eds), *Des ingénieurs pour la Lorraine – Enseignements industriels et formations technico-scientifiques supérieures, XIXe–XXe siècles* (Nancy: Editions Serpenoise, 1998), 251–86.
54. See Pierre de Latil, *La Pensée artificielle* (Paris: Gallimard, 1953), 28.
55. For a full account of the 'chronaxie period', see Joy Harvey, 'L'autre côté du miroir: French Neurophysiology and English Interpretations', and Jean-Claude Dupont, 'Autour d'une controverse sur l'excitabilité: Louis Lapicque et l'Ecole de Cambridge', in *Les sciences biologiques et médicales en France, 1920–1950* (Paris: CNRS Editions, 1994) 71–80, 83–97.
56. Harvey, op. cit. note 55, 71.
57. Louis Couffignal, *Les machines à penser* (Paris: Editions de Minuit, 1952), 94.
58. Pierre-Eric Mounier-Kuhn, 'Le Plan Calcul, Bull et l'industrie des composants: les contradictions d'une stratégie', *Revue historique*, Vol. 290, No. 1 (January 1995), 123–53; and Mounier-Kuhn, 'L'industrie informatique française de 1945 aux années soixante', paper given at a conference on 'Leçons d'Unidata' (Paris, 7 June 1995), in Pascal Griset (ed.), *Informatique, politique industrielle, Europe: entre Plan Calcul et Unidata* (Paris: Editions Rive Droite, 1998), 13–28.
59. For a full account of these developments at Grenoble, see Louis Bolliet, 'Jean Kuntzmann (1912–1992): un extraordinaire pionnier', paper given at the Third INRIA Colloquium (Sophia Antipolis, South France, 13–15 October 1993), in INRIA (ed.), *Histoire de l'informatique* (Sophia Antipolis: INRIA, 1993), 1–3
60. *De Bourbaki à la Machine à Lire, Journée d'Hommage à René de Possel* (Paris: Ecole Normale Supérieure, 1994), 20–23.
61. Pierre-Eric Mounier-Kuhn, 'Calculateurs électroniques et nouveaux systèmes d'armes: interactions armées/recherche/industrie (1946–1959)', in Maurice Vaïsse (ed.), *La IV^{e} République face aux problèmes d'armement* (Paris: Association pour le développement et la diffusion de l'information militaire [ADDIM], 1998), 376–405.

62. Michel Grossetti and Pierre-E. Mounier-Kuhn, 'Les débuts de l'informatique dans les universités', *Revue française de sociologie*, Vol. 36 (1995), 295–324.
63. Jacques Arsac, 'Des ordinateurs à l'informatique', paper given at a colloquium at Grenoble (May 1988), in Philippe Chatelin (ed.), *Histoire de l'informatique en France*, Vol. 2 (Grenoble: Institut National Polytechnique de Grenoble [INPG], 1988), 31–44.
64. See Anne Brygoo, 'L'AFCET et l'informatique', and Colette Hoffsaes, 'Histoire de l'AFCET', in Chatelin (ed.), op. cit. note 63, Vol. 1, 157–66, 269–91.
65. ANF, DGRST, 'Electronique', DIRE, RE 130/11 (1967–68), including several documents: *Le Monde*, 2 June 1966 ('Pour rivaliser avec les américains, la France veut créer une industrie de calculateurs électroniques'); *Electronic News*, 9 October 1967; Rapport du Centre des hautes études de l'armement, section 'Economie', sujet d'études No. III (1967–68), 'Conditions et modalités d'une politique sélective de développement des industries de pointe au sein de l'économie européenne: l'exemple de l'informatique (Pierre Audouin, Yves Lecerf)'. The latter report emphasized the domination of the American computer industry: 'In 1965, 88.5% of exported electronic computers came from the USA. At the end of 1964: 24,500 computers were found in the world, 18,500 in the USA, 6,000 in Europe'. See also Girolamo Rammuni, 'La mise en place d'une politique scientifique', *De Gaulle en son siècle*, Vol. 3 (Paris: La Documentation Française, 1992), 321–83.
66. Pierre Audouin, 'Le Plan Calcul Français (1966–1974)', in Chatelin (ed.), op. cit. note 63, Vol. 2, 13–18, at 13.
67. Arsac, op. cit. note 63, 40–44.
68. Michel Barré, 'La CII dans le Plan Calcul', in Chatelin (ed.), op. cit. note 63, Vol. 1, 85–92, at 85.
69. ANF, DGRST, 'Electronique', DIRE, RE 130/26.
70. Ibid., RE 130/19.
71. Ibid., RE 130/19: *Bulletin de la recherche scientifique et technique* (February 1969), Supplement 1, 133–34.
72. Ibid., RE 130/19: Pierre Aigrain, proceedings of a press conference (October 1978).
73. Jean-Claude Simon, 'L'enseignement de l'intelligence artificielle et de la reconnaissance de forme à l'institut de programmation', in Chatelin (ed.), op. cit. note 63, Vol. 1, 419–24.
74. Larissa Adler Lomnitz and Laura Cházaro reported the same prejudice at work in their Mexican study: L.A. Lomnitz and L. Cházaro, 'Basic, Applied and Technological Research: Computer Science and Applied Mathematics at the National Autonomous University of Mexico', *Social Studies of Science*, Vol. 29, No. 1 (February 1999), 113–34, esp. 'Can Basic Research be Technical?', 117–18.
75. Andler, op. cit. note 24, 384.
76. Michael Fortun and Silvan S. Schweber, 'Scientists and the Legacy of World War II: The Case of Operations Research (OR)', *Social Studies of Science*, Vol. 23, No. 4 (November 1993), 595–642. See also the paper in this issue by Philip Mirowski, 'Cyborg Agonistes: Economics Meets Operations Research in Mid-century', *ibid.*, Vol. 29, No. 5 (October 1999), 505–38.
77. Theodore M. Porter, 'Quantification and the Accounting Ideal in Science', *Social Studies of Science*, Vol. 22, No. 4 (November 1992), 633–52.
78. Grossetti & Mounier-Kuhn, op. cit. note 62, 313–18.
79. McCorduck, op. cit. note 16, 171.
80. Weizenbaum, op. cit. note 20, 200–26.
81. AGD, and interviews.
82. Brigitte Chamak, *Le Groupe des Dix ou les avatars des rapports entre science et politique* (Paris: Editions du Rocher, 1997), 15–23.
83. AGD: Robert Buron, 'L'homme et la société de l'an 2000', paper to group meeting (22 April 1972).
84. AGD: Henri Laborit's talk in December 1968 to a meeting of *Objectif* 72, a political group founded in 1966 by Robert Buron, 2–6, at 2:

> La politique étant une activité humaine, l'Homme étant un être vivant, pourquoi un biologiste, qui par définition s'intéresse aux choses de la vie, n'aurait pas une vue particulière de la 'chose politique'? L'homme étant de plus un être vivant qui pense, qui a conscience de son existence, pourquoi le biologiste, surtout s'il est orienté professionnellement vers l'étude des mécanismes cérébraux de la prise de conscience, ne pourrait pas être utile à l'action politique?

85. AGD: Edgar Morin's talk in December 1968 during the same meeting of *Objectif* 72, 6–8, at 8: 'Les sciences humaines constatent les grands problèmes du développement de l'homme, mais ne peuvent les résoudre'.
86. AGD: Jacques Robin's talk in December 1968 during the same meeting of *Objectif* 72, 9–16, at 12: 'La biologie et les autres sciences de la vie disposent enfin de moyens suffisants pour s'appliquer à l'étude de l'homme, de son évolution et de la Société, ainsi qu'à l'étude de l'environnement de l'homme'.
87. Jacques Attali, polytechnician, was a student in the *Ecole nationale d'administration* (ENA) from 1968 to 1970, and then taught economics at the Ecole Polytechnique; from 1981 to 1991, he was one of François Mitterrand's advisors. Michel Rocard was also a student at the ENA. He was the national secretary of the Association of Socialist Students as early as 1955, and founded the PSU (*Parti socialiste unifié*); from 1967 to 1974 he served as national secretary of the PSU, but then he left the PSU for the *Parti socialiste*. In 1981 he was the Minister for Agriculture, and became Prime Minister in 1988, despite a strong rivalry with François Mitterrand. Jacques Delors was a Christian Democrat who joined the *Parti socialiste* in 1974.
88. AGD: quotes from Boissel's text, 'Cybernetics and Hierarchy' (7 September 1970), 6–7.
89. Heims (1991), op. cit. note 31, quotes at 65, 66.
90. The events of May 1968 emerged from a movement of revolt against the consumer society. Students began to demonstrate on 22 March with leaders from the extreme left, such as Daniel Cohn-Bendit. Because of the harshness of the government's response and the intervention of the police in the universities, demonstration followed demonstration. A general strike started, and both students and workers stated their demands. The social crisis was followed by a political crisis. De Gaulle, the President, was in favour of severe repression, whereas his Prime Minister, Georges Pompidou, tried to play for time. The state was divided and weakened. On 29 May, De Gaulle disappeared for a day. The political crisis ended the following day. De Gaulle denounced what he called 'totalitarian communism'. The left lost the legislative elections in June; De Gaulle won. See Edgar Morin, Claude Lefort and Jean-Marc Coudray, *Mai 1968: la Brèche* (Paris: Fayard, 1968).
91. Tohru Moto-oka, 'Les ordinateurs de la cinquième génération', *La Recherche*, No. 154 (April 1984), 516–25.
92. With Henri Atlan, a biologist, Maurice Milgram and Françoise Fogelman, computer scientists, and Gérard Weisbuch, a physicist.
93. Artificial neuronal networks are a mathematical method for resolving problems based on the network pattern described by neurophysiologists for the brain (components connected to one other without central control): see Mikel Olazaran, 'A Sociological Study of the Official History of the Perceptrons Controversy', *Social Studies of Science*, Vol. 26, No. 3 (August 1996), 611–59.
94. Jean-Pierre Dupuy, Jean-Marie Domenach, Paul Dumouchel and Isabelle Stengers (philosophers), Henri Atlan (biophysicist) and Francisco Varela (neurophysiologist) were among the first members of the CREA. Daniel Andler, a logician, Dan Sperber, an anthropologist, François Recanati, Pierre Jacob, Pascal Engel and Joëlle Proust, all philosophers, entered the CREA subsequently.
95. ANF, DGRST, RE 160/22; CESTA, RE 292, RE 295, RE 297, RE 558.
96. Eureka was created in July 1985 by ministers of 17 countries and members of the European Communities Commission during the European Meeting on Technology:

see Jean-Paul Karsenty, *Analyse socio-économique de la coopération scientifique et technologique européenne – genèse et ambitions d'Eureka* (unpublished PhD thesis, Department of Economics, Paris I University, 1987).

97. In France, the term 'cognitive science' is often used in the plural, whereas it is used in the singular in the USA and the UK, reflecting a will to build a unified science.
98. Newell's talk was entitled 'Architectures for Intelligence: Between the Knowledge and the Symbol Levels' (4 June 1985), in the proceedings of *Cognitiva 85*, CESTA, *Cognitiva 85: De l'intelligence artificielle aux biosciences*, Vol. 1 (Paris: CESTA, 1985), 1–3.
99. ANF, CESTA, RE 297, liasse 297.
100. The Order in Council relating to the dissolution of CESTA (dated 17 November 1987) was published the following day, in *Journal Officiel de la Republique Française* (Paris: Direction des Journaux Officiels, 18 November 1987), 13430.
101. The first report, *Sciences de la communication*, was written by Dominique Wolton in 1985, and published in 1989 by CNRS. The succession of reports on *Sciences cognitives* written in 1989 by Jean-Pierre Changeux, in 1991 by Alain Berthoz, and in 1992 by Bernard Guibert, were requested either by the Ministry of Research or by CNRS. The report *Sciences de la Cognition*, written by Jean-Gabriel Ganascia in 1995, was requested by both the Ministry of Research and CNRS.
102. 'Human and Social Sciences', 'Engineering Sciences', and 'Sciences of Life' are three departments of CNRS.
103. Jacques Monod, Jean-Pierre Changeux and François Jacob, 'Allosteric Proteins and Cellular Control Systems', *Journal of Molecular Biology*, Vol. 6 (1963), 306–29. For an analysis of the 'invention of allosteric regulation', see Angela Creager and Jean-Paul Gaudillière, 'Meanings in Search of Experiments and Vice-versa: The Invention of Allosteric Regulation in Paris and Berkeley, 1959–1968', *Historical Studies in the Physical Sciences*, Vol. 27 (1996), 1–89.
104. Jacques Monod, Jeffries Wyman and Jean-Pierre Changeux, 'On the Nature of Allosteric Transitions: A Plausible Model', *Journal of Molecular Biology*, Vol. 12 (1965), 88–118.
105. Jean-Pierre Changeux, *L'Homme neuronal* (Paris: Fayard, 1983), 134–40.
106. *Rapport sur les sciences cognitives* (1989), copy given to me by Jean-Pierre Changeux, 24.
107. Brigitte Chamak, *Etude de la construction d'un nouveau domaine: les sciences cognitives. Le cas français* (unpublished PhD thesis, History of Sciences, Paris VI University, 1997), 262–6.
108. Jean-Gabriel Ganascia, *Les Sciences Cognitives* (Paris: Flammarion, 1996).
109. Jerry Fodor, *The Language of Thought* (Brighton, Sussex: The Harvester Press, 1975).
110. For a critique of Fodor's fundamental arguments, see Jeff Coulter, *Rethinking Cognitive Theory* (New York: St Martin's Press, 1983), 6–26.
111. Gardner, op. cit. note 1, 89.
112. Pylyshyn, op. cit. note 3, 260.
113. Daniel Dennett, *Brainstorms: Philosophical Essays on Mind and Psychology* (Montgomery, VT: Bradford Books, 1978), 110. For an analysis of Dennett's ideas, see Coulter, op. cit. note 110, 26–33.
114. Daniel Dennett, *Consciousness Explained* (Boston, MA: Little, Brown, 1991), Chapter 6; French translation, *La Conscience expliquée* (Paris: Odile Jacob, 1994), 217–83, at 262.
115. See John Holland, *Adaptation in Natural and Artificial Systems* (Cambridge, MA: MIT Press, 1992), 105.
116. Frank Rosenblatt, 'The Perceptron: A Probabilistic Model for Information Storage and Organization in the Brain', *Psychological Review*, Vol. 65 (1958), 386–408; Rosenblatt, *Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms* (New York: Spartan Books, 1962); see also Olazaran, op. cit. note 93.
117. Marvin Minsky and Seymour Papert, *Perceptrons: An Introduction to Computational Geometry* (Cambridge, MA: MIT Press, 1969), 9.

