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Cognitive Science

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Cognitive science is a multidisciplinary approach to the study of mind and intelligence. Its main goals are to draw the architecture of cognition and to understand how cognition enables an organism to interact with and to produce adaptive behaviour within its environment. Cognitive science has also been defined as the study of the different forms of intelligence that characterize the domains of humans, animals and machines (Von Eckardt 2001). Because of the complexities intrinsic to the study of the mind and of the different levels and perspectives from which it may be studied, some theorists prefer to speak of 'cognitive sciences' in the plural (Miller 2003).

Some characteristics that were defining of cognitive science in the 1960s are now considered of doubtful utility, while others that were initially marginal occupy a central role in current theorizing. A consequence of the dynamic and multidisciplinary nature of cognitive science is that it is often unclear whether it should be defined based on its object of study (the mind) or on a particular epistemological and methodological approach to it (the simulative or computational one). The only way to avoid this question is to conflate ontology and methodology, an option that presents problems of its own. For these reasons, the nature of cognitive science is better understood from a historical perspective. The proximal intellectual roots of cognitive science may be situated around the middle of the 20th century with the rise of cybernetics (Wiener 1948). This new science claimed that complex machines have to have control systems (that is, subcomponents of their architecture in charge of governing their inner functioning and their interactions with the external world), and that all such systems are to be considered instances of the same natural kind. Control systems began to be considered as machines in their turn and, because Turing machines (Turing 1936), of which digital computers practically are physical incarnations, were provably able to simulate the functioning of any other finite machine, digital computers began to be used to understand and duplicate control systems. The next step on this path was to view the mind as a control system in its turn (Miller et al. 1960) and to therefore claim that it is a machine (Chomsky 1957) and can be simulated by a digital computer. The final pillar of the burgeoning discipline was the reification of the analogy, that is, the claim that human minds – all minds, actually – are digital computers (Newell and Simon 1976).

These final steps took place in the mid-1950s when some disciplines began to view computer simulation as the unifying methodology for the study of the human mind and its cognitive processes (Bara 1995). A specific event, which is often taken to be the birth date of the new science, is a symposium on information science that was held at the Massachusetts Institute for Technology in Boston on the 11th of September 1956 (Gardner 1985). The converging disciplines were philosophy, psychology, computer science (later to become **artificial intelligence**), neuroscience, linguistics and anthropology (Keysers et al. 1978). The formalization of the enterprise as a properly recognized scientific discipline took place in 1977 when the journal *Cognitive Science* commenced publication, and was completed with the first conference of the Cognitive Science Society in 1979 at the University of California at San Diego.

The subcommunities within psychology that underwent the 'cognitive revolution' (Miller 2003) were thus able to abandon behaviourism, which had considered that mind and cognition were unamenable to scientific inquiry. The simulative methodology was based on the functionalistic assumption that the physical structure on which cognitive processes are built in the human body is substantially irrelevant. If, given an input, a computational model can reproduce the same output of a mental process, it may be claimed that such a model reproduces that process, and this is claimed to be all that needs to be understood about it (Turing 1950; Pylyshyn 1984).

This close relationship between artificial intelligence and psychology thus lies at the very heart of cognitive science. Human beings are conceived of as information processors with limited capacities and top-down architecture, capable of coding, elaborating, storing and retrieving symbolic structures that represent the objective external world (Neisser 1967; Lindsay and Norman 1977). **Knowledge** representation and organization (Collins and Quillian 1969; Pylyshyn 1973; Minsky 1974; Bobrow and Collins 1975; Schank and Abelson 1977; Kosslyn 1980) rapidly began to be viewed as the kernel of cognition and accordingly became the central topic of cognitive science. This was followed by **reasoning** and thought (Johnson-Laird 1983; Newell and Simon 1972; Wason and Evans 1975). Great attention was also devoted to the study of perception (Winston 1975; Marr 1982; Ellis and Young 1988), attention (Broadbent 1958; Deutsch and Deutsch 1963; Norman and Shallice 1980), memory (Atkinson and Shiffrin 1968; Shallice and Warrington 1970; Craik and Lockhart 1972; Schank 1980; Baddeley 1986), and language (Chomsky, 1957, 1965, 1980; Winograd 1972; Grosz et al. 1986; Ellis and Young 1988). In the 1980s, substantially the same cognitive functions also began to be studied through connectionist models, which rejected the top-down architecture of cognitive functions and used distributed models of cognition, with an emphasis on learning (McClelland et al. 1986; Rumelhart et al. 1986; Elman et al. 1996; but see Fodor and Pylyshyn 1988).

Beginning in the 1980s, both the simulative methodology and the identification of mind and computation began to be questioned (Searle 1980). A diversity of criticisms has since led to a matching variety of reactions and further developments. In terms of community size, the most successful of these criticism/development blocks is the substitution of the brain for the digital computer. Claims about the importance and the specificity of the neurological substrate on which cognitive processes rely, as well as the fast technological advancements in neuroimaging techniques, has led cognitive neuroscience with its methodology to be elected as the new core discipline of cognitive science (Gazzaniga 1999). Here, cognitive processes are claimed to be better (or only) understood if they are linked to the activity of specific brain regions or neural networks. The functionalistic assumption and the 'arrows-and-boxes' approach of classical cognitive science are recast in terms of the isomorphism principle (Eysenck and Keane 1990), which assumes that a correspondence exists between the cognitive architecture of the mind and the physical structure of the brain. This principle is commonly understood as the notion that cognitive processes are segregated in dedicated submachines called modules.

Assumptions about the **modularity of the mind** here tend to be cast in so-called 'Darwinian' rather than in strictly Fodorian terms. The main difference is that Fodor's (1975, 1983) modules are supposed to be unintelligent, non-inferential submechanisms that are in charge of feeding the central processes with the raw materials starting from which they begin actual computations. However, Darwinian modules are supposed to be simple, domain-specific, locally intelligent mechanisms that operate within a completely distributed model of cognition (Minsky 1986), where the very existence of general-purpose central processes is claimed to be impossible from an evolutionary viewpoint (Barkow et al. 1992; Cosmides and Tooby 1994a, 1994b; Pinker 1997). Accordingly, the cognitive processes investigated and their modular physical counterparts are defined as types of organism/world interactions like social cognition, parenting and foraging rather than more abstract functions like memory or attention. The study of cognitive impairments and of their double dissociations in patients with specific brain damages, and the use of neuroimaging techniques to understand which brain regions are more active during the execution of specific cognitive tasks have thus become crucial steps in the construction and the falsification of hypotheses about the architecture of human mind (McCarthy and Warrington 1990).

A second criticism/development block has been concerned with the allegedly too abstract and disembodied description of cognition given by classical cognitive science, and has worked from the assumption that only the empirical study of real organism/world interactions may yield a real understanding of cognition (Agre 1995). This claim has often been associated with the rejection of the notion that **representation** is the central property of cognition (Brooks 1991a, 1991b). Taken together, these claims have led to the development of autonomous robotics (Maes 1991), which is the material engineering of simple artificial agents that are able to move and to perform simple tasks in the real world. Robotics has thus become able to trade concepts and metaphors with biology and its subdisciplines..

A third criticism of classical cognitive science has been its alleged incapability of (or lack of interest in) dealing with topics such as **context** and **culture**, and with the social and ontogenic features of the mind in general. Classical cognitive science is taken to have preferred a supposedly universal, rational and rigidly innate idea of the mind. Here, scientific focus has been shifting from the mind and brain to the whole organism that is formed by a biological body with a biological mind, placed into an environment that includes language, culture, values, and the individual's personal history. The physical, interpersonal and sociocultural context in which cognition takes place, which was treated by early cognitive scientists as noise, has thus gained increasing importance (Westbury and Wilensky 1998; Bruner 1990), and studies of culture (Hutchins 1995; Cole 1996; Tomasello 1999), situated cognition and activity (Agre 1997; Clancey 1997; Wenger 1999) and the bodily bases of cognition (Lakoff and Johnson 1980; Johnson 1987; Clark 1997) have begun to flourish.

The fourth and most radical departure from the classical perspective has been based on the re-evaluation of consciousness and subjectivity as the main – or only – feature of cognition. It has been argued that classical cognitive science's adoption of the 'view from nowhere' (Nagel 1986) is a fatal mistake and that no comprehension of the mind is possible while its subjective nature is neglected. This has led subcommunities of researchers to delve into studies of consciousness (Nagel 1974; Maturana and Varela 1980; Edelman 1992; Searle 1992; Chalmers 1996;

Damasio 1999) and sometimes to even adopt views based on radical constructivism and phenomenology (Guidano 1987, 1991; Dreyfus 1990; Varela et al. 1991; Varela 1996). As discussed above, the extent to which works like these still pertain to cognitive science – and probably, therefore, the very future of the discipline – depends on whether the discipline itself is defined on ontological or methodological grounds.

See also

Artificial intelligence; Cognitive anthropology; Cognitive linguistics; Cognitive pragmatics; Cognitive psychology; Computational pragmatics; Inference; Intentionality; Knowledge; Modularity of mind thesis; Philosophy of language; Philosophy of mind; Psycholinguistics; Rationality; Reasoning; Representation and computation.

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