

COMPUTATIONAL MODEL

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Computational Model

Primary Disciplinary Field(s): Cognitive Psychology, Cognitive Science, Artificial Intelligence (AI)

1. Core Definition

The **Computational Model**, central to the field of cognitive science, represents a comprehensive framework positing that the human mind operates fundamentally like a digital computer or an information processing system (IPS). This conceptualization suggests that mental and psychobiological procedures—including perception, memory, reasoning, and decision-making—can be understood as systematic operations executed upon internal representations of the world. In this context, thinking is equated with computation, whereby the mind constructs specific **symbolizations** of external occurrences and items, and subsequently operates involved series of functions, or algorithms, on these symbolic structures. This model moves away from the purely observable input-output mechanisms favored by behaviorism, focusing instead on the complex, internal, step-by-step maneuvers that dictate how people process information, solve problems, and perform daily actions. It provides a formal, mechanistic explanation for cognitive abilities, allowing researchers to simulate and test theories of mental function using structured programming and mathematical formalisms.

This approach is often encapsulated within the **Computational Theory of Mind (CTM)**, which asserts two primary claims: first, that mental states are comprised of symbolic representations; and second, that mental processes consist of computational operations defined over the syntactic properties of these symbols. The analogy draws a clear parallel between the brain and computer hardware, and the mind and computer software, suggesting that while the physical substrate (neurons vs. silicon chips) differs, the underlying logical architecture of information manipulation remains analogous. Therefore, a computational model serves not merely as a loose metaphor, but as a rigorous hypothesis that mental functions are decomposable into discrete, executable steps, much like instructions in a computer program, allowing for predictive modeling of human behavior under varying conditions. The fidelity and complexity required to accurately model specific psychological phenomena necessitate highly detailed flowcharts and formal languages, providing the methodology through which cognitive psychologists attempt to reverse-engineer the mind's operational structure.

2. Etymology and Historical Development

The genesis of the Computational Model is inextricably linked to the confluence of several mid-20th-century developments: the advent of the digital computer, advancements in formal logic, and the intellectual shift known as the **Cognitive Revolution**. Before the 1940s, psychology was dominated by Behaviorism, which largely dismissed internal mental states as unobservable and

irrelevant to scientific inquiry. However, the theoretical groundwork laid by mathematicians and logicians, particularly **Alan Turing**, proved critical. Turing's concept of the **Turing Machine** demonstrated that any computable function could be executed via a simple, idealized machine following a finite set of rules, providing the philosophical and mathematical infrastructure necessary to conceive of intelligence itself as fundamentally computational.

Following World War II, the practical construction of electronic computers provided a physical realization of Turing's abstract model, catalyzing the belief that complex human cognition could be similarly analyzed. Pioneers like Claude Shannon, who linked information theory to communication, and Norbert Wiener, who developed cybernetics, established the vocabulary of information flow, feedback loops, and control mechanisms. By the 1950s, researchers like Allen Newell and Herbert A. Simon began constructing the first genuine computational models of human thought, resulting in programs like the Logic Theorist (1956) and the General Problem Solver (GPS). These programs successfully simulated human reasoning processes--such as forming goals, identifying differences between current and desired states, and applying operators to reduce those differences--lending immense empirical weight to the idea that the mind's operations could be formalized computationally. This period marked the foundational shift away from stimulus-response associations and toward the internal architecture of the mind, firmly establishing the computational paradigm as the dominant explanatory framework in the emerging field of cognitive science.

3. Key Characteristics (The Computer Metaphor)

The efficacy of the Computational Model rests heavily on its rigorous application of the computer metaphor, which outlines specific characteristics assumed to govern mental processes. The core assumption is that cognition involves the manipulation of discrete, identifiable mental symbols. These symbols are not vague associations but well-defined, abstract tokens that stand for objects, concepts, or properties in the external world. Crucially, the operations performed on these symbols are purely syntactic; that is, the computational rules only care about the form, structure, and position of the symbols, not their meaning (semantics). The meaning emerges when the symbols are interpreted by an observer (the human subject) or when the system interacts with the environment. This distinction allows the model to separate the 'hardware' (the neural substrate that executes the process) from the 'software' (the functional program that defines the computation).

Another defining characteristic is the reliance on **algorithms**. Mental processes are modeled as specific, unambiguous sequences of steps that guarantee a correct solution or output given a specific input. Whether processing language, retrieving a memory, or solving a mathematical equation, the computational model dictates that the mind executes these tasks through disciplined, step-by-step processing. Furthermore, these models emphasize the concept of limited capacity--the constraints imposed by working memory, attention, and processing speed--which mirrors the

limitations inherent in physical computer architecture (e.g., RAM capacity or clock speed). By incorporating these constraints, computational models gain ecological validity, reflecting known limitations in human performance.

4. Underlying Mechanisms (Symbolization and Function)

The function of a computational model hinges on two inseparable components derived directly from the source material: the construction of **symbolizations** and the operation of involved **series of functions**. Symbolization refers to the critical process of encoding raw sensory data into a format that the cognitive system can process. For instance, when an individual perceives a chair, the raw retinal input (photons hitting the eye) must be converted into an internal, abstract representation--a symbol or set of symbols--that codes for attributes such as "four legs," "flat seat," and "used for sitting." This internal representation must be stored and accessed in a manner consistent across different instances of perceiving "chair."

Once the symbolizations are established, the system applies a specific series of functions. These functions are the dynamic, operational components of the model, often conceived as production rules (e.g., IF THEN). For example, in a computational model of chess playing, the symbols might represent the board state, and the functions would be algorithms designed to evaluate possible future moves, prioritize certain outcomes, and select the best next step based on a structured heuristic search. The efficiency and complexity of these functions determine the model's explanatory power. By dictating precise, step-by-step maneuvers, these models successfully account for the highly structured nature of human cognition, such as the systematic application of grammatical rules in language production or the logical steps taken during deductive reasoning. The ability of the computational approach to specify these internal dynamics makes it invaluable for generating testable hypotheses about the flow and transformation of information within the human brain.

5. Significance and Impact

The Computational Model has served as the bedrock of cognitive science and related fields for over half a century, exerting a profound influence on research methodology and theoretical development. Its significance lies primarily in providing a rigorous, formal vocabulary for describing mental life, moving the study of the mind from philosophical speculation to empirical, testable science. Prior to this model, concepts like "thought" or "intention" were difficult to operationalize; the computational framework offered the necessary tools--algorithms, data structures, and flowcharts--to make these concepts tangible and replicable in laboratory settings and computer simulations. This formalization allowed for direct comparison between human cognitive performance and machine performance, propelling the field of Artificial Intelligence.

The impact extends deeply into specific areas of psychology and AI. In psychology, computational models have successfully illuminated processes such as memory retrieval (e.g., ACT-R models), visual perception, and problem-solving heuristics. In AI, the early computational approach led to **Good Old-Fashioned AI (GOFAI)**, where intelligence was pursued through explicit programming of symbolic knowledge and logical rules. Although modern AI has diversified, the principles derived from symbolic computational models remain vital for expert systems, planning, and knowledge representation. Furthermore, the model provided a unifying theoretical framework, linking neurobiology (the physical implementation) with psychology (the functional description) and computer science (the formal tools), thereby establishing cognitive science as a truly interdisciplinary endeavor.

6. Debates and Criticisms

Despite its dominance, the Computational Model faces significant theoretical and empirical challenges. One of the most famous critiques is John Searle's 1980 **Chinese Room Argument**, which challenges the fundamental premise of CTM. Searle argued that merely manipulating symbols according to rules (syntax) does not constitute genuine understanding or consciousness (semantics). A computer executing a perfect translation program for Chinese possesses no meaningful understanding of Chinese; it is merely performing computations. This argument suggests that the computational approach, by relying exclusively on syntactic manipulation, misses the crucial element of mental life: intentionality and subjective meaning.

Empirically, the rise of **Connectionism** (or parallel distributed processing) provided a powerful alternative paradigm. Connectionist models, based on artificial neural networks, argue that cognition emerges not from sequential symbolic processing, but from the parallel, sub-symbolic activity of interconnected units resembling neurons. These models excel at learning and pattern recognition tasks that are difficult to program explicitly using symbolic rules, suggesting that much of human cognition might be emergent rather than strictly algorithmic. More recently, the movement toward **Embodied Cognition** has challenged the computational model's inherent dualism, arguing that cognition is not solely an abstract process occurring in a disembodied "mind-software," but is fundamentally shaped by the body's interactions with the physical environment. Critics assert that by focusing strictly on abstract representations and step-by-step rules, the computational model often fails to account for the fluidity, speed, and biologically constrained nature of real-world human behavior.

Further Reading

[Computational Theory of Mind \(Wikipedia\)](#)

[The Cognitive Revolution \(Wikipedia\)](#)

[Turing Machine \(Wikipedia\)](#)

[The Chinese Room Argument \(Stanford Encyclopedia of Philosophy\)](#)

[Embodied Cognition \(Wikipedia\)](#)

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