118. Whereas neural-net researchers were asking for money, critics claimed that progress in neural networks was not possible. Supported by ARPA funding, the initial leading group of AI researchers had a privileged access to economic and computing resources. ARPA's decision not to fund neural-net research appears as an important factor in the rejection of this approach. Some researchers continued working in neural networks throughout the 1970s, but they were displaced from the AI field. Rosenblatt continued his work on perceptrons, but his death in 1971 in a sailing boat accident left the neural-net field without its most charismatic leader. For more details, see Olazaran, op. cit. note 93, and Guice, op. cit. note 19.
119. Churchland (1986), op. cit. note 2, 6.
120. Francisco Varela, *Connaître les sciences cognitives; tendances et perspectives* (Paris: Seuil, 1989), 104; Varela, *Autonomie et connaissance* (Paris: Seuil 1989); and Varela, *Inscription corporelle de l'esprit: Sciences cognitives et expérience humaine* (Paris: Seuil, 1993).
121. See Michel Morange, *Histoire de la biologie moléculaire* (Paris: La Découverte, 1994), 52.
122. Evelyn Fox Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology* (New York: Columbia University Press, 1995), 93.
123. Kay, op. cit. note 42, 44.
124. Francis H. Crick, 'On Protein Synthesis', *Journal of the Society of Experimental Biology*, Vol. 12 (1958), 138–63.
125. Keller, op. cit. note 122, 93.
126. See Herbert Simon and Allen Newell, 'Heuristic Problem Solving: The Next Advance in Operations Research', *Operations Research*, Vol. 6 (January–February 1958), 1–10.
127. Allen Newell and Herbert A. Simon, 'Computer Simulation of Human Thinking' (Santa Monica, CA: The Rand Corporation, P-2276, 20 April 1961), published in *Science*, Vol. 134 (20 December 1961), 9–19.
128. According to a major principle often attributed to William of Occam: do not multiply 'entities' beyond necessity: see the remark by Hubert Dreyfus (1972), op. cit. note 20, on this point: French translation, *Intelligence Artificielle: mythes et limites* (Paris: Flammarion, 1984), 214.
129. Keller, op. cit. note 122, 103.
130. Erwin Schrödinger, *What is Life?* (Cambridge: Cambridge University Press, 1944).
131. Francis Crick, *What Mad Pursuit: A Personal View of Scientific Discovery* (New York: Basic Books, 1988), quotes at 146, 149.
132. The 'Vienna Circle' was founded by Moritz Schlich in 1920. Its members were: Rudolph Carnap, Otto Neurath, Herbert Feigl, Friedrich Weissmann, Edgar Zilsel, Victor Kraft, Philip Frank, Karl Menger, Kurt Gödel and Hans Hahn.
133. Rudolf Carnap, *Der logische Aufbau der Welt* (Berlin: Weltkreis, 1928).
134. See, for example, Weizenbaum, op. cit. note 20, and Coulter, op. cit. note 110.
135. See Fleck, op. cit. note 16.
136. Coulter, op. cit. note 110, 33.
137. Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: The University of Chicago Press, 1962), Chapter 9, esp. 92.
138. For a comprehensive survey, see Christopher Langton, *Artificial Life*, Vols 1 & 2 (San Diego, CA: Addison-Wesley, 1989 & 1991).
139. Keller, op. cit. note 122, 6.

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