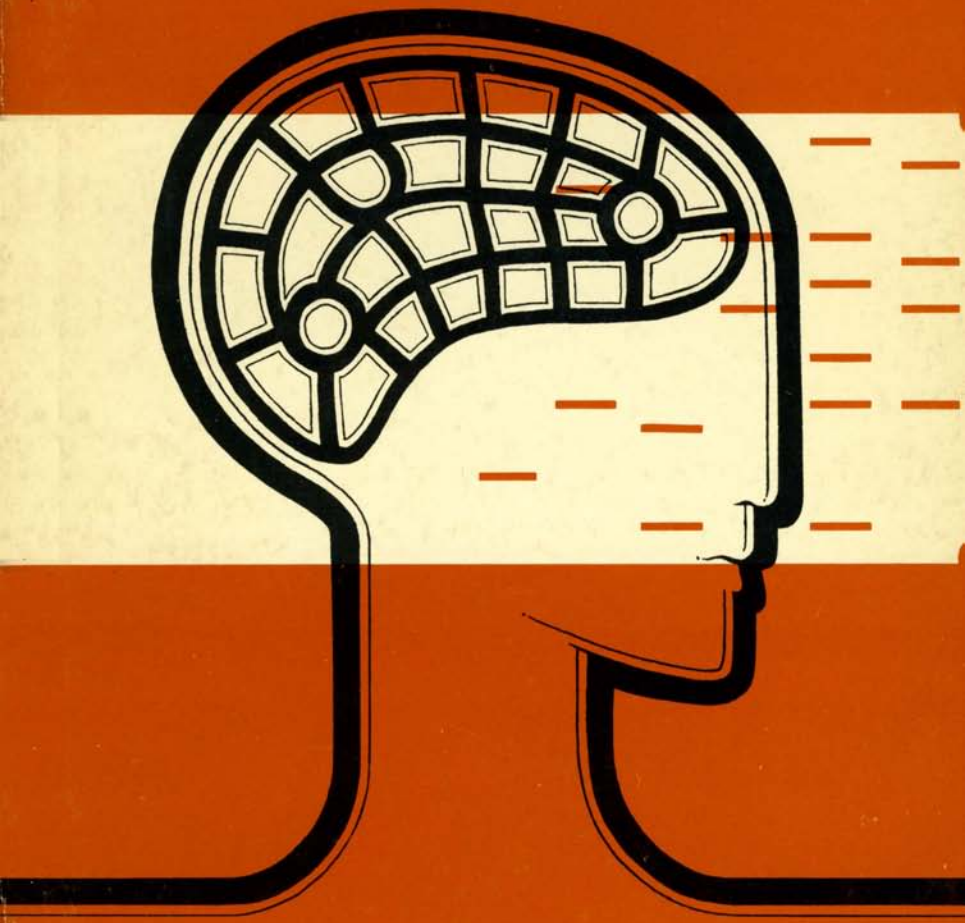
THE COMPUTER AND THE BRAIN



John von Neumann

A YALE PAPERBOUND

$1.45 (U.K. 10/6 NET)

The Computer and the Brain

by John von Neumann

The Computer and the Brain

New Haven and London: Yale University Press

Issued as a Yale Paperbound January 1963
Printed by The Carl Purington Rollins Printing-Office of the Yale University Press, New Haven, Connecticut.

Library of Congress catalog card number: 58-6542

Preface

To give the Silliman Lectures, one of the oldest and most outstanding academic lecture series in the United States, is considered a privilege and an honor among scholars all over the world. Traditionally the lecturer is asked to give a series of talks, over a period of about two weeks, and then to shape the manuscript of the lectures into a book to be published under the auspices of Yale University, the home and headquarters of the Silliman Lectures.

Early in 1955 my husband, John von Neumann, was invited by Yale University to give the Silliman Lectures during the spring term of 1956, some time in late March or early April. Johnny was deeply honored and gratified by this invitation, despite the fact that he had to make his acceptance subject to one condition—namely, that the lectures be limited to one week only. The accompanying manuscript would, however, cover more fully his chosen topic—The Computer and the Brain—a theme in which he had been interested for a considerable time. The request to abbreviate the lecture period was made of necessity, as he had just been appointed by President Eisenhower as one of the members of the Atomic Energy Commission, a full-time job which does not permit even a scientist much time away from his desk in Washington. My husband knew, however, that he could find time to write the lectures, for he had always done his writing at home during the night or at dawn. His capacity for work was practically

unlimited, particularly if he was interested, and the many unexplored possibilities of automata did interest him very much indeed; so he felt quite confident that he could prepare a full manuscript even though the lecture period would have to be somewhat cut. Yale University, helpful and understanding at this early period as well as later, when there was only sadness, sorrow, and need, accepted this arrangement, and Johnny started his new job at the Commission with the added incentive that he would continue his work on the theory of automata even if it was done a little *en cache.*

In the spring of 1955 we moved from Princeton to Washington, and Johnny went on leave of absence from the Institute for Advanced Study, where he had been Professor in the School of Mathematics since 1933.

