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tivations. Complex global behavior emerges as a result of interaction between many simple local processes. The most prominent exponent of simplified brain models is the class of models known as connectionist or parallel distributed processing (PDP).

Assuming that cognition is the result of neural processes and that these processes can be treated as information processes, the approaches taken in computational neuroscience promise to be fruitful. An important step that has to be taken is to consider also epistemiological concepts; they are especially important in investigating the problems of knowledge representation and language. However, the basic question remains: are human brains capable of understanding themselves?

[*See also* Artificial Intelligence; Connectionism; and Cybernetics.]

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—MARKUS PESCHL

COMPUTER. If it were distinguished only by its number-crunching ability, the computer would be no more than a better abacus. From a semiotic perspective, such a device would be relevant in regard to automating operations corresponding to a well-defined category of signs, such as those that represent quantities in some way. That quantities can be represented iconically, indexically, or symbolically is a matter of cultural record, as is the fact that there are many number systems (e.g., binary, decimal, and hexadecimal). Nevertheless, the type of representation is relevant for defining the ever-changing cognitive condition of the human being. Some representations are very close to what they represent; others tend to become more general or to reach increasing levels of abstraction.

Many types of devices have been built over time in order to accommodate the ever-growing need for calculations posed by practical tasks of augmented complexity or by theoretical endeavors. These devices embody literally human knowledge of numbers: at the end of the nineteenth century in England, the word *computer* applied to people who carried out astronomical calculations professionally. They also embody understandings of proportions and rules for addition and subtraction in that their physicality and their functionality are interdependent. The degree of abstraction implicit in the reality of a machine, which logic and mathematics advanced as such machines became increasingly abstract, fundamentally affected this physical limitation. Before the first computer was ever built, computers had already been conceived of as theoretical machines able to process on a symbolic level. The Turing machine, the archetype of the modern computer, is such a theoretical construct.

On the object level, there are at least three aspects of computers that have semiotic relevance; computation, interface (the interaction between persons and computers), and networking (the integration of machines and programs in an underlying structure facilitating human interaction). On a metalevel, semiotically relevant aspects pertain to: representation, understanding (the semantics of computation), and learning of self-awareness (self-organization in pursuit of lifelike properties such as adaptation, self-learning, awareness, self-criticism, and immunity). These lists are not exhaustive.

Computers are basically semiotic engines. Regardless of their implementation, as digital computers or as devices working in any number system, computers process symbols. Embodied in a computer are a logic (Boolean in current computer technology), data (today almost exclusively in digital format), and instructions (in the form of programs). Semiotically, this meeting of logic, signs, and operations can be described as semiosis (i.e., sign processes), which in principle is open-ended. The logic is embedded in the hardware and reflected in the structure and function of the programming language. Programs can also be at least partially embedded in matter (in particular in the silicon chips), although they are written as "applications" and provided in the form of instructions. The data to which logic is applied and upon which operations are carried out stands for measurements, thoughts, emotions, and so on. As a semiotic engine, the computer is fed by the inexhaustible energy of sign-based human activities, interactions included.

Such descriptions could not shed much light on the subject of computers and computation if they were only yet another attempt to capture for semiotics a field of inquiry and practical application to which semiotics itself has contributed little or nothing. But the intellectual history of computers does not start with silicon. The magnificent semiotic project of Gottfried Wilhelm Leibniz (1646–1716) articulated the goal of a *calculus ratiocinator*; many other projects, such as those by Ramón Lull (1232–1316), Blaise Pascal (1623–1662), John Napier (1550–1617), and others prepared the stage for the applications pursued by Charles Babbage (1792–1871) that he embodied in his analytical engine. Charles Sanders Peirce (1839–1914), who himself probably became involved in the attempt to build contraptions able to support sign processes, discussed the semiotic significance of such attempts and suggested a complete set for performing any sign calculus through the operations of insertion, omission, and substitution. Joseph-Marie Jacquard (1752–1834), Herman Hollerith (1860–1929), Howard Aiken (1900–1973), and J. W. Manchly (1907–1980), for instance, constructed such machines. Others, such as Norbert Wiener (1894–1964), Herbert Simon (b. 1916), Allen Newell, Vannevar Bush (1890–1974), and Marvin Minsky (b. 1927), to name only a few, gave them their underlying semiotic identity. In the process of dedicating a great deal of effort to designing languages suitable for programming, computer science appropriated the convenient semiotic distinction of syntax, semantics, and pragmatics.

Not too many computer scientists and even fewer semioticians have recognized the need for integrating semiotic considerations into the current dynamics of technological change. They are aware that semiotic considerations proved very useful in approaching the fundamental problem of interface (the iconic interface is the better-known example of this application) and in the design of computer-supported interactions, such as the ones pertinent to the networked world. Vannevar Bush will probably be remembered less for his technological genius, embodied in the differential analyzer (an analog computer built in 1930 at the Massachusetts Institute of Technology) and more for his anticipation of nonlinear-thinking applications such as those embodied by the World Wide Web. Semiotic engineering, too, is in the process of gaining well-deserved legitimacy.

Computation as a semiotic substratum and supported by semiotic considerations is only part of the ongoing efforts to deal with issues of human intelligence, virtual reality, and artificial reality. Semiotics has little if anything to contribute to implementations of neural networks, algorithms, parallel processing, and similar issues. The significance of semiotics becomes apparent, however, in addressing notions of appropriateness (which signs optimally support a certain human endeavor), distinction (which features and which correlations support processes such as pattern recognition and image understanding), and integration (design and implementation of multimedia expressions). Multimedia, in that it unites various data types, is a computational challenge. But it is even more a semiotic experience of a type different from that embodied in the processing of single, homogeneous data types.

What generally qualifies the semiotic approach is dedication to the entire effort of computation—that is, a commitment to ensuring the coherence of the integrated sign processes that are facilitated and carried through computationally. A good interface will never automatically guarantee the success of a program. A good program (as relative as this is in a world of rapidly successive versions) that has difficult interactions will perform only at a percentage of its potential. A coherent, integrated semiotic strategy extends to everything that supports and defines the activity. In some way, such a semiotic strategy is the metaprogram that unites software, data flow, input/output performance, connectivity, process and human interface, cultural and social acceptance, and learning.

As a still young technology in a phase of rudimentary evolution, computers maintain the semiotic engine on a level still detached from the application at hand, rather than as part of it. The challenge probably lies in the integration of computers into human pragmatics in order to make them appear as extensions of human intellect and skill. At that level, the semiotic engine should display awareness of the sign processes and should be able to initiate semioses appropriate to the goal pursued.

[*See also* Abacus; Artificial Intelligence; Computer-Mediated Communication; Icon; Index; Interface; Metalanguage; Number Representation; Semiosis; *and* Turing.]

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—MIHAI NADIN

COMPUTER-MEDIATED COMMUNICATION.

COMPUTER-MEDIATED COMMUNICATION. A new form of human communication made possible by links between personal and mainframe computers, modems, and telecommunication lines, computer-mediated communication transpires in "cyberspace," an abstract, disembodied space consisting only of information and electronic pulses, in which the ordinary coordinates of physical space and time are suspended. "The Net" (for "network" or "network of networks") has become a meeting place for millions of people. Remarkable new forms of "virtual culture" are now developing in this intensely semiotic domain of human interaction. At the present time, messages are still mainly typed and textual, although graphics and sound and video clips are increasingly being added. The technology for video conferencing—oral, computer-mediated face-to-face communication including visual images in real time—exists.

Interpreted broadly, the term *computer-mediated communication* includes not only person-to-person and person-to-group communication but also person-to-computer contacts in which individuals access files or interact with programs on remote computers. Global computerization is breaking down the traditional distinction in print culture between the solo-authored, decontextualized written text and th to-face personal conversation. Thus, within mi or hours of examining a document via the Wide Web—a system of links between digital fi text, sound, or graphics, effortlessly accessed by computers around the globe—a person can co its author(s) by electronic mail (e-mail) and be dialogue.

While corresponding through e-mail can be as a mere acceleration of time-delayed commu tion, group communication based on the basic e mode puts large numbers of individuals in in synchronous interaction. Discussion-list messag posted to a central address and automatically tributed to the personal accounts of all other scribers. In some groups, a moderator edits distributes messages in batches.

Synchronous modes enable individuals logge simultaneously to "chat" by typing messages to other in real time. For instance, just as face-to speakers hear their interlocutors formulating messages as they are spoken, when the "talk" f tion is activated on the Unix operating system, individuals can read each other's messages as the being typed. In addition to specialist or lobbyist works, there are real-time, collective role-playing tasy games of long duration in which individ develop fictional personae, either of the same or opposite sex, and interact in virtual rooms.

Early research conducted in the late 1970s concerned with the effects of the new medium or ganizational functioning, efficiency, and hierarch relationships. Many perceived the medium as c anonymous, and lacking in "social presence" beca of "reduced bandwidth" and the absence of non bal cues such as facial expression. Alongside this going research tradition, newer approaches focus on the linguistic, playful, and expressive aspects computer-mediated communication are of greater terest to students of semiotics, discourse analysis, ciolinguistics, folklore, and anthropology.

Digital writing is strikingly dynamic, playful, a even speechlike and challenges currently held beli among folklorists and students of rhetoric, oral lit ature, and the history of literacy about the uniq ness of oral culture. Oral culture is believed, example, to be agonistically toned, whereas writi subject to processes of decontextualization, supp edly neutralizes this component of human inter tion. Yet even in ordinary e-mail, both private a