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Abstract Cognitive Science is a promising field of research that deals with one of the most fundamental questions ever: how do beings know? However, despite the long and extensive tradition of the field it has not yet become an area of knowledge with scientific identity. This is primarily due to three reasons: the lack of boundaries in defining the object of study, i.e. cognition, the lack of a precise, robust and consistent scientific methodology and results, and the inner problems derived from its interdisciplinary nature. This paper presents a background review, a theoretical frame and a humble reflection on these topics in order to arouse the internal debate among readers once more.

Keywords Philosophy of cognition · Philosophy of Cognitive Science · Sociology of Cognitive Science · Scientific theory · Interdisciplinary science

1 Introduction

What is cognition? This is probably not an original way to begin a paper because this has been one of the most frequently posed questions in research works of the field for a long time. However, it strikes us as necessary to raise it once again since it has not yet been solved and more and more people are not asking it. In spite of several decades of debate, the definition of cognition is still an open issue. The commitment to establish a well-defined and broadly accepted concept of cognition is crucial for Cognitive Science to obtain its own

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scientific identity.[1] To this end, it would be very helpful to establish what cognition is not at least. The aim of this paper is not to postulate the definite concept of cognition but to encourage the Cognitive Science community to jointly try to compose and fix the boundaries of Cognitive Science. "Jointly" is another key point for the sake of success. It is not the first time that a proposal of joint work and agreement arises with the same objective (Boden 2006). However, since the Cognitive Science community intends to be interdisciplinary (later it will be discussed why it only "intends") and the researchers involved come from different fields, each one has tried to impose his particular view of cognition instead of contributing with his molehill. This disagreement has kept the question open until nowadays. It has also prevented Cognitive Science from constituting itself with its own scientific identity, in spite of having common targets, objectives and promising and emerging research lines.

The lack of an epistemological definition might have produced the current lack of rigor, which is present in some current and (unfortunately) extended argumentation lines: firstly, experiments and research, and then the attempt to justify the work as cognitive. There is a need for agreement in the object of study and the research methods, not only among different disciplines (where disagreement is somehow reasonable), but also within the single disciplines. As Adams and Rowlands state, there is a need for a mark of the cognitive (Adams 2010; Rowlands 2008).

The paper is organized as follows: Sect. 1 deals with the concept of cognition. First a philosophical and historical perspective of the concept is presented, focusing on the fundamental aspects of knowledge and the process of knowing. In Sect. 2, some general aspects of cognition are introduced and many modern definitions of the concept, from different fields, are reviewed and commented upon. This section ends by pointing out the existing definition problem. Section 3 is devoted to Cognitive Science and discusses the different descriptions from several disciplines and then questions both the interdisciplinary and scientific character. The paper ends in Sect. 4 with some concluding remarks, preliminary suggestions, and encourages asking and answering the open questions highlighted.

2 About Cognition

2.1 Cognition and/or Knowing and Knowledge

Although Philosophy has always been considered to be part of Cognitive Science, this discipline has not been taken into account seriously by other disciplines, because it was not thought it could enrich them, until fairly recently (Brook 2009; Dennett 2009; Thagard 2009). It is only now when the pragmatic role of Philosophy in the Cognitive Science scenario is becoming clear (Bechtel 2010). Since classical philosophers and wise men were the first (at least documented) people who cared about and questioned human cognition and thinking, let us start with a pinch of philosophical history of knowledge and the process of knowing. In this sense, the theory of knowledge is a mandatory starting point.

2.1.1 Knowing and Thinking the Knowledge

On the one hand, the näive or natural theory of knowledge considers human knowing as a process by means of which human beings construct the consciousness that reproduces reality,

[1] i.e. recognition of the set of its aims, concepts and methods as a different and separated approach from the current sciences or areas of knowledge.

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with all its structure and order. On the other hand, the critical theory of knowledge defends the existence of an intermediate element (language, symbol, etc) between the subject and reality. The need of human beings to structure the phenomenological disorder together with the mandatory search for axioms and truths by which any kind of knowledge is consolidated, have led Philosophy to question the foundations and limits of knowledge from the very beginning.

The theory of knowledge according to Aristotle's logic focuses on knowledge at the moment of thinking, on the analysis of the structures that put order in the operations of thinking and, definitely, on the modes of talking about and referring to reality. Accordingly, Aristotelian logicism established the bases to reason about the intimacy of thinking: the operations of mind and its movement.

Previously, Plato put the Universal Forms as the base of philosophical knowledge. As a consequence of the aim of turning Philosophy into a science, Plato established the philosophical principles on Ideas (i.e. true, timeless and immutable realities). This ideal universe, which projects into reality by a kind of architect or eternal maker, is used by Plato as an argument for the prioritization of the mind against a world of phenomena and the reality subsumed in change. Thus, Plato began a reflective thread that will last for the entire history of philosophical thought. He opened a branch that claims for the existence of innate places in the mind. From this point of view, true knowledge can only be searched in the mind, unlike Aristotelian realism that considers empirical and observable truth as the right path to any knowledge, in spite of the affirmation of the priority of thought.

The establishment of two clearly opposite planes, such as the real and the mental, the subject and the object, has became a central philosophical problem in the process of knowing. In fact, all philosophy has been qualified from this dichotomy. Although Aristotle and Plato were the first to make the problem an entity, it has been modern philosophy that has been concerned with the consequences.

Cartesian rationalism constitutes the modern subject, the thinking self, by the prioritization of the mind and the recognition of some kind of mental innateness. This rationalism recognizes a subject who feels like the owner of himself and who self-confirms within his own cognitive process. Contrary to this view, the empirical philosophy of Locke or Hume denies any possibility of innateness. They think that any subject is born absolutely empty and that any newly conformed idea is a weakened copy of a sensorial impression. Thus, this empirism defeats the presence of any idea in the mind: thinking requires thinkable material in the form of sensations and experiences.

From this latter affirmation, Kant went a step further. He stated too that there is no idea without sensorial impressions. However, he completed the argument by adding that sensorial impressions are blind without ideas. From this point of view, something exists within the mind in opposition to the world of phenomena. Kant defines this subject-side aspect as categorization. Through categorization, the subject orders a chaotic reality. This ordering allows the elaboration of thoughts by joining ideas that are nourished by reality. Accordingly, the subject and the object are joined by a categorizing reason, which dictates the forms of knowing and the limits of knowledge. Nevertheless, Kant concludes that the authentic being, the self being, can only happen in the mind.

The search for the being inside the subject is the target of post-Kantian philosophy. The different concepts between the object and the subject produced different philosophical lines. For instance, under the view of language philosophy, language is the contact point between reality and the subject, and therefore the limits of language are the limits of the referential and constructable world. Besides, philosophical symbolism states that symbols are at the midpoint between subject and object, and all reality is structured from them.

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The phenomenology by Husserl kept dealing with the search for the paths to truth in the structures of human knowing. For Husserl, the concept of intentionality is a central point, considering that any conscience is conscience of something. Consequently, all knowledge has to originate from an intentional act in order to be able to gain access to reality. Intentionality makes sense in a mental process by which the subject becomes aware of the phenomena. This phenomenological intentionality (firstly developed by Brentano in the XIX century and then continued by Husserl in the XX century) is perhaps the most influent concept in the modern Philosophy of Mind, as John Searle affirms nowadays. Searle postulates that subjective states establish relationships with the environment through intentionality or, in other words, the manner by which the mind refers to objects or states in the world (Searl 1983).

2.1.2 Thinking About Cognition

From the philosophical point of view, cognition (or science of thinking) covers aspects like seeing, thinking and reasoning, and also incorporates intentional states, beliefs and wills, as well as non-conscious states. With this approach, every cognitive process is explained in terms of information processing, which is intimately related to the mind. The mind, conceived from its syntactical and semantic structures (close to the language of thought by Fodor 2008) is the place where modern philosophical problems about gnoseology and theory of knowledge are opposed.

Thinking about the mind has driven Philosophy to raise some key matters about the mind through questions like: Do mental states imply sensorial qualities or qualia, or just imply contents like propositional or intentional states? Is the mind dependent on the physical world or are they just different things? What are the fundaments of mental causality? How can we talk about a concept so loaded with philosophical prejudgments such as consciousness? These questions were raised by the mid-XIX century by Willem Wundt, Franz Brentano and William James, and they are still in force. It might be said that these matters lay the bases of the Philosophy of Mind. From them, Gilber Ryle released what can be considered as the fundamental work of the modern Philosophy of Mind, "*The concept of the Mind*." (Ryle 1949) Ryle affirms that nothing exists similar to the mind in the way conceived by the previous philosophical tradition. Ryle's work encouraged other new studies about sensation and perception (Armstrong 1961; Sellars 1997), the possibility of knowledge of others' minds (Theory of Mind) (Kenny 1992) and intentionality (Anscombe 2000).

Nowadays, there exist several alternatives to the classic mind-body dualism. David Armstrong proposes the Theory of Identity (Armstrong 1999): for every state of mind there is a corresponding neural state. Patricia and Paul Churchland criticize mental realism (Churchland and Churchland 1998), i.e. the human's common way of conceiving the mind. Functionalism by Davidson (2001) affirms that mental facts are physical facts, but they cannot be reduced to any definition or natural law. Finally, Patricia Churchland proposes a kind of co-evolutionism in order to develop a Philosophy of Mind that really intends to understand the mind problem, from different disciplines (interdisciplinarity) and from different explanation levels, with no split (if possible) between philosophy and science.

To summarize, it seems that Philosophy throughout history, had to confront the problems of knowing which processes take part in the acquisition of knowledge and how reality intervenes or modifies these processes. The conclusion was that maybe just the interaction between the subject and the object is the only way to acquire any knowledge.

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2.2 Bounding the Definition of Cognition

Some authors have dared to define the necessary and sufficient conditions for cognition within a promising debate (Adams 2010; Rowlands 2008). However, let us do a much simpler but also interesting exercise here: the revision of different modern definitions of the term '*cognition*'. Several key issues have to be taken into account in the definition. The first one concerns whether cognition is inherently human or it can be extended to mammals, other animals (Boysen and Himes 1999), or even artificial systems (Hoffmann 2010; Kozma et al. 2007). A second controversial issue is whether cognition is innate or is acquired throughout development (Samuels 2004) and, in this latter case, how might the environment and context influence the acquisition.[2,3] The third important aspect to be examined in a definition of cognition is whether it is subdivided into different tasks or modules and how these modules interact (Butterfill 2007), if they really do. Another interesting matter is the ultimate function of cognition, i.e., the reason for its existence (Goodson 2002). Finally, the last key issue is related to the voluntary character of cognition and the implications of consciousness on it (Baars et al. 2003; Banks and Farber 2002; Serrano and del Castillo 2011).

2.2.1 Cognition at the Beginning

Although they were not the first authors to deal with cognition, Herbert Simon and Allen Newell can be considered the parents of the interdisciplinary Cognitive Science, since they were pioneers in proposing a mechanistic definition and explanation of the cognitive phenomena, thus joining Psychology and Computer Science for the very first time.

They proposed the Physical Symbol Systems hypothesis, which states that the process of human thinking is a kind of symbol manipulation (Nilsson 2007). This manipulation is basically described as the acquisition of a physical input that is then mapped into symbols, which are in turn combined into structures and manipulated by some processes to produce new structures. In this sense, for Simon and Newell computers could think as humans do, thus establishing the principles of AI.

Yet at that time, they also boosted the idea of a Unifying Theory of Cognition (Newell 1990), the need for a set of general assumptions that necessarily and sufficiently determine all the cognitive processes regardless of the concrete domain information and representation. Therefore, they supported a holistic and fundamentalist approach to the study of cognition.

2.2.2 Definitions from Engineering

The second block of definitions presented below comes from several current members of *euCognition*,[4] the European Network for the Advancement of Artificial Cognitive Systems funded by the European Commission in 2006. It is important to notice that the term 'artificial' appears in the network title.

Thus, for instance, Mike Denham states[5] that "Cognition is the ability to relate perception and action in a meaningful way determined by experience, learning and memory". Accordingly, cognition is a reactive process and so it might be present in all animals. However,

[2] Journal of Cognition and Development, Cognitive Development Society, http://www.cogdevsoc.org/jcd/jcd-home.php.

[3] Cognitive Development Journal of the Jean Piaget Society, http://www.piaget.org/Journal/index.html.

[4] http://www.eucognition.org.

[5] http://www.vernon.eu/euCognition/definitions.htm.

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this is contradicted by the expression '*meaningful way*', whose definition is as controversial as cognition itself. Moreover, it is influenced by the environment because it is a compound of two modules, such as learning and memory, and past experience. From this definition cognition seems to be useful for interaction with the world.

According to Christian Bauckhage,[5] "Cognition is the ability to ground perceptions in concepts together with the ability to manipulate concepts in order to proceed toward goals." In this case, the ground concept is the same as Denham's, but Bauckhage includes into cognition the ability to internally map and manipulate concepts in the mind. So, some internal processes of the mind are also part of cognition if these processes are driven to achieve previously posted goals. Notice that in the latter two definitions cognition is an ability and therefore it could be acquired or improved throughout time.

In a similar way, Alex Pinz states[5] that "Cognition is the act of segmenting and recognizing a perceptual event and grounding (binding) it to a symbol (meaning)." As in Bauckhage's definition, cognition seems to map perception inputs into concepts (symbols). However, Pinz puts more emphasis on the perception process itself, by qualifying segmentation and recognition as cognitive primitives.

The relation between perception and action is also taken into account in Patrick Courtney's view of cognition. For him,[5] "Cognition is the ability to plan, reason, adapt and act according to high level motivations or goals, using a range of senses, typically including vision, and maybe communication." In addition to the connection between input and output, Courtney focuses on intermediate processes such as planning, reasoning and adapting. These aspects together with the 'high level' motivations or goals give cognition a human nature. This is one of the few definitions that explicitly consider communication as a cognitive process, although according to other authors communication would be implicitly included by terms like 'act' and 'adapt'.

Concerning communication and more specifically language, Katerina Pastra thinks[5] that "Cognition allows to perceive, learn, reason, plan and express itself through language and action and do so intentionally, i.e. it must be able to understand the intentionality of others and demonstrate intentionality when engaged in communication." Once again, interaction with the world together with the internal processing of information are considered to be part of cognition. The newly introduced issue is related to the social context in which communication by language is essential. In addition, Pastra goes beyond language and includes in cognition not only self-intentionality but also the understanding of others' intentionality, i.e. the Theory of Mind (Saxe and Baron-Cohen 2007).

From Cecilio Angulo's perspective,[5] "Cognition is self-aware processing of information." Angulo introduces consciousness as part of cognition by the term 'self-aware'. Nevertheless, from such a general definition, it can be deduced that cognition is an internal treatment of information, whatever information means and whatever the aim of this process is.

Consciousness is also a central issue for Markus Vincze's concept of cognition. He considers[5] that "Cognition is when I know what I am doing, when I can judge how good or bad it is, and explain why I am doing it." From this point of view, cognition would be restricted to human beings, because it implies judgment, intention and motivation.

Cognition is also expressly defined as human by Jordi Gonzalez. He thinks[5] that "Cognition are the human capabilities activated due to perception, which are enhanced with learning and reasoning skills and which implies a physical reaction within the environment. The cultural context, within which cognition is performed, plays an important role, too." From this perspective, it seems that learning and reasoning do not form part of cognition because they simply enhance cognition. It can be extracted from Gonzalez's definition that cognition

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only plays a role under perception queries. The definition concludes by highlighting the importance of context in the performance and development of cognition.

Maria Petrou, despite considering human exclusivity, goes even further to a more abstract concept :[5] "Cognition is the state of mind when we understand something without being able to define it. (If cognition were definable, it would be implementable in a Turing machine)." In contrast to all the preceding definitions, Petrou describes cognition as a state of mind and not as an ability or capability. This means that cognition is transitory and that human beings are not cognitive or their behaviors are not cognitive at every moment. Nevertheless, in spite of stating that cognition is not definable, Petrou actually proposes a definition full of other enigmas such as what triggers that state of mind, what understanding really means, or how human beings cannot define something that they actually understand. It is worth mentioning here the view of Harnad and Scherzer (2008). Following the line of Petrou's argument, the latter authors encourage scientists to construct a machine capable of passing the Turing Test (Copeland 2009) and then to study whether cognition and consciousness emerge from that machine.

In order to become substantially immersed in philosophy, András Lõrincz proposes[5] a rather abstract definition: "Cognition falsifies the homunculus fallacy." The homunculus fallacy is a situation of infinite regress which falsifies the original argument (Dennett and Kinsbourne 1992). In the classical argument, brought from the vision field, a little man in the mind is supposed to interpret the brain stimuli from the eyes. But who is interpreting in the mind of the little man what he sees? Another little man and so on and so forth. This infinite regress invalidates the original argument. According to Lõrincz, cognition is the ending point of the regress, the man who interprets perception events with no other man who re-interprets its perception. In this sense, since the homunculus does not exist, everything that is capable of interpreting sensorial stimuli has cognition, and therefore can be considered as cognitive.

Apart from some philosophical and diffuse *addons* and other divergences, the definitions above seem to share a core view of cognition as a set of processes that make a system (either biological or artificial) manage the perceptual information from the world in order to interact with that world in a flexible manner so that it can adapt for success.

Most people who design and implement cognitive systems, either hardware, software or both, generally qualify these systems as cognitive because they are able to learn, flexibly act and adapt to a complex environment according to their perception of the world. However, this is contradictory to their definitions of cognition. According to some of them, neither learning nor reasoning are cognitive processes. In addition, most authors include within their definition of cognition too much abstract and epistemological open concepts, such as consciousness, self-awareness, knowing, intention or cultural context, which indeed are, by now, hard to realize in a physical or logical system since little is known about them, and there is little consensus (Serrano and del Castillo 2011). So, the question is, why do some researchers attribute the qualifier '*cognitive*' to their system's dynamics when the authors themselves have a very different idea of cognition? The answer might be extracted from a regrettable issue of the current situation of science. Unfortunately, science development usually depends on funding. If a topic is in fashion then research work on it will be more likely to be funded and even commercialized. Accordingly, if the term 'cognition' appears among the priority topics in, let us say, the call of a European Framework Program or any other funding plan, either private or public, many people will re-adapt their own view of cognition in order to make their research suitable for funding, as might be interpreted from Tjeerd Andringa's perspective: "Cognition: the algorithms and representations that determine fitness", which nonetheless is a valid definition too, of course. This way, Cognitive Science becomes so broad a discipline that everybody is able to work on it. This is one of the reasons why the

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boundaries of the concept of cognition must be well defined, at least if it intendeds to isolate Cognitive Science with a self identity as well as if someone would like to be considered as a cognitive scientist. It must nevertheless, be said that all the attempts of the definition of cognition above are worthy of admiration since it is a difficult task that just a few dare to tackle.

2.2.3 Definitions from Other Fields

Besides the approaches of computer scientists, physicists and engineers just explained, let us discuss now what psychology, neuroscience and other fields tell us about cognition. For instance, if one consults the Florida Institute for Neurologic Rehabilitation website[6] the brain injury glossary of terms states that "Cognition is the conscious process of the mind by which one becomes aware of thoughts and perceptions, including all aspects of perceiving, thinking, and remembering." From this perspective, there exists a clear isolation between perception and thinking, both being cognitive. As well as thoughts, a new element has been explicitly considered as cognitive in this definition: memory, through the process of remembering. Notice that here consciousness is central for cognition too.

In the glossary of the Brain Tumor Foundation of Canada website[7] cognition appears as "a generic term involving perceiving, recognizing, conceiving, judging, sensing, reasoning, remembering and imagining." Once again, cognition is defined as a set of processes among which memory is included. In this case, the cognitive processes are refined by splitting thinking in imagining and reasoning, splitting perception in perceiving, recognizing, conceiving and sensing (emotions are introduced here) and also including judgment.

According to the glossary of the Centre for Neuro Skills,[8] cognition is "the conscious process of knowing or being aware of thoughts or perceptions, including understanding and reasoning." The differentiation between thoughts and perception is highlighted, and understanding is included as a cognitive process. Notice that consciousness and awareness are essential concepts for cognition once again. Notice too that in the definition, cognition is the same as knowing although this is not an accurate equivalence, as explained before.

From the psychology field, Christopher L. Heffner, in the dictionary of his website AllPsych ONLINE[9] presents cognition as "the process of receiving, processing, storing, and using information." This concept of cognition as an information processing flow is widely extended among psychologists (Josephs 2000). From this point of view, perception, memory and reasoning are cognitive processes. However, it is not so clear what using information means although it might be deduced that it refers to acting or carrying out a high-level task such as natural language communication or problem solving.

For the anthropologist D'Andrade (1995) cognition is the pool of mechanisms by which human beings acquire cultural knowledge, i.e. the knowledge that is learnt from and shared with other humans and that is embedded in language and artifacts. The anthropological view of cognition focuses on the human internal thought related to culture. Moreover, it also stresses that cognition is the opposite of emotion and body, i.e. that thinking is neither feeling nor acting.

For the fields just mentioned, cognition seems to be particular to human beings and innate. All of them consider cognition to be related to the mental process underlying human behavior,

[6] http://www.floridainstitute.com.

[7] http://www.braintumour.ca.

[8] http://www.neuroskills.com.

[9] http://allpsych.com.

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either in individual or social contexts. For some, consciousness is essential. For others emotion is not part of cognition. However, all of them seem to agree that perception, memory and thinking or reasoning are fundamentally cognitive processes.

There are many cases in which the definition problem appears and introduces confusion (Marris et al. 2008). For instance, there are general historically confusing concepts such as *paradigm shift, complexity, tipping point or significant* (to mention just a few). Within specific areas, ideas such as epigenetic, race, stem cell or the well-known (maybe not so well) consciousness are some examples of highly controversial and ambiguous matters among the scientific community.

The definition problem leads to very common misunderstandings such as the identification of bio-inspiration (for instance, Neural Networks or Evolutionary Computation) as cognition. The diversity and ambiguity of the terminology avoids the consolidation of solid concepts. Since most of these concepts are the object and target of the studies, the definition problem decreases the seriousness and rigorousness of the scientific disciplines and delays their progress (Cromwell and Panksepp 2011). It is understandable that the highly competitive world drives scientists to research and obtain results quickly. However, for the sake of science and the love of knowledge, the fundamentals of the concepts needs to be studied in depth before just doing research (or rather experimenting) on them.

3 About Cognitive Science

Once a review of the definition has been done, we should obviously ask about the science that deals with cognition, cognitive science (CS). The scientific identity for CS has been questioned for a long time since its introduction into the scientific community. It is likely that most of the arguments against CS have their origin in the fuzzy and too broad definition of cognition, as stated before. However, this is not the only reason that has driven the opponents to try to displace CS out of the science fields. Among others, the difficulties in establishing correlations between theory and experiments, the complexity of the design of those experiments as well as the lack of experimental results, and the *multidisciplinary war* are the main drawbacks to convince researchers all over the world of the scientific nature of CS.

3.1 Defining Cognitive Science

In order to maintain the discourse methodology of the paper, several definitions of Cognitive Science are now presented below. In this instance, the definitions are situated at different moments throughout CS history rather than in different research areas.

At the very beginning of CS, just three years after the publication of the first issue of the *Cognitive Science Journal*,[10] the first regular publication with that title, Donald A. Norman defined CS as a discipline created from shared interest among the people who study cognition from different points of view (Norman 1981). For Norman, the crucial point of CS is the understanding of cognition, either real or abstract, either human or artificial. The main objective is the understanding of the principles of intelligent and cognitive behavior in order to better understand the human mind, to boost mental capacities and the development of intelligent devices.

[10] It is widely accepted that the first steps of Cognitive Science happened at MIT during a symposium organized by the Special Interest Group in Information Theory, in 1956. However, it was not until 1976 that an official program was created with the Cognitive Science name, by the Alfred P. Sloan Foundation (for more details see Miller 2003).

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A little later, by 1985, the "cognitive revolution" was already being talked about (see Miller 2003 for a brief but complete history of CS and the "cognitive revolution"). By then, Howard Gardner introduced CS as the science that answers old epistemological questions related to the nature, elements, sources, evolution and communication of knowledge (Gardner 1985). Note that Norman considered CS as a discipline. Three years afterwards, Gardner called it science.

In Varela 1990, elaborated a compilation of Cognitive Science and its future tendencies. Varela defined CS as modern scientific analysis of all the dimensions of knowledge. By that time, some of the questions about the scientific nature of CS had already been posed and this probably led Varela to refer to CS as Cognitive Sciences, in the plural, rather than a singular entity. The plural denomination was also shared by other related researchers such as Miller (2003).

By the beginning of the 1990s, CS was becoming so broad and confusing that some authors felt the need to clarify ideas and make revisions (as this paper modestly tries to do). One of the most significant contributions was done by Barbara von Eckardt. In her opinion, CS is a field that studies cognition by using resources from several disciplines, including Cognitive Psychology, Artificial Intelligence, Linguistics, Philosophy, Neuroscience and Cognitive Anthropology (von Eckardt 1993). The interdisciplinary characteristic of CS has been highlighted from the beginning. However, this characteristic acquired more significance in the 1990s due to disagreement among areas. By that time, the different disciplines had clearly become split although they still maintained the common object of study.

In order not to bore the reader, only one more relatively up-to-date definition is presented. For Paul Thagard, CS is the interdisciplinary study of intelligence and mind, covering Philosophy, Psychology, Artificial Intelligence, Neuroscience, Linguistics and Anthropology. Again, CS is defined in terms of the disciplines that are supposed to compose it.

As can be seen in all the definitions above, although CS came from people of different disciplines, the first efforts concentrated on determining the aims and objects of study by sharing information and techniques from among all the fields involved. Insofar as CS evolved, the initial philosophy of cooperation moved to a rather individual form of work in common objectives (not so common, as said before) under a fictitious interdisciplinary layer. Interdisciplinarity is a double-edged sword. If it is real, it can lead closer to universal knowledge. If not, it may introduce confusion and barriers to the development of science.

3.2 Interdisciplinary? Science

It must be clearly stated here that the interdisciplinary character is not a requirement for a science to constitute as such. In fact, there are many highly specialized sciences that have been consolidated for centuries. However, CS was proposed as a new and separated (although overlapping) area of knowledge from the current ones just because of the interdisciplinary approach on which it relies. What is argued here is that this interdisciplinary character has not been properly achieved and so it has been rather detrimental. The criticism is that one of the differential features of CS is not actually such a feature.

There is no doubt that the initial intentions about the proposal of an interdisciplinary science were actually promising. In fact, it might be the way to discover more universal "truths", or widely accepted ones at least, under the assumption that if one can achieve the same conclusion from different views and disciplines that conclusion is more likely to be generally true. In addition, in a real interdisciplinary environment the achievements of a subdiscipline can put other subdisciplines out of local maxima and soften the typical and particular slants. In this way, the discoveries and techniques from each field can make one another evolve.

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Unfortunately, interdisciplinarity has never become real. This is proved by the fact that new proposals of cooperation between different areas are posted again from time to time. Every effort to jointly combine techniques and theories in the search for a common objective has failed throughout CS history. This is because interdisciplinarity slowly turned into multidisplinarity (Schunn et al. 1998), since everyone has tried to defend their own field of knowledge (against what?) every time a disparity appeared (like the definition problem of cognition).

As Sperber (2003), said after thirty years the different disciplines have not yet been integrated. They have just appropriated a few concepts and techniques from the others. In Miller et al. 2003, determined the interdisciplinary state of CS with a very well-known descriptive figure. Such a figure represents an interaction graph between six different disciplines (Psychology, Philosophy, Linguistics, Anthropology, Neuroscience and Computer Science), where each connecting line represents an area of interdisciplinary inquiry (existing by that date) that involves the tools of the two connected disciplines. From Miller's current point of view, all possible links could be instantiated now. However, this is a not the real thing. Several more disciplines can now be included in the graph, thereby increasing the complexity of the issue. Moreover, the relations are not equally weighted at all.

A study of paper citations from and to CS journals (Goldstone and Leydesdorff 2006) in 2004 shows a balanced situation. On the one hand, 14.7 % of the CS cites were to psychology papers, 13.4 % were to neuroscience, 8.7 % to social sciences, 5.9 % to education and 5.9 % to computer science. On the other hand, 15.2 % of the papers that cited a CS essay were from computer science, 7.6 % from psychology, 5 % from neuroscience, 4.5 % from education and 3.8 % from social sciences. In this sense, a more recent study presented the evolution of the percentage of authors by discipline who have published a work in Cognitive Science at the beginning of every decade since 1978 (Gentner 2010). The study shows how the percentage of AI researchers has been decreasing from 48 to 20 %, and how the percentage of psychologists has been increasing from 26 % to more than 50 % during the last three decades. This is what the author called "the conquest of Cognitive Science by Psychology", which will be totally committed by the year 2038 if the present trend continues. From these results, it seems that some disciplines are more determined than others to become influenced by different areas of knowledge, such as Computer Science. In addition, some disciplines, such as Social Sciences or Philosophy for instance, seem to discriminate against CS. This is due to the unintentional 'monopoly' of CS by some disciplines, which are not actually interested in interdisciplinary approaches although they are placed under the CS label. According to Goldstone's study (Goldstone and Leydesdorff 2006), 51 % of the CS papers in 2005 used 'Psychology' as a keyword, followed by 'Linguistics' (17 %), 'Artificial Intelligence' (13 %) and 'Neuroscience' (10 %).