Johnny was born in Budapest, Hungary, in 1903. Even in his early years he had shown a remarkable ability and interest in scientific matters, and as a child his almost photographic memory manifested itself in many unusual ways. Reaching college age, he studied first chemistry and then mathematics at the University of Berlin, the Technische Hochschule in Zurich, and the University of Budapest. In 1927 he was appointed Privatdozent at the University of Berlin, probably one of the youngest persons appointed to such a position in any of the German universities within the last few decades. Later Johnny taught at the University of Hamburg, and in 1930, for the first time, crossed the Atlantic, having accepted the invitation of Princeton University to become a guest lecturer for one year. In 1931 he became a member of the faculty of Princeton University, thus making his permanent home in the United States and becoming a citizen of the New World.

During the 1920's and 30's Johnny's scientific interest was ranging widely, mostly in theoretical fields. His publications included works on quantum theory, mathematical logic, ergodic theory, continuous geometry, problems dealing with rings of operators, and many other areas of pure mathematics. Then, during the late thirties, he became interested in questions of theoretical hydrodynamics, particularly in the great difficulties encountered in obtaining solutions to partial differential equations by known analytical methods. This endeavor, carried forward when war clouds were darkening the horizon all over the world, brought him into scientific defense work and made him more and more interested in the applied fields of mathematics and physics. The interaction of shock waves, a very intricate hydrodynamic problem, became one of the important defense research interests, and the tremendous amount of calculations required to get some of the answers motivated Johnny to employ a high-speed computing machine for this purpose. The ENIAC, built in Philadelphia for the Ballistic Research Laboratories of Army Ordnance, was Johnny's first introduction to the vast possibilities of solving many yet unresolved questions with the aid of automation. He helped to modify some of the mathematical-logical design of the ENIAC, and from then until his last conscious hours, he remained interested in and intrigued by the still unexplored aspects and possibilities of the fast-growing use of automata.

In 1943, soon after the Manhattan Project was started, Johnny became one of the scientists who "disappeared into the West," commuting back and forth between Washington, Los Alamos, and many other places. This was the period during which he became completely convinced, and tried to convince others in many varied fields, that numerical calculations done on fast elec-

tronic computing devices would substantially facilitate the solution of many difficult, unsolved, scientific problems.

After the war, together with a small group of selected engineers and mathematicians, Johnny built, at the Institute for Advanced Study, an experimental electronic calculator, popularly known as the JONIAC, which eventually became the pilot model for similar machines all over the country. Some of the basic principles developed in the JONIAC are used even today in the fastest and most modern calculators. To design the machine, Johnny and his co-workers tried to imitate some of the known operations of the live brain. This is the aspect which led him to study neurology, to seek out men in the fields of neurology and psychiatry, to attend many meetings on these subjects, and, eventually, to give lectures to such groups on the possibilities of copying an extremely simplified model of the living brain for man-made machines. In the Silliman Lectures these thoughts were to be further developed and expanded.

During the postwar years Johnny divided his work among scientific problems in various fields. Particularly, he became interested in meteorology, where numerical calculations seemed to be helpful in opening entirely new vistas; part of his time was spent helping to make calculations in the ever-expanding problems of nuclear physics. He continued to work closely with the laboratories of the Atomic Energy Commission, and in 1952 he became a member of the General Advisory Committee to the AEC.

On March 15, 1955, Johnny was sworn in as a member of the Atomic Energy Commission, and early in May we moved our household to Washington. Three months

later, in August, the pattern of our active and exciting life, centered around my husband's indefatigable and astounding mind, came to an abrupt stop; Johnny had developed severe pains in his left shoulder, and after surgery, bone cancer was diagnosed. The ensuing months were of alternating hope and despair; sometimes we were confident that the lesion in the shoulder was a single manifestation of the dread disease, not to recur for a long time, but then indefinable aches and pains that he suffered from at times dashed our hopes for the future. Throughout this period Johnny worked feverishly—during the day in his office or making the many trips required by the job; