The formalization and automatization of thought

The seeds of the formalization of thought were sown by the French philosopher René Descartes in the 17th century [2]. Descartes argued that thinking is reasoning, and that reason is a chain of simple ideas, linked by applying strict rules of logic. With his '*cogito ergo sum*', Descartes was the first precursor of cognitive science (even if he was wrong about the dualism of mind and brain). Then, in the 19th century, it was an English mathematician, George Boole, who invented symbolic calculus, in which logical operations like *or*, *and*, and *if-then* are expressed as simple mathematical computations using 0 and 1 [3]. Boole's dream was to translate all operations of the human mind into elementary mathematics. Part of this dream was realized in the 20th century thanks to the Swiss psychologist Jean Piaget, who showed how elementary psychological mechanisms (mental actions and operations) gradually construct logical and mathematical thinking between infancy and adulthood [4]. This was also shown by the French neurobiologist Jean-Pierre Changeux in his 'neural Darwinism', which describes the tight links between logic, mathematics and the brain [5], links we can now observe directly by means of functional brain imaging [6].

It was another French philosopher, Julien Offroy de La Mettrie, who sowed the seeds of the automatization of thought in the 18th century [7]. La Mettrie dared claim that humans were machines (according to Descartes, only animals were so). Based on this premise, he began his mechanistic attempt to naturalize the human mind. This attempt took on a more modern form in the 20th century when the English mathematician Alan Turing imagined a virtual device (the Turing machine) that could translate any humanly computable mathematical problem into a sequence of simple operations [8]. This was the invention of the algorithm, the basis of what was to become computer science and the germ from which artificial intelligence was born.

The cerebral bases of thought

The second European root of cognitive science, the cerebral bases of thought, dates back to the early 19th century when the Austrian neurologist, Franz Josef Gall, ventured the idea that the human mind is divided into multiple mental functions, and that each of these functions corresponds to a part of the cerebral cortex. Gall is cited by Fodor in the introduction of his seminal book, *The Modularity of Mind* [9], which has made an indelible mark on computational research in cognitive science. Gall's localization method or 'phrenology' (interpretation of bumps on the skull) was quite fanciful, however, and it was not until the 1860s that the French neurologist Paul Broca achieved the first scientific localization of a mental function (language) in the human brain [10]. Cognitive brain mapping had thus been launched. The project was pursued in the 20th century, first in cognitive neuropsychology using brain-damaged patients (as Broca had done), and latterly via functional brain imaging of healthy subjects.

As this brief European history shows, the growth of what is now called cognitive science – although first instituted as an academic discipline in the US [1] – has taken place on both sides of the Atlantic. Clearly, then, the cognitive revolution is a long-standing, transatlantic enterprise, not just a recent American one.

References

1 Miller, G.A. (2003) The cognitive revolution: a historical perspective. *Trends Cogn. Sci.* 7, 141–144
2 Gaukroger, S. (2003) Descartes, René. In *The Encyclopedia of Cognitive Science* (Vol. 1) (Nadel, L., ed.), pp. 947–950, Macmillan
3 Boole, G. (1854) *An Investigation of the Laws of Thought, on Which Are Founded the Mathematical Theories of Logic and Probabilities*, Macmillan
4 Fischer, K. and Kaplan, U. (2003) Piaget, Jean. In *The Encyclopedia of Cognitive Science* (Vol. 1) (Nadel, L., ed.), pp. 679–682, Macmillan
5 Changeux, J-P. and Connes, A. (1998) *Conversations on Mind, Matter, and Mathematics*, Princeton University Press
6 Houdé, O. and Tzourio-Mazoyer, N. (2003) Neural Foundations of Logical and Mathematical Cognition. *Nat. Rev. Neurosci.* (in press)
7 Thomson, A. (1996) *Julien Offroy de La Mettrie: Machine Man and Other Writings*, Cambridge University Press
8 Copeland, J. (2003) Turing, Alan. In *The Encyclopedia of Cognitive Science* (Vol. 4) (Nadel, L., ed.), pp. 427–430, Macmillan
9 Fodor, J. (1983) *The Modularity of Mind*, MIT Press
10 Finger, S. (2003) Broca, Paul. In *The Encyclopedia of Cognitive Science* (Vol. 1) (Nadel, L., ed.), pp. 426–429, Macmillan

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The cognitive revolution in Europe: taking the developmental perspective seriously

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'The only duty we owe to history is to rewrite it'
Oscar Wilde

We can do little but to share Miller's view [1] that cognitive psychology was born in the 1950s. However, his article distorts the role of psychology in the birth of cognitive science. On two occasions, Miller proposes that psychology could not play a role in the cognitive revolution because of its narrow focus on behaviorism. We would like

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to stress, however, that this claim applies only to the American tradition of psychology.