The CS situation is now so critical that it is now referred to as Cognitive Sciences and not as a single discipline. This denomination is extending quickly since the communities from every research field have decided to create specialized subfields with the adjective 'cognitive'. Thus, Cognitive Anthropology, Cognitive Linguistics, Cognitive Psychology, Cognitive Neuroscience, Cognitive Computation and Philosophy of Mind are now subdisciplines considered to be part of CS. Instead of being advatageous, this explicit designation of specialization is contrary to the original concept of CS, in spite of the shared adjective "cognitive" which just refers to the object of study. In addition to all these drawbacks, another one has recently emerged: the reinvention of CS with the look of "apparently new" disciplines with new denominations, such as Artificial Psychology (Friedenberg 2008), which is fed by contributions from Philosophy, Cognitive Psychology, Neuroscience, Computer

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Science and Robotics from an engineering perspective (now the reader can understand why it is "apparently new").

Let us introduce one of the core divergences among all the cited cognitive disciplines by examining their particular aims. Cognitive Anthropology is an unified subfield of Cultural Anthropology that attempts to understand and describe how people conceive and experience the world in society (Casson 1994; D'Andrade 1995; Solomon 2000). Cognitive Linguistics is a part of Linguistics that intends to give explanations about language which integrate with the current knowledge about the mind, i.e. language usage must be explained by the underlying mental processes (Geeraerts and Cuyckens 2007). Cognitive Psychology deals with the study of memory, language processing, perception, problem solving and thought (Sternberg 2002). Cognitive Neuroscience is a subfield of Neurology that joins the psychology tools about behavior together with the new techniques of measurement of the brain function in order to discover how the brain processes the information to generate behavior (Bechtel et al. 2001). Finally, Cognitive Computation tries to simulate behavior by computational models and algorithms (Fum et al. 2007) and addresses the computational aspects of cognition (Kozma et al. 2007).

As can be deduced, the intersection of the objectives between areas is minimal, with the exceptions of a few of them. All the cited subfields deal with cognition, not only from different views and techniques but also with different and non-overlapping aspects of cognition. Therefore, it is the moment to launch again a proposal of real inter-cooperation, taking into account the past problems so as not to make the same mistakes. The researchers from each field should look at cognition not with the particular glasses of other fields but with a lens composed of all the areas of knowledge which tries to understand cognition. To this end, these lenses should be strongly encouraged to young researchers and students (Nelson 2011). In addition, researchers must assure themselves that their theories can be explained by the theories and techniques from most of the other fields, and vice versa, that their techniques and assumptions can explain theories from the other areas, and even if they cannot, researchers should also question reason and not let it go. Perhaps, a tentative unforced solution would rely on the formulation of questions that intrinsically involve several disciplines, such as the one dealt with by Margaret A. Boden: "Is Life Necessary for Mind?" (Boden 2009)

3.3 Scientific Identity

As mentioned earlier, one of the major arguments against the scientific character of CS is the fuzziness of the object of study, i.e. cognition. As long as there exists a definition problem and wide disagreement among researchers, CS cannot be considered as a pragmatic science because its aims are not clear at all. One could think that science is exploratory and is constantly redefining its concepts throughout time. Under this view, a science might not have a well-defined target. However, CS emerged as an alternative approach for the search of a Unifying (holistic) Theory of Cognition. This is a very general concept. If it is not well defined or bordered it could go against the main idea behind the creation of CS. Another drawback is the dark side of interdisciplinarity, which unfortunately predominates in CS, as explained before.

In addition to these two key issues, other arguments have been used throughout time against the scientific identity of CS. The main ones are related to experimentation and results. For Lino Iglesias, two conditions about the construction of theories should be satisfied in order to consider CS as an authority discipline in the study of cognitive processes (Iglesias 2006): the theories must rely on experimentation and must be supported by results obtained during periods long enough to inspire confidence in the scientific community (Yarkoni et al. 2010).

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The fact is that most of the disciplines called to form CS have a powerful and varied set of experimental techniques. However, since they have not actually worked together the results are not relevant enough for the theories. Even more, the scientific identity of some of those disciplines is still an open issue, such as Computer Science (Tedre 2011). Nevertheless, although CS is considered almost 40 years old, the periodical disruptions and disagreements have broken the continuity of the theories and results.

Unfortunately, for a part of the scientific community CS is still a philosophical and theoretical set of debates rather than a natural science. Although cognition relies on some physical laws, other aspects may escape the analytical methods (for these philosophy and social sciences are needed). These latter aspects make the experiments difficult to design and dependent on self-assumptions and a priori interpretations. Consequently, the results are weakly relevant and possibly contradictory in comparison with previous ones. This is another point that could be solved by real interdisciplinarity, because the experiments could be more accurately designed if the knowledge and techniques from several fields are taken into account all together. An integrated view can also help solve another threat against CS as an alternative science: the difficulty to state a holistic theory of cognition (Crevier 1994). Some people currently argue that a science is not so if it cannot generate general and consistent theories about its object of study. Thus, the more integrated the disciplines the more holistic and consistent the theories. Once again, we should not forget that the delimitations of the object of study (definition) can help elucidate whether a theory is fully explaining the intended phenomena or not.

