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COGNITIVE SCIENCE

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SUMMARY

Cognitive science is the interdisciplinary study of mind and brain, combining the concepts, methods and insights of large parts of psychology, neuroscience, evolutionary biology, linguistics, philosophy, anthropology and other social sciences, and formal methods from computer science, mathematics and physics. It capitalizes on polar oppositions such as function (the cognitive/peceptual/motor/emotional faculties and abilities identified by psychology, linguistics and philosophy) vs form (the biological, mechanical, or formal-computational realizations of these functions); infant vs adult; normal vs inpaired; human vs prehuman, non-human primate and non-primate animal; natural vs artificial; individual vs social/distributed. It is entering a phase of explosive development as neuroimaging techniques bring new methods of evidence-gathering to the field at just about the moment where it has reached a level of integration, sophistication and knowledge which were simply unthinkable when it emerged half a century ago. Cognitive science thus understood is a major challenge and undertaking in pure science for the XXIst century. The potential for applications, in the medical and psychiatric realm, for sensory and motor prostheses, for normal, remedial, and compensatory education, for cognitive, communicative, and decision-making tools is enormous. The impact on individual, social, and cultural practices and self-understanding, with implications in the political, economic, and ethical realms, cannot be underestimated. Finally, the stimulation which cognitive science brings to its core contributing disciplines, and to the general movement of scientific and cultural ideas, is considerable.

Europe, which holds a large part of the responsibility and merit for launching cognitive science and fuelling it with some of its key insights, has of late been lagging behind the US and Japan, and must make a very resolute effort to catch up and remain in the lead, in the face of the increased level of competition brought about by China, which is giving cognitive neuroscience top priority. Europe is motivated to do so, in part for reasons shared with its competitors, in part for reasons of its own, such as the specific problems of a diverse, multicultural, complex, and ageing population. It also has the means to realize this ambition: cutting-edge teams in various areas, strong traditions in the core disciplines, a respect for diversity which has preserved a pool of seminal ideas and active traditions which will be needed in the search for the more sophisticated and differentiated ideas required as the simple intuitions of the early stages no longer suffice, last but not least an excellently trained population of top students. Building a strong European cognitive science is a goal which all the members of the EC can contribute to, as all of them can, and have begun to, promote research in the field, which does not require the heavy artillery of 'big science',

However, there are many obstacles standing in the way, some having to do with the handicaps shared by all of European science, some related specifically to cognitive science, such as, an unfocused perception of its nature and potential in academic institutions and policy-making bodies; the competition of reigning branches in the core disciplines; a less than positive attitude towards interdisciplinary work; a reluctance to change basic organizational patterns, and a generally slow pace in the implementation of innovative policies.

The report recommends a resolutely top-down approach to get European cognitive science off the ground, based on a combination of 'Europeanized' centers of excellence, thematic networks, direct encouragement of pre-identified teams of excellence and the usual competitive call for proposals. It also proposes a number of concrete measures to avoid the perhaps overly-emphasized pitfalls of this policy style. It identifies some of the key areas in which decisive action is needed, either to save islands of excellence threatened with extinction, or to promote work in areas where progress is crucially required. In order to finalize the diagnosis and policy choices to be made, and to conduct an ongoing, proactive application and adjustement of these choices, an assessment of operations in progress, and the planning of the next stages, the report suggests the creation of a High Authority for Cognitive Science in Europe.

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1. Introduction

Cognitive science is undoubtedly the most ambitious scientific enterprise of the XXIth century. To what extent and at what pace it will turn out to meet its goals, what amount and depth of knowledge it will produce as it moves ahead, these are matters for debate. But there is no denying the magnitude of the theoretical developments underway, while the promises for essential societal and economic applications are considerable. Nor is there any reason to believe the present trend will be reversed in the next couple of decades, as the US, already in the lead, Japan, which also benefits from an early start, and now China, are massively investing in the area.

The fact is that Europe, after a promising start, is lagging behind, despite a great tradition in many of the contributing disciplines and some extremely productive teams and institutes in a number of areas. The reasons for this will be analysed in this report, but they include in particular a misperception of the very aim and scope of cognitive science, made worse by the lack of agreement about the proper way to name it. It is therefore important at the outset to provide a working characterization of the field [see also the box on 'Cogsci's many labels', appendix 1].

The scope of cognitive science is nothing less, in general terms, than the mind, or rather, the functions and processes of the mind, which are also, to a large extent, those of the brain. Its agenda, in other words, is that of psychology. However, it is not simply psychology, not even scientific psychology as it developed through the XIXth and first half of the XXth century, it is psychology pursued by novel means, with contributions of disciplines which are also centrally concerned with the mind, and carry with them a set of methodologies which taken together have made it possible to overcome some of the drastic limitations of the traditional programmes in scientific psychology. While psychology has long ceased to be a unified field, cognitive science, by considerably broadening the toolboxes of previous paradigms of scientific psychology, has transformed its ill-formed initial ambitions into a sheaf of connected research programmes, conceptually well-founded, and covering not only the traditional topics of memory, problem-solving, categorisation and the like, but also emotions, social cognition, linguistic competence, perception, action, selfhood, consciousness, etc. The result is that, in contrast with past eras in psychology, knowledge acquired in cognitive science can be exploited and enriched by a whole range of pure and technological disciplines, ranging from computer science, to health science, human and social science, education, law and government, industrial processes, trade, etc. Cognitive science thus stands poised, at the brink of the IIIrd millenium, to contribute to a profound renewal of some of the major scientific and societal pursuits of mankind.

The main contributing disciplines, next to psychology proper, are neuroscience, linguistics, computer science, philosophy and social science ; mathematics and physics provide increasingly important modelling tools. This is true today, as it was when cognitive science emerged, roughly 50 years ago, in a form continuous with its present state. However it has undergone rather profond changes, in internal structure as well as direction, during this half-century, and it is quite important to realize that cognitive science (henceforth, more often than not: cogsci) today looks quite different from the picture which many observers have retained from the 1970-80's. On the one hand, cogsci (whatever other label it might be given in some local traditions) draws its importance and impetus from its ability to include and integrate all seriously tenable scientific approaches to the mind (sometimes called the mind/brain, as a way of indicating that, at a minimum, the mind cannot be studied in complete ignorance of the fact that it is materially realized in, or supported by, human brains). Far from being a mere paradigm, one among several pretenders, it now purports to be *the* scientific field devoted to the topic. On the other hand, cogsci has moved away from some of the choices made in its initial phase; in its present phase, its structure, contributing programs, priorities, relations with neighboring disciplines, are quite different. Details will be provided in §4 below.

One decisive feature of the present situation is the considerable increase, in both absolute and relative terms, of the contribution from neuroscience. Many would say that the emergence of the brain sciences is the major scientific event of the end of the XXth century, and that the premier scientific endeavor of the XXIst century is the deciphering of the brain, both the most complex system in nature, and the most central to our being as individuals, as people and as species. They often go on to say that the rise of cognitive science is nothing over and above the emergence of neuroscience, and they sometimes propose that we no longer use the phrase 'cognitive science' *tout court*, and call the field instead 'cognitive *neuro*science'.

It is quite important to distinguish here what is a mere *verbal* dispute from what amounts to a *substantive* disagreement on the proper, or rather optimal, perimeter of the enterprise.

Most proponents of “cognitive neuroscience” as the most appropriate label agree that the study of the brain includes as a primary goal the study the brain's higher functions, conveniently grouped under the traditional category *mind,* and that other disciplines or subdisciplines, those regularly mentioned as components of cognitive science, play an important role. Here the issue is a verbal one, with a possible variance in emphasis, but no deep disagreement and no untoward strategic consequence.

However there is a more extreme defense of cognitive neuroscience, which consists in denying the centrality of any field outside neuroscience proper. Here the disagreement is on substance and method, not labeling. This exclusive reliance on the resources of pure neuroscience (and more particularly of systems neuroscience, of which cognitive neuroscience is that part which concerns itself with the central nervous system) is in all probability a strategic mistake, as will be argued in more detail further on [see also Appendix 3, 'The structure, function and place of neuroscience in the study of cognition'].

The main point is that cognitive neuroscience cannot fulfill its full ambition without the contribution of the other cognitive sciences, on which it has up to the present point heavily relied, and which it even more crucially needs in order to reach its ultimate goal, *viz.* a scientific understanding of the brain as an integrated system supporting the entire array of the mental functions.

The rise ('Phase I': see §2.c below) of the field under scrutiny in the present report rests, as a matter of historical fact, on this decisive insight. There is a danger, at this juncture (the transition from 'Phase II' to 'Phase III'), that the tremendous growth of new methodologies in the neurosciences, especially functional neuroimaging, whose importance is unquestionable, might entail a loss of essential connections with approaches arising in the other disciplines.

Another connection which has played a crucial part in the emergence of the field and is at risk for opposite reasons is the one relating the study of *natural* cognition to *artificial* cognition (whatever that phrase is taken to refer to exactly). The extreme view, here, consists in identifying the two, and although it was held in the early days of artificial intelligence, it no longer appears plausible. On the other hand, there is a danger of overreacting. and of losing the benefits of a sound interaction. As Wolfgang Bibel rightly insists, and as illustrated in particular by work supported under FP6 by the 'Cognition' Unit E5 in the context of IT (see http://www.cordis.lu/ist/directorate_e/cognition/projects.htm), we should not lose the insight of the founding fathers of cogsci/AI: the fields have common roots and common goals, although they should no longer be seen as necessarily headed for fusion.

In short, the future of cognitive science may well depend on maintaining a balance in which cognitive neuroscience does not take pride of place, in which formal and computational models remain an important source of inspiration, and even more crucially in which a dynamic self-understanding of the tenets, gains and aspirations of the field is maintained through a tradition of interdisciplinary, both constructive and critical, dialogue. The last condition gives particular responsibility to philosophy, which alone has the requisite professional competency [see Appendix 4, 'The function of philosophy in cognitive science'].

However at this very juncture lies what may be a historical opportunity for Europe: Due in part to its strong traditions in all the core disciplines concerned, including philosophy, in part to the very fact that it has accumulated a handicap during the current phase, Europe is in a position to take the lead, or at least to become again a major player, in Phase III, by defending and reaping the scientific and societal benefits of an *integrated, fully interdisciplinary cognitive science*.

Cognitive science: One, several, or none?

Critical reflection on the existence and structure of the field

Few people doubt that such fields as neuroscience, robotics, linguistics together with natural language processing, developmental psychology, psychopathology and psychiatry, prosthetics, computer-based aids, etc., are active areas with a huge economic and societal potential. Presumably far fewer people would be inclined to say the same about cognitive science, despite the fact that the aforementioned fields are immersed in, or intimately connected to, cognitive science.

To a certain extent, this is a verbal matter: there are probably many more people, world-wide, who have some sort of opinion about England and Scotland than there are with thoughts about the United Kingdom. But the verbal issue is part of a larger problem, which will be summarized in the form of a series of five question-answer pairs.

Question 1. Can cognitive science really claim to include all of its participating disciplines?

Answer. Yes and no. Yes, if you are thinking of those parts of these fields which are open to interaction with parts of other fields; in other words, as soon as one does neuroscience, psychology, linguistics, philosophy, anthropology, etc. in an interdisciplinary spirit, and in accordance with a naturalistic style of theoretical inquiry, then one is in effect contributing to cognitive science. No, if by 'participating disciplines' you mean the totality of the 'official' fields of neuroscience, psychology, linguistics, computer science, philosophy, etc. First, there are vast areas, within these disciplines, which are not related in any interesting way (that we can imagine today) to cogsci; second, some approaches are less amenable, for reasons of form or content or both, to interdisciplinary, naturalistic connections with cogsci as currently developed. This can change over the years, and a striking fact is how quickly the cognitive 'virus' has been recently spreading in the traditional disciplines. Among these, psychology and linguistics are the most susceptible to complete absorption in, or (a distinction without a difference) interfacing with, cogsci.

Question 2. But then, does cognitive science do any real work of its own?

Answer. Yes: it is telling people working in all those areas that they are really working on different parts of the same huge object. Cogsci provides the proper framework in which to situate studies conducted on the immense variety of capacities/levels combinations, and it provides a very general principle of articulation of the fragments of knowledge accumulating in many corners of the pure and applied sciences and technology. Something similar was, and still is, achieved by the notion and institution of 'physics', whose function was, and remains, to tell people working on simple machines, on fluid dynamics, on planets, on chemical susbtances, on electricity, on magnetism, on light, on heat, etc., whether as theoreticians, experimentalists, or engineers, that they are in fact working on different areas and levels of what we now call the physical world.

Question 3. Doesn't cognitive science rest, then, on some central, substantive hypothesis, which both explains the added value it seems to bring now, but which also exposes it to the risk of refutation or obsolescence: wouldn't cognitive science go down with this master hypothesis, should the latter fall into disrepute?

Answer. The thought here would be that a substantive hypothesis is needed in order to assert the unity or actual existence of that 'huge object'. It is a fact that several noted thinkers have claimed as much. What we have actually witnessed is how cognitive science, over the last fifteen years or so, has freed itself from allegiances to the substantive hypotheses which launched the field during 'Phase I'. This in no way implies that cogsci has given up on the search for general principles: but it is mature enough to let them gradually emerge in a back-and-forth, give-and-take process of conjectures and refutations, typical of the established natural sciences, rather than hang them on the wall as inviolable rules of the game.

Question 4. Well, then, it seems as if cognitive science is really nothing but a family of more or less loosely related research programs, which only share the fact of having to do with this or that aspect of nervous activity and its products. So why use the singular rather than the plural and not talk about 'the cognitive sciences'?

Answer. A lot of ink has been spillt about the singular/plural issue. In French, the plural is the normal case, the singular (which is rare) denoting an affirmation of theoretical unification which most participants in the field do not endorse. In English, 'science' can be used collectively, as in 'science' *tout court,* or in 'social science', both of which are current and imply no commitment to a unity thesis. This is also the sense in which 'cognitive science' is employed in English, being the most commonly used, neutral phrase (*unmarked*, in the linguists' jargon), whereas 'the cognitive sciences' is *recherché* and indicates an effort to disclaim unity (as a fact or as a horizon) – this had been the editorial choice of the main encyclopaedic effort in the field, the *MIT Encyclopaedia of the Cognitive Sciences.*

Grammar in this instance is too unreliable and variable to serve any useful purpose.

Question 5. Must we then conclude that the cognitive sciences have no unity, no organizing principle, no structure?

Answer. These are not the same thing. Cogsci, plural or singular, has no more, but perhaps no less unity, than the life sciences (especially if these extend to medicine, on one end, and theoretical biology and artificial life, on the other). Cognitive science has a number of organizing principles, comparable to (and in part shared with) those in biology. Finally, it has quite a bit of structure. It has a core, made up of a restricted number of fully interdisciplinary research programs, in which several disciplines jointly lead to a thoroughly novel view of some capacity, a view which can no longer be understood as a mere addition to psychology, or neuroscience, or linguistics, etc., and which opens up new avenues (rather than closing an investigation). Some examples are provided in Section 4.B. Around that core are a number of fairly well-delineated bidisciplinary ventures: classical computer models of reasoning (essentially what AI aims for, in conjunction with computational psychology), cognitive neuroscience (involving basically systems neuroscience and psychology), natural language processing (computer science and parts of linguistics), formal semantics (linguistics and logic), complex-systems physical and mathematical models of neural processes, theories of higher cognition (involving mostly psychology and philosophy), etc. Finally, there is a vast outskirt of mostly monodisciplinary work, immersed in a local tradition, but making contact with, and developed in the spirit of, the more central parts of cogsci.

2. The socio-economic challenge for Europe

a. Pure versus applied cognitive science

We shall distinguish throughout the present report 'pure' and 'applied' cognitive science. The demarcation is not at all sharp or stable, and plays a role mostly in the appraisal of the field as a whole, with a view to policy-making. There are several reasons for holding on to it here:

(i) Over-emphasizing the potential for applications is a constant temptation in the present cultural mood: "What's in it for the economy, for society?" is a legitimate question, for sure, but it cannot be treated separately from: "How much do we need to learn concerning the basic mechanisms before we can develop durable, far-reaching, robust applications?" Premature search in the 60s and 70s for economic and industrial benefits went against the best interests of the burgeoning fields of artificial intelligence (AI), so-called 'intelligently computer-aided instruction' (ICAI), etc. It contributed mostly negatively to the relations between (that part of) cognitive science and the social sciences (with well-deserved criticism for 'tunnel vision', damning estimates of shallow computer models, etc.).

Therefore a primary duty of policy-makers is to reaffirm at the outset the need for a tremendous effort in basic research, which alone can sustain durable applications.

(ii) Fortunately however, just as in other realms of inquiry, the mind/brain need not be thoroughly understood on the theoretical level before we can start deploying available knowledge with a view on specific applications. Such deployment is already underway, and in fact cogsci is beginning to reach a point where parts of it can be put to serious use. In several sectors, we are entering into an era where the basic knowledge secured is enough for making progress in applications, although regarded at the theoretical level, it may in some cases felt to be still very partial or unsatisfactory. The reason for this is that the applications are up till now relying on a purely intuitive, and often deeply mistaken, view of basic cognitive operations in the human agent, a view which the newly available understanding provided by cogsci can correct with considerable gain, being a far better approximation to the phenomenon than the intuitive view, or even the unintuitive view propounded by, say, a computer scientist, an educator, a health professional, an economist, playing amateur psychology or physiology. This kind of dual development pattern is quite familiar from physics and engineering, and from biology and medicine, for example. Much more will be said on this matter, which is rather more intricate in the situation at hand than in these classical examples, in section 3 below. But the simple message here remains: applications can and should be pursued despite the relative immaturity of pure cognitive science.

(iii) But the socio-economic challenge for Europe is twofold. It does not merely consist in developing applications of cognitive science, and reaping the benefits. It also requires taking as full a part as possible in the 'cognitive revolution', *i.e.* in the world-wide pursuit of a scientific description of the mind/brain. Regardless of how *useful* in socio-economic terms this knowledge will turn out to be, not to participate in this major scientific undertaking would have a deleterious effect on the entire European scientific structure: some of the best minds would have to leave Europe to realize their full potential, the participating disciplines would wither in Europe, lacking the stimulus which will propel them forward in the most advanced research areas, etc. In fact, we are unfortunately witnessing something of the sort happening under our eyes; but as we shall see, the trend can be reversed.

(iv) To sum up, basic research in cognitive science is a priority for two distinct though related reasons: it is necessary (though not sufficient) to secure Europe's position in the scientific elite of tomorrow, and it is necessary (though not sufficient) to develop directly beneficial applications in ICTs, health, education, etc.

b. Direct and indirect benefits

Besides the direct benefits which cognitive science can bring, there are important indirect benefits to be drawn from the stimulation which it provides to neighboring disciplines.

Among the hard sciences, the more susceptible are mathematics, computer science and the physics of complex systems. Cognitive science, especially the study of the perceptive and motor functionalities of the brain, raises novel problems for mathematics (see Korn 2003 and Appendix 2). Computer science is trying to gain a better understanding of neural coding and information processing (characterized at the level of neural processes); and of course, as explained in detail in the report on information technology (Bibel 2005), computer science also requires understanding of human information processing (characterized at the higher functional levels) in reasoning, problem-setting and problem-solving, creative thinking, uncertainty management, choice, memory, dialogue and negotiation, natural language processing, etc. to create programs capable of emulating and possibly surpass these human capabilities. Finally, complex systems raise entirely new problems for mathematical physics, and require fresh approaches in model-construction; as nature's most elaborate and adaptive complex system, the brain both requires and suggests novel ideas. Complexity is also at work at higher functional levels, those of the brain's productions, when for example one wishes to understand how beliefs or rumors propagate: the same abstract models apply to this social phenomenon, to the transmission of messages with the help of self-correcting codes, and to constraint satisfaction and phase transitions in a vitreous medium.

Possibly the most drastic changes however will be those undergone by the social sciences. There are immediate contributions of cognitive science to all topics making essential reference to the individual's mental capacities: cognitive economics is an emerging field owing its existence to the search for a more realistic model of the cognitive processes of individual agents and groups of agents; similarly social psychology increasingly seeks inspiration from cognitive psychology (*e.g.* making use of explicit models of so-called automatic mental processes, or of concept acquisition, mastery and recall), and a new field of cognitive sociology is opening up somewhere in between cogsci and sociology. Linguistics is of course central to cogsci, and anthropology was from the start an active participant in the genesis of cognitive science. No matter to which of the sciences of man one turns, from demography to law, from history to paleography, from urban planning to the theory of art, there is an obvious role to be played by a science of mental processes, in the widest sense.

But these lines of inquiry fall on the side of applications or exploitation of cogsci and to this extent really belong to its *direct* benefits. *Indirect* benefits are those which accrue from the sort of *spirit* and know-how which are the hallmark of cogsci: by proposing a very different approach to the human realm, one based, on the side of ontology, on naturalism (the thought that man is part of the natural order, whether seen from phylogeny, from ontogeny or from end-state functioning), and on the side of methodology, on a keen sense of empirical issues and of scientific theorizing. Hard as it is to characterize it in a way which fully informs and convinces outsiders, the fact remains that cogsci brings with it a certain sharpness of vision, a certain robustness, which contrasts with more traditional styles or attitudes prevalent in the sciences of man and society. By no means has cognitive science the ambition or the tools to *replace* these disciplines. It merely invites them to take a fresh look at old problems, and perhaps to let go of some deeply entrenched commitments, such as the assumption of the essentially homogeneous, unstructured initial texture of the human mind, whose distinctive attributes are through and through historically constructed.

c. Three phases in the development of cognitive science

Cognitive science emerged long before its current label was minted, *viz.* roughly sixty years ago (the label was slowly adopted beginning in the late 1960s). Its development has gone through three stages, the third of which has just begun:

- From, roughly, 1945 to 1970, there appeared all the major themes and research agendas which can in retrospect be seen as forming the matrix from which cogsci as we know it emerged. This was the era of the pioneers. We shall refer to this period as *Phase I*.

- From the early 1970s to the end of the 1990s, cogsci underwent a process of quantitative development, accompanied by the formation of academic institutions such as graduate programs, institutes, departments, journals etc. This is what we label *Phase II*.

- In the last few years, cogsci has, on the one hand, shifted its center of gravity towards neuroscience and, on the other hand, reached an explosive stage in qualitative and quantitative increase. This is the dawn of *Phase III*.

Phase I. Europe took off to a very good start. Although the field is often presented as an American invention, and while many of its sources were indeed American, starting with the cybernetics movement (see in particular the Macy conferences (1946-1953), the Hixon symposium (1948)–*cf.* Heims 1991, Dupuy 1994/2000; the emergence of the first computers:

cf. Goldstine 1972, Randell 1982; , the foundation of generative grammar by Chomsky and of artificial intelligence by Minsky, McCarthy, Newell and Simon and others- *cf*. Gardner 1985), in fact the very idea, if not the name, of cognitive science can be traced to European minds, such as the British mathematician Alan Turing and his student Donald Michie, a pioneer of AI and machine learning, the Swiss developmental psychologist Jean Piaget, the Russian social and developmental psychologist Lev Vygotsky, the French biologist and Nobel laureate Jacques Monod ; some of these prominent thinkers were also organizers: Michie set up a world-class center in Edinburgh, Piaget founded in Geneva, as early as 1955, the International Center for Genetic Epistemology (with funds from the Rockefeller Foundation), Monod created the *Centre Royaumont pour une science de l'homme* (which organized, *inter alia*, the famous Chomsky-Piaget encounter in 1975- *cf*. Piatelli-Palmarini 1979). Europe was then at the forefront of research in (what is now known as) cognitive neuroscience and especially neuropsychology, developmental psychology, general cognitive psychology, generative linguistics, robotics, neurophysiology, mathematics for complex systems, a form of pre-cognitive, naturalistic anthropology, experimental economics, etc. It was essentially free of the American obsession with behaviorism and the generally anti-theoretical stance of many American research programs in psychology and the social sciences. It also had developed strong views on the necessary integration of disciplines, and included antidotes to the 'tunnel vision' which was to dominate the field in the subsequent phase, by emphasizing the importance of social and cultural factors in development.

Phase II. In the US, two foundations, the Sloan and the Systems Development Foundations, gave out large grants (over 17 million dollars for Sloan, 26 for SDF) during the decade 1977-1987 to a number of academic centers for setting up interdisciplinary institutes in cognitive science (examples are: The Center for the Study of Language and Information (CSLI) in Stanford; the Institute for Cognitive Studies in Berkeley; various structures at UCSD, MIT, Penn, Northwestern, Carnegie-Mellon, Yale, U. Texas at Austin,...). The NSF and the DOD also made large funds available for pure and applied cognitive science, which allowed departments of psychology, brain science, linguistics, computer science, physics, electrical engineering, applied mathematics to expand in the direction of cognitive studies, in particular to bias their hiring policies in favor of scientists with an interest in cognition. Philosophy got interested to the point where soon philosophy of mind, with its close associate philosophy of language, became the most active branch in many departments, displacing philosophy of science. Interdepartemental graduate programs in cogsci were set up, as there was clearly an opening on the academic market, as well as in innovative sectors of industry (man-machine interface, natural language processing etc.) The University of California at San Diego went as far as to create an entire department of cognitive science in 1986. Similarly, Japan, prompted in part by an ambitious vision of AI (the so-called 'Fifth Generation'), in part by a strong tradition in robotics, in part by an interest and know-how in the brain sciences, set up powerful centers such as the Riken Brain Science Institute (Riken BSI) in 1997. More recently, the McDonnell-Pew Foundation has devoted considerable resources to the development of cogsci in English-speaking countries.

Meanwhile, in Europe, similar developments were taking place, but on a considerably smaller scale, and at a slower pace. The two main factors which prevented cogsci in Europe from gaining the sort of dynamics which it was acquiring elsewhere are, first, the reluctance of funding sources to divert serious amounts of money away from the established disciplines, and more generally the lack of mobility of the national scientific communities; and second, the specific resistance put up by the establishments within each discipline against the cognitive turn which some in the discipline wanted to take. Cogsci had for a long time a rather poor reputation in many scientific subcommunities, and those, near the top, who were inclined to favor it, were outnumbered. We'll take a closer look at this resistance in the next section, as it is far from having entirely subsided.

What did save European cogsci, to such an extent that, despite its relative weakness, it remains a major player on many fronts, was a combination of factors, mainly:

(i) The traditions developed during Phase I, in limited circles, were kept alive and renewed locally by small interdisciplinary groups, often led or encouraged by philosophers (*e.g.* The Centre for Research in Cognitive Science in Sussex, CREA in Paris, The Cognitive Science Center at the University of Amsterdam, the center in cognitive science at Lund University in Sweden, an homonym concentration at the University of Barcelona, etc.); connected with this, journals such as *Cognition,* edited in Paris, and learned societies, such as the European Society for Philosophy and Psychology, founded in the early 1990s by a mostly Franco-British group, helped scholars and students think of their work as fitting most naturally in the framework provided by cogsci;.