While behaviorism flourished in the US, two prominent developmental psychologists, Piaget in Switzerland and Vygosky in Russia, were setting the paths for an integrated view of the human mind. Vygotsky adopted a socio-historical approach to cognitive development, which emphasized the way in which development evolves through social interaction, cultural practices, and the internalization of cognitive tools. We will not comment further on Vygotsky's enterprises, as their long lasting influence indicates how integral a role he played in the early days of cognitive science [2].

Piaget was initially trained as a biologist. However, he is best remembered as a creative developmental psychologist who was fascinated by one particular question, namely, the mode of construction of knowledge in terms of its means of acquisition both over the course of early scientific enquiry and during the development of the infant and the child.

Miller emphasizes the importance of the creation of Bruner's Center for Cognitive Studies, at Harvard, in 1960. This was opened 5 years *after* Piaget had founded the International Center for Genetic Epistemology (ICGE) in Geneva with the financial support of the Rockfeller Foundation. The Center was active for more than 30 years and attracted scientists from all over the world. The work carried out at the ICGE resulted in the publication of 36 volumes in a special collection published by the Presses Universitaires de France, Paris. Several of these volumes are available in English (see [3] for the most recent one). Genetic epistemology is in its essence multidisciplinary, a fact that was emphasized by Piaget who stated that 'to work in such a discipline it does not suffice to be a psychologist vaguely acquainted with a smattering of philosophy and biology: one must be, moreover, a logician, a mathematician, a physicist, a cybernetist and a historian of science, to mention the essential' ([4], p. 44).

This was also reflected in the research programs that developed on both sides of the Atlantic. They shared the conviction that the study of the mind should not be undertaken by a single discipline but rather required the contribution of conceptual and methodological tools borrowed from the different scientific fields. Miller's story of the American cognitive revolution, however, leaves the reader with the impression that interdisciplinary inquiry was conceived, and pursued, as a *scientific objective* in itself. By contrast, the interdisciplinary nature of the ICGE project was clearly stated as a *means* of providing a broader and theoretically founded research program, namely the study of mind and knowledge considered as biological products of a developmental process.

Stressing this distinction might help to explain the historical outcomes of the cognitive revolution and may also be informative for the future of cognitive science. Despite the multiplicity of the connections established between disciplines (see Miller's polygon, Fig. 1 in [1]), there is no doubt that one of the most influential links in the cognitive revolution occurred between psychology and computer science, the latter providing a long-lasting metaphor for the former. However, this in turn contributed to the relative confusion that already existed between the intents of the cognitive revolution (i.e. rehabilitating the study of mind) and one of its powerful tools (computer simulation). This confusion, along with its reductionist counterparts, led Bruner to withdraw from this movement during the post-revolution years [5]. Computers do not mimic development, nor do they build representations and meanings.

Another approach to cognitive science, then, emerged in Europe during these years. This approach did not only inspire 'a small army of followers' ([1], p. 142), but more importantly, it shaped a complementary perspective on cognition, which was developmental and cultural in nature. According to such views, for which Piaget and Vygotsky were the main proponents, the organization of the human mind is the product of biologically and culturally mediated processes of development. Hence, studying the human mind cannot be achieved without studying the developmental mechanisms that give rise to cognitive abilities and constrain their organization. The constructivist framework, in which high-level representations are derived from lower ones, is a crucial contribution to cognitive science [6]. This research program was born in the 1950s and is still very much alive, taking the developmental perspective seriously [7].

References

1 Miller, G.A. (2003) The cognitive revolution: a historical perspective. *Trends Cogn. Sci.* 7, 141–144
2 Frawley, W. (1997) *Vygotsky and Cognitive Science. Language and the Unification of the Social and Computational Mind*, Harvard University Press
3 Piaget, J. (2000) *Studies in reflecting Abstraction, Psychology Press* (orig. published 1977 in French)
4 Piaget, J. (1972) *Insights and Illusions of Philosophy*, Routledge
5 Bruner, J. (1990) *Acts of Meaning*, Harvard University Press
6 Drescher, G.L. (1991) *Made-Up Minds, a Constructivist Approach to Artificial Intelligence*, MIT Press
7 Karmiloff-Smith, A. (1994) Precis of 'Beyond Modularity: a developmental perspective on cognitive science'. *Behav. Brain Sci.* 17, 693–745

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Tactile sensation via spatial perception

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If a sensory brain state plays an unusual functional role, does the phenomenology go with the role or the brain state? If the phenomenology goes with the functional role, that supports functionalism, which is the view that

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