To conclude, the counter-argument left concerns the tools and methods for analyzing thought. Currently, there does not exist any commonly accepted means for measuring and analyzing cognition as a whole. Obviously, the tools to be used are the typical ones from each discipline which, in most cases, are widely accepted, validated and tested. What is needed then is an adaptation and integration of all the tools taking into account the object of study and a methodology of work which CS currently lacks. In this sense, for instance, Ron Sun has recently exposed numerous arguments for computational cognitive modeling (Sun 2009), not just as a tool for implementing theories or as a human data matching procedure, but as a methodology for both assessing and also creating serious theories of cognition, even at holistic level.[11]

Nevertheless, CS is a relatively young science that needs to be consolidated. For now, cognitive scientists share a common objective and an approach to the study of the mind, in which taking some non-experimentally contrasted assumptions as a starting hypothesis does not imply considering those assumptions as truths nor implies achieving false results, since nothing is actually known about them a priori (von Eckardt 1993).

4 Concluding Remarks

This paper has presented a criticism of some of the core features that differentiate CS as a science with its own identity. The arguments exposed are not intended to be applied to the source sciences that feed CS. Throughout time they have been well established and consolidated as areas of knowledge and they do not form part of this debate.

As stated before, one of the main limitations of CS in the search for its scientific acceptation is the fuzzy and broad concept of cognition, the object of study. There is a critical need to precisely define such a concept for the CS community to work together in the same

[11] Please, consider this as a simple example and not as an inclination to any specific area.

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direction. A joint effort from all the areas of knowledge involved must be made to establish the boundaries of cognition so that it can be stated what cognition is not, at least, thus firmly focusing the target of study, which is the first step for being a consolidated science. For instance, a tentative beginning would be to clearly determine the aspects about cognition described at the beginning of the section "Bounding the Definition of Cognition." Another interesting contribution would be to elaborate of a kind of ontology or hierarchy of the accepted cognitive processes or determine sufficient conditions for a process to be cognitive (Adams 2010; Rowlands 2008).

Moreover, those who call themselves cognitive scientists should open their minds to other areas of knowledge and points of view, giving CS a real interdisciplinary character. This interdisciplinary environment is more necessary now than ever, since more disciplines are coming into the CS scene, such as Sociology, Sociobiology, Ethology, Evolutionary Ecology and even Art, Culture, Moral and Ethics (Illes and Chin 2007). It is what is known as Distributed Cognition (Perry 2003). The more disciplines involved the more probability of divergence if interdisciplinarity is not well understood. Conversely, a real interdisciplinary environment could drive researchers far beyond the limits of knowledge that are currently conceived. In fact, CS could use (real) interdisciplinarity as an argument for its scientific nature, introducing itself with new concepts such as *metascience* or, even better, *interscience*. To this end, researchers must relax their own beliefs and listen to the theories and methods from as many of the other fields as possible. They should constantly question whether their theories could be explained by the other fields as well as whether the theories from other areas could be supported and tested by their own techniques and assumptions. Furthermore, another problem to confront is that the very few current real interdisciplinary proposals are somewhat confusing and do not guarantee successful results. The great effort and risk, which an authentic heterogeneous work implies, are other aspects that make researchers, either young or senior, desist and abandon the idea of seriously working in a real interdisciplinary way (Nelson 2011). Nonetheless, science is like that. It is a bet that can succeed or fail, but it always teaches us where not to apss at least (although the idea that the negative results are not interesting nor susceptible to publication is surprisingly accepted). This spirit and atmosphere should be spread to students and young researchers by tutoring jointly with new academic programs in which interdisciplinary knowledge is the base (Nelson 2011), although a certain level of specialization is unavoidable afterwards, of course.

For the sake of both scientific identity and real interdisciplinarity, it strikes us as crucial to design a set of methodologies of thought and work for CS. These methodologies should take into account all the disciplines and techniques. As a starting point, one might think of a basic methodology such as: raise an hypothesis, check whether the hypothesis makes sense with the support of theories and results from all the possible fields (if it does not make any sense try to answer why), try to prove the hypothesis with the techniques from as many fields as possible, integrate and analyze all the results and their implications in all the fields and check if they are coherent with previous findings and, finally, adapt the theories and raise new hypotheses based on the newly discovered knowledge. As said before, this could be just a tentative initial seed (and obviously very nave) to more elaborated procedures that would give CS a serious scientific overtone. The cooperation and integration of different areas would thus be made easier with the same purposes, as well as an approximation to more holistic and confidential explanations of cognition (Bechtel 2009).

At this point, the reader could think that this paper has tried to re-invent the wheel, and the reader would be right. It is not at all the first time that someone makes a request for an intellectual appointment in order to finely shape CS as a real scientific discipline (Gardner 1985; Miller 2003; Schunn et al. 1998; Sperber 2003; Thagard 2003; Varela 1990; von

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Eckardt 1993). However, it is necessary to re-invent the wheel from time to time to prevent the initial conception and unity of CS from getting out of control. This paper has modestly intended just to make CS believers (it actually means believers, and not just supporters) and not believers too think about the current problems and controversial issues surrounding CS. It has proposed a few simple starting ideas, and given heterogeneous and interdisciplinary views for each point so that the reader can have at his disposal the most holistic information to re-consider or not his current point of view. Anyway, the background purpose of this essay is to arouse the CS debate once more with the very optimistic expectation that it be the last and definitive one, as was thought before.

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