(ii) A decisive orientation towards cutting-edge cogsci was taken by some first-class centers in one or the other of the contributing disciplines (*eg* psychology, especially in Britain; neuroscience, especially in Germany, France and Italy; linguistics, especially in France, Italy and the Netherlands, soon followed by Germany; logic and computation, especially in Britain, the Netherlands and France; etc, -- these are not meant to constitute an exhaustive or exact list; in fact, many of these centers were isolated in their own country, and existed as *de facto* nodes in informal European and international networks).

As a prime example one can mention the enormous expansion of comparative linguistic studies that took place from the late seventies in connection with the introduction of Principles and Parameters models of language invariance and variation (Chomsky 1981) . Far from offering mere contributions of descriptive linguistics, this direction of research is an integral part of the study of language as a biologically determined cognitive capacity, as the precise identification of language invariance and variation is an essential component of the study of the biological bases for language. The fundamental idea is that the biological endowment expresses a universal architecture for language, named Universal Grammar. This system contains parameters, binary choice points, which express the possible linguistic variation. A particular language is Universal Grammar with parameters fixed in specific ways. This approach offered a powerful and flexible tool for language comparison, and comparative studies quickly flourished. The Parametric model was developed in Europe as much as in the US, as the publication flow show; the initial impulse for the European development came from France, Italy and the Netherlands, and then comparative studies developed all over Europe. Ever since the late seventies, a European association, GLOW, holds an international annual meeting which has set the standards for this direction of studies. The main reference textbooks (Haegeman, Radford) have been produced in Europe.

(iii) On a much broader scale, the role played by Britain, which alone in Europe was able to develop strong programs in nearly every area of cognitive science, but especially in cognitive psychology and cognitive neuroscience, as well as computational models and philosophy.

Phase III. Several phenomena coalesced towards the end of the 1990s and led to an explosive development of cogsci worldwide:

(i) Cogsci's success during Phase II, unhindered by failures or competition, followed an exponential curve which reached a critical point around that time;

(ii) Neuroscience took possession of new imaging tools which opened up a new frontier towards which literally tens of thousands of scientists converged;

(iii) Cogsci was finally perceived as an unequalled source of inspiration for several basic disciplines, on the one hand, new technologies on the other (*cf,* the

'NBIC' movement: Nordmann 2004, Roco & Bainbridge 2001). Correlatively, cogsci opened up internal frontiers and released a number of scientists, mostly of the younger generations, from the strictures imposed by a misplaced sense of loyalty to their discipline.

(iv) The Asian giants (Japan, China, India) decided to give priority to cogsci (not necessarily under that name) and threw in, or announced their intention to invest, some immense resources in the field.

Europe is now at a distinct disadvantage. Despite the efforts deployed during Phase II, it seldom succeeded in creating world-class centers large enough to reach critical mass, to attract a high enough proportion of the very best students, and to federate all the relevant disciplines and paradigms. The number of technological platforms and sophisticated equipment is way below target. The best young scientists, often Europeans with an extensive international experience, have all too many professional reasons to choose North America, Australia, Japan over Europe to take root and found labs and schools. Some of the most innovative traditions are dying out without replacement. The barriers between pure and applied research are still in place in several, though not all, the old scientific leading nations. The European Community, held back by the subsidiarity principle, was unable to make up for the lack of determination of national policies. It also overemphasized finalized programs in areas which were insufficiently theory-intensive to lead to durable progress, at the expense of vastly more promising and less costly basic research.

These negative factors have common roots, which will be explored in the next section.

d. Facing up to the global challenge

Europe, thankfully, has not lost so much ground that it cannot catch up in a few years. It can count on many excellent groups which simply need better working conditions, including financial resources, in order to attain world-class visibility. There is already a lot going on, and Europe's forces in certain areas are a tremendous asset. There is an enormous interest in cogsci among the new members of the Community. Despite standards of professional living which are, on average, way below the US, many American and other non-European scholars choose Europe as their base, finding there not only well-identified advantages in terms of quality of life, but also a milieu hospitable to ideas which are not sufficiently (or not at all) represented elsewhere, as well as excellent students who are only waiting to be attracted to the field. European labs train a sizeable number of US and other non-Europeans doctoral students. The US, Australia, Japan hire European PhDs routinely.

What needs to be realized is the global challenge raised by the international race towards an understanding of the mind/brain, at a juncture where the life sciences, the modelling sciences and the social sciences have finally discovered methods, concepts and ideas which ground an entirely novel style and depth of collaboration. The error which must be avoided at all cost is to mistake the part for the whole: pleas for neuroscience, pleas for ICT, pleas for robotics, pleas for prosthetic medicine, pleas for scientific mental healh care, pleas for a renaissance of the social sciences, all such pleas are delivered and heard. What is still missing is a sufficient awareness of the proper scale and context of these legitimate arguments: cognitive science appropriately construed.

What is lacking at this point, at both national and European levels, is a proper sense of the priorities involved. Cognitive science is no less important than genomics and post-genomics, or high-energy physics, or cosmology, or durable development, and it is either much cheaper or much more feasible or both. It is an area in which some countries will emerge winners, and some will be left on the side. Europe has every reason to be among the winners.

It has the *justification:* cognitive science holds the key to many knowledge-intensive activities; in fact, it is almost a truism that the *knowledge society* should have *cognition* as a top priority *(almost* because as stressed in this report, cognitive science is not merely about knowledge in the commonsense construal of the term; but it does investigate knowledge in that sense, with tools which include much more than the usual attributes or determinants of knowledge). It has the *need;* a multi-lingual, multi-cultural, multi-modal society wants as many tools it can get to enhance information, dialogue, comprehension, fusion, evolution, individual and collective learning, decision making; an ageing society needs every resource to understand and enhance the last third of the life-cycle; a leisure society wants a far richer repertory of non-utilitarian activities; a service-oriented society wants to gain control over more of the tools which make services more productive and more user-friendly; etc. Finally, Europe has the intellectual *resource,* as argued at length in the present report.

3. Global perspective: assets and handicaps of European cognitive science

There will be more said about handicaps (subsection A) than assets (subsection B) in the present section. The reason for this imbalance is two-fold. First, handicaps are what calls out for affirmative action, and in the case at hand, a number of fairly simple measures can be proposed as remedies (*cf.* Section 6). Assets, on the other hand, rest for the most part on the strengths in a number of well-established disciplines, and with some exceptions are under no immediate threat. Second, European assets have been summarized in the preceding sections, and will be discussed in some detail, albeit not exhaustively, in the central Section 4 below. Opportunities are on the positive side, though, and constitute a form of asset: they will be briefly presented in subsection B. Recommendations for making the best of assets and opportunities (while circumventing the threats and handicaps) will be found in Section 6.

A. Handicaps and threats

a. Cultural factors

(i) The analytic/continental divide

Technically speaking this division concerns professional philosophy only. It is widely agreed that by and large, there are two basic styles of philosophy, one, roughly, inherited from German idealism, the other from British empiricism, Central European logical positivism or empiricism, and American pragmatism. The first, sometimes called 'Continental', tends to be historically inclined, is mostly attentive to phenomenology and existentialism, gives priority to the construction of broad worldviews over arguments and concrete examples, has closer links with art, particularly literature, history and politics than with science, towards which it generally feels in opposition. The second, definitely labelled 'analytic' (or 'analytical' in British English), has no enduring interest in the history of philosophy, regards most of the post-Kantian tradition as mistaken, considers itself as continuing the modern rationalist tradition by following in the footsteps of Russell, Moore, Frege, the Vienna Circle around Carnap, Neurath and Reichenbach, the Polish logic school, favors problem-setting and problem-solving over world-making and cultural agenda-setting, believes in stepwise progress and cumulativity in philosophy as in the sciences, to which it feels in close proximity both stylistically or methodologically and in topic choice, and is generally inclined towards interaction with inquiries and skills concerned with concrete issues in contemporary life.

This 'divide' is anything but clear-cut and definitive; in fact, many observers believe that it is destined to remain a feature of XXth century philosophy and that we are already witnessing a wide redistribution and crossing-over. Perhaps so, we may well be seeing the end of a 'hundred year war'. The hard fact of the divide remains, and has been decisive in shaping the intellectual landscape in which cogsci emerged.

For contingent reasons (the most important of which is World War II), although analytic philosophy owes most of its initial inspiration to thinkers from Continental Europe (Descartes, Leibniz, Kant, Frege, Brentano, Wittgenstein, Twardowski, Tarski, Carnap, Neurath, Schlick, Hempel, Popper, von Mises, etc.), it has taken root, over the last 50 years, in English-speaking countries. Continental philosophy, on the other hand, is labelled after its geographical distribution: it is the reigning philosophical style in countries such as France, Germany, Italy, Spain. As might be expected, Northern Europe (the Netherlands, the Nordic countries, Poland) lean on the analytic side, while retaining strong ties with the Continental tradition.

This excursion in the typology of philosophy may seem out of place in the present report. Not so: analytic philosophy has had, on the whole, a beneficial influence on the development of cogsci, and this is directly correlated with the fact that Britain and Northern Europe have been and remain more hospitable to cogsci than the rest of Europe. This, as we will see, is by no means an all-or-nothing affair, and it may well be about to undergo an interesting reversal. However, the analytic/continental divide is a crucial factor, mostly a negative one in our perspective, and one which should be borne in mind in policy-making: (i) the Continental tradition had impeded the development of cognitive science by hindering cross-fertilization with the sciences of man, and creating a climate of ideological hostility; (ii) because of this, the divide has projected onto the European map of cogsci: analytically-oriented countries have tended to foster cooperation with the sciences of man, continental-leaning countries have pushed cogsci in the arms of the natural sciences and mathematics. Not all of this is necessarily negative, and may in fact be turned around, but it does indicate an inhomogeneity in the European cognitive-scientific landscape.

(ii) The situation in philosophy

Of course, the most immediate effect of the divide stems from the direct involvement of philosophy in cognitive science. As a matter of historical fact, and for pretty straightforward reasons (having to do with the problem-solving attitude, regard for science and empirical data, expertise in matters logical, linguistic and broadly scientific, relative freedom with respect to tradition), a crushing majority of contributions and contributors from philosophy belong to the analytic side of the divide. (Interestingly, the rare contributions of the continental side come from phenomenology, and are essentially critical; the author of the present report has taken part in this critique, so he cannot be suspected of blind prejudice in favor of the analytic camp.) The flip side is that a rather huge proportion of the philosophical population, in Continental countries, has kept out of the cognitive revolution, with consequent impoverishment of both: analytic philosophy has drawn considerable benefits from cogsci, in terms of vitality, jobs, opening up to new ideas (including continental ones!), second only to what cogsci has gained. If more philosophers, and more of philosophy, were to participate, no doubt the benefits would grow in proportion. To what extent this can be encouraged remains however to be determined.

Optimists in countries (such as the Nordic countries) less affected by the "philosophy war" believe that the analytic/continental divide is no more than a relatively brief episode in the history of the discipline and that is about to be overcome, in fact in part to the salience of themes from cogsci, which exert an equal attraction on phenomenologically-trained and analytically-trained young scholars. No one is in a position right now to confidently predict whether this positive outlook will be borne out.

(iii) The situation in psychology

Cognitive psychology, which started out as a school within a subfield of experimental psychology, and has by now all but engulfed it entirely (leaving out various orientations in applied psychology), has met with constant and resolute opposition from psychoanalysis and psychiatry, and in many European countries, especially with Continental loyalties in philosophy, the best students interested in the workings of the mind have been drawn away from scientific psychology. Combined with the pull exerted by strong traditions in physiology and neurology, the psychoanalytic (sometimes called clinical) current has all but dried up experimental psychology in many countries such as France or Italy, and to a far lesser extent in German-speaking countries, again sparing the British Isles (which also harbored a vigorous psychoanalytic school), Budding cognitive psychology has felt the need to insulate itself from psychoanalysis and psychoanalytic psychiatry, with their militant anti-science stand. This, again, has resulted in missed opportunities and mutual impoverishment. Again, the divide is perhaps less strongly felt, and less deleterious, in the Nordic countries.

(iv) The situation in social science

Indifference at best, cold and not so cold war on some occasions, have been the preferred form of intercourse between the cognitive and the social sciences in Europe. Relations have not been exactly friendly elsewhere, but European social science has tended to regard cogsci with particular mistrust. The reasons are two-fold. The first, which is not specific to Europe, is that cogsci has seemed for a long time, with some exceptions as always, to ignore the social dimension of human existence and thought, and has tended to focus on the individual, as generic member of a species, rather than the social, historically situated individual. This was, and is, in no case easy to integrate in a social-scientific world-view. What made it particularly unpalatable to many social scientists working in Europe was the deep-seated conviction that man is through and through a socially constructed being, with no non-trivial determinations stemming from his belonging to the natural order. This went along with a broadly progressive-liberal view in politics, and a enduring fascination with themes from existentialist and constructivist thinkers. This was, and is, chiefly a matter of doctrine and scientific judgment. The second reason has to do with intellectual styles: the Continental influence, in the philosophical sense, has pervaded much of continental social science, making it reluctant to engage in a step-by-step, empirically based, argumentative critical dialogue with the analytically-minded cognitive scientists.

(v) The perverse effects of the primacy of theory: the impoverished and insulated applied sciences and arts. Gresham's law

Up to this point, we have been considering trends and tensions within basic science. In most of Europe, again, the part where philosophy tends to be the Continental variety, theoretical knowledge is often regarded as superior to, and clearly separate from, practical knowledge and skills. The best minds are strongly invited to join the ranks of theoretical fields, leaving the more modest pursuits of applied knowledge to more modestly endowed intellects. Needless to say, this hierarchy is not based on reason or efficiency, and is nothing but a cultural bias, not a universal law, although it certainly comes in the wake of a long tradition in the West, with traces in the US and elsewhere. Theoreticism hits Europe particularly hard. The result is an impoverishment of the applied fields, such as education, health, engineering, the liberal arts, etc. This is true in all areas, but our concern here is with cognition. As the theoreticians are loath to stoop to 'educate' the 'professionals' (and possibly also up to their necks trying to remain cutting-edge under unfavorable circumstances), the task is left to some more or less well-meaning popularizers, or worse, fuzzy-minded or mediocre theorists, who give cognitive science a bad name. According to Gresham's law, bad money drives out good: any decent presentation of cogsci, of its goals, assumptions, and possible contributions, is simply inaudible today for a large fraction of the general public and for many professional sectors. Neuroscientists, some of them famous, great producers of trade books, transmit a competent and appealing but often biased image of cogsci, as nothing over and above neuroscience conducted by cultivated, imaginative and humanistic biologists. The best, or least noxious, popular books on cogsci tend to be the work of philosophers, psychologists and linguists.

(vi) Pessimism

Cognitive science, although axiologically neutral *qua* pure inquiry, taken in its wider context is a contemporary avatar of Enlightenment. In practical terms, its goal is to secure a much more faithful and complete picture of human nature, whose cognitive-neural determinants far outweigh any other (such as, say, mechanical-metabolic), in order to identify or better circumscribe some of the sources of human ills and pains, collective and individual, mental and physical, and some of the resources which could be tapped within the human body/mind. This knowledge, both negative (the dismissal of ignorance, error and prejudice) and positive (the understanding of the capacities of the mind/brain) is presumed to bring with it recommendations, if not fail-safe recipes, for improving the lot of mankind.

This rubs European 'wisdom' the wrong way. First, Europeans have learnt the hard way that scientific enterprises do not necessarily lead to obvious improvements in the human condition: evil and powerlessness do not recede as a mechanical effect of knowledge progressing. In that sense, in so far as there is a European *Zeitgeist,* it is profoundly alien to the optimism of Enlightenment. Second, scientists and intellectuals incline towards skepticism (which is nothing but epistemic pessimism) regarding any claim of radical novelty in the distribution of scientific roles: they are firm disbelievers in 'new sciences' of any stripe. Scientific revolutions, and breakthroughs do occur, but seldom do they dislodge established disciplines, according to this view. Previous proclamations in the same ballpark as (what is commonly perceived as) cognitive science, such as cybernetics, general systems theory, or artificial intelligence, have not led to the promised landslide, thus fortifying the skeptic's refusal to take what he sees as the latest fad seriously. Third, cogsci straddles the natural and the human sciences, thus crossing what many European thinkers see as an inviolable border: the naturalistic stance of cogsci is repulsive to them. Worse, any breakthrough in the naturalistic account of human phenomena (*e.g.* the unreasonable efficacy of chemicals in alleviating mental illness) they see as mostly bad news: freedom, and the privilege of social and historical conditions as sole genuine constraints limiting that freedom, are both put in question.

b. Institutional factors (general)

(i) The sclerosis of academic systems

Cogsci can be developed only by people capable of absorbing the culture, know-how and concepts of at least two or three disparate scientific fields, and of mastering new paradigms which don't belong to any one particular discipline. Most European academic structures are unfavorable to the emergence of such competencies. There is a tendency to specialize early in the university curriculum, and interdisciplinary programs are rare and looked down upon (a student trained in X+Y is seen as neither completely part of the X culture, nor of the Y culture, except if she is stunningly gifted, in which case she would have done just as well, say the critics, without the benefit of the X+Y program). Students with an obvious potential to become brilliant mathematicians, physicists or philosophers do become brilliant mathematicians, physicists or philosophers with an appalling regularity, instead of turning to new fields, which hold promises for a much more fulfilling and adventurous career on average. Strong fields remain, at best, strong, weak fields remain, in general, weak, and very little can be done to break disciplinary barriers and let ideas and people flow from overcrowded, overworked 'star' fields to understaffed, underworked areas where (it is thought–a partly self-fulfilling thought) mostly unremarkable people try to eke out an academic living.

(ii) Centralization and winner-take-all effects

Academic systems in Europe tend to be somewhat, or very, centralized, with the result that decisions taken at the top have a disproportionate role in shaping the priorities of every institution at every level. The result is that once a field has been singled out for development (say, high-energy physics, molecular biology, genomics, history of philosophy, algebraic geometry or what not), that field is in a position to sweep the board. This winner-take-all effect is obviously destructive, as no room is left either for traditional specialties (say, marine zoology, systems neuroscience, philosophy of science) or for emerging paradigms which haven't made it to stardom.

(iii) Defective management of science; scattering of resources and insularity, breeding subcritical institutions

Of course, the winner-take-all phenomenon just mentioned is counterbalanced to some extent by conservatism. It takes a Margaret Thatcher to have whole departments closed down. The more typical European policy is to let just about everyone and everything live, or survive, and when complete thrombosis sets in, to create yet another layer of structures, institutes, etc. This humane attitude has a price: resources end up being shared by so many institutions that few of them have the means of attaining critical mass. This combines with a tradition of internecine conflicts and national or provincial jingoism to perpetuate a situation in which many European centers remain subcritical (in qualitative or quantitative terms or both), and try to find breathing space outside Europe, by linking up with US, or, increasingly, Japanese, and soon Chinese, centers.

Mismanagement of science in Europe takes many further, well-chronicled, forms (forced retirement; inadequate salaries; poor assessment methods which substitute quantity for quality; prestige and political considerations driving strategic choices; inadequate administrative help; complex structures and channels; incredibly slow decision processes; etc.) which are not specific to cogsci of course, but which affect it more than better-established fields. Whereas, due to the lack of structures and the intrinsic difficulty of reaching international standards in interdisciplinary, emerging fields, cognitive scientists need rather more moral, technical, instiutional and administrative help than their colleagues in mainstream science, what they in fact get on average is less, as if somehow they should have to pay a price for taking a side step and launching in nonstandard enterprises. The outcome is that they can devote a lower proportion of their work week to actual research, which in the long run is simply disastrous. We are reaping the bitter fruits of this institutional impotence, with both senior and junior prime movers retiring with no successors, or leaving Europe, with nobody to replace them: this is a field where, if someone goes, the approach or paradigm which she promoted simply disappears from the European landscape.

(iv) US domination

Speaking of jingoism, most researchers in cognitive science abhor any consideration of 'American domination'. For good reasons: first, the very idea of a national science hails back to 'German physics' and 'Soviet genetics', and cognitive scientists subscribe to a naturalistic, Enligthenment, universalist view of inquiry; second, accusations of 'American domination' are usually brought out against cogsci, or against 'mainstream' cogsci, by defenders of 'national traditions' in the human sciences. The fact remains however that in many fields, especially emerging ones, the sheer power and efficiency of US science leads American scientists to a position of quasi-monopoly (sometimes leaving a share for the British) at the level of agenda-setting. Combined with the linguistic handicap, and material conditions which are far from optimal, this state of affairs unquestionably leads to an underestimation of European forces, with consequences on job satisfaction, rewards, and self-confidence.

c. Science policies and sociological factors (with specific import on cogsci)

(i) Competition vs. cooperation: the many faces of cogsci

Cognitive science has many faces [see box on 'Cogsci's Many Labels', appendix 1], and this is both an asset and a liability. The problem is not particularly European: in the US and Japan also, cognitive science is sometimes presented as an outgrowth of neuroscience, sometimes as a modern form of psychology, sometimes as the long-awaited wedding of neuroscience and psychology, sometimes as a joint venture of linguistics, informatics and logic, sometimes as artificial intelligence and advanced computer science, sometimes, as in this report, broadly and somewhat abstractly as the convergence of many disciplines on a given object of inquiry. These various presentations are compatible, just as Venus can be thought of as Venus, as the morning star, as the evening star, as l'étoile du berger, etc. The various facets are not identical, to be sure, but this is no different from say, the configuration of mathematics, a fortiori physics or biology or history or economics: it would seem that as soon as a discipline is broad enough to play a lasting role in culture and science, it is bound to be presentable only in the shape of partial views. Moreover, this multiplicity of overlapping subterritories is a major factor of robustness and creativity.

The specific handicap this carries for cogsci, however, is that what should be, as a description, a sheaf of compatible partial views, and, as a practice, a collaborative effort, sometimes takes the appearance of inconsistency, on the descriptive plane, and competition, on the practical plane. The suspicion on the receiving end (characteristically, policy makers meeting with cognitive scientists of one or the other persuasion) is that there really is no such thing as cognitive science, except as a convenient front. And when the same policy maker meets in quick succession with a cognitive scientist from neuroscience arguing that functional imagery is what the field is all about, followed by an evolutionary psychologist who claims that cogsci is the path to social and human sciences finally becoming truly scientific, with beneficial consequences in decision-making, government, psychiatry etc., followed by a solid-state physicist who sees cogsci as centered on the physical-mathematical approach to the brain, followed by a specialist of AI whose business is to make computers 'intelligent' or the world-wide web truly responsive to the user, or again to promote 'ambient intelligence' (see W. Bibel's 2005 report), that policy maker may well decide to put things in perspective and do little or nothing until the dust settles.

He can also make the wrong policy choice. G. Orban argues, for example, that the Neuroscience program of Quality of life under the Sixth Framework Programme was nothing short of "a disaster": "To think that the complex functioning of the brain and its diseases could at present be understood by studying genes was a huge mistake. It will take long time and a strong systems neuroscience before we can integrate molecular and systems neuroscience and find the tenuous and tortuous links between genes and cerebral function", Orban is not claiming that these links are not important, to the contrary, but he points out that the timing was wrong. After the disappointing beginnings of automatic translation in the 1950s, and of AI in the 1960s and 1970s, this is yet another example of the cardinal importance of strategic scheduling; and this requires extremely high-quality, cutting-edge information which is not always easy to come by in the higher echelons of policy-making, which are usually occupied by defenders of entrenched paradigms.

Only insiders to the emerging field can provide the proper perspective. Yet, for familiar reasons, more is demanded of greenhorns than of seasoned members of the scientific club: the former need to prove their purposiveness, the unity of their field, the soundness of their judgment, etc., with a degree of certainty which the latter would be quite incapable of providing. Unfair as it may seem to them, cognitive scientists need to make an effort to establish ever more strongly their scientific standing; this requires, inter alia, that they speak with roughly the same voice.

(ii) The aristocratic nature of the disciplinary structure in Europe

In Europe, particularly continental Europe, disciplines are unequal. In France for example, mathematics and physics vie for the title of queen discipline, without any fear of being contested. Computer science is fairly low in the pecking order, and psychology is just about at the bottom. Generally, the sciences of man are regarded as second-rate. Philosophy, once extremely prestigious in Latin countries and Germany, has slid down and is no longer the preferred choice of more than a handful of the best students (with once again an exception for Britain and other analytically-inclined countries).

This poses a serious problem for cognitive science in Europe, as compared to countries where such a rigid scale would seem unintelligible. Indeed, not only do its key subfields not belong to mother disciplines among the most highly-prized (note however that the pecking order is beginning to change under the pressure of the student masses, who are deserting the star fields), but a creative practice of cogsci rests on a deflationist view of disciplines. Someone imbued with thoughts about whether some concept, explanation or novel idea is part of *real* 'mathematics', 'physics', 'linguistics', 'anthropology', ' philosophy' or 'biology', is presumably not going to immerse himself productively in cognitive science. Thus there is a need to shake away the aristocratic, fixist conception of disciplines still too prevalent among European students and scholars.

(iii) The two (plus two) cultures

Cogsci straddles not only disciplines, but scientific cultures. As has already been pointed out, and will become very obvious in Section 4 below, the natural sciences and the sciences of man contribute about equally to cogsci, which simply wouldn't be what it is or aims to be if one or the other 'culture' somehow dropped out of view. This collaboration, although not unique (economics, demography, geography provide other examples), sits uneasily with a tradition, strong in Europe and well-entrenched in Continental philosophy, which follows the German philosopher Dilthey (1833-1911) (rather than, for example, and significantly, the British philosopher John Stuart Mill (1806-1873)) in finding a difference in nature, not just degree of development or topic, between the *Geisteswissenschaften* and the *Naturwissenschaften*. Cogsci cannot accommodate such a sharp bifurcation, although there is some room for negotiation. In practice, the sciences of man must at least be willing to consider the possibility that the natural sciences may have a contribution to make to some of their investigations, and vice-versa.

The situation is further complicated by the intervention of yet two other cultures. One is engineering, admittedly close to natural science, but with a very different perspective.

Engineers design complex mechanisms which perform preassigned functions, and are rather indifferent to laws: to take up a distinction owing to the famous and recently deceased evolutionary biologist, Ernst Mayr (1904-2004), engineers are interested in 'proximal' causes. Physicists are mostly after 'distal' causes: they seek a theoretical understanding of why the mechanisms which are at work are doing what they are doing, rather than something else, and why these mechanisms and not others have been recruited to do what they are doing; they are interested in *general constraints*, in explanations which are as overarching as possible. Mathematicians plunge even deeper into the search for basic intelligibility [see box on 'Mathematics in cognitive science', appendix 2]. Biology sits somewhere in between, and in fact the brain is forcing a redistribution of roles and priorities between these fields. There remains, nonetheless, a rather profound cultural difference between the engineer's and the natural scientist's approaches, and again, divisions in Europe are more rigid than in other parts of the scientific world, impeding progress.

Similar remarks can be made concerning the fourth culture implicated in cogsci, *viz.* the health sciences. Physicians, psychiatrists, physical therapists, speech therapists, prostheticians, optometricians, etc. are a very different lot again. Their theoretical interests are very limited; they obviously have a lot in common with the engineers, yet they share with the human sciences a concern with human beings, but with a specific emphasis on the ailing individual, and the demand that something be done *now*, whatever the state of the *theoretical* art.

Why would this be a problem? Well, just consider one example: how easy is it to get a joint MD-PhD in Europe, as compared to the US? On a higher level of generality: How high is cognitive science, or just systems neuroscience, on the priority list of medical research in Europe? The answer is, unfortunately, pretty low, and it would be even lower if it weren't for the specific concern regarding Alzheimer's disease (see Section 6).

(iv) The cognitive sciences as oppressed minorities in their mother discipline and the competition from domineering forefront programmes

We come to one last limiting policy factor playing against the harmonious development of cogsci in Europe. Not only are the major disciplines bound to a pretty rigid hierarchy, as we just saw; but within each of these, there is a pecking order on the subdisciplines. As an example, take mathematics: it took decades for probability theory to join the club of respectable mathematical specialties, and it still hasn't made it to the top; logic took even longer, and remains near the bottom of the ladder. Every discipline has similar gradients of nobility.

For cognitive science, this presents a very specific problem. It so happens (or is there a rationale for it?) that the contributing subdisciplines generally enjoy, within their mother discipline, a rather low reputation, or at least, a low level of popularity among students, the professional elite and the policy makers. This seems to be true across the board, *i,e.* for all major disciplines, and in most of Europe, with the exception, now expected, of Britain and other parts of Northern Europe. The sorts of philosophy, psychology, biology, mathematics, physics, anthropology, social science, and computer science which intervene in cogsci have generally low standing within their respective parent discipline. The problem here is two-fold. On the one hand, as for previous obstacles, these hierarchical divisions hinder the flow of gifted students, fecund ideas, and above all, funds, towards the subdisciplines most relevant to cogsci. On the other hand, the need for each of these subdisciplines to fight for respectability and material and human resources leads them to claim for themselves, within cognitive science, a lion's share of the credit, and to resist criticism from other subsectors. Thus, some thirty years ago, when artificial intelligence, which viewed itself at the time as the admiral ship of the cognitive fleet, was subjected to rather sharp questioning from within philosophy, brain science or psychology, it viewed these criticisms as not only theoretically unfounded (as one would expect, and is fair enough), but also as politically undesirable, and bordering on treachery, because it weakened the already precarious hand of AI within computer science. A very similar situation has developed over the last few years, with respect to cognitive neuroscience: it claims the lead role, and is extremely touchy when workers in other branches of cogsci challenge the claim, because here too the vital issue of its standing within biology is engaged ; to relativize the contribution of cognitive neuroscience amounts, in the eyes of its propounders, to weaken its position in the competition against an all-too-domineering post-genomics.

d. The lure of commonsense theories of mental processes

(i) Naïve theories of the mind, and their unreasonable efficiency

Cognitive science purports to be a *science* of man, and carries with it a set of values, norms and methods which together allow it to shape a *scientific image* of its object, to be contrasted with its *manifest image*. The very idea that entities can possess a widely different nature than what commonsense attributes to them, is familiar and has in particular been emphasized by the American philosopher Wilfrid Sellars, who coined the phrases italicized above. However, regarding the human realm, this dichotomy meets with considerable resistance, for several reasons of which only one, of most direct concern to us here, will be spelt out.

To a large extent, the manifest image of man (shorthand for member of the human species) intervenes in many applications under the guise of commonsense, or (technically) *naïve* psychology, by which is simply meant here our commonsense knowledge of how the mind works and what it contains. We are guided, in our everyday dealings, by a well-adapted mental toolkit which allows us to identify entities and some of their crucial properties, and plan our own actions accordingly. Tigers, stones, dormant waters, human beings, lava, light, shadows, mushrooms, flies, dead branches, rainstorms behave in very different ways, respond to circumstances in very different ways, bring about very different results, and it is crucial to our survival and prosperity to be able to predict, and sometimes to explain, these properties. This toolkit of skills or tacit knowledge constitutes, as it were, the basic cognitive apparatus of humans (see §4.B.3, *Core knowledge,* below). Some of the resources in that toolkit are, or through informal education become, self-conscious, and thus deployable in general and counterfactual reasoning, for example in the context of a planning task: this constitutes a first layer of knowledge about the primary knowledge. Next, thousands of years of cumulative hard thinking, especially in learned circles (philosophical, political, literary), has lead to the constitution of yet a second layer of knowledge, which may be called for short philosophical or nonscientific psychology. Commonsense psychology is a mix of those two layers, unsystematic, lay psychology and cumulative, consciously pursued and transmitted, learned psychology.

There are excellent evolutionary reasons why commonsense psychology works in a large array of circumstances. Insofar as predicting, planning and explaining skills are important for survival, one may surmise that to a large extent lay psychology is itself part of our natural cognitive endowment, and had been selected for due to its functional virtues in certain important situations common in the pleistocene, when natural selection was putting the last touches on the human lineage. The learned layer has, to a large extent, been selected for through cultural evolution: literary, political, philosophical psychology has gradually been refined so as to yield explanations and predictions which were judged, on balance, to be true and/or useful in situations common in the cultures where they evolved.

(ii) The limits of commonsense

Over the last couple of centuries, psychology has become a scientific domain, much the way physics, chemistry, geology, meteorology, metallurgy, taxonomy, physiology, etc. became scientific domains, following in the steps of the 'folk' knowledge which had accumulated in the course of human history, alternately building upon, refining and partly undermining or overthrowing it. It has become accepted wisdom that the physical and life sciences are to a very large extent at variance with the corresponding bodies of folk knowledge. Not so, by a very long shot, for psychology and cognitive science. It is still widely believed that the pronouncements of folk or 'intuitive' psychology are on balance scientifically sound. And this is precisely where the role of cognitive science in social science, health, education and advanced ICTs is essential.

There are areas of competence, and contexts, in which commonsense psychology, possibly marginally improved by empirical findings, delivers the necessary characterizations of those skills which are being simulated, interfaced or enhanced. But there are large areas where this is not the case. At least three large families of circumstances come to mind: those where commonsense psychology has very little of value to propose (eg : lexical access, grammar, 3D-vision, motor planning, etc.) ; those where commonsense may be prey to a massive error about the underlying nature of a familiar phenomenon (a prime candidate for this might be voluntary action; another might be consciousness; yet a third might be visual perception); and finally those where the natural boundaries are crossed, due to technological advances (eg: decision-making in complex man-computer networks) or cultural changes (emotional disturbances in today's workplace, warfare etc.), or both (advanced technologies in non-Western and/or non-affluent populations). In fact, these examples are so well-publicized that one may be tempted to regard the issue as trivial. It is not: 'converging technologies' have precisely set out to create situations which are to an order of magnitude further removed from the pleistocene, and commonsense fixes will no longer be remotedly adequate to deal with those.

There is a deep reason for the persisting belief that our commonsense views suffice for all practical purposes. It was alluded above, in connection with the historical-constructivist views of large segments of European philosophy and social science. The idea again, which has been widely held during most of last century, is that wo/man has no nature, and thus can be taught or shaped into very nearly any possibly cognitive/mental structure. Knowledge of the natural basis of her/his cognitive abilities is thus not essential, bearing at most on matters of quantitative limits (memory, computational speed, proneness to error, resistance to fatigue, etc.). Native cognitive resources, it is held, have almost no relevance at all. But this idea is increasingly seen as deeply mistaken: the evidence is overwhelmingly in favor of very strong constraints on possible adult cognitive architectures stemming from the innate, species-specific endowment. *Tabula rasa* is thus as profound an error as the symmetric raw reductionism, which implausibly claims that thermodynamics or quantum physics is all you need to account for human existence, just because human beings are, 'at bottom', systems subject, at the macroscopic level, to the laws of thermodynamics, and at the microscopic level, to Schrödinger's equations.

The mistake is compounded by the naive positivistic assumption that we somehow possess the basic concepts needed to account for human cognition, such as seeing, hearing, understanding, reasoning, believing, deciding, emotions and so forth. Surely scientific psychology must preserve these as *explananda,* just as Newtonian dynamics had to account for the rising of the sun and the sinking of the ship. But is doesn't follow that seeings, hearings, decidings, emotions need be among the basic categories of cognitive science any more than risings of the sun and sinkings of ships belong to the vocabulary of physics.

e. The threat of dismemberment or dilution

We have mentioned and characterized at some length a whole slew of problems, and the question arises whether these could lead, through some process of negative synergy, to the eventual disappearance of cognitive science. The threat actually exists, and not only in Europe. Cognitive science is pulled in opposite directions also in the US. It is quite obvious that neuroscience is tempted to withdraw from the federation, and implement within its walls, and with its own troops, that part of the research program of cogsci which it deems worth pursuing, and which, not coincidentally, is what it feels is within its reach. Symmetrically, computer science is poised to reimport all or most of what we can label, for brevity's sake (see W. Bibel's 2005 report for details and nuances) the *engineering* dimensions of cogsci. Europe, on this count, has an additional handicap and perhaps a trump card. The handicap is that the uncertainties and rivalries, in a context of scarcity, could lead each partner to give up on the alliance, and for mostly tactical reasons side with the skeptics. Cognitive science would then let itself be dismembered, or diluted in a vaguely defined ensemble of disparate research programs, some of which would simply be the antiquated paradigms it sought to displace.

The trump card which Europe may yet hold is the faith which many European cognitive scientists have retained, and which has perhaps been comforted by the adverse conditions they have known. There may exist a vision, original to Europe, of an integrated cognitive science, which could be lost, elsewhere, in the abundance of programs in neuroscience and computer science and the relative ease with which monodisciplinary programs can be funded, as long as they pay lip service to one or the other.

B. Assets and opportunities

a. Centers of excellence, strong paradigms, excellent students

Although it would require careful quantitative data to support the claim, it is obvious to anyone familiar with the international situation that Europe boasts a rather large number of centers and teams which contribute to the cognitive sciences at the very highest level, and whose contribution is second to none. The scientists involved, whether junior, confirmed or senior, are by vocation as well as necessity highly connected internationally, and thus intellectually mobile and forward-looking.

In some areas, such as robotics, neuroscience, psychophysics, statistical and dynamical models, logic, developmental psychology, pharmacology, linguistics, ... (the list is not supposed to be complete), Europeans are in the lead or among the world leaders.

To mention but a few examples, reference was made earlier to the unique European role in theoretical linguistics, and its expansion to comparative and acquisition problematics. Also in the related fields of neurolinguistics, langage-related neuroimaging, or again formal semantics and formal pragmatics, Europe is in the lead. Semantics is an area in which European scholars are making a major difference. Within the generative tradition, parametric choices have until quite recently been thought to be largely limited to morphology and syntax. They were thought to have no impact on meaning. This is in contrast with the thesis of linguistic relativism (dating back to Sapir and Whorf) that has also had a considerable impact. Recent work enables to set this debate on a new footing, by identifying precise ontological structures and mapping hypotheses from syntax into such structures that can help reformulate the question whether speakers of different languages "conceptualize the world differently", in ways that may well lead to precise answers. These questions are now being investigated anew also thanks to the refinement of formal tools developed in modern semantics (in works by Chierchia, Longobardi, Cheng and Sybesma, Dayal, much of which is European based).

Another example is systems neuroscience, and in particular non-human primate imaging, where Europe leads.

Finally, the pool of well-trained, open-minded, highly motivated, autonomous students is considerable.

b. The We Try Harder principle

Being ahead is not an enduring advantage. Europe is not leading the race, and this can motivate her to try harder, to seek deeper principles, better thought-out experiments, novel theoretical conjectures, original forms of interacting and networking, new (and forgotten) sources of inspiration. This is no mere wishful thinking. For example, the Functional Imaging Laboratory at University College London has a success rate (measured in experiments useable in publications) which is about three times the average for US labs. Some of the most intriguing lines of research have emerged over the last few years in European labs (several are mentioned in Section 4). The yearly meeting of the European Society for Philosophy and Psychology are generally regarded as more innovative than the biannual conferences of the (American) homologous society after which it was created. Two of the most interesting journals for philosophers of mind and for theoretically-inclined cognitive scientists (*Mind* and *Mind and Language*) are published in Britain. As mentioned earlier, one of the most innovative international society in theoretical linguistics is GLOW (Generative Linguistics in the Old World), founded in 1977 and based in Europe.

The We Try Harder principle only works when business is brisk. But this is precisely the situation. Linguistics, philosophy, modelling are undergoing a period of unprecedented growth. More vividly perhaps, for the first time ever scientists have all the tools to study the different integration levels of the brain including the network level. This is based on the development of fMRI in the non-human primate (NHP) and of multi-electrode recording. In this later field, important for neuroprosthesis, Europe had missed the boat, but thanks to recent EU project such as Neurobotics it is catching up fast. Thus for the first time ever, there is the prospect that we can squarely attack the study of complex brains such as ours. Despite the difficulties with NHP work, Europe has a trump card. The crucial interface between functional imaging and cognitive neuroscience in the NHP is fMRI in NHP, a field that Europe has started and is still leading: 60% or more of the publications are from the two European groups: Tubingen and Leuven (the two other centers worldwide being Tokyo and MGH–Boston, but the latter is mainly carried by a Belgian researcher who is about to return to Belgium). Imaging in NHP is the only known fail-safe method of validation of the imaging techniques.

c. The flip side of European handicaps

Interestingly, many of the features of European intellectual traditions, institutional set-ups and research policies which were listed above as having a negative effect on the development of the field could play, in a slightly different context, to its advantage.

(i) Old-world sophistication. Simple-minded ideas are the right way to begin. The weight of venerable theories, inconclusive attempts, intricacies and case-based or occasion-sensitive variability, stands in the way of formulating bold conjectures which get the ball rolling. However there may come a point where sophistication and breadth of compass can be advantageous. It may turn out that European frames of mind are propitious matrices for fruitful complexification, boundary-crossing, combination of typical cogscientific approaches and research programs bred in other circles.

(ii) Strong traditional disciplines. In particular, Europe can take advantage of the strengths of its well-established and, as we just saw, overly protective classical disciplines. Once they can be persuaded to look into some issues raised in cogsci, mathematicians, classical philosophers, historical linguists, anthropologists, sociologists, etc. can try and apply some of the powerful paradigms which they master and which proved themselves in different contexts. Such ideas need not have occurred to cognitive scientists of the first generations: a perspective both opens some avenues and hides others from view. There is in fact one clear example of this, which is a novel implication in the philosophy of neuroscience of some phenomenologists, taking after Husserl and Merleau-Ponty. Nationalities aren't what matters: some Americans are among them, and some Europeans who work in the US; what does matter is that Europe has kept alive certain traditions which have not gained much ground in other regions, and has a reservoir of young people trained in these traditions who are ready to reinvest their expertise in cogsci.

(iii) Resistance to fads and externally-imposed agendas. The very reluctance about closing down less than cutting-edge labs, and the tradition of letting most unsuccessful ideas die out with their carriers, may turn out to be a blessing. By preserving intellectual variety, by refusing to yield to one-dimensional scales of international success, Europe keeps a stock of ideas, most of which will die without reproducing, but some of which may well make their way to a late blooming when early birds peter out. At any moment many strains of scientific thought are alive, though not necessarily successful, in the recesses of European campuses and institutes, and conformism, paradoxically enough, is limited by provincialism and an instinctive conservatism and/or pride against rallying the most recent bandwagon.

(iv) Felt need to give stamina to venerable disciplines. Although far from universal, there is in some departments in the classical disciplines the realization that in order to attract bright and original students, and in order to give them improved prospects of a challenging academic career, the repertory of themes and methodologies would profit a lot from the input of the cognitive sciences, whether directly, or as provider of fresh ideas. Simplistically, rather than have one more dissertation on Kant's moral philosophy or Descartes' superlative doubt, a philosophy department would do well to offer a topic on, say, self-awareness and voluntary movement as revealed by neuropsychology and developmental psycholgy, buttressed by neuroscience. And the same would go, mutatis mutandis, for departments of mathematics, social science, economics, linguistics, etc.

d. The experience of variety: an irreplaceable source of insights and experiments for cognitive science

Among the advanced regions in the world, Europe is quite unique in presenting a huge collection of cultures, languages, mores, social skills, political systems, etc. which, on the one hand, present endless variations, and on the other, are closely packed together, so that one can often find, for any given dimension, examples which differ along this dimension without differing significantly on all. Put slightly differently, Mill's method of difference is more applicable to European societies and cultures than to most other large groups of sizeable societies and cultures. Or again, given one European society, it is fairly easy to find another which can serve as 'model' of it (in the sense of an animal model used for exploring human functions or reactions to, say, a new drug): many important factors are kept constant from one to the other, and the 'effect' of a change in one 'parameter' can then be assessed by examining other, relevant, differences and invariances.

This repertory of 'subjects' constitutes a unique source of conjectures, experiments (thought experiments, real experiments, experiments set up for non-scientific purposes by the societies themselves as they adopt or try out some particular change), and comparative observations. To our knowledge, outside of linguistics and psycholinguistics, this opportunity has not been tapped. One reason may be that cognitive scientists have for a long time focused on generic individual capabilities, rather than social skills which present the same very general sort of differences and commonalities as are attributable to natural languages. Another reason may be that cognitive science in its early phases has thought prudent to consider first *large* differences, *e,g.* differences between members of literate and non-literate societies, or between people with a sophisticated conceptual system for magnitudes and people with a rudimentary system. But probably the most important reason for neglecting the European repertory is that comparing social, political, cultural, value systems has traditionally been thought as the proper domain of the social sciences, including social psychology, a group of disciplines whose relations with cognitive science, as we saw, has been at best lukewarm. The 'social turn' in cogsci could in the coming period conjoin with the timid 'cognitive turn' in some sectors of social science to bring about a sea change, together with an interest in exploiting the European 'corpus' for approaching problems in cogsci.

e. Specific benefits of applications of cogsci for European societies

(i) Preliminary remark: shallow *vs* deep applications of cogsci

It was explained at some length above (§A(d)) that folk or commonsense notions about the mind cannot be assumed to be adequate for the purposes of applications, whether in social science, in the liberal arts, or in technologies. In fact, mistaken notions may well be at the root of failures or limited success in those areas, and the hope is that cognitive science can contribute to progress by offering better approximations to true theories of the mind.

This immediately leads to the following possible objection: to the extent where cogsci is far from having secured highly supported models of the mind/brain, how can it provide what is said to be needed?

The situation is of course not at all unusual: in fact, it is the rule rather than the exception. For example, metallurgy started long before physics or chemistry were born, and later in its development took advantage of initially far from complete and far from robust theories in solid-state physics, which paved the way for the present stable situation in which a mature technology fully connects with an all but complete basic science.

In the case at hand, at the cost of simplifying the situation, one may distinguish between shallow and deep applications of cogsci. Economics is a field in which most if not all applications are of the shallow type, although this may begin to change with the emergence of 'neuroeconomics'. A typical paradigm in 'cognitive economics' will consist in imposing some constraint on a decision process, or a learning process, based on some schematic notion of memory or other computational limitations of the agent ; or again, on the format of the representations she might use in deciding on a particular course of action. These constraints are shallow in the sense that they are not based on a detailed and robust theory of the actual processes involved, but on very schematic hypotheses made plausible by what has emerged from a casual inspection of some psychological results. There is nothing wrong with proceeding in this way, insofar as it pushes economics in a more naturalistic and realistic direction, and suggests new models and alternative mechanisms.

Deep applications require engaging in truly interdisciplinary research. An example is provided by the study of 'racial knowledge' acquired by children (*cf.* Hirschfeld 1996) : a topic typically belonging to social psychology and education science is treated with sophisticated tools of cognitive psychology and evolutionary theory, involving extensive theorizing, and open to detailed experimental investigation. Other examples involve theories in visual perception and motor control applied to highly specialized piloting tasks (aircraft, air traffic control, weapon systems, security systems in nuclear plants) ; or decision-making under uncertainty and duress ; or again, context-dependent interpretation of verbal messages. There is no clear-cut border between deep and shallow of course: it is a matter of degree of engagement of actual empirical theories about cognitive (perceptual, motor) processes, of the depth and experimental support available, etc.

(ii) Cogsci applications for a better-connected yet diverse Europe

One major aim of the European enterprise is to unite and synergize without incurring the risk and the cost of uniformizing. This may seem like trying to square the circle. Political and cultural forces are at play, and cogsci has little to offer on this dimension. It has, however, the potential of procuring tools which could bring the problem closer to being tractable.

The linguistic issue is the most obvious. It involves multiple cogsci-intensive concepts and solutions. It is technological only to the extent that technology, in the present instance, embodies a huge body of theoretical knowledge, not all of it is yet available in fact. It is not a mere question of 'automatic translation', or rather, automatic translation is not a mere matter of putting together parsers and lexicons and implementing them on fast, ubiquitous devices. Conceptual structures, contextual effects, shared background knowledge, notions of cultural acceptability, of acceptable violations of grammaticality, of acceptable approximations to faithfulness, of degrees of formality, of understanding, etc., all come into play. Mention is made in W. Bibel's 2005 report of projects such as "Open mind common sense database" or CYC whose aim is to construct giant databases of commonsense knowledge, comprising millions of items. This may be an important part of the solution which has up till now evaded the best efforts of the AI and NLP communities. On the other hand, the solution may turn out to rest on a very different approach. One thing is certain, and that is that cogsci is the proper framework for looking at the problem, whether hands-on or taking the broader perspective– and asking questions such as: how far can we hope to get, at what cost, why are we failing, etc.

Nor is the linguistic issue limited to automatic translation. Language learning and bilingualism or multilingualism, for example, are interesting and difficult issues for psycholinguistics, neurolinguistics, and cognitively informed social psychology.

Language is at once intimately tied with, and a metaphor of, the more general capabilities involved in any attempt to link up two or more European communities. Although one may well feel dubious about the contributions which cogsci could eventually propose, defeatism is unwarranted. Systematic attempts at understanding what is involved in border-crossing, communication, comparison, learning from example, perceiving others as different and/or same, etc., cannot but enhance our know-how and enrich our tool-box. Considering the magnitude of the problem and of the resources already engaged in proposing partial solutions, it would be unwise to neglect an approach which holds serious promises and is quite a bit less costly than traditional ones.

Last, but not least, education is among the most important factors for Europe, and requires particular attention as the various educational systems need to be both respected and modified so as to meet, on the one hand, the needs of our times, and, on the other, the quest for mutual compatibility within the boundaries of Europe. Cogsci is beginning to reach a point where it can be fruitfully engaged in R&D on education (see §6.d.1 and Appendix 4).

(iii) Cogsci applications for world-construction

Here we venture into fairly unchartered territory, and speculate on possible developments in the next 10-20 years or more. The general idea is that cognitive science may contribute to a better, and perhaps even a novel, understanding of the processes which lead to the formation of what constitutes a 'world', in the rich sense of the word: the open-ended set of meanings which we think of ourselves as inhabiting.

This may appear to be, on the one hand, the ultimate scientistic utopia, and on the other, not particularly connected to Europe *per se*. Regarding the first worry, we should again, as above, think in gradual terms: cogsci may well remain forever at the door of certain mysteries regarding the human condition, but this does not mean it has no hope of getting somewhat and perhaps considerably closer than on previous attempts to a theoretical understanding of certain of its essential dimensions. More specifically, we would not have squandered the taxpayer's money and the precious time of scientists and policy-makers if at the end of the day (say, the end of the 10th PCRD), we had secured some understanding of how certain basic concepts involved in the individuals' and the groups' self-understanding are 'represented', how they are acquired, which changes they can incur, what variations are permitted by general constraints of a biological or computational nature. There is something to learn about how a human being, at various ages, in various cultures, exposed to various experiences, thinks of what she knows and what she merely believes, of what she has and has not learned, of what can and cannot be learned, of her capacities for free or constrained action, of her loyalties, relationships to individuals and groups, of her selfhood and her identity, of sameness and difference, of what constitutes a possible home, of how a home fits in a group of homes, of what is a norm, a value or a preference, of what are one's own norms, values and preferences as opposed to the other person's, etc, etc. It may be thought that literature and history, or perhaps philosophy, have already taught us more on these topics that science ever will. Or it can be suggested that this is what social psychology and to some extent psychoanalytic theory are all about. The vision offered here, speculatively but not gratuitously, is that the former provide no scientific knowledge, but ideas worth exploring (this was Auguste Comte's idea of the role of fiction); and that the latter suffer from a lack of robustness which cogsci might be able to make up for. The goal would be, then, to characterize a naïve theory of 'existence' or 'world' (a form of 'core knowledge' possibly composed of a sheaf of naïve theories such as naïve epistemics, naïve morals, naïve sociology, etc.; but possibly having no such structure, or having quite a different one, an interesting result in itself). Certainly ideas of the sort of are very much in the air already, with pilot studies of the conceptual or nonconceptual perceptions of self and other, the huge literature on consciousness, and much (fairly undisciplined but suggestive) talk about 'presence', 'situated cognition' and the like (see *e.g.* Clark 1997). The proposal just proferred is somewhat more specific, and at the same time wider, but it is of the same very general flavor.

Finally, why would these topics be of particular interest in a European perspective? The answer is obvious. First, it may be claimed that Europe has a wealth of traditions which provide multiple accesses to these questions; while it would be ridiculous to suggest that other scientific communities would lack the resources to attack them fruitfully, it may perhaps be claimed that if any community has them, then Europe has them too, and that this large topic could motivate a number of young scientists and philosophers, not necessarily trained in a strict analytic tradition for example. Second, and more to the point in the present subsection, Europe has a particular interest in gaining a more perspicuous understanding of the cognitive underpinnings of world-making. For, after all, the question Europe has to face is, how can someone be at once herself (a human being, a person), a Sicilian postal worker, an Italian citizen, and a European woman? What difference does it make, how can one make it more interesting, of life-enhancing, or less straining, to be all these things at once?

4. Overall structure of cognitive science and EU activities in the area

§ 4.A. presents the general structure of the cogsci field, in brief coordinates. It includes, on the one hand, a very straightforward reminder of the main disciplines involved, for the sake of general orientation, and on the other, some of the reasons why cogsci is not, by a long shot, a summary or a sum of these disciplines. It introduces a list of topic-clusters which serve as organizing principle of the presentation offered here.

§ 4.B. provides some middle-grained characterizations of each topic-cluster, and illustrates them with some of the most prominent current research topics emblematic for each part of the working taxonomy, together with a listing of major centers around Europe involved.

A. The general structure of the field

Cogsci is structured by several criss-crossing taxonomies:

- A disciplinary taxononomy, where the taxa are, at the basic level, the contributing disciplines (from the more central: psychology, neuroscience, linguistics, philosophy, computer science, anthropology,...; to the more peripheral: economics, sociology, paleontology, mathematics, physics, optometry, psychiatry, education,...); at the superordinate level, the disciplinary clusters or cultures (the formal sciences; the physical sciences; the life sciences; social science and philosophy; engineering; the medical sciences...); at the subordinate level, the various special branches, at several degrees of precision (*e.g.*developmental psychology; neuroanatomy...; developmental study of concept acquisition; neuroanatomy of the visual cortex,...) and with frequent border- and levels-crossing.
- A functional taxonomy, where the taxa are the cognitive-perceptual-motor functions; with, again, several levels, ranging from the more general (vision, language, reasoning, action) to the more fine-grained (color vision, lexical access, grasp,...); this is the taxonomy which is usually favored by cognitive scientists, for it gives salience to the cooperation of disciplines focussing, from their distinctive viewpoints, on a shared object of study, and it makes room for the major theories which give the field its substance and dynamics.
- A levels taxonomy, which resembles that in the biological sciences, where form and function, organ and organism, system and subsystems are distinguished.
- A paradigm taxonomy, which is the one causing the most difficulty, as it arises from differences in judgment about the relative importance, typicality and efficiency of the various disciplines, functions and levels distinguished by the three other taxonomies. Thus generative syntax, classical artificial intelligence, neural-net modelling or connectionism, functional imagery-based cognitive neuroscience, evolutionary psychology, action-based theories of perception, signal detection theory, formal learning theory, to mention but a few examples, are at once special branches of, and (controversy-provoking) paradigms within, cognitive science.

Attempts are regularly made to discipline the field by imposing on it various 2- or 3-dimensional grids, each cell of which is supposed to contain a reasonably coherent and self-standing research area. Useful as such grids can be in some contexts, the task of devising an equidistant and exhaustively encompassing taxonomy of areas and subjects in cognitive science is an illusory one, due to the complexity of the field and its multifarious, continually mutating charactexr. Nonetheless, there are structuring principles and fairly well established, though mobile and sometimes discontinuous inner borderlines.

Perhaps the most basic distinction is that venerable heritage of comparative anatomy as it emerged in the XVIIIth century: *form* versus *function*. Here, 'form' is the brain, or rather, the brain structures at various levels of aggregation; and 'function' is the mind, or rather, the mental (including perceptual, motor and emotional/motivational) processes at various temporal scales. This distinction is transformed, in the contemporary context of cogsci, by the notion of *information:* the key idea is that mental processes are at bottom informational (although some clarification remains to be provided on what this means precisely). So that functions are to be analyzed as operating on information. On the structure side, then, there are physical (biological or man-made) mechanisms which *realize* or *implement* these informational processes: this is usually rendered by the term 'computational' (which *must*, on pain of a rather tragic misunderstanding, be interpreted in this very general sense: far from all cognitive scientists subscribe to the computer model of the mind, and some even claim to be wary of the form/structure distinction; still, the characterization provided up to this point, with a suitably supple construal of 'information' and 'computation', would draw the assent of almost everyone working in the field). Cogsci subscribes, in general terms, to a program which consists in determining *what* it is that the brain does, and *how* it does it. To a first approximation, psychology, linguistics, social science, sometimes with the help of philosophy and logic, are in charge of the *what* part of the program; and neuroscience, with the *how* part. However, this way of putting the division of labor does not do justice to four important aspects of the inquiry:

(i) The project of building artifacts endowed with informational capabilities comparable, in some interesting respects, to those of the adult human brain, implicates a notion of realization which is broader than the one offered by the brain sciences: artificial intelligence, as part of computer science, and other modelling approaches drawing on a variety of paradigms from physics and mathematics, are important contributors to cogsci.

(ii) Normal adult human brains and minds are just one (important) case in a large family which includes human infants and children, abnormal, diseased, lesioned and senescent subjects, pre-Sapiens humans, and non-human animals: developmental psychology and neuroscience, neuropsychology, psychiatry and pharmacology, ethology, paleontology, anthropology and evolutionary biology all have an essential role to play.

(iii) The *what* and the *how* cannot be completely dissociated: the deep structures of the mind, or in other words the basic categories on which to found a theory of mental functions (which is what psychology, linguistics etc. aim for) are presumably not determinable on the sole basis of psychological, linguistic, ... experimentation, secunded by conceptual and logical analysis. Neuroscience will almost certainly (and in fact has begun to) force a reconsideration of these basic categories. Symmetrically, neuroscience cannot establish a research program on its own: it wouldn't know what to look for without the help of the other disciplines (see also *Appendix 3*, 'Neuroscience- Greatness and limitations').

(iv) Over the last ten or twelve years, it has dawned upon many cognitive scientists that the initially plausible distinction between the individual mind/brain and the collective effects or properties of communities of minds/brains, immersed in a material/informational environment has severe limitations. In this respect, minds are not just brains understood at the functional level. *Externalism* is the general research program, pursued on many fronts, which stems from the intuition that minds are to a degree much greater than initially imagined socially and environmentally constituted entities. The social sciences, evolutionary biology, ecology are called in for help at this juncture.

The renowned *MIT Encyclopedia of the Cognitive Sciences* (MITECS) comprises an introductory section which classifies the cognitive and brain sciences into six domains: (1) computational intelligence, (2) culture, cognition, and evolution, (3) linguistics and language, (4) neuroscience, (5) philosophy, and (6) psychology. This isn't a bad way of sorting things out, but it isn't the only way: it is probably a good way of cutting the pie in what seems, from a certain viewpoint (the two general editors are a psychologist and a philosopher), to be roughly equal shares. The encyclopaedic structure of the work proceeds to undo what the introduction does: it thoroughly reshuffles the domain.

The working taxonomy in the present report is intended to constitute a sort of cross-classificatory nexus that takes into account contributions from all these domains, while focusing on some convergent themes and paradigmatic examples within each.

What I have aimed for is a sketch and a working classification that takes into account the topics according to a sort of intuitive logic starting from the individual agent as a cognitive system and finishing with the interplay agent-environment and the results conferred by this dynamics to the re-conceptualized cognitive system. We can thus discern a series of topic-clusters like 1) *perception and action*, 2) *memory, attention, and consciousness*, 3) *core knowledge,* 4) *categorization, the lexicon, the ontology*, 5) *learning*, 6) *language and representation*, 7) *choice, rationality, decision*, 8) *culture and social cognition*.

As can be expected, the aforementioned topics are approached by a variety of disciplines, cross-cutting the classical boundary social vs. natural sciences. We encounter pure social sciences such as philosophy, anthropology, sociology, or economy, but also linguistics, psychology (cognitive, experimental, developmental), the cognitive neurosciences, finishing with formal areas devoted to the mathematical and physical modeling of distinct aspects of the cognitive system, with impact in robotics, AI, and artificial life.

Apart from the disciplines involved, one can also discern certain *conceptual frames* in approaching the subjects. Cognitive science is practised in a variety of *styles of thinking:* informational/computational thinking (fashioned by the passage from the classical to the connectionist, and then the dynamical models of cognitive processes), brain thinking, evolutionary thinking, medical thinking, comparative thinking. These styles are not necessarily emblematic of a domain or another, where say evolutionary thinking would be the logo for anthropology. There is interesting philosophical work which draws upon evolutionary insights, for instance. These are rather vectors of mentality that characterize in a coarse-grained manner the primary background ways of understanding and approaching the issues.

One key idea that is stressed throughout this report is that in order to cope with competition stemming especially from the United States and Japan, Europe needs to defend the scientific and societal benefits of an *integrated, fully interdisciplinary cogsci*. This is why we need to orient research toward programs in which *interdisciplinary fusion* plays a major role. Confining the topics exclusively to one or another particular discipline will not bring progress. We need multi-leveled projects in which fundamental research is explicitly carried out with an eye on applications, industrial and technological effects being at stake.

The fusion of neuroscience and robotics for augmenting human capabilities

A vanguard, and somewhat untypical, example of *interdisciplinary fusion* is the *Neurobotics* project at the Scuola Superiore Sant'Anna in Pisa, Italy, funded under the 6th FWP. The ultimate objective of the *Neurobotics* project is, according to its coordinators, very ambitious, yet clear and well defined: to introduce a leap, a discontinuity in the craft of robot design, thus literally going 'Beyond Robotics'. This discontinuity will be sought by a strategic alliance between neuroscience and robotics, which will go well beyond present, mostly fragmented, collaborations, and lead to overcome state-of-the-art of robotics worldwide. The coordinators of the project believe that the scientific,

technological and cultural environment in Europe is mature to face this challenge, whose impact in engineering and medicine could be comparable to that recognized to 'big science' projects. *Neurobotics* is intended to systematically explore the area of Hybrid Bionic Systems (HBSs). It will investigate three platforms which involve different degrees of hybridness: *Beyond Teleoperation*, *Beyond Ortheses*, *Beyond Prostheses*.
The 'heritage' of *Neurobotics* will be the kernel of a new community of European researchers, with strong links to non-European top scientists (e.g. in US and Japan), able to dominate the scientific, technical, industrial, societal and ethical aspects of this novel discipline and to exploit it to the benefit of the EU citizens.
(http://www.neurobotics.org/neurobotics_leaflet_dec_04v2.pdf)

Integration requires particular attention to the particular cognitive function one wishes to understand and explain. This systematic, theoretical stance is at once difficult to enforce, and yet indispensable for a fairly swift integration of the single-level, partial views which emerge from experimental investigations and modelling efforts.

It is often remarked however that this kind of research is carried out in a fragmentary way, leading to incomplete patterns, and lack of common, shared knowledge between the participants involved. One would like to see *steps toward completeness*, and in this respect philosophy, with its synthesizing and monitoring capabilities, whether practiced by teams of professional philosophers, or by groups in reflective scientists, can play a pivotal role in the systematization of material in disparate areas which address the same topic from different viewpoints. There is also a need for making available and deployable the enormous amount of knowledge accumulated: something like a 'cognomics' program has been suggested by Roberto Casati, an Italian philosopher working in Paris and world-wide, who is also a typical multidisciplinarian (see §6.c.5.3 for a brief description). Finally, one also needs to evaluate the ethical aspects and the directions and effects involved in the unfolding of various research programs, and in this respect philosophical studies are also helpful.

B. Some major topics

This section is intended to cover some of the most prominent current research topics, together with references to some of the major centers around Europe involved in their undertaking. The method is to focus on two or three paradigmatic cases for each topic-cluster identified in §4.A. It is crucial to note that no attempt has been made to cover every or even most of the major branches of cognitive science. The format chosen is rather that of an anthology, whose purpose is to illustrate important trends, with an eye to novelty and, in the present instance, interdisciplinarity on the one hand, European strengths on the other. The boxes fill their various customary roles, but are not necessarity representative of mainstream research: to the contrary, they often illustrate pioneer approaches or underappreciated dimensions of the field.

1. *Perception and action*

The passage from *perception to action* is standardly considered to be isomorphic to the classical box-style passage from the input to the output of a cognitive system. Studies are generally carried out over the regular perceptual modalities (visual, auditory, olfactory, gustatory, tactile/cutaneous), combined with the so-called haptic perception (the representation of the perceiver's proximal surroundings, critical in guiding the manipulation of objects), proprioception (the sense of the position of body parts), and kinesthesia (the sense of movement of body parts). Much of the attention is devoted especially to the visual and auditory modalities, which benefit from the presence of clear-cut ways of characterizing and controlling stimulus presentation–wavelength for vision and frequency for auditory pitch. It is much more difficult to discern how the olfactory system encodes and decodes information, for instance, due to the lack of such an element that allows the discretization of the perceptual continuum in this case; this, plus the enormous differences in olfactory sensitivity between humans and other animals, make olfaction such a fascinating topic. Psychophysics, psychoacoustics, comparative neuroscientific study and modeling are to be corroborated here with attempts to replicate the structure and functions of the perceptual modalities concerned in artificial systems, leading to devices such as artificial retinas, instruments of active vision, architectures for visual navigation, auditory prosthetics, cochlear implants, compressors of audio signals, etc. Afferent, bottom-up sensory stimulation is to be seen in conjunction with efferent, top-down motor command leading to action. Action necessitates a prior intention from the part of the cognitive system, and there are many studies that focus on local links in the chain leading to the motor output.

However an important trend today, illustrated in robotics but with much support in psychophysics and physiology, stems from the rejection of the traditional model of intelligent systems as being composed of a central system acting as a symbolic information processor, with perceptual modules as inputs and action modules as outputs, to the more flexible models in which there need to be no clear distinction between the three sub-systems. Perception and action are involved in a constant interplay in the so-called *subsumption architectures* containing layers combined through mechanisms of suppression and inhibition. The approach, pioneered, *inter alia*, by Rodney Brooks from the MIT AI Lab, is also supposed to give an incremental path from very simple systems to complex autonomous intelligent systems. Some scholars such as Alain Berthoz, head of the LPPA at Collège de France in Paris, go as far as to deny the real existence of vision as a function separate from action.

Why robotics is important for cognitive science[1]

Robotics –together with AI– is important for cognitive science in general, since it allows theories to be tested. Cogsci cannot rely exclusively on experimental and observational evidence and theories based on a priori (deductive) reasoning. Constructive theories that take data as a starting-point for drawing further inferences need to be tested, and this can be done e.g. by computer modelling. Modelling is a significant tool for cogsci. One example is provided by the LUCS robotics lab in the Department of Philosophy and Cognitive Science at Lund University, Sweden, where theories about e.g. attention (individual and joint) and basic communication are tested and developed in tandem. Robotics, in contrast to old-fashioned AI, offers the opportunity to test theories in the real world, that of true objects, space, time and causes, rather than in (theory-laden) representations of the real world. It is also well-suited for investigating the kind of situated and distributed cognition that is pervasive to the thought processes in humans and other primates, and in other kinds of animals as well.

This kind of research deserves to be called *cognitive robotics*, and it is, some claim, a vital part of the research in cogsci. Furthermore, robotics provides a direct link from cogsci to the industry, and therefore also has another major role to play - that of implementing the research in society.

This view is far from being universally shared. Cognitive robotics is usually not very welcome in departments of computer science. Symetrically, many cognitive scientists remain dubious about the enterprise and/or its relevance to cognitive science. But to those defending the theoretical and practical importance of cognitive robotics, this only reflects the need for giving it a proper place in cogsci, which depends on a stronger integration with areas such as psychology and philosophy.

[1] This box is essentially based on a remark by Ingar Brinck (Lund University).

Change blindness

Change blindness consists in the failure to see or to detect in a visual scene soem large changes, which in circumstances other than those of the experiment are easily noticeable. Presented with an initial visual frame α which gets slightly modified into a frame α' via various techniques, subjects typically fail to grasp the change that occurred during the interval. Changes are arranged so as to occur simultaneously with some kind of extraneous, brief disruption in visual continuity, such as the large retinal disturbance produced by an eye saccade, a shift of the picture, a brief flicker, a "mudsplash", an eye blink, or a film cut in a motion picture sequence (O'Regan *in* Nadel 2003).

For more telling pictorial illustrations, one can visit these two links:
http://www.usd.edu/psyc301/Rensink.htm
http://viscog.beckman.uiuc.edu/djs_lab/demos.html

The relevance of change blindness for cognitive science is prominent, due to its straightforward connections to the understanding of attention, perception (especially visual perception), and even consciousness. It is part and parcel of a well-established line of research in experimental psychology that started in the 1970's and that concerns visual short-term memory. The earlier work addressed many of the same theoretical issues revivified by more recent research, including limitations on memory capacity, links between attention and awareness, and the integration of information over time. However, an overarching theoretical framework linking these issues was never developed.

The interpretations offered for the phenomenon have multiplied and allow researchers to draw various sorts of links to other issues. Usually, the upshot is that attention is needed to see change or that there is no perception of the visual world without prior attention to it. However, some (Mack & Rock 1998) suggest the claim should be rather that there is no *conscious perception* of the visual world without attention to it, since there are such things as unconscious percepts, an unconscious encoding of sensory stimulation, an implicit/unconscious perception. These findings inspired further insights into the nature of focused attention, the nature of visual short-term memory, and the relation between them. Given that attention is limited, our perception of dynamic events in a scene requires careful attention management.

At the forefront of this research in the world are Daniel Simons at the Department of Psychology of the University of Illinios at Urbana-Champaign in the USA, Ron Rensink at the Department of Psychology of the University of British Columbia in Canada, Kevin O'Regan at the Laboratory of Experimental Psychology of the CNRS in France and Dan Levin at the Department of Psychology of Kent State University in the USA. At the Attention and Visual Memory Laboratory of the Department of Experimental Psychology of the University of Cambridge, research is also conducted on iconic memory and change blindness.

In Europe there are also a number of centers focusing on vision in humans and animals via studies with eye-tracking devices. Examples are the Sussex Vision Lab at the Sussex Centre for Neuroscience or the eye-tracking labs at the Max Planck Institute for Psycholinguistics in Nijmegen, Holland.

Artificial retinas

Artificial retinas provide an example of how fundamental research can really matter for applications. An artificial retina is an optical intelligent sensor, in the form of a monolithic integrated circuit, in which each pixel has both a photosensor and resources for image processing.

European scientists have joined the race to produce an artificial retina with research that could help restore the sight of thousands of people suffering from retinal disease. Claude Veraart, Ordinary Professor at the Université catholique de Louvain where he heads the Neural Rehabilitation Engineering Laboratory, says that a prototype device has been implanted in two patients so far, according to a Reuters report. He said that 15 teams of researchers are working on the problem, but that the Belgian trials have produced the best results so far. The Belgian team co-ordinates a pan-European research effort, involving scientists in France and Germany.

As with similar work in the United States, the prosthetic retina works by bypassing the natural retina and artificially stimulating the optic nerve, in line with signals from a tiny digital camera mounted on a pair of glasses.

The technology could be used to treat conditions like macular degeneration, or retinitis pigmentosa, a condition where the eye's photoreceptors are inactive, but the connection from the eye to the brain is intact.

Veraat said the device would likely cost around €20,000. The European Commission said it would be available commercially by 2010, possibly as early as 2008. The Commission has also made grants totaling €2.79m available for research into treating blindness and partial visual impairment. (see http://www.theregister.co.uk/2005/02/22/eyes_ec_2010/)

However, this way of dealing with the problems raised by visual impairments (with the mediation of optic nerve stimulation) is only one strategy, maybe not the most successful or promising overall. A certain number of difficulties are raised by the procedure of feeding information back to the brain via a direct interface. As a consequence, it would be perhaps advisable as well to take the work of growing neurons on silicon (discussed more extensively in Appendix 4) *cum grano salis* for the time being. As a response to this possible line of criticism, one may mention the neuro-ophtalmological work done by Dr. Florian Gekeler from the University Eye Hospital in Tübingen, Germany on subretinal implants. His work shows that light entering the eye would not be strong enough to power photocells to stimulate retinal neurons, and thus his device uses an infrared diode mounted in a lens frame to deliver the necessary amount of light.

One research strategy to be explored and that might lead to better results than those obtained from cortical implants concerns implants in the lateral geniculate nucleus (LGN), the part of the thalamus that relays signals from the retina to the primary visual cortex. At this early stage in visual processing in the brain, input from the eyes is more straightforwardly mapped. However, one downplay of a visual prosthesis based on an LGN implant would be the involvement of very invasive deep brain implant surgery for rehabilitation.

Research on artificial vision, vision substitution and synthetic vision technologies continues to be, nevertheless, an endeavor with clear-cut expected benefits for people suffering from various visual impairments, a virtual bridge between fundamental research and quasi-industrial applications.

2. *Memory, attention, and consciousness*

These essential mental phenomena or functions are grouped together due to their obvious interrelations: the content of conscious experience can be seen as a subset of the representational content of short-term memory, while attention and consciousness are often seen as highly interdependent phenomena. Even if types of memory are in a way modalities of consciousness, due to their reconstructive character, a large part of the mnesic processes are also unconscious (implicit and explicit memory). Regarding attention, most psychological investigation has centered on selective attention and the mechanism used to change attention from one channel to another. There is also work on automaticity, the process by which certain cognitive processes can be performed without any conscious effort by the subject. Memory must be understood as both a biological process, in which a time-based consolidation process converts actively stored information into passive memory, and a psychological one in which information passes from an easily accessible conscious state into the permanent past. With respect to long-term storage, a ternary classification of its components is usually employed: episodic memory (an assumed store of personal events), semantic memory (knowledge of language, concepts and general facts about the world), and procedural memory (any form of memory whose contents are not consciously available- motor skills, perceptual learning, grammar acquisition, classical conditioning).

European research into phenomena pertaining to the three functions is rich in results and achievements. Landmark studies include those carried out on the capabilities of *working memory*, by the renowned British psychologist Alan Baddeley, former Director of the MRC Applied Psychology Unit, Cambridge, now Professor at the Department of Experimental Psychology of the University of Bristol, studies on *blindisght*[2], by Emeritus Professor of Psychology Larry Weiskrantz at the Department of Experimental Psychology, University of Oxford or studies on *sleep* conducted by Michel Jouvet of Claude Bernard University of Lyon in France. Among the recent emergent poles of interest, one could mention Stanislas Dehaene's hypothesis of a *global neuronal workspace* as a scientific theory of consciousness, or studies on the possibility of what may be called *artificial (machine) consciousness.* There are many potential applications of studies on the relations between the three functions, chief among them neuropharmacological treatments that stimulate deficient brain areas in troubles such as the *attention-deficit hyperactivity disorder.*

[2] Damage to a region of the visual cortex can cause blindness in the corresponding field of vision. If an object is held in that region of the visual field, then that object will not be perceived. Blindness occurs with respect to that region of vision. However, Weiskrantz's findings indicate that things are not so simple as this. A patient referred to as "D.B." had to have some of his visual cortex removed and this caused him to be unable to see anything in a certain region of the visual field. However, when something was placed in this region and D.B. was asked to guess what that something was (usually a mark like a cross or circle, or a line segment tilted at some angle), he found he could do so with gret accuracy. The accuracy of these "guesses" came as a surprise to D.B. himself, and he still maintained that he could perceive nothing whatever in that region.

Artificial consciousness

Artificial consciousness (AC), also known as machine consciousness (MC) or synthetic consciousness, is a field related to Artificial intelligence whose aim is to produce a rigourous and objective definition of consciousness, in a mathematical sense, and build a theory toward implementating it in a model or a cognitive architecture.

The idea of producing an artificial sentient being is extremely ancient, and is featured in numerous myths (the Golem, the Greek promethean myth, mechanical men in Chrétien de Troyes, Frankenstein being examples). In science fiction, artificial conscious beings often take the form of robots or artificial intelligences. Artificial consciousness is an interesting philosophical problem because, with increased understanding of genetics, neuroscience and information processing, it may be possible to create a conscious entity.

It may be possible biologically to create a being by manufacturing a genome that had the genes necessary for a human brain, and to inject this into a suitable host germ cell. Such a creature, when implanted and born from a suitable womb, would very possibly be conscious and artificial. But what properties of this organism would be responsible for its consciousness? Could such a being be made from non-biological components? Can the techniques used in the design of computers be adapted to create a conscious entity? Would it ever be ethical to do such a thing?

Neuroscience hypothesizes that consciousness is generated by the interoperation of various parts of the brain, called the neural correlates of consciousness, or NCCs. Proponents of AC believe computers can emulate this interoperation, which is, however, not yet fully understood.
(http://en.wikipedia.org/wiki/Artificial_consciousness)

Europe is a place where interest in machine consciousness has recently sprung. A series of workshops and symposia have been held, the latest being one administered by the Center for Research in Cognitive Science of the University of Sussex and entitled Next Generation approaches to Machine Consciousness: Imagination, Development, Intersubjectivity, and Embodiment (12 - 13 April 2005) (http://www.sussex.ac.uk/cogs/1-4-2.html).

Past symposia and workshops, including ones in the US, include Can a Machine Be Conscious? (13-16 May, 2001) at The Banbury Center of the Cold Spring Harbor Laboratory, financed by the Swartz Foundation (www.theswartzfoundation.org), Models of Consciousness Workshop: In Search of a Unified Theory, Birmingham 2003, the Exystence conference on Machine Consciousness (Sep 29th - Oct 1st, Turin 2003), and the Workshop on Machine Models of Consciousness held on June 29th 2004 in Antwerp.

Although there are many skeptics with regard to the very possibility of AC (such as the philosopher John Searle at the University of Berkeley or the mathematician Roger Penrose of the University of Oxford), Europe needs to solidify interests in this area, corroborated however with research on robotics and ambient intelligence (the now classical quarrels concerning overfunding Strong AI programs [the attempts to build *genuinely* intelligent machines] functioning as hindsight), since the stakes are high. In US, the MIT Artificial Intelligence Lab (http://www.csail.mit.edu/index.php) is a flourishing place for Weak AI [whose goal is machines with various forms of intellligence *susbtitutes*], while the objectives of the Japanese Riken Brain Science Institute (http://www.brain.riken.go.jp/), in its *Creating the Brain Division* are no more and no less than to advance technologies that investigate principles by which autonomous information systems integrate with consciousness, that enable the full-scale operation of a neuroinformatics system, establish a brain-style mathematical information science, produce a brain-style robot system, and produce a brain-style computer with emotion and consciousness, one capable of living with humans.
(http://www.brain.riken.go.jp/english/a_about/a4_about.html).

Links: http://www.machineconsciousness.org/

Neuropharmacology and attention-deficit hyperactivity disorder (ADHD)

The disorder hints at symptoms such as lack of concentration, very short periods of attention, and physical agitation. It is often diagnosed on children so turbulent that playing or normal schooling are totally impossible for them.

Neuroimagery has shown that the children suffer from a neurological dysfunction in which their brain is partially 'disconnected'. Their limbic system functions perfectly, but certain cortical regions seem to work in slow motion.

Neuroimagistic data confirms that a significant number of regions in their right hemisphere, such as the anterior cortex (an area associated with fixing attention on a given stimulus), a part of the higher auditory cortex, and the prefrontal cortex (charged with drive control and act planning) are inactive.

It is hypothesized that children suffering from ADHD are unable to apprehend a 'global image' of their environment, the world seeming fragmented, filled with concurring stimuli that rival to capture their attention.

Neuropharmaceuticals such as Ritalin are considered as adequate remedies for ADHD. Chemical substances belonging to the family of amphetamines raise the production in the cortex of neurotransmitters

whose action limits attention troubles. The induced cortical activity tends to inhibit the limbic system, substituting reflection for action and reinforcing the control of behavior and concentration.
Problems arise, however. Surveys have estimated that as many as 10% of high school students and 20% of college students have used prescription stimulants such as Ritalin illegally (see D. A. Kapner, www.edc.org/hec/pubs/factsheets/ritalin.html).

3. *Core knowledge*

Core knowledge is intended here to cover subjects usually clustered under headings like naïve physics, naïve biology, naïve mathematics, naïve psychology, naïve sociology, and the like. It refers to the commonsense, uneducated beliefs that people hold about the way the world works (physics), how people classify and reason about the organic world (biology), how people think of magnitudes and numbers, on which they perform addition and subtraction, how they rank order and compare continuous amounts, when no units seem readily available (mathematics), how people explain human behavior in terms of beliefs, desires, intentions, expectations, preferences, hopes, fears, and so on (psychology, or, as it is sometimes technically called, 'theory of mind': see the box on 'Autism' below), how people recognize and reason about those groupings of individuals that constitute the social world (sociology). These abilities appear quasi-spontaneously, without much education in the particular areas and constitute the nucleus of a body of knowledge which can become more specialized and profound with the deployment of instruction and experience (see also §3.A.d above).

Complex cognitive skills such as reading and calculation and complex cognitive achievements such as formal science and mathematics may depend on a set of building block systems that emerge early in human ontogeny and phylogeny. These core knowledge systems show characteristic limits of domain and task specificity: Each serves to represent a particular class of entities for a particular set of purposes. By combining representations from these systems, however, human cognition may achieve extraordinary flexibility. Studies of cognition in human infants and in nonhuman primates (and other cognitively advanced animals such as some species of birds) therefore may contribute to understanding unique features of human knowledge.

Number and language

We have the intuition that our thoughts are inseparable from, indeed dependent upon, the words we use for them. This is especially so for numerical cognition where the claim is that some basic aspects of numerical cognition depend crucially on language, be it knowledge of the vocabulary of counting words or the recursive capacities of syntax and morphology. This argument has been made from neuropsychology, where arithmetical facts are held to be stored in a verbal format, from neuroimaging, where numerical tasks appear to activate language areas, from developmental psychology where counting words are claimed to be necessary for concepts larger than three or four and, most recently, from studies of Amazonian tribes whose language lacks counting words.

Brian Butterworth, Professor of Cognitive Neuropsychology at University College, London and founding editor of the academic journal "Mathematical Cognition", is one of the leading European researchers in the field of numerical cognition, Stanislas Dehaene, Director of the Cognitive Neuroimaging Unit (INSERM-CEA unit 562), Service Hospitalier Frédéric Joliot, Orsay, France, author of *The Number Sense* (N.Y.: Oxford University Press, 1997).

Butterworth, in joint work with Rochel Gelman, from the Rutgers University Center in Cognitive Science and recipient of a three-year grant from the James S. McDonnell Foundation in order to study dyscalculia, has recently questioned the thesis that language is necessary for mental representation and manipulation of numerosities greater than 4.

The question they pose themselves is whether the ability to develop numerical concepts depends on the ability to use language. They consider the role of the vocabulary of counting words in developing numerical concepts and they challenge the 'bootstrapping' theory which claims that children move from using something like an object-file – an attentional process for responding to small numerosities – to a truly arithmetic one as a result of their learning the counting words. Butterworth and Gelman also question the interpretation of recent findings from Amazonian cultures that have very restricted number vocabularies. Their review of data and theory, along with neuroscientific evidence, imply that numerical concepts have an ontogenetic origin and a neural basis that are independent of language.

Links: http://www.mathematicalbrain.com/

Autism

Uta Frith, Professor in Cognitive Development at the University of London and Deputy director of the UCL Institute of Cognitive Neuroscience, has extensively worked on autism, the chief disorder associated to a truncated theory of mind module (as a core knowledge system). The following paragraph is an extract from the homonym article in MITECS (Frith 2001) (see also the full-length book Frith (2003)):

'The diagnosis of autism is based on behavioral criteria. The chief criteria as set out in ICD-10 (WHO 1992) and in DSM-IV (APA 1994) include: abnormalities of social interaction, abnormalities of verbal and nonverbal communication, and a restricted repertoire of interests and activities. Behavior suggestive of these impairments can already be discerned in infancy. A recent screening instrument, based on a cognitive account of autism, appears to be remarkably successful at eighteen months, involving failure of gaze monitoring, protodeclarative pointing, and pretend play (Baron-Cohen et al. 1996). These appear to be the first clear behavioral manifestations of the disorder. Contrary to popular belief, failure of bonding or attachment is not a distinguishing characteristic of autism.'

Autistic persons are interested in parts, rather than contextual elements and wholes. They are adept at tasks like puzzle assembling and remembering random word lists, but they have difficulties when it comes to understanding the essence of a message or gesture. They are good at syntax, but bad at semantics, as one might say.

Frith has thus developed a hypothesis entitled 'the weak central coherence' hypothesis, according to which individuals with autism often outperform matched nonautistic individuals on tasks in which success depends upon processing of local features, and underperform on tasks that require global processing.

Another European who was extensively worked on autism is Simon Baron-Cohen, Director of the Autism Research Centre at the University of Cambridge. Co-author (with L.Cosmides and J. Tooby) of *Mindblindness: an essay on autism and theory of mind*, MIT Press, 1995, Baron-Cohen concludes that children with autism suffer from "mindblindness" as a result of a selective impairment in mindreading: they are gravely lacking in 'naïve psychology' or 'theory of mind', the ability by way of which we ascribe mental states such as thoughts, desires, knowledge and intentions to other people, interpreting, predicting and participating in social behaviour and communication. For autistic children, the world is essentially devoid of mental entities.

Joint attention

Joint attention could be defined in a nutshell as the ability to find and follow another person's focus of attention. Some time around their first birthday, most infants begin to engage in a behavior that is designed to bring it about - say, by means of pointing or gaze-following - that their own and another person's attention are focused on the same object. Described as manifestations of an emerging capacity for *joint attention*, such triangulations between infant, adult and the world are often treated as a developmental landmark and have become the subject of intensive research among developmentalists and primatologists over the past decade. Fuelling researchers' interest in all these disciplines is the intuition that joint attention plays a foundational role in the emergence of communicative abilities (see also §4.B.6 of the present report), in children's developing understanding of the mind (see also §4.B.3 and §4.B.8) and, possibly, in the very capacity for objective thought (see also §4.B.4).

Typical questions addressed by research on joint attention may be listed as follows: How should we explain the kind of mutual openness that joint attention seems to involve, i.e. the sense in which both child and adult are aware that they are attending to the same thing? What sort of grip on one's own and other people's mental states does such awareness involve, and how does it relate to later-emerging 'theory of mind' abilities? In what sense, if any, is the capacity to engage in joint attention with others unique to humans? How should we explain autistic children's seeming incapacity to engage in joint attention? What role, if any, does affect play in the achievement of joint attention? And what, if any, is the connection between participation in joint attention and grasp of the idea of an objective world? (see Eilan et al. 2005)

Research on joint attention is carried out not only in the fields of developmental psychology, comparative psychology, or animal cognition, but in epigenetic robotics as well, minimally insofar as understanding how a robot could learn to interpret human gaze in order to spot salient objects in its environment is concerned (see, e.g., Kaplan & Hafner forthcoming).

A growing number of philosophers have expressed their interest as well in the topic, concretized, inter alia, in the Eilan et al. 2005 volume which may be seen as a fruitful interdisciplinary collaboration between psychologists and philosophers.

Among the European centers involved in research (on developmental/comparative, philosophical and artificial scales) on joint attention one could briefly mention the Max Planck Institute for Evolutionary Anthropology, the University of Warwick, or the Sony Computer Science Laboratory in Paris.

4. *Categorization, the lexicon, the ontology*

The reason for clustering *categorization, the lexicon and ontology* is that they all involve the interaction of several disciplines, and are different aspects of the processes by which cognitive systems develop and deploy categorization schemes in their commerce with the world. Non-linguistic discrimination is to be considered in tandem with linguistic sophistication and fixation of the items which constitute one's conceptual scheme. According to Paul Bloom (Bloom 2000), children learn words through sophisticated cognitive abilities that exist for other purposes. These include the ability to infer others' intentions, the ability to acquire concepts, an appreciation of syntactic structure, and certain general learning and memory abilities. Although other researchers have associated word learning with some of these capacities, Bloom is the first to show how a complete explanation requires all of them. The acquisition of even simple nouns requires rich conceptual, social, and linguistic capacities interacting in complex ways. Ontology regards the components of the fundamental structure of reality–events, processes, properties, objects, states of affairs, and the like. Recent interdisciplinary research in artificial intelligence, formal and computational linguistics, biomedical informatics, conceptual modeling, knowledge engineering and information retrieval has lead to the realization that a solid foundation calls for serious work in ontology, understood as a general theory of the types of entities and relations that make up their respective domains of inquiry. In all these areas, attention has started to focus on the *content* of information rather than on just the formats and languages in terms of which information is represented. The clearest example of this development is provided by the many initiatives growing up around the project of the Semantic Web. And as the need for integrating research in these different fields arises, so does the realization that strong principles for building well-founded ontologies might provide significant advantages over ad hoc, case-based solutions. The tools of Formal Ontology address precisely these needs, but a real effort is required in order to apply such philosophical tools to the domain of Information Systems. Reciprocally, research in the information science raises specific ontological questions which call for further philosophical investigations (http://fois2004.di.unito.it/).

BFO- Basic Formal Ontology

BFO is a project based at the Institute for Formal Ontology and Medical Information Science (IFOMIS) at Saarland University in Saarbrücken. It comprehends an interdisciplinary research group with members from Philosophy, Computer and Information Science, Logic, Medicine, and Medical Informatics. IFOMIS aims to establish itself as a center of theoretically grounded research in both formal and applied ontology. Its goal is to develop a formal ontology that will be applied and tested in the domain of medical and biomedical information science.

The activities of IFOMIS in the field of biomedical ontology have been acknowledged by a major grant under the European Union's 6th Framework Programme for Research and Technological Development. IFOMIS thereby constitutes part of the *Network of Excellence on Medical Informatics and Semantic Data Mining*, which includes sixteen research institutions from throughout Europe and for which in total 5 Mio € have been allocated.

IFOMIS also received a major award from the Volkswagen Foundation. Thus, 913.200 Euros were allocated for the project "*Forms of Life: Philosophical Dimensions of Contemporary Biomedical Research*" of Professor Barry Smith of the Institute for Formal Ontology and Medical Information Sciences (IFOMIS) of the University of

Leipzig – in collaboration with Professor Heinz Sass of the Institute for Genetics, University of Leipzig and Professor Pirmin Stekeler-Weithofer, Institute for Philosophy, University of Leipzig.

Ontology has the task of developing robust category systems for the management of data of all kinds through the application of methods derived not only from information science and its neighboring disciplines but also from philosophy. Medical ontology seeks a structured representation of the medical domain in a form that is accessible to both human beings and computers. It should lead to more efficient ways of handling the huge amounts of data accumulated through clinical studies and serve also the development of translation-systems which can make medical data accessible to both expert and non-expert users.

The construction of the system BFO (for: Basic Formal Ontology) comprehends formal representations of basic ontological structures such as space and time, quality and relation, role and process, function and system, body and environment. BFO has two central axes: SNAP BFO, a series of snapshot ontologies of *enduring entities* such as substances, qualities functions, and roles; and SPAN-BFO, an overarching ontology of *processes* unfolding in time. In addition BFO embraces a theory of granular partitions which allows the representation of ontological structure at different scales or granularities, from molecules to galaxies.

BFO can be applied to entities of all types and in all regions of being. By extending its formal representations through the addition of medical content, BFO is transformed into the system MedO (for: Medical Ontology). MedO is a regional ontology, comprehending sub-ontologies relating to sub-disciplines of medicine such as anatomy and physiology. SNAP-MedO will serve as the basis for the ontology of anatomy at successive levels of granularity, from molecular and cell anatomy to clinical and surgical anatomy. SPAN-MedO will serve as basis for the ontology of physiology. Thus it will comprehend within its domain the physical and chemical processes in the living human organism in its normal functioning (passages extracted from the 2002 Report of IFOMIS, available online at http://www.ifomis.uni-saarland.de/Publications/report2002.pdf).

Web epistemology

webepistemology.org is a platform for studying the impact of the web on the mechanisms of collective knowledge production, organisation and distribution. A major part of this project is devoted to analysing the stakes and goals of scientific research management and policies with regard to the web.

The epistemic impact of the web

In order to understand the importance of the epistemic impact of the web, one must realise how much is done on the web and with the web for the development of knowledge. This includes the quantity of documents uploaded, the quantity of documents accessed, the number of web-surfers and webmasters as well as their geographical and social distribution.

Of great importance is the role of the Web in the democratisation of knowledge : The Web allows a redistribution of scientific resources within the research community and seems to narrow the divide between science and society.

Web surfing as an epistemic practice

Given the huge amount of documents provided by the web, the web-surfer has the task to find the most appropriate strategy for his goal. How does he do that? Which strategies and cognitive resources does he use in order to navigate the Web? To which extent surfers' navigation is determined by the structure of the web rather than by the surfer's goals and preferences? How do scientists use the Web for their own research?

Authority and epistemic deference

The processes through which the surfers will rely on information provided by a site rather than by another highly depend on the dynamic structure of the Web. The question, thus, is what are the constraints set by the structure of the web on surfing and what are the epistemological consequences of these constraints, i.e. how they contribute to driving a user's selection of reliable content. What is at stake, is the processes through which the reliability of a document is assessed.

Relevance

Relevance and reliability are the two properties we wish to find in an answer to a specific query. How is relevance attained in surfing? How is the relevance property structuring the Web? What are the epistemic consequences of relevance assessment processes of the Web? How does these processes relate to those assessing quality?

Distributed Cognition

As any cognitive device, the Web together with its users consists of a system of dynamic distribution of information. It is therefore possible to apply the expertise developed by cognitive science to the study of the web.

Arguably, the study of the Web and its users as forming a cognitive device may bring some insights in the general study of cognition.

http://webepistemology.org

5. *Learning*

Among the large-scale cognitive phenomena, learning is perhaps the most characteristic. It seems so intimately connected to the very idea of intelligence that it is difficult to imagine one without the other. No full-fledged intelligence, as far as we know, can evolve without intensive learning; and learning requires at least a modicum, and, in its higher manifestations, a considerable amount, of intelligence.

On the other hand, learning is so broad and so vague as to seem to defy a global scientific understanding. It is also dangerously intertwined with other large-scale processes such as memory and development or maturation. As a first shot, one can think of learning as 'any transformation undergone by a cognitive system whereby that system acquires a new disposition'. But this is not much more that an invitation to think harder.

And in fact, there is no agreed-upon definition of learning: the word points to different things in different contexts. Learning also carries with it certain loyalties and dislikes. During the era of behaviorism (roughly the first half of the XXth century), learning was the key concept of scientific psychology. Turing, a forerunner of the cognitive revolution, wrote in famous article published in 1950 that learning was of such decisive importance to the development of an intelligent computer that one would have to devise a way in which the computer would learn spontaneously from its environment, much like a human child, rather than being spoon-fed all the information it would need.

The early phase of cognitive science was on the whole disinclined to view learning as a productive notion, except in well-circumscribed circumstances. For example, Chomsky famously argued in favor of a conception of the linguistic human ability consisting in a 'language acquisition device [LAD]', which is an essentially inborn ability of the infant which allows her to pick up, without any formal training, the competence of a 'native' speaker in the natural language spoken around her. This process was understood as a form of induction from incomplete data. This led to a generalization named 'formal learning theory', which was developed in the late 1960s onward. It was characterized by a highly *modular* view of cognition: there is no such thing, according to this modular view, as general intelligence or a general capacity for learning; or at least, such general entities are not central to human cognition. What is central, by contrast, are domain-specific, and/or modality-specific capacities, language being a prime example.

At about the same time as linguists and psychologists were developing this paradigm, AI specialists were elaborating a rather different approach called 'machine learning', which typically studied the conditions under which a computer could acquire the 'mastery' of a concept (such as: 'red-or-blue polygon' or 'downward-pointing arrow in an ellipse') from exposure to examples and counterexamples.

The 'connectionist revolution', whose manifesto appeared in 1986 (Rumelhart *et. al.* 1986*)*, put learning (as a domain-general capacity) at the very heart of cognition. Learning, in the connectionist context, amounts to the acquisition of the ability to discriminate between two (or more) classes from among a potentially infinite set of stimuli, on the basis of a supervised (or in some cases, unsupervised) examination of a finite sample.

Today, learning is back in favor and many cognitive scientists seem willing to take it as a major scientific category, despite or because of its considerable breadth and variability (see Jain *et al.* 1999) . It also covers areas such as those concerned with the use of external artifacts in cognition, with an enhancing and augmenting role, by offloading the charge in working memory, the human-computer interfaces and interactions and the areas concerned with the development of algorithms for artificial systems. Work in neuroinformatics and computational neuroscience is paradigmatic here.

PAC Learning

The PAC learning model is a probabilistic framework for the study of learning and generalization. It is useful not only for neural classification problems, but also for learning problems more often associated with mainstream artificial intelligence, such as the inference of Boolean functions. In PAC theory, the notion of successful learning is formally defined using probability theory. Very roughly speaking, if a large enough sample of randomly drawn training examples is presented, then it should be likely that, after learning, the neural network will classify most other randomly drawn examples correctly. The PAC model formalises the terms `likely' and `most'. Furthermore, the learning algorithm must be expected to act quickly, since otherwise it may be of little use in practice. There are thus two main emphases in PAC learning theory. First, there is the issue of how many training examples should be presented. Secondly, there is the question of whether learning can be achieved using a fast algorithm. These are known, respectively, as the *sample complexity* and *computational complexity* problems (Anthony & Biggs 2000)

In a seminal paper by L. G. Valiant (1984), a simple and appealing model is proposed that emphasizes three important notions concerning learning.

First, learning is *probabilistic*: a finite sample of data is generated randomly according to an unknown process, thus necessitating that we tolerate some error, hopefully quantifiable, in the hypothesis output by a learning algorithm. Second, learning algorithms must be *computationally efficient*, in the standard complexity-theoretic sense: given a sample of m observations from the unknown random process, the execution time of a successful learning algorithm will be bounded by a fixed polynomial in m. Third, learning algorithms should be *appropriately general*: they should process the finite sample to obtain a hypothesis with good generalization ability under a reasonably large set of circumstances.

In Valiant's original paper, the random process consisted of an unknown distribution or density P over an input space X, and an unknown Boolean (two-valued) target function f over X, chosen from a known class F of such functions. The finite sample given to the learning algorithm consists of pairs <*x, y*>, where x is distributed according to P and $y = f(x)$. The demand that learning algorithms be general is captured by the fact that the distribution P is arbitrary, and the function class F is typically too large to permit an exhaustive search for a good match to the observed data.

A typical example sets F to be the class of all linear-threshold functions (perceptrons) over n-dimensional real inputs. In this case, the model would ask whether there is a learning algorithm that, for any input dimension n and any desired error e > 0, requires a sample size and execution time bounded by fixed polynomials in n and $1/$e, and produces (with high probability) a hypothesis function h such that the probability that $h(x)^{1}f(x)$ is smaller than e under P. Note that we demand that the hypothesis function h generalize to unseen data (as represented by the distribution P), and not simply fit the observed training data (Kearns 2001).

6. *Language and representation*

The rubric *Language & representation* points to the wide-ranging area of linguistic, psychological, neuroscientific, anthropological and philosophical studies concerning topics like the acquisition, comprehension and production of language, the interrelations thought-language, the cerebral-functional architecture of the language faculty, or the cross-species study of language-like representational systems. 20th century linguistics has been marked by the Chomskyan framework of *Universal Grammar* or what is called the *principles and parameters* program, in which all the languages of the world are seen as stemming from a common root, comprising a series of principles inborn in our cognitive architecture. Chomsky has recently dubbed his current framework of thinking on the issues the *Minimalist Program*, in which the initial contentions are somehow weakened, but the seminal character of his work is discernable in the debates engendered over long-standing issues like the innate and the acquired (Elman et al. 1996, Tomasello 2003). Alternative promising programs, like *Optimality Theory* (Prince & Smolensky 2004), have been put forward, and it is this variety that could drive us forward toward new ideas and re-framing of certain issues in new lights. The interface language-thought is extremely important as well, due to its potential in the elucidation of the steps required in the functional decomposition of our cognitive architecture, with consequences in a *psychotectonic* project, the project of building an artificial mind. We need to understand the processes behind rational thought with a keen eye on the representational systems underlying it. Is tokening a thought something going on in an internalized natural language or something quasi-independent from such a language? One needs clarifications on these topics while studying their characteristics on a phylogenetic, ontogenetic (developmental), as well as cross-species scale.

The Netherlands are regularly considered as a leader in the field of linguistics in the world. Holland particularly has a tradition of combining research in logic, language and computer science to yield original results. Main centers include the Institute for Logic, Language, and Computation of the University of Amsterdam, on the more theoretical side and the Max Planck Institute for Psycholinguistics in Nijmegen. France also has a series of top programs in the field (Paris, Nantes, among others), collaboration with universities from Holland being thoroughly pursued. France has a great tradition in the field of pragmatics, and in the last years various *contextualist* trends have begun to solidify into promising research agendas. In Germany, formal semantics and pragmatics have begun to spring, particularly due to the *Semantiknetzwerk* (research network for semantics), funded by the German Research Foundation (DFG) under the label SA 925/2 within the program *Scientific Networks*. It brings together a group of mostly junior German and foreign researchers to investigate the interaction of linguistic semantics and pragmatics. The Semantiknetzwerk is an independent project associated with the ZAS (The Centre for General Linguistics, Typology and Universals Research is a university-independent research centre located in the federal state of Berlin) which started functioning in Septembrt 2004; the principal investigator is Uli Sauerland.

Multilingualism and the brain

In a multilingual and cosmopolitan society such as the European one, a better understanding of the neural mechanisms and more abstract structures at play in language learning, comprehension and production is wanting. Concerted research in linguistics and cognitive neuroscience is carried out around two main questions, mainly directed with respect to bilingualism, but extendable for the higher order cases: (1) Does a bilingual or multilingual speaker represent each language in different areas of the brain?, and (2) What effect does age of second (third, etc.) language acquisition have on brain representation? Concerning (2), recent work using event-related potentials (ERP) supports previous behavioral findings suggesting that second language learning is better in those who learn their second language early. This has straightforward implications insofar as educational policies have to take into account the need for optimal internalization within a so-called *critical period* in which neural plasticity is present to a high degree. The construction of a European citizenship also brings the problem of diversifying the choice of languages available in school curricula. Concerning (1), the general conclusion at which researchers have arrived is that bilinguals' two languages are represented in overlapping brain areas.

However, as the authors of the article 'Bilingualism and the Brain' in MITECS (A. E. Hernandez and E. Bates) conclude, 'despite the progress that has been made in addressing the relationship between bilingualism and brain representation, and although strides have been made in the psycholinguistics and cognitive neuroscience of bilingualism, much work remains to be done. This research will necessarily involve behavior and the brain. Clearly the issue of bilingual brain bases involves both a rich multidimensional information space as well as a rich cerebral space. Understanding how the former maps onto the latter is a question that should keep researchers occupied into the next century and beyond' (p. 81).

Links:http://www.mitteleuropafoundation.it/,http://www.myhealthsense.com/F020910_bilingualism.html

Language acquisition

Noam Chomsky and his followers have developed a view of language as being on the one hand too complex to be learnable from scratch, on the basis of a casual exposure to sentences heard in the environment, and on the other hand, having all the characteristics of an innately programmed organic capability. Language 'grows' in a child much as wings grow on a flegdling. The human infant is born with a Universal Grammar, which is part of the human genome.

The parametric approach championed in the 1980s was applied to comparative linguistics to yield a simple and attractive model of language acquisition: according to this view, a critical component in the acquisition process is the setting of UG parameters by the child on the basis of experience. This "selective" approach to the fundamental syntactic properties appears to be the natural counterpart, on higher levels of linguistic articulation, of the selective mechanism of acquisition of the basic phonetic properties of the language which has emerged from the experimental study of the initial cognitive state (Mehler & Dupoux 1990). The parametric approach has been very actively pursued, over the last twenty years or so, in various centers in Europe (Essex, Edinburgh, Utrecht, Potsdam, Milan, Siena,…), in close collaboration with US centers (MIT, UCLA,…). The annual meeting of GALA (Generative Approaches to Language Acquisition), an association based in Europe, is now the most important annual colloquium in the domain of acquisition and development studies, basically on a par with the older and prestigious Boston University Colloquium on Language Development.

This Chomskyan view of language as an innately specified organ has been challenged on various grounds during the years. The idea that there are underlying innate linguistic structures that facilitate the acquisition of a natural language is to be seen in opposition to the idea of language as an artifact that is rather constructed by the learner in the process of internalization, on a different basis than that provided by the unfolding of innate elements inscribed in the species' genome.

Michael Tomasello, director of the Department of Developmental and Comparative Psychology of the Max Planck Institute for Evolutionary Anthropology in Leipzig, is one of the leading proponents of this latter stance.

In his book *Constructing a Language: A Usage-Based Theory of Language Acquisition* (Harvard University Press, 2003), Tomasello presents a comprehensive usage-based theory of language acquisition. Drawing together a vast body of empirical research in cognitive science, linguistics, and developmental psychology, Tomasello demonstrates that we don't need a self-contained "language instinct" to explain how children learn language. Their linguistic ability is interwoven with other cognitive abilities.

Tomasello argues that the essence of language is its symbolic dimension, which rests on the uniquely human ability to comprehend intention. Grammar emerges as the speakers of a language create linguistic constructions out of recurring sequences of symbols; children pick up these patterns in the buzz of words they hear around them.

All theories of language acquisition assume these fundamental skills of intention-reading and pattern-finding. Some formal linguistic theories posit a second set of acquisition processes to connect somehow with an innate universal grammar. But these extra processes, Tomasello argues, are completely unnecessary--important to save a theory but not to explain the phenomenon.

Tomasello's conclusions are in turn severely criticized by generativists such as G. Chierchia, who argues that Tomasello underestimates the role of Universal Grammar and parameter setting in language growth, relying on an unfounded unilateral emphasis on what he calls the "intention reading" capacity. In the attempt to understand what is specific to language and what is part of more general non domain specific acquisition devices, Tomasello, they claim, disregards much evidence that goes in the opposite direction. His standpoint ought be counterbalanced with the results put forth over the past 10-15 years by researchers like Avrutin (Utrecht), Clahsen (Essex), Weissenborn (Berlin) and Guasti (Milan-Bicocca), to mention some of the most influential and productive ones. Such results and theoretical proposals conjugate attention to empirical findings, and a mix of theoretical and experimental sophistication which is exactly what cognitive science ought to be striving towards.

7. *Choice, rationality, decision*

Choice, rationality, decision is a topic-cluster that takes into account work in fields like the experimental psychology of reasoning, formal philosophy or linguistic pragmatics that focuses on the relations between reasoning and rationality or the importance of pragmatic and contextual effects in reasoning tasks. Research carried out by people like Daniel Kahneman, 2002 Nobel Prize laureate in economic sciences, fits into this topic-cluster. Kahneman has studied the importance of context in decision-making and the shortcuts people take ever since the 1970's, when he began publishing his groundbreaking work with the late Amos Tversky. His findings on the psychological motives that determine decisions have implications for economists, especially in areas such as individual savings behavior or participation in the stock market. Kahneman and Tversky's landmark paper on decision-making under circumstances where there is uncertainty was published in *Econometrica* in 1979. Prior to this publication, economists assumed humans made rational decisions. Economics was also a non-experimental science that relied on real-world observations. Today, largely because of Kahneman's work, experimental economics is burgeoning. In an article based on his Nobel Prize lecture, published in *American Psychologist* (September, 2003), Kahneman reviews studies on intuitive judgment and decision- making in the context of two related concepts. These are accessibility (the ease with which thoughts come to mind) and the distinction between effortless intuition and deliberate reasoning. His paper shows how the psychology of judgment and the psychology of choice share basic principles, once again drawing together lines of research that are usually studied separately.

The Adaptive Toolbox

Director of the Center for Adaptive Behavior and Cognition of the Max Planck Institute for Human Development, Gerd Gigerenzer has advanced a view according to which one needs an ecological standard of rationality, that is, judgment algorithms that perform well in the real world, regardless of their adherence to formal inference methods (e.g. multiple regression, Bayes' theorem).

Gigerenzer coordinated together with Reinhard Selten, 1994 Nobel Laureate for Economics, a book entitled *Bounded Rationality: The Adaptive Toolbox* (MIT Press, 2001), the characterization of which follows:

In a complex and uncertain world, humans and animals make decisions under the constraints of limited knowledge, resources, and time. Yet models of rational decision making in economics, cognitive science, biology, and other fields largely ignore these real constraints and instead assume agents with perfect information and unlimited time. About forty years ago, Herbert Simon challenged this view with his notion of "bounded rationality." Today, bounded rationality has become a fashionable term used for disparate views of reasoning.

This book promotes bounded rationality as the key to understanding how real people make decisions. Using the concept of an "adaptive toolbox," a repertoire of fast and frugal rules for decision making under uncertainty, it attempts to impose more order and coherence on the idea of bounded rationality. The contributors view bounded rationality neither as optimization under constraints nor as the study of people's reasoning fallacies. The strategies in the adaptive toolbox dispense with optimization and, for the most part, with calculations of probabilities and utilities. The book extends the concept of bounded rationality from cognitive tools to emotions; it analyzes social norms, imitation, and other cultural tools as rational strategies; and it shows how smart heuristics can exploit the structure of environments.

http://www.amazon.com/exec/obidos/tg/detail/-/0262072149/002-0295912-4524832?v=glance

Behavioral finance

Dennis Hilton, professor in the Psychology Department of University of Toulouse II, is recognized across the globe as a leader in the field of behavioral finance, the study of how psychology affects financial decision-making and financial markets. In Germany as well, scientists at the University of Mannheim are leaders in the field of behavioral finance.

Based on findings from psychology, behavioral finance deals in particular with the issue of how individuals interpret information and then translate this into investment decisions. A large number of studies have concluded that investors again and again fall into the same psychological trap: shares on which gains have been made are sold too early and shares on which losses have been made are sold too late. Besides overestimating their own capabilities, one of the reasons for this is an uneven degree of risk awareness on the part of many investors. They behave in a risk-averse manner in winning situations and are willing to take risks when in a losing situation.

Links: http://www.behaviouralfinance.net/ , http://www.iqpc.com/cgi-bin/templates/document.html?topic=230&event=5822&document=46376

8. *Culture and social cognition*

Social cognition refers to those aspects of mental life that enable and are shaped by social experience. It takes into account the rich social context in which cognition evolves and occurs. Cognition is to be thought as a prelude to action and interaction rather than as an end unto itself. Studies are carried out on social cognition in animals, especially in primates, but also on pathologies like autism, in which the so-called *theory of mind* module is affected. Phylogenetical aspects of socialization, together with the grounding of cognitive functions pertaining to mentalization in ontogenetical development are also extensively studied. Much work is devoted to *metacognition*, broadly defined as any knowledge or cognitive process that refers to, monitors, or controls any aspect of cognition. It has important effects on advances in self-regulation and reflective thinking, the demands of formal schooling, and the modeling of metacognitive activity by parents, teachers, and peers. There is an important connection between metacognition and theory of mind, in the sense that both are concerned with the study of cognition about cognition, although theory of mind studies assess younger children' appreciation of the role of mental states in the prediction and explanation of other people's behavior, whereas metacognitive studies examine older children's knowledge of mental processes in the self, often in an academic context. Other key words in this context are *metareasoning* and *metarepresentation*. Many philosophers (e.g., Clark 1997, Bermúdez 2003) contend that *second-order cognitive dynamics* (thoughts about thoughts, either one's own or other's, but mostly one's own) is the emblematic feature of human cognition, distinguishing it from animal cognition.

In Europe there are programs and centers that offer a cultural perspective on cognition. They mainly combine research in evolutionary psychology with research in anthropology. One could mention the Jean Nicod Institute in Paris (where Dan Sperber, proponent of the so-called *theory of relevance* in pragmatics, of the *massive modularity* hypothesis, and of the idea of a *epidemiology of representations* is based), the Max Planck Institute for Evolutionary Anthropology, the Center for Adaptive Behavior and Cognition of the Max Planck Institute for Human Development (where Gerd Gigerenzer, interested, among other things, in *models of bounded rationality*, *social intelligence*, and *ecological rationality* is based), the Psychology Department of the University of Manchester (each discipline on their research agenda was awarded a 5 at the 2001 Research Assessment Exercise in the UK), the Institute of Cognition and Culture at Queen's University, Belfast (where Harvey Whitehouse, a specialist in Melanesian religion-'cargo cults', is based) or the University of Reading (where Steven Mithen, a specialist in cognitive archaeology, is based).

An emergent theme for the future concerns the study of intercultural variability, a project that is already occupying full-stage in the US. At the Rutgers University Center for Cognitive Science, for instance, Stephen Stich (http://www.rci.rutgers.edu/~stich/) is coordinating a series of research groups concerned with the culture-cognition interactions or the role of intra-cultural intuitions in the apprehending of various ideas.

The International Culture and Cognition (ICC) Program

Link: http://icc.isr.umich.edu/ICC_Home.html

The International Culture & Cognition program or ICC is a multidisciplinary virtual Institute devoted to exploring the interactions between mind and culture.

ICC is a joint initiative of the University of Michigan Culture & Cognition Program and Institute for Social Research and the Institut Jean Nicod in Paris, but includes member institutions and faculty from four continents and a dozen nations.

ICC provides access to resources for students, researchers, and instructors in the academic areas that bear upon how cultural environments impact individual minds and how individual minds impact cultural environments. These academic areas include (but are not limited to) cultural, biological, and cognitive anthropology; developmental, cognitive, social, and evolutionary psychology; archeology; linguistics; philosophy; religious studies; and area studies.

The Director of ICC is Dan Sperber (Institut Jean Nicod). The Associate Director is Justin Barrett (University of Michigan). Members of the leadership team also include Lawrence Hirschfeld (Michigan), Richard Nisbett (Michigan), and Scott Atran (Michigan and Institut Jean Nicod).

Mirror neurons

The discovery of mirror neurons in the frontal lobes of macaques and their implications for human brain evolution is one of the most important findings of neuroscience in the last decade (the renowned neuroscientist V.S. Ramachandran considered that 'mirror neurons will do for psychology what DNA did for biology: they will provide a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments'- http://www.edge.org/3rd_culture/ramachandran/ramachandran_p1.html). Mirror neurons are active when the monkeys perform certain tasks, but they also fire when the monkeys watch someone else perform the same specific task. There is evidence that a similar observation/action matching system exists in humans. The mirror system is sometimes considered to represent a primitive version, or possibly a precursor in phylogeny, of a simulation heuristic that might underlie mindreading.

Today, mirror neurons play a major explanatory role in the understanding of a number of human features, from imitation to empathy, mindreading and language learning. It has also been claimed that damages in these cerebral structures can be responsible for mental deficits such as autism. (presentation from http://www.interdisciplines.org/mirror/language/en)

The group that pivotally contributed to this finding is based at the Department of Neuroscience of the University of Parma in Italy, directed by Giacomo Rizzolati.

Metacognition

Broadly defined, *metacognition* is any knowledge or cognitive process that refers to, monitors, or controls any aspect of cognition. Although its historical roots are deep (e.g., James 1890), the study of metacognition first achieved widespread prominence in the 1970s through the work of Flavell (1979) and others on developmental changes in children's cognition about memory ("metamemory"), understanding ("metacomprehension"), and communication ("metacommunication"). Metacognition is now seen as a central contributor to many aspects of cognition, including memory, attention, communication, problem solving, and intelligence, with important applications to areas like education, aging, neuropsychology, and eyewitness testimony (Flavell, Miller, and Miller 1993; Metcalfe and Shimamura 1994) (*apud* Moses & Baird 2001)

It is a well-established fact that sensory feedback can regulate interaction between perception and action. Work in this area however generally ignores the specific contribution of metacognitive feedback, i.e. the internal cues relative to informational states that are extracted from feedback obtained in ongoing tasks by the cognitive system. Several pieces of work that mainly belong to metamemory and action control research have shown the central contribution of control and monitoring of informational states and processes in tasks such as learning new facts or skills, retrieving information from memory, controlling emotion or planning action.

It is recognized today that such a metacognitive feedback plays a crucial role both in the fine-tuning the execution of an action according to the context of a task and in taking into account one's own mental competence in order to react appropriately to various task demands. Attentional judgements are needed to evaluate the quality of perceptual information required by a specific kind of action, metamemory judgments to contextually reevaluate correction and relevance of previously selected plans of action, and meta-emotional and metarepresentational judgments are involved in monitoring the social interactions (behavioral and linguistic).

(http://apic.hautetfort.com/archive/2004/11/27/presentation_of_the_seminar_en.html)

5. SWOT synthesis

Strengths

- Present resources
  - Some outstanding teams and centers. The elite in the field highly sophisticated and well-connected
  - Particular strengths in robotics, neuroscience, psychophysics, statistical and dynamical models, logic, developmental psychology, pharmacology, linguistics, ...

- Potential for development
  - Strong traditions in participating disciplines, variety of paradigms maintained, resistance to conformity
  - Excellent students with broad training

- Europe as a source of empirical data
  - Ideal mix of variability and comparability: Mill's method of differences applicable to tease apart factors in the production of socio-cultural, political and economic systems, representations and skills

Weaknesses

- Resources
  - European centers: generally too small, too poor, and marginal within the overall system and/or the disciplinary matrices
  - Insufficient flux of top young people from Europe
  - Insufficient flux of confirmed or junior scientists from outside Europe because of usual complexities and rigidities + generally subcompetitive work conditions

- Insufficient quality of work
  - Some fields encumbered with mediocre people, giving the field a bad name and relaying impoverished vision to potential developers and users (very clear in such fields as education)

- Institutional obstacles
  - Rigid academic system; hiring of the right people difficult; training programs hard to set up
  - Scattering of resources: too many small entities, too many non-communicating power structures, each based on a particular field or academic culture (*eg* engineering with computer science etc., medecine with psychiatry, natural sciences with neurobiology and psychology, human sciences with linguistics and philosophy...)
  - Relative rarity of close industry/academia links for R&D; underdeveloped culture of high-level applied research

- Cultural factors
  - Participating disciplines low in academic pecking order (in some countries)

- Contributing branches suffering low status within their parent discipline
- Underdevelopment in some supporting traditions (analytic philosophy, empirically-minded psychology and social science...) in some countries
- Pessimism about science-based cures to social and political ills
- Skepticism about new paradigms; poor image of interdisciplinarity among "hard nosed", serious scientists
- Unfocussed perception of cogsci outside the field (and sometimes inside, too)
- Insufficient autonomy and trust accorded to young scientists

Opportunities

- Motivation
  - Europe has unique need for cogsci applications and thus motivation to develop it:
    - Translation and transposing
    - More generally, border-crossing, communication, comparison, capitalizing on other cultures and styles, synergizing without uniformizing, establishing coherence and consistency, legibility, learnability
    - World-construction (government, grassroot self-determination, self-awareness, teaching, socializing in a larger vocabulary of concepts and norms....)
  - Classical disciplines feel the need to vary the fare offered to best students

- The We Try Harder Principle
  - Europe can learn from mistakes and limitations in the US and Japan, and it can take its time to identify windows of opportunity and polish strategies

Threats

- Competitive disadvantage and winner-takes-all phenomena at international scale
  - US (and now Japan and soon China) dominate agenda, journals, referreeing system, conference program committees; overwhelming power of resources and numbers

- Competitive disadvantage and winner-takes-all phenomena at European scale
  - Among forefront projects, such as post-genomics, nanotech, etc., cogsci risks being squeezed out, due to lack of visibility and political leverage (compounded by dispersion of voices speaking in its favor)

- Misperception of cogsci within the policy-making circles
  - Cogsci misperceived by policy makers, pushing it in unfruitful directions or towards lopsided development; or completely diluted or disbanded
  - Cogsci seen as superfluous by potential users in research, due to erroneous belief they can get the information they need without expert help (relying on commonsense notions)

- Cultural resistance
  - A science war develops between "humanistic" social science, clinical psychology, philosophy and humanities and "dehumanizing", "reductionistic" cogsci

6. Forward look

a. Three very general goals

G1 Establish a European Research Area in Cognitive Science

Subgoals

G1.1 Remove obstacles which stand in the way of full potential

Sub-subgoals

G.1.1.1 Lower the level of tension in the academic communities concerned, both within the boundaries of cogsci, and across these boundaries; this requires a long-term effort and the leadership of respected figures; not to be left to the lower ranks

G.1.1.2 Simplify and unify procedures for collaborations, while remaining flexible on format; the ultimate goal is to foster enduring communities of outstanding scholars straddling national and academic boundaries, and involving the training of graduate students, collaborative research and sharing of resources (platforms and infrastructures)

G.1.1.3 Adopt a proactive strategy with respect to the fears and resistances which cognitive science will provoke in the general public (issues of 'neuroethics', and the role of computers, informational networks and impersonal entitities in daily life and matters of policy)

G1.2 Encourage synergies

Sub-subgoals

G.1.2.1 Facilitate intra-Community enduring collaborations, multilevel but not necessarily multilateral

G.1.2.2 Define goals which involve pure and applied research and development, preferably belonging to several ‘cultures’ (formal, natural-scientific, medical, engineering, social-scientific...)

G.1.2.3 Create a user-friendly database allowing the European cogsci community to get to know itself much more thorougly and systematically

G1.3 Develop European-wide and /or world-wide tools

Sub-subgoals

G.1.3.1 Identify tools (databases, e-learning programs...) which either do not exist at all, or are not sufficiently available to Europeans or adjusted to their needs; see below for some suggestions

G.1.3.2 Fund the creation and update of such tools, retaining ownership by the Commission (via the High Authority proposed below); or link up with similar enterprises launched by other countries or international bodies such as OECD

G2 Raise the scientific level of European cogsi, aiming for parity with US-Japan-China in the next 20 years

Subgoals

G2.1 Raise the standards in the participating disciplines

Sub-subgoals

G.2.1.1 Facilitate access of outstanding scientists to positions of effective control, in effect reducing the role of the old ruling elites in the participating disciplines

G.2.1.2 Attract foreign scientists in academic positions in the field

G.2.1.3 Facilitate and support the establishment of European journals and learned societies in the participating disciplines

G.2.1.4 Avoid supporting mediocre projets (better to support none than to support the least mediocre); encourage this policy also at national levels as far as possible

G2.2 Capitalize on strong teams and traditions

Sub-subgoals

G.2.2.1 Facilitate access of outstanding scientists to positions of effective control, in effect reducing the role of the old ruling elites in the participating disciplines

G.2.2.2 Attract foreign scientists in academic positions in the field

G.2.2.3 Define and support priorities in which European teams have a competitive advantage

G.2.2.4 Encourage and support cooperation between very strong European and non-European teams, generally on a bilateral, rather than multilateral, basis

G2.3 Secure a share of the elite of the coming generations of scientists

Sub-subgoals

G.2.3.1 Divert some of the best students and young scholars from Europe away from the mainstream topics in the traditional star disciplines and get them involved in cognitive science

G.2.3.2 Divert some of the best non-European students and young scholars away from non-European PhD programs and labs and get them to come study and work in Europe.

G.2.3.3 Facilitate return of European postdocs residing in the US and elsewhere outside Europe (Japan is becoming a major player in cognitive neuroscience and functional imagery in part due to Japanese students trained in the US and returning to Japan to establish their own labs)

Recommendation: Facilitate and establish high-quality and attractive European graduate programs

Recommendation: Create 1 to 5-year positions allowing top-class scientists to leave their home institution or department to participate in research in a European center of excellence. (Roughly: Marie-Curie chairs of excellence, but a contingent reserved for cognitive scientists and no conditions of nationality.) Special programs should be set up for reintegrating European postdocs.

G3 Anchor cognitive science in multiple ways in European R&D

Subgoals

G3.1 Encourage involvement of hitherto unconcerned academic institutions

G3.2 Establish long-term alliances with powerful industrial labs

G3.3 Encourage involvement of private foundations

G3.4 Set up a European agenda of goals for cognitive scientific R&D

b. Areas requiring resolute action

b1. Strengthening the core disciplines

The core disciplines are the prime support and provide the forces necessary for pursuing the central goal of cognitive science. They in turn require support, but it must be provided in a discriminate fashion: the resources must be funneled to the teams and projects that directly concern cognitive science. These interacting parts have a dual role to play: they *provide* knowledge, they must also *assimilate* knowledge coming from the other disciplines, and be vectors of change and adjustment for the entire core discipline to which they belong: as, say, neuroscience brings unsuspected perspectives on brain functions, cognitive psychology must take them in, modify accordingly its own views, but also propagate the necessary changes to other parts of psychology, say clinical, social, industrial, differential,... This is especially true of philosophy and the social sciences, insofar as they are for the most part still very far removed from an understanding of cogsci, and they are responsible for a enormous sector of scholarly research, self-understanding and policy-research.

Policy makers should bear in mind more particularly the following disciplinary areas which require support; some have been clustered together for reasons of size and strong mutual dependency:

i. Systems neuroscience, with particular emphasis on cognitive neuroscience
ii. Psychology: developmental and adult
iii. Neuropsychology, psychopathology, psychiatry
iv. Psychophysics, artificial vision, robotics
v. Animal cognition, comparative psychology, paleontology, evolutionary biology, anthropology
vi. Linguistics
vii. Philosophy: epistemology, logic, philosophy of mind, philosophy of language, ontology, philosophy of science
viii. Social science: economics, sociology, social psychology

All of these fields are of crucial importance, and are far from being assured to prosper in the absence of strong voluntary action on the European scale. This applies even to systems neuroscience, which could be thought to be flourishing, thanks to the expansion of neuroimaging techniques, but in fact is being squeezed almost out of existence under the combined pressure of the micro-level specialties (cellular and molecular neuroscience) and empirical functional imagery. More generally, the sad paradox of cognitive science is that it is an immense territory, of decisive importance, with a pitifully small contingent of scientists to explore and exploit it. In many of the above fields, there would be typically less than 5 worthy candidates in Europe (and no more than double that number world-wide) to fill a top-level senior chair.

b2. Supporting much more resolutely key lines of research

As in Section 4, a more perspicuous view of the priorities can be obtained by cross-referencing the field by topics as well as core disciplines. The following list thus provides *themes* in basic research (applications are listed under (d) below) which will be more particularly pursued by appropriate multidisciplinary combinations. The list cannot claim to reflect a full consensus in the profession; it should be completed, revised and perhaps throroughly restructured by a representative scientific body of the highest caliber. It is provided here as a first approximation, with *no* order of priority implied:

i. Neural coding
ii. Non-human primate research, incorporating functional imagery
iii. Learning: multilevel approaches, from neuron to social groups
iv. Neural bases of cognitive impairments
v. Genetic correlates of impaired and normal differential cognitive abilities
vi. Interfaces: man/computer, brain/computer
vii. Social cognition, distributed and situated cognition; learning, theory of culture
viii. Higher cognitive functions, emotions, motivations

ix. Theory of knowledge and belief, logical modelling, realistic formal models of rationality and decision-making; cognitive (and neuroscientific) approaches to economics and politics
x. Theories of computing

b3. Developing theoretical tools

Somewhat arbitrarily, we single out three themes which could well be part of the previous list, but whose level of formal abstraction sets them somewhat apart. They are quite theoretical in nature, but are to function as essential tools, with maximal scope, in cognitive science as it will develop in the next 20-30 years. In some ways, they will serve cognitive science much like the calculus served nascent, and mature, physics. It so happens that the strong European traditions in mathematics, theoretical computer science and theoretical physics gives Europe a competitive advantage.

i. Complex systems theory: the conceptual and mathematical foundations of multi-level analysis of the brain and other natural or man-made systems
ii. Biological computing: principles of neural information processing, to be deployed in the resolution of structure-function problems in neuroscience (how the brain achieves the desired informational transaction, and what transaction is achieved by a given brain structure) and in artificial computing devices
iii. Integration of imaging techniques: multi-electrode recordings, fMRI, MEG, evoked potentials, optical imaging and yet other highly sophisticated methods of measuring brain activity need to be integrated into single models; this requires new mathematical and statistical models.

c. European scientific policy: Centers, networks, projects, instruments, knowledge bases

Contrary to other major scientific fields, in which Europe should presumably restrict its role to the stimulation of cooperations between powerful and well-established national systems of scientific institutions and industrial research labs, cognitive science, as has been repeatedly stressed in this report, does not enjoy strong and durable institutional support at the national level, with the exception of the UK, despite impressive efforts on the part of the Max Planck Gesellschaft, the French CNRS, and other agencies. Europe can, and must, pursue a much more central and deliberate policy in order to construct, within the next few years, durable and high-quality support systems for cognitive science, while developing a European vision of the field.

What is proposed here, after consultations with several leading scientists, is a coordinated system comprising a set of initiatives at various geographic and temporal scales. Of course, such a policy should be reviewed, refined, modified and implemented by some High Authority such as the one proposed below.

c1. Centers

Bringing together for extended periods of time scholars in all or some of the major contributing disciplines is essential. Long-armed collaborations can, and do achieve a lot, but there is nothing which can replace day-to-day, eye-to-eye contacts, in offices, near the phocopying or the coffee machine, during discussions with students, visitors and postdocs, etc. The fear of constructing expensive institutions which are obsolete before they are fully functional, or fall in the hands of local scientific mafias, is legitimate, but it would be suicidal to give up entirely. There is no need to argue for this, as unfortunately the no-centers policy has been tried and shown to fail. Some might want to argue that advanced tele-technologies have been insufficiently exploited, and that they have now reached a point of user-friendliness and dissemination as to make the very idea of a center hopelessly old-fashioned. This is not the place to discuss this idea ; suffice perhaps to mention the contrary opinion expressed, in relation to business organizations, by such a hotbed of technology as the Xerox Research Center Europe (http://www.xrce.xerox.com/):

> "The current trend towards hot desking, virtual teams, outsourcing, email and teleworking is a potential threat to an organisation's ability to produce value and innovation on an ongoing basis. This is because they disrupt traditional face-to-face information exchange and can create 'unconnected islands' of expertise. Informal face-to-face exchanges and conversations at work encourage innovation and the potential for business growth."

How many centers should Europe support, and how should they be put together?

Let us begin with the second question. Whether Europe can create one or several 'European Institutes for Advanced Studies in Cognition' (EIASC) is beyond the present rapporteur's competence. What should be stressed in this regard is the following possibility. The EC could turn a (small) number of already existing centers, or concentrations of workers in the field, into European centers, on a limited time basis (say, 10 years with a mid-term review). After having selected such a center, the High Authority would tailor its contribution to the specific needs of the center, which would typically include renovation and extension of existing premisses, purchase and maintenance of heavy equipment, positions, doctoral and postdoctoral support, possibly some positions for high-level scientific administrators. Such a *Europeanized* Center would operate under the executive authority of a Scientific Board which would have been selected by the EC and the local authorities, on a parity basis. It would have privileged interactions with similar Centers, and with well-targeted institutions outside of Europe.

Under such a system, the cost of an EIASC would be a fraction of what it would cost to build, fund and staff from scratch. The formula would also circumvent two major stumbling blocks: unfair competition between European and national systems, and scarcity of high-level personnel. An EIASC would also be an ideal venue for returning European postdocs, as well as non-European visitors, whether or not susceptible eventually to reverse brain-drain.

A reasonable number of EIASCs of this sort would be in the order of 3 to 5.

c2. Networks

Networks would complement the EIASCs. They would link up research sites of limited size, in Europe, each of which would have the mastery of some, but not all, the interdisiciplinary interfaces, or converging technologies, needed to make progress. Each network would thus be able to extend fragmentary forms of integration into a broader view of a given topic. The research teams working within a network would retain their autonomy and identity in their respective national systems, and would interact on the basis of complementarity of advanced techniques applied to the same topic, The EC authorities would provide the funds required for numerous inter-lab visits, workshops, and networking tools.

Doctoral and postdoc scholarships should be attributed on the basis of projects concerning two or more of the nodes in the network.

c3. Projects

This is the most familiar kind of support, and there is no need to elaborate. As usual, the EC, possibly through the High Authority described below, would promulgate scientific priorities and issue calls for offer. There are however two important provisos to propose:

(1) Cognitive science is still a very young field, in which many completely novel insights can occur, changing the problem situation and the topical organization in deep ways. Thus, room should be made for 'blue-sky research', which would not be required to obey any form of constraint in content or form, and would stimulate scientific imagination,

(2) As suggested also in the W. Bibel's report, part of the European funding should be provided as awards, rather than bursaries given to the winners of a call for offer. The reason for this is twofold: first, professionalism in grant-proposal writing does not coincide entirely with scientific excellence and fecundity; there are too many good proposal writers whose scientific output does not deserve privileged treatment, and, much worse, there are outstanding scientific groups which are poor at meeting deadlines, finding the requisit (often contrived) partnerships, and writing up proposals. In addition, giving out awards (large and in small numbers) saves a huge lot of time (and thus money) on the source and on the target sides; if also modifies the spirit of the transaction, favoring honesty and realism over hype and self-aggrandizement.

c4. Instruments

Cognitive science needs large amounts of first-class brain power and important parts of its work can be conducted with minimal material means. However, cognitive scientists today need all sorts of equipment, costly functional imaging tools of all kinds (fMRI, MEG, TMS, etc.) , of course, but also such medium-cost (100-300 k€) tools as eye-trackers, systems for voltage-sensitive dye imaging of cortical networks, test cabins for normal and non-normal subjects of different ages, and of course computing systems. Multielectrode recordings on awake monkeys performing natural tasks require advanced technologies, There is also the need to work on vigile monkeys, an essential and irreplaceable link between human studies, limited for obvious ethical reasons, and models, which are developed in abstracto and require empirical validation. Japan for example boasts hundreds of monkey workstations, while they are rare in Europe (Guy Orban's Laboratory for Neuro- Psychophysiology at theMedical School of Leuven University, in Belgium, being a brilliant representative). Genetically-modified species (mice, possibly also rats, fruit flies,...) allow for voltage-sensitive proteins being attached to large families of neurones, which then can be observed by optical imaging as mentioned above; alternatively, in the case of drosophilia, genes can be directly put in correspondence with perceptual-cognitive-motor capabilities. This is not meant as an exhaustive list of the instruments required. The social sciences, cognitive ethology, linguistics require further proprietary tools.

c5. Knowledge bases

There are three very different kinds of data bases whose need is pressing:

(1) A directory of research in cognitive science, including all the concerned fields, pure and applied, with intelligent and user-friendly cross-referencing of people, places, keywords, funding agencies, networks etc. This would be for the use of the participants, but also of professionals and leaders outside the field who wish to make contact with the appropriate community or research team for their own purposes.

(2) A brain data base. This is at once a top priority for Europe, which cannot let the US impose a monopoly, and a matter requiring careful consideration, due to complicated technical and deontological issues; a special task force should be set up, which could comprise people such as Henry Markram (director of the Brain and Mind Institute at Lausanne), Yves Frégnac (director of UNIC, a CNRS lab at the Orsay-Gif campus near Paris), Wolf Singer (director of the Max Planck Institut for Brain Research in Frankfurt) and others.

(3) A 'cognomics' data base, which would make available to insiders and outsiders alike the large and ever growing mass of information produced by the cognitive sciences and their applications. Thousands of relevant articles are published each year. Functions are continuously identified thanks to properly oriented brain scanning techniques. The purpose of this instrument, which would stand to pure and applied research on cognitive processes and systems much the way genomics stands to biological and health sciences, would be to establish standardized protocols, benchmarking tools, a uniform vocabulary, meta-analytical and data-mining tools to make relevant information available to workers in machine design but also the cogsci community at large[3].

d. R&D

There are indefinitely many potential applications of cognitive science, given the increasingly central character of mind and knowledge in contemporary societies. However, not all have yet reached a reasonable probability of being in effect realizable in the short or medium term. Others do not require massive doses of sophisticated knowledge in the cognitive and brain sciences (see 3.B.d.i, "Shallow vs deep applications of cogsci"). The role of cogsci in such 'low implication' cases is to insure the quality of the information which reaches potential developers. In the present state of affairs, the quality is low, sometimes disastrously so.

The areas in which there definitely is going to be momentous progress and in which Europe can acquire a leading position (and had better not miss the opportunity) are fairly clear (see also Appendix on *Major Applications of Cogsci) :*

d1. Education. Initial, continuing, remedial, education will reach in the course of the XXIst century an unprecedented salience in the post-industrial societies, so that a better education for more people, with fewer excluded due to age, handicap, lack of motivation, family and social circumstance, will be a crucial factor in the international competition. There is a need to gain a much deeper, theoretically grounded, comprehension of the learning processes, in particular, drawing on the insight that learning is generally *not* the effect of a general capabiliy applied to any topic at hand, but results from combining domain-specific, or modality-specific abilities guided by metacognitive skills, which can themselves be trained and strengthened. Contrary to popular belief, this is an area where cognitive psychology (as

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[3] The idea has been put forward by Roberto Casati (Institut Jean-Nicod, CNRS-ENS-EHESS, Paris) in a note prepared for a FET meeting, held 21-22 April 2004 in Brussels, in a session on "Intelligence and cognition research".

opposed to neuroscience) has the lead role, as J. Bruer, head of the McDonnell Fondation and a major contributor to the cognitive approach to education, never tires of arguing.

There are two kinds of products to be developed in the area: methodologies and tools. Methodologies help give better education to more people, and will result in a general enhancement of European capabilities in all fields. Tools, methodologically motivated, are books, interfaces, software for learning, and these are an industrial output which Europeans can sell worldwide.

d2. Mental health. Over a third of all pathologies are caused by disorders of the nervous system, from depression to Alzheimer's disease, from autism to phobias, learning disabilities, obsessive-compulsive disorders, from epilepsy to dystonia and Parkinsons's disease, etc. Pharmacology is of course a major player here, and will increasingly owe its efficiency to basic neuroscience, and less to empirical know-how. But the real hope is to prevent or permanently repair dysfunctional brains. In addition, outside pathologies, there are essential dimensions of 'healthy' individuals, such as pains, moods, personality, motivation, resistance to adversity, resilience to maltreatments, etc., which have a neurological basis and can be studied by neurocognitive means. The economic and social benefits of even modest progress on this front are incalculable.

d3. Informational tools. Computers, data bases, communication, information in the lay sense (political and social issues and organization, polls...)...; language processing, automatic or semi-automatic translation, data mining; consistency-checking, simplification and synthesis of legal codes, norms, regulations, reasoning and decisions; decision-making aids, economic aids

d4. Perceptual/motor tools: Robotics, artificial intelligence, image interpretation and artificial vision, motor and perceptive prostheses; computer-aided surgery; multimodal environments, design tools for industry, architecture, city planning, arts (especially performing arts and cinema), emergency control, military and security operations; machine, vehicle handling, sports

e. High Authority for Cognitive Science in Europe (HACSE)

To the extent that the present report has successfully argued in favor of a resolute, proactive European strategy in cognitive science, the question is posed of how such a strategy should be deployed. The picture and conclusions presented here are tentative at best, and possibly faulty in important respects. Many issues have been set aside, others cry out for clarification. For this reason alone, the need is felt of a body with sufficient scientific authority and policy-making experience. Then there is the considerable task of implementing the agreed-upon guidelines, coordinating with neighboring programs, selecting the project and institute leaders, assessing the ongoing operations, surveying the European, international and national landscapes, and conducting periodic foresight exercices.

These should be the missions of an EC-appointed body of high-level experts, which could be named the High Authority for Cognitive Science in Europe (HACSE). Recruitment of its chair and members should be conducted with the utmost care.

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Appendix 1

Cogsci's Many Labels

Looking at the MITECS-style classification of domains intra cogsci, and the labels one can discern from mainstream contributing journal names, covering entire disciplinary fields (e.g. *Cognitive Science*, *Cognitive Psychology*, *Artificial Intelligence*, *Neuroscience*, *Neuropsychologia*) or subject areas (*Cognition*, *Neural Networks*, *Web Semantics*, *Brain and Cognition*, *Brain and Language*, *Journal of Memory and Language*, *Journal of Neurolinguistics*), or by browsing through lists of centers and programs in cogsci around Europe and around the world, one can find various nomenclatures for cogsci-related academic structures and enterprises. They are *not* meant to be *strictly ynonymous*, nor is it their self-understanding that they are. In fact, the names chosen often reflect a particular vision of the field, of its natural boundaries, of its central concerns, of its core topics.

Cognitive science is the mainstream denomination, to be found in the title of the leading regulatory organization of the domain, the *Cognitive Science Society,* and in the names of a few departments (UCSD, Johns Hopkins,...) and many graduate programs or research entities. Sometimes one speaks of cognitive science*s* (in the plural), but many believe that every science is cognitive somehow, since it is an epistemic endeavor per definition. Perhaps *science(s) of cognition* would be more equidistant, since it delimits more clearly cognition as an object of inquiry and not as an attribute of the science in discussion. But *cognitive science* as a nomenclature fits well with one of the main ideas of this report, namely *interdisciplinary convergence,* with or without a strategy or *fusion*.

Cognitive studies is a name that tries to bridge the apparent hiatus between a hard scientific tradition and the more social, humanistic-laden part of the domain. It is to be found worldwide- the University of California at Berkeley has an Institute of Cognitive Studies, the Ecole normale supérieure in Paris has a Department of Cognitive Studies, there is a Tufts University Center for Cognitive Studies, a Cognitive Studies concentration at Cornell University, etc.

Informatics is the name chosen by the large and venerable group at the University of Edinburgh. It is defined (see http://www.inf.ed.ac.uk/about/vision.html) as "the study of the structure, behaviour, and interactions of natural and engineered computational systems".

Neuroinformatics is the label chosen by a series of institutions such as INI Zürich, established at the end of 1995 by the University of Zürich and the Swiss Federal Institute of Technology, the University of Edinburgh, the Ruhr-Universität Bochum in Germany or the THOR Center at the Technical University of Denmark in Lyngby. The main goals of research in the field are the discovery of *the key principles by which brains work* and *their implementation in artificial systems that interact intelligently with the real world*. Neuroinformatics is an emerging discipline which attempts to integrate neuroscientific information from the level of the genome to the level of human behavior. A major goal of this new discipline is to produce digital capabilities for a web-based information management system in the form of interoperable databases and associated data management tools. Such tools include software for querying and data mining, data manipulation and analysis, scientific visualization, biological modeling and simulation, and electronic communication and collaboration between geographically distinct sites. The databases and software tools are designed to be used by neuroscientists, behavioral scientists, clinicians, and educators in an effort to better understand brain structure, function, and development (http://www.neurovia.umn.edu/IGERT/)

Biological Cybernetics is the name of one of the Max Planck Institutes in Germany. The institute works in the elucidation of cognitive processes. The departments, "Cognitive and Computational Psychophysics" (formed in 1993) and "Physiology of Cognitive Processes" (founded in 1997) employ complementary methodological approaches to the systems analysis of complex processes in the brains of primates. The department "Empirical Inference for Machine Learning and Perception" (founded in 2001) works in the field of statistical learning theory and their application in various fields - ranging from computer vision to bioinformatics. The department of the 'High-Field Magnetic Resonance Center' (founded in 2003) works on the development of new contrast agents as well as (with the finishing of the MR center in 2006) the methodical enhancement and application of the imaging techniques.

Logic, Language, and Computation is a juxtaposition of research themes constituting the name of a research institute of the University of Amsterdam, in which researchers from the Faculty of Science and the Faculty of Humanities collaborate (The Institute for Logic, Language and Computation (ILLC)). ILLC's central research area is the study of fundamental principles of encoding, transmission and comprehension of information. Emphasis is on natural and formal languages, but other information carriers, such as images and music, are studied as well. Research at ILLC is interdisciplinary, and aims at bringing together insights from various disciplines concerned with information and information processing, such as logic, mathematics, computer science, linguistics, cognitive science, artificial intelligence and philosophy.

Language and information are two of the themes that one encounters in the name of a very important research center at Stanford University, namely the Center for the Study of Language and Information (CSLI), an Independent Research Center founded in 1983 by researchers from Stanford University, SRI International, and

Xerox PARC (now just PARC). CSLI is, according to the presentation on their website (http://www-csli.stanford.edu/), 'devoted to research in the emerging science of information, computing, and cognition. This new science had its origins in the late 1970s as computer scientists, linguists, logicians, philosophers, psychologists, and artificial intelligence researchers, seeking solutions to problems in their own disciplines, turned to one another for help.

Study of information, computation and cognition was the title of the joint NSF-SDF workshop held in Washington in the Spring of 1985, and of the highly influential report which came out of it.

Appendix 2

Mathematics in cognitive science

Mathematics played an important role in the development of cogsci from the latter's inception. The three paradigms (classicism/symbolicism, connectionism, and dynamicism) are each characterized by the deployment of specific mathematical techniques–for a brief reminder, the theory of computation (Turing machines) is the landmark for the first paradigm, learning algorithms and linear algebra define connectionism, while in dynamicism cognitive activity is understood as a series of mathematical state transitions plotted along different possible trajectories, mental operations being described through equations that capture the behavior of the whole system, rather than focusing on the logical or syntactic transformations within specific subsystems, as the case was for symbolicism.

Currently (see the Berthoz et al. report), it is considered that the most important mathematical successes are (a) the cases of dynamical networks that simulate cerebral plasticity (with contributions from statistical physics and the geometry of dynamical systems to simulate neural networks), and (b) the analysis of movement and its regularities so as to develop a robotics approaching animal ductility (the favored techniques being non-linear differential equations and their numerical methods to describe and reproduce the complexity of action and movement).

Regarding the mathematics used in cognitive neuroscience, it has to be noted that one needs to distinguish between (i) the mathematical tools used in the realization of experimental protocols and the exploitation of data, on the one hand, and (ii) the mathematical domains within which the main theories and explanatory models are to be found, on the other hand.

With respect to (i), one can find basic tools, such as Euclidian geometry (2D and 3D), the probabilistic calculus and statistical tools, Fourier transforms, etc.

Insofar as (ii) is concerned, the domains are much more diverse, depending in great part on the level and scale at which theories are to be placed: non-linear differential equations or processes (neuron models), equations with partial derivatives (image treatment, vision, control, learning), the theory of attractors and coupled oscillators (neuronal assemblies), statistical mechanics (spin glass, neural networks), linear algebra: matrices, tensors, quaternions (coordinate change, frames of reference), graph theory (anatomical and functional models of cerebral activation), topology and computational geometry (grid, smoothing, segmentation), theories of information and decision: Fischer information, mutual information, optimal estimators (Kalman), verisimilitude, Bayesian inference, population coding, etc. (see the Berthoz et al. report, Arbib 2003) Focusing on some particular examples, one could mention the representation via wavelets, the geometry and the dynamics of neuronal receptor fields, work on formal neural networks or Bayesian analysis.

The representation via wavelets concerns the representation of information (audio, video signals, learning stimuli), in which harmonic analysis (multiscale analogs of Fourier transforms on waves) plays a pivotal role.

The geometry and dynamics of neuronal receptor fields is at play when considering simple cells in V1 that have receptor fields whose receptive profiles (transfer functions) are partial derivatives of Gaussian integrals.

Work on formal neural networks is multi-faceted and constitutes a bridge between the second and third paradigm in cogsci (connectionism and dynamicism), but also a bridge between at least two conceptual frames-informational/computational thinking and brain thinking.

Bayesian analysis is relevant especially in light of the fact that the application of probabilistic calculus to a series of psychophysical problems allows a natural combination between the knowledge an observer has from observing the environmental regularities and the knowledge induced by his sensory organs (see the Berthoz et al. report).

Appendix 3

The structure, function and place of neuroscience in the study of cognition

As in the case of cognitive science, neuroscience gives rise to verbal as well as substantive issues. We should at the outset distinguish between two kinds of contrast: (i) there is a contrast in *levels* of aggregation, which is nothing but the usual molecule/cell/tissue/organ/system hierarchy central to biology, applied to the central nervous system (CNS) ; (ii) there is a contrast between *functions* of the CNS, which range from the control of digestion, blood circulation, breathing, posture and balance, ... to the various and interlocking cognitive-perceptual-motor-emotional-motivational functions. *Systems* (or *integrative*) neuroscience is the study of the CNS at the higher levels of aggregation, in contrast, for example, with molecular and cellular neuroscience. *Cognitive* neuroscience is (generally) understood as that part of systems neuroscience which is concerned with the cognitive functions (broadly construed).

Disagreements arise, first, as to the relative importance and autonomy of systems neuroscience in relation to molecular and cellular neuroscience; and second, as to the relative importance and autonomy of cognitive neuroscience in relation to the other component disciplines taking cognition as their object of study.

With respect to the first set of concerns, this report can do no better than refer the reader to informed opinions such as those of Wolf Singer, and of many senior cognitive neuroscientists who have repeatedly stressed the essential contribution of systems neuroscientists of the previous generation, and sounded the alarm at the threat of a virtual disappearance of this perspective, as senior representatives retire and the rising generations seem divided between the cell and molecule perspective on the one hand, and functional imagery on the other.

Wolf Singer, the director of the Max Planck Institute for Brain Research in Frankfurt, suggests that the European Commission needs to massively invest into *systems neuroscience*. Even if we have successfully decomposed the brain into its parts and have learned a lot about neurons, the building blocks of the brain, intra- and extracellular signaling systems and the basic principles of signal transduction among neurons, and we have a clear picture on the mapping regions in the brain-functions (structure-function relations), we know very little about how exactly the functions are brought about by the complex interactions among myriads of distributed neurons and strategies of subsystem integration[4]. According to Wolf Singer, understanding brain functions at such a deeper level will be crucial for the understanding of diseases affecting higher cognitive functions and emotions such as schizophrenia and cyclothymia.

Important implications of fundamental neuroscientific research are to be found in the neuropharmacological industry: we now have drugs which act on the higher cognitive functions, such as concentration, or executive function in general, regarded as a cognitive system (see also the box on *Neuropharmacology and the attention-deficit hyperactivity disorder (ADHD*) in §4.B, 2). But the mechanisms responsible for these drugs' efficacy remain to be fully elucidated: again, what we have found out at the molecular and cellular levels is a necessary step, but does not yield a satisfactory explanation, nor a sufficient basis for making decisive progress in the diagnosis, prognosis and therapy of mental disorders.

A second debate within the neuroscientific community concerns the robustness and contribution, present and future, of functional imagery to cognitive neuroscience. Speaking for the optimistic view are the opinions of many prominent psychologists, neurologists and neuroscientists (see in particular Frackowiak & Jones (2003)), and the fact that practically no one in the field today would be willing to forego the tools and insights provided by neuroimagery. The number of papers published every year which rely on, or are exclusively constituted by, results of neuroimaging experiments, is in the tens of thousands, which is all the more striking as these experiments are more expensive by at least one order of magnitude than classical experiments in psychology and psychophysics. On the other hand, as argues Guy Orban, head of the Neuro- and Psychophysiological Laboratory in Leuven, in which imagery is done on a wide scale on both human and non-human primates: "Functional imaging is only a component of cognitive neuroscience and its limitations at present are many. If the task of neuroscience in the cognitive science concert is to indicate how cognition is achieved, functional imaging does not do a good job. At best it can provide a coarse description at the network level of the cerebral regions involved. There is not even a sound way to observe the functional links between the active regions. Many claims are made about imaging, very few are proven. Yet there are ways to validate functional imaging, an enterprise in which Europe has a lead [imaging on non-human primates]. Also the limitations are often neglected. Neuroimaging consists in indirect measurement of millions of neurons using a vascular interface. It does measure activity level not specificity. Many efforts are deployed to improve fMRI so as a to measure selectivity. So far these methods fall short."

Now concerning the second set of issues, regarding the place and connections of cognitive neuroscience among the sciences of cognition, it is difficult to summarize in a few lines the arguments on both sides. I can try to sketch some lines pointing to the main issues at stake, referring the reader to a longer discussion in Andler (2005).

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[4] The task of neuroscience is not only to identify the parts of the brain and the neuronal properties involved in particular functions but also to unravel how these properties are brought about by the cellular and subcellular levels of organization. Systems analysis and molecular biology have to work in a concerted way (Orban & Singer 1991: 3).

Cognitive neuroscience has begun to illuminate and demystify many aspects of human thought, feeling and behavior. It is undeniably a field of capital importance: for example, understanding brain functions is a necessary prerequisite for the understanding of diseases and syndromes etiologically connected to the nervous system, representing a considerable proportion among maladies (35%).

Since the brain underlies all volitional behaviors, understanding cognition and the organization of human activity from a neuroscientific point of view will have effects on learning and development, personality studies, but also legal implications, suggesting the need for a reconstrual of the concept of *person*.

As has been argued in this report, with respect to the idea that cognitive neuroscience may replace, with its bottom-up approach, the classical top-down approach favored by cognitive psychology, and constitute the core of cogsci in the future, exclusive reliance on the resources of pure neuroscience is in all probability a strategic mistake (see Fodor 1999) . It resembles in a way the initial unfulfilled ambitions of AI (see Andler 2005). The current opinion is that, over the past years, the typical integrated research characterizing cogsci has been threatened by the temptations of dismemberment, in the sense that neuroscience and applied computer science have put to shade cognitive psychology and AI, the promises of classical or 'Good Old Fashioned Cognitive Science' being carried further just by linguistics and philosophy (Smolensky & Legendre 2005). But the line defended here is that if we are to keep sight of our ultimate goal, which is nothing short of a scientific understanding of the brain as an *integrated system* supporting the entire array of the mental functions, the only workable strategy is *disciplinary* integration, with contributing disciplines working together so as to set a proper *agenda*. One needs not only received, pre-packaged theoretical blueprints in the background when approaching a certain cognitive function via neuroscience, but also a bias-free strategy, which consists precisely in a better theoretical understanding of the function under consideration, deploying all the necessary resources, empirical as well as conceptual. When it comes to cogsci, we should always be cautious when confronted with more or less *monolithic endeavors*.

Beside this kind of worry, there are a host of crucially important ethical implications- in the last years, a new field, *neuroethics*, has emerged. Beside the beneficial effects when it comes to *the treatment of cognitive disorders*, problems arise if confronting the issue of *cognitive enhancement* for healthy people. According to Farah 2005, we could group into three general categories the ethical issues surrounding brain enhancement: 1) health issues- safety, side effects, unintended consequences, 2) social effects- the freedom to remain unenhanced may be difficult to maintain in a society where one's competition is using enhancement, barriers such as cost will prevent some who would like to enhance from doing so, 3) philosophical issues- brain enhancement challenges our understanding of personal effort, accomplishment, autonomy, and the value of people as opposed to mere objects.

The deterministic and physiological nature of all behavior raises important challenges to the view of *human nature*. We are now at a stage when more and more neuroscientific findings suggest that not only perception or movement, as the received view goes, are mechanistically-prone to be modeled, but that even *human personality*- character, consciousness, sense of spirituality could be considered as nothing more and nothing less than mere physical structures. As Farah asks (p. 38), 'is there anything about people that is not a feature of their bodies?'

In the decades to come we are bound to witness an exponential growth of public debates concerning the societal implications of cognitive neuroscience, mirroring the debates surrounding molecular genetics and recombinant DNA technology. This is a prediction that Martha Farah and Paul Bloom, among others, are relying upon. Bloom, already mentioned in §4.B, 4, is a Psychology Professor at Yale University and he has recently worked on the so-called 'innate dualistic intuitions' (see Bloom 2004), according to which we are natural dualists, seeing the world, as Descartes did, as containing physical things (or bodies) and social entities (or souls). He is interested in how this common-sense dualism emerges in development, and the implications that it has for domains such as morality and religion. Recent neuroimaging research has even shown a characteristic pattern of brain activation associated with states of religious transcendence, such as Buddhist meditation and Christian prayer. Thus, Bloom considers that 'The clash between dualism and science will not easily be resolved, and the stakes are high. The same sorts of heated controversies that raged over the study and teaching of evolution over the last hundred years are likely to erupt over psychology and neuroscience in the years to come.'

(http://www.edge.org/3rd_culture/bloom04/bloom04_index.html)

We should note that even if, in the years to come, the neuroscientific worldview will tend to occupy center-stage, the effects on the mentality of people will be very problematic. In philosophy of mind, a 30 year-old debate about the virtues of folk psychology in opposition to the neural explanation of the dynamics of beliefs and desires is still not over. Replacing a framework that is so familiar and common, or considering it as a mere interpretative stance, a useful fiction that helps one understand oneself and others, is a deeply problematic act. What if, with time, neuroscience will suggest that religion and spirituality are just heuristic or pragmatic fictions, that regulate one's internal dynamics, without any attached metaphysical signification? This raises big questions, and we need to be very careful when it comes to the scope and power of neuroscientific explanation, especially in the light of its current incomplete status. Similar worries arise with respect to theories and physics, where a theory of everything, a holistic theory that integrates the fundamental forces of the universe into a coherent theoretical framework, is searched for. But current physics is incomplete, and one could even argue for the possibility of integrating the dualistic intuitions and the naturalistic results on the background of a *tertium quid* (see Chalmers 1996).

Cognitive neuroscience is a crucial and a wonderful theoretical and practical endeavor, its results are powerful and the range of applications clearly immense, but we should beware of the temptation of *eliminativism* to which some of its defenders (including some philosophers) fall prey, and we should also never lose sight of the ethical issues involved.

Appendix 4

The function of philosophy in cognitive science

At first glance, philosophy has a dual role to play in cognitive science. First, it stands to cognitive science much the way it stood, at various junctures in history, to astronomy, mechanics and (more broadly what got to be known as) physics: it provides the budding new science with both a world-view and some suggestions as to how to go beyond it in order to overcome the puzzlements which arise from this world-view. Philosophy then becomes the emerging or growing science's sparring partner as it tries out a succession of alternative pictures. In this role, philosophy functions as philosophy of science, in its proactive form, and is a cooperative activity of both professional philosophers and conceptually-oriented scientists. A complementary role here is the historical-critical one of putting new ideas and concepts in perspective, and linking them with ideas and concepts from the past, abandoned for the right or the wrong reasons, or simply forgotten, or distorted beyond recognition.

The second role played by philosophy in cognitive science has no clear counterpart in other areas of science. As Howard Gardner puts it (Gardner 1985), the agenda of cogsci is the one set by the two and a half millenia old tradition of Western philosophy (to which one may well add, at least, the even more ancient tradition of Indian logic, which comprised much of what is included today under the labels of epistemology, philosophy of language and philosophy of mind). Philosophy has had an exclusive role to play in defining the basic analytic categories pertaining to thought, knowledge, perception, emotion and so forth, and the two centuries of scientific psychology of which cogsci is a continuation have not rendered philosophy redundant, quite the opposite: as the various branches and programs of cogsci have developed, the relevance of philosophy has grown, to the point where, just as in previous times physics was the main provider of problems for mathematics, cogsci has become in less than a generation the major source of activity for philosophy. Here philosophy functions as philosophy of mind broadly construed, which includes, beside philosophy of mind in the somewhat narrower sense of philosophy of psychology (roughly, the attempt to sort out the basic categories of the mental, and their relation to the basic categories of the natural world), epistemology (or philosophy of knowledge and belief), philosophy of language, and ontology. In addition, there is a branch, or rather an orientation, of philosophy, *viz.* phenomenology, which can be roughly defined as an examination of the way in which world, body and mind actually *appear* to the conscious mind, which is increasingly brought to bear on cogsci (see *e.g.* Andler in press).

Now the two functions which philosophy fill in cognitive science are not sharply divided. More importantly, they combine on one crucial task (here I am endebted to Ingar Brinck of the Department of Philosophy and Cognitive Science of Lund University, Sweden, whose written comment I am essentially reproducing in what follows).

As has been repeatedly stressed, cogsci crucially relies on an eventual integration of the results secured by its core disciplines. This integration is absolutely necessary not only for the research in the separate disciplines to have an impact on cognitive research in general, but also for the implementation of cogsci in society (with a further impact on economy, politics, and so forth).

It is easy enough to recognize that the assimilation of knowledge from different fields is important. The less obvious part is to understand that this cannot be done without additional original work. To integrate what on the surface might seem as diverging data and results requires developing new concepts that can be used within different disciplines, and that make possible comparative research while also heightening the level of understanding between the different areas. Also required is the development of general theories that bring together ideas from the various areas, put them together in a constructive way, and make the synthesis comprehensible to all parts involved. Specialised researchers are normally less skillful at this, exactly because they are specialists.

Philosophers who are trained in the philosophy of science and epistemology have a particular skill for critically assessing theories and methodologies. Philosophers invested in cogsci are especially suited for constructing as well as evaluating the global theories that urgently are needed for further integration of the field of cogsci.

So far the contribution of philosophy to cogsci has mainly been on specific issues. This is all very well, but it does not exhaust the uses cogsci could make of philosophy. More specifically, philosophers should be encouraged to work also on global issues that relate the various subdisciplines (theoretical work grounded in experimental data and performed in close contact with specialists in the individual disciplines, and work on the development of new methodologies based in the integration of various current methods).

There is counterpart to the fundamental role of neuroscience as an integrating and grounding factor for the empirical results obtained inall areas of cogsci. But there is a discipline playing a corresponding role for high-level theory integration, namely, philosophy. Philosophy is the only one of the disciplines that together make up cogsci that is of relevance to all the others, because of its traditional preoccupation with general problems on both a metascientific and commonsense (everyday) level.

Moreover, the core philosophical terminology directly connects to the terminology used in economy, politics, and so on. This makes philosophy particularly well-suited also for articulating research in cogsci in a way that makes this research accessible for society at large.

Appendix 5

Major Applications of Cogsci

The *Blackwell Companion to Cognitive Science* has a special section devoted to *cognitive science in the real world*, in which applications in the domains of education, ethics, everyday life environments, institutions and economics, legal reasoning, mental retardation and science, in general, are discussed. One could also mention applications having to do with handicaps, expertise, art or sport, as well as robotics, the latter being perhaps the most straightforward. Due to space limitations, in the present appendix we will focus on only a few such major applications, concerned with education and the so-called multimodal interfaces.

Education

The applications of cognitive science in the educational process are straightforward: studies on learning and its dysfunctions (such as dyslexia or dyscalculia) make one re-consider the type of education needed by affected persons and orient research towards assistive software capabilities. No less important, in the long run, are the benefits which would accrue from a theoretically well-founded vision of the learning processes in normal children and adults.

A better understanding of the neural underpinnings of learning mechanisms and cognitive functions involved in the educational process (memory, attention, metacognition) has obvious implications. We mentioned ADHD in §4.B and the problematic aspects raised by the use of certain remedial neuropharmaceuticals in Appendix 3.

Education constitutes a virtual geometrical place of applied cogsci, since a thorough understanding of the vital learning processes unfolding in ontogeny is a must for the deployment of adequate curricula and teaching methods.

Some European countries, such as France, via the *Ecole et sciences cognitives* program[5] (see the 'Ecole et sciences cognitives' report), have given a prominent role to the cognitive science-education interface, an area from which countless issues are stemming: how are we to conceive second-language acquisition in light of discussions concerning a critical age for its internalization, how are emerging technological props and aids (cognitive prosthetics) changing the very idea of a *cognitive process*, in which ways robots integrated in school environments influence children's idea of an interpersonal relationship, etc.?

The *Ecole et sciences cognitives* program considered nine themes as having priority:

a) genetics and cognitive development, b) memory: development, dysfunctions, c) emotional development: regulations and dysfunctions, d) acquisition and regulation of social competences, e) the acquisition of communication in school, f) strategies of the teacher in situations of interaction, g) from naïve to scientific knowledge, h) knowledge, arithmetical know-how, their deficiencies, i) development and learning of artistic activities and perceptions.

Regarding the importance of props and aids in the educational process, there is a lot of work in the so-called Vygotskyan perspective (from Lev Vygotsky, 1896-1934, the celebrated Russian 'constructivit' psychologist who is currently enjoying a spectacular revival), as a collaborative enterprise between teacher and learner using a specially designed environment with ad hoc props. Education is thus described at a level intermediary between individual cognitive development and cultural transmission, thus linking and perhaps locking together the psychological and the cultural level (Bruner 1996). Computer supported collaborative learning (CSCL) is often approached in neo-Vygotskian ways; for instance, a forthcoming contribution by Giyoo Hatano, a professor of psychology and learning sciences at the Human Development & Education Program of the University of the Air in Japan at the CSCL conference to be held in Taipei, Taiwan in May-June 2005[6], is intended to investigate the process of collaborative learning via a two-level analysis of activity- conceptualizing the target phenomenon of individual cognition in a socio-cultural context as a collective or intermental process, as well as specifying what occurs in the intramental process of each individual as reflecting the intermental process (see http://www.cscl2005.org/keynote_hatano.htm).

OECD, Directorate for Education, Brain & Learning
Link: http://www.oecd.org/about/0,2337,en_2649_14935397_1_1_1_1_1,00.html

[5] The program *Ecole et sciences cognitives* was launched in April 2000 for 4 years by the French Ministry of Research (during the period April 2000-September 2001 the operation was integrated to the local *Cognitique* program)

[6] An internationally-recognized forum for the exchange of research findings related to learning in the context of collaborative activity and the exploration of how such learning might be augmented through technology(see also http://www.cscl2005.org/)

Is the current classroom model of learning “brain-unfriendly”? Why are students failing to master numeracy and literacy skills efficiently enough to be employable? Why are one out of six students disruptive and school-haters? What is the impact of the advent of the computer in the lives of today’s learners?

In the today's climate of growing doubts about the effectiveness of state-controlled social provision of services, the emerging findings of *cognitive neuroscience* call into question some of the fundamental building blocks of traditional education such as schools, classrooms, curricula, teachers (as we understand the profession today), including concepts like intelligence or ability.

The “Brain and Learning” project is working towards a better understanding of the learning processes of an individual’s lifecycle.

The Project aims to establish a direct link between brain and learning specialists , in the hope that the resulting mental alchemy will yield new approaches and ideas, about how what the brain does is educationally relevant; to actively pursue data sources from research to synthesise existing and emerging findings from cognitive and brain science; to dispel popular misunderstandings of the brain and its relationship to learning and teaching; and to make the results of the project widely accessible to include non-specialists.

Multimodal interfaces

One of the research themes of, for instance, the Laboratory of Computer and Information Science of the Department of Computer Science and Engineering of the Helsinki University of Technology is that of *multimodal interfaces* (http://www.cis.hut.fi/research/multimodal/).

When we communicate with each other, we use more than just words to express ourselves. We use our hands for gestures and we point to things we want to draw attention to. We look at the other person's lips to better understand spoken words and we look into the other person's eyes for subtle emotional cues. That is, human communication is not carried on a single channel, e.g. speech, but rather is carried on many different channels that together convey a complex combination of apparent actions and many subtle messages and expressions. Only taken together do these multiple channels express our individual personality or intent. Motivated by this, companies such as Advanced Interfaces (www.advancedinterfaces.com) have pioneered both fundamental research and interfaces that exploit the "multimodal" nature of human communication. The goal of these interfaces is to allow one to communicate with a computer in a natural and effortless way, far beyond using a keyboard and mouse.

Projects involve the development of software libraries for incorporating multimodal input into human computer interfaces. These libraries combine natural language and artificial intelligence techniques to allow human computer interaction with an intuitive mix of voice, gesture, speech, gaze and body motion. Interface designers will be able to use this software for both high and low level understanding of multimodal input and generation of the appropriate response.

Links: http://ww2.cs.fsu.edu/~jocaloza/cen5720/proj/summary.html , http://www.advancedinterfaces.com/research/multimodal_interfaces_1/main.html

Neuroengineering

Neuroengineering is defined as the interdisciplinary field of engineering and computational approaches to problems in basic and clinical neurosciences. It concerns technologies able to *interface brain and machine*. There are two major levels where biological interfaces are being applied: **peripheral**, such as prosthetic limbs, and **neural**, whereby a special computer chip is placed directly into contact with the brain.

In the US, the field has acquired in recent years a growing popularity, with many academic programs and laboratories focusing on research financially supported by NIH (The National Institute of Health), but especially by DARPA (the US Defense Advanced Research Projects Agency)[7].

In Europe, several laboratories are tackling this challenging endeavor. One could mention the Institute of Neuroinformatics (INI) in Zürich (see also Appendix 1, ‘Cogsci’s many labels’) or the *Neurobotics* project at the

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[7] In 2002, DARPA allocated US$24 million — almost 10% of DARPA's basic research budget — to a two-year project involving mathematicians, biologists and materials engineers charged with developing technologies to interface brain and machine. DARPA’s vision is to reach a point when the brains of fighter pilots, for example, could be connected direct to the controls of their planes. By sending signals to the plane by radio waves, and using cameras on the front of the plane to relay images into the visual areas of the brain, pilots could even control fighter jets from the safety of the ground. A second vision is to allow complex evasive manoeuvres to be programmed into future versions of memory implants, allowing the pilots to perform moves they may not actually have learned through traditional training, reminding us of *Matrix*-like scenarios in which one could simply implement into one’s brain algorithms for performing various tasks, modulo the regular initial learning phase.

Scuola Superiore Sant'Anna in Pisa, Italy (see also §4, *incipit*). The development of brain-machine interfaces is conditioned by more basic work on the interaction between neurons and silicium microstructures or minuscule electrodes and more work needs to be done on the biocompatibility of different materials, since the brain views an implanted electrode as a foreign invader and sends cells to encapsulate the electrodes in tissue, preventing signal transmission. One thus needs to develop a non-invasive and reliable method of recording brain signals, existing medical scanning procedures such as magnetic resonance imaging (MRI) and positron emission tomography (PET) not possessing the resolution to monitor the activity of individual brain cells[8]. In Europe, physicists Peter Fromherz and Alfred Stett from the Department of Membrane and Neurophysics of the Max Planck Institute for Biochemistry in München, were among the first to have declared, back in 1995, in the journal *Science News*, that reliable interfaces neurons-implanted microstructures are nevertheless possible (*Le Monde*, Oct. 17 1998, p. 24), and recent research has shown that they are, moreover, strongly envisageable in the coming decades. It is now possible for human nerve cells to grow on integrated circuits.

A paradigmatic breakthrough in brain-interfacing described research in which *monkeys controlled a robotic arm with thought alone*. By having a special piece of hardware connected to two monkey's brains, Miguel Nicolelis and his colleagues from Duke University, North Carolina were able to record the brain pathways fired when the monkeys were controlling a joystick. This joystick was moving a robotic arm in the next room that the monkeys could see, whilst they tried to move it towards a target. This enabled the scientists to see precisely which brain signals caused forward, back, left and right arm movements.

Neuroscientists Sam Deadwyler of Wake Forest University and Ted Berger at the University of Southern California have teamed up to tackle the hippocampus, an area of the brain involved in the storage of memories. They aim to test *whether silicon chips can replace parts of our brain*. Their focus is a three-stage chain of regions within the hippocampus that signals are passed through during memory storage. The researchers want to see if they can build a microchip that can take signals from the first region and relay them to the final stage, bypassing the middle part of the chain. A synthetic hippocampus could help those suffering from Alzheimer's disease, stroke and epilepsy.

Richard Andersen's lab at Caltech shows the first use of a region (relatively) distant from primary motor areas for brain readout in a reaching task (the parietal reach region in the posterior parietal cortex). Using a very small number of neurons (8-16 cells), the investigators were able to achieve a 60-70% accuracy in predicting reach movements to a particular target (out of 8 total targets). Researchers in Andersen's lab intend to develop a *neural prosthetic system* that would record the plans to make movements from cortex, interpret these neural signals, and use them to operate external devices such as a robot limb, a muscle stimulator or an autonomous vehicle. Joint recent work with, *inter alia*, Hans Scherberger from INI Zürich, has focused on the decoding of intended goal movements together with expected value signals that can be used to continuously monitor a paralyzed patient's preferences and motivation, so as to develop a *cognitive-based prosthetic*.

The latter type of research suggests (Musallam et al. 2004: 262) that all kinds of cognitive signals can be decoded from patients. Thus, recording thoughts from speech areas could alleviate the use of cumbersome letter boards and time-consuming spelling programs in order to ease communication, while recordings from emotion centers could provide an online indication of a patient's emotional state.

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[8] MRI measures blood flow and PET traces the movement of molecules tagged with a radioactive isotope.

Appendix 6

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NOTA BENE. What follows is not *an attempt at a cognitive science bibliography, however selective. It only lists works which are referred to in the report.*

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Appendix 7

List of boxes

Appendix 8

European Cognitive Science Centers

This list makes no claim of completeness or systematicity. It would indeed be a worthwhile undertaking to construct a well-reasoned list. Besides obvious problems of information collection and scientific assessment, there is the complication that in some cases, there exists locally an attempt at bringing together, either within an actual building, or through formal networking, a number of groups from various disciplines, with or without an interdisciplinary teaching program; while in other places, cogsci is the simple emerging effect of the proximity, both geographic and scientific, of teams within various departments (psychology, linguistics, neuroscience, informatics, philosophy,...). The list, as it stands, shows a widespread interest and investment in cogsci. In terms of critical mass and outreach, however, an enumeration of locations which can compete with the major institutions in the US and Japan would be far shorter.

> Austria

? Department of Philosophy of Science, University of Vienna (http://www.univie.ac.at/Wissenschaftstheorie/)
? Institute for Psychology, University of Salzburg (http://www.sbg.ac.at/psychologie/institut/personen.htm)
?Institute for Theoretical Computer Science, Technische Universität Graz (http://www.igi.tugraz.at/English.html)

> Belgium

? Katholieke Universiteit Leuven, Laboratoire de Neuro- et Psychophysiologie, http://neuroserv.med.kuleuven.ac.be/index.php, Center for Computational Linguistics (http://www.ccl.kuleuven.be/)
? Université Catholique de Louvain, Faculté des Sciences Philosophiques (http://www.isp.ucl.ac.be/)
? Université Libre de Bruxelles, Cognitive Science Research Unit within the Interdisciplinary Center for the Study of Cognition and Language (http://srsc.ulb.ac.be)
? The Artificial Intelligence Laboratory at the Vrije Universiteit Brussel (VUB AI-lab) (http://arti.vub.ac.be/)

> Bulgaria

? Central and Eastern European Center for Cognitive Science, New Bulgarian University, Sofia (http://www.nbu.bg/cogs/center/)

> Denmark

? Centre for Language Technology, Copenhagen University (http://cst.dk/uk/index.html)
? Natural Interactive Systems Laboratory, University of Southern Denmark, Main Campus Odense (http://www.nis.sdu.dk/)
? Nordita- Nordic Institute for Theoretical Physics (http://www.nordita.dk/)
? THOR Center for Neuroinformatics, Technical University of Denmark, Lyngby (http://eivind.imm.dtu.dk/thor/)

> Finland

? Helsinki Brain Research Centre (http://www.hbrc.helsinki.fi/)
? Laboratory of Computer and Information Science of the Department of Computer Science and Engineering of the Helsinki University of Technology (http://www.cis.hut.fi/)
? University of Helsinki, Cognitive Brain Research Unit (http://avocado.pc.helsinki.fi/)

> France

Paris site: Ecole normale supérieure, Collège de France, Université René Descartes, Université Pierre et Marie Curie, and partners

• ***ULM Campus***
Department of Cognitive Studies, *Ecole normale supérieure,* Paris [DEC], http://www.cognition.ens.fr/
including:
- Institut Jean Nicod (UMR 8129, CNRS/ENS/EHESS) (http://www.institutnicod.org/)
- Laboratoire de sciences cognitives et psycholinguistique (UMR 8554, CNRS/ENS/EHESS) (http://www.lscp.net)

and other labs in cognitive neuroscience and functional imagery, in computational neuroscience, in theoretical linguistics, in neuropsychology, in psychophysics and neuroscience of audition, in logic, rationality and reasoning,...

Laboratoire de Physique Statistique de l'ENS (UMR 8550), Centre d'études des systèmes complexes et de la cognition (CENECC) (http://www.lps.ens.fr)

• ***SALPETRIERE Campus***
CHU Pitié-Salpétrière
including:
- Neurosciences Cognitives et Imagerie Cérébrale, UPR 640 CNRS (http://www.ccr.jussieu.fr/cnrs-upr640-lena/)
- Personnalités et conduites adaptatives (UMR 7593 CNRS/UPMC)

• ***SAINTS-PERES Campus***
UFR biomédicale (http://www.biomedicale.univ-paris5.fr/)
including:
- Laboratory of Experimental Psychology, CNRS (http://lpe.psycho.univ-paris5.fr/)
- Laboratory of Neurophysics and Physiology (UMR 8119, CNRS/Univ, René Descartes) (http://www.neurophys.biomedicale.univ-paris5.fr/)
- Laboratoire de Neurobiologie des Réseaux Sensorimoteurs (UMR 7060, CNRS/Univ, René Descartes) (http://www.biomedicale.univ-paris5.fr/lnrs/fr/)
- Laboratoire de Physiologie Cérébrale (UMR 8118, CNRS/Univ, René Descartes)

• ***COLLEGE DE FRANCE Campus (***http://www.college-de-france.fr/)
Physiologie de la perception et de l'action (UMR 9950)
Communications cellulaires
Neurosciences cognitives

• ***OTHER locations***
- Laboratoire d'Informatique de Paris 6 (LIP6, UMR 7606), Equipe ANIMATLAB
- CREA- Centre de Recherche en Epistémologie Appliquée (UMR 7656 CNRS/Ecole Polytechnique) (http://www.crea.polytechnique.fr/)

... and more

Orsay-Gif site
- Cognitive Neuroimaging Unit (INSERM-CEA unit 562), Service Hospitalier Frédéric Joliot, Orsay (http://www.unicog.org/main/pages.php?page=Home)
- UNIC (http://cns.iaf.cnrs-gif.fr/Main.html)
- Neurospin Project (http://www.meteoreservice.com/neurospin/)

Lyon
- Institut de Sciences Cognitives, Lyon (http://www.isc.cnrs.fr/)

Toulouse
- Department of Psychology , University of Toulouse II (http://www.univ-tlse2.fr/ufr-psycho/index.html#e-ergo)
- Cerveau et Cognition (UMR 5549), Toulouse (http://www.cerco.ups-tlse.fr/)
- Institut des Sciences du Cerveau de Toulouse (IFR 96 du CNRS, de l'INSERM, des universités Toulouse 2 et 3 et du CHU)

Marseille
- Institut de Neurosciences Cognitives de la Méditerranée (UMR 6193) (http://www.incm.cnrs-mrs.fr)

> Germany

? BERLIN: Center for Adaptive Behavior and Cognition of the Max Planck Institute for Human Development (http://www.mpib-berlin.mpg.de/en/forschung/abc/); ZAS (The Centre for General Linguistics, Typology and Universals Research, Berlin) (http://www.zas.gwz-berlin.de/index.html.en?about)
? BOCHUM: Institute for Neuroinformatics, Ruhr-Universität Bochum (http://www.neuroinformatik.ruhr-uni-bochum.de/top.html)
? FRANKFURT: Max Planck Institut for Brain Research in (http://www.mpih-frankfurt.mpg.de/global/eindex.htm)
? LEIPZIG: Max Planck Institute for Human Cognitive and Brain Sciences (http://www.cns.mpg.de/); and Max Planck Institute for Evolutionary Anthropology in Leipzig (http://www.eva.mpg.de)
? MANNHEIM: Behavioral Finance Group, University of Mannheim (http://www.behavioral-finance.de/)

? MUNICH: Max Planck Institute for Human Cognitive and Brain Sciences (http://www.mpipf-muenchen.mpg.de); and Department of Psychology, University Munich
? SAARBRÜCKEN: Institute for Formal Ontology and Medical Information Science (IFOMIS), Saarland University (http://www.ifomis.uni-saarland.de/)
• STUTTGART: Institut für Maschinelle Sprachverarbeitung (http://www.ims.uni-stuttgart.de/institut/index.html.de)
? TÜBINGEN: University of Tübingen, Dpt. of Linguistics; Neuroscience (http://www.neuroscience-tuebingen.de/general_information/index.php) and Max Planck Gesellschaft Institutes:

- MPI for Biological Cybernetics (http://www.kyb.tuebingen.mpg.de/)
- MPI for Developmental Biology (http://www.eb.tuebingen.mpg.de/)
- Friedrich-Miescher- Laboratory (http://www2.fml.tuebingen.mpg.de/)

• POTSDAM: Interdisziplinäres Zentrum für Kognitive Studien (http://www.ling.uni-potsdam.de/kogni/kogni/stseite.htm)

> Great Britain

LONDON

? School of Psychology, Birkbeck, University of London (http://www.psyc.bbk.ac.uk/); and Department of Philosophy
? UNIVERSITY COLLEGE LONDON:

- ***QUEEN SQUARE SITE***
  - Institute of Cognitive Neuroscience, (http://www.icn.ucl.ac.uk/)
  - Functional Imagery Laboratory, Wellcome Department of Imaging Neuroscience, Institute of Neurology (http://www.fil.ion.ucl.ac.uk/fil.html)
  - Gatsby Computational Neuroscience Uni (http://www.gatsby.ucl.ac.uk/)
- ***GOWER STREET SITE***
  - Department of Psychology (http://www.psychol.ucl.ac.uk/)
  - Department of Philosophy (http://www.ucl.ac.uk/philosophy/)
  - Department of Phonetics and Linguistics http://www.phon.ucl.ac.uk/)

? CAMBRIDGE: Department of Experimental Psychology, University of Cambridge (http://www.psychol.cam.ac.uk/); and MRC Cognition and Brain Sciences Unit (http://www.mrc-cbu.cam.ac.uk)
? OXFORD: Department of Experimental Psychology, University of Oxford (http://www.psych.ox.ac.uk/); and Oxford McDonnell Centre for Cognitive Neuroscience (http://www.cogneuro.ox.ac.uk/centre/)
? BANGOR: Department of Psychology, University of Wales (http://www.psychology.bangor.ac.uk/)
? BIRMINGHAM: School of Computer Science (http://www.cs.bham.ac.uk/; Division of Neuroscience (http://www.neuroscience.bham.ac.uk/); and School of Psychology (http://psg275.bham.ac.uk/)
? BELFAST: Institute of Cognition and Culture, Queen's University, Belfast (http://www.qub.ac.uk/icc/)
(http://www.icn.ucl.ac.uk/)
? BRISTOL: Department of Experimental Psychology, University of Bristol (http://psychology.psy.bris.ac.uk/)
? EDINBURGH: School of Informatics, University of Edinburgh (http://www.inf.ed.ac.uk/)
? GLASGOW

? MANCHESTER: Psychology Department, University of Manchester (http://www.psych-sci.manchester.ac.uk/psychology); and Department of Optometry and Neuroscience, University of Manchester Institute of Science and Technology (UMIST) (http://www2.umist.ac.uk/optometry/)
? NEWCASTLE
? NOTTINGHAM: Institute of Neuroscience, University of Nottingham (http://www.nottingham.ac.uk/neuroscience/); and Department of Psychology
? READING: The School of Psychology, University of Reading (http://www.psychology.rdg.ac.uk/)
? St. ANDREWS: The School of Psychology, University of St. Andrews (http://psy.st-andrews.ac.uk/); Theory of Computation (http://www.dcs.st-and.ac.uk/research/theory/)
? SUSSEX: The Centre for Research in Cognitive Science, University of Sussex (http://www.sussex.ac.uk/cogs/)
? PLYMOUTH: Centre for Neural and Adaptive Systems, University of Plymouth (http://www.tech.plym.ac.uk/soc/research/neural/home.html)
? YORK

> Greece

? Interdisciplinary Program of Graduate Studies in Basic and Applied Cognitive Science, National & Kapodistrian University of Athens and Athens University of Economics and Business (http://www.cs.phs.uoa.gr/en/)

> Ireland

? University College Cork, Department of Computer Science (http://www.cs.ucc.ie/)

> Italy

? University of Parma, Faculty of Medicine and Surgery, Department of Neurosciences, Section of Physiology (http://www.unipr.it/arpa/mirror/english/index.htm)
?NALS Group- Neural Autonomous Learning System, University of Roma 1 (http://titanus.roma1.infn.it/)
? Scuola Superiore Sant'Anna in Pisa, ARTS Lab (http://www.sssup.it/sssup/jsp/section.jsp?sec_id1=528&sec_id2=71064&lang=it)
? Sector of Cognitive Neuroscience, International School for Advanced Studies (SISSA), Trieste (http://www.sissa.it/cns/)
? University of Milan-Bicocca: Facoltà di psicologia (www.unimib.it/facolta/psicologia)
? University of Siena: Centro interdipartimentale di Studi Cognitivi sul Linguaggio (CISCL), University of Siena (www.ciscl.unisi.it)
? University of Venice: Department of linguistic sciences

> Netherlands

? The Cognitive Science Center at the University of Amsterdam (http://www.csca.uva.nl/csca/home.cfm)
? The Institute for Logic, Language and Computation (ILLC), University of Amsterdam (http://www.illc.uva.nl/)
? Max Planck Institute for Psycholinguistics, Nijmegen (http://www.mpi.nl/world/)
? Groeningen
? Utrecht

> Norway

? The Cognitive Science Laboratory of the Department of Psychology at the University of Tromsø (http://uit.no/getfile.php?SiteId=89&PageId=1935&FileId=171)
? The Text Laboratory, Faculty of Humanities, University of Oslo (http://www.hf.uio.no/tekstlab/English/index.htm)

> Portugal

? Project – a Center for Cognitive Science at the University of Porto (http://sigarra.up.pt/iricup_si/noticias_geral.ver_noticia?P_NR=174)

? Instituto de Filosofia da Linguagem, Universidade Nova de Lisboa (Institute for the Philosophy of Language, New University of Lisbon) (http://www.ifl.pt/menuframeingles.htm)

?Centro de Filosofia da Universidade de Lisboa (Philosophy Centre, University of Lisbon) (http://www.centrofilosofia.org/)

> Romania

? Coneural — Center for Cognitive and Neural Studies, Cluj (http://www.coneural.org/)

? 'Concepts, Representations, and Mental Content. Contemporary Themes in the Foundations of Cognitive Science' Research Project at the Department of Philosophy, University of Bucharest (http://www.fil.unibuc.ro)

> Spain

? LOGOS Grup de Recerca en Lògica, Llenguatge i Cognició, University of Barcelona (http://www.ub.es/grc_logos/presentation/index.htm)H

? Institute for Logic, Cognition, Language and Information (ILCLI) and the Dept. of Logic and Philosophy of Science of the University of the Basque Country, San Sebastián (http://www.sc.ehu.es/ilwlaanj/ilcli.html)

> Sweden

? Cognitive Research Group (CoRe), Department of Computer Science, University of Skövde (http://www.ida.his.se/ida/research/groups/cognitive/)

? Lund University Cognitive Science (http://www.lucs.lu.se/)
? Multidisciplinary Center for Cognitive Science within Göteborg University & Chalmers University of Technology (http://www.sskkii.gu.se/)
? The Centre for Information Technology and Cognitive Science in Stockholm (http://www.dsv.su.se/research/kogc/)

> Switzerland

? GENEVA: Department of linguistics, University of Geneva (www.unige.ch/linge); Faculty of Psychology and Education; Psycholinguistics Unit (www.unige.ch/fapse/PSY)
? Computational Neuroscience, Institute of Physiology, University of Berne (http://www.cns.unibe.ch/)
? Institute of Neuroinformatics (INI), Zürich (http://www.ini.unizh.ch/)
? Laboratory of Computational Neuroscience, Lausanne (http://diwww.epfl.ch/w3mantra/)
? The Brain Mind Institute, Lausanne (http://bmi.epfl.ch/)

***Obs.:

Information needed on the following countries:
Cyprus,
Czech Republic,
Estonia,
Hungary,
Latvia,
Lithuania,
Luxembourg,
Malta,
Poland,
Slovakia,
Slovenia (Laboratory for Cognitive Modeling, University of Ljubljana, Department of Artificial Intelligence-
http://lkm.fri.uni-lj.si/)
Croatia,
Turkey,
Serbia and Montenegro

General links: http://www.ling.uni-osnabrueck.de/trommer/cogsci-unis.html

Appendix 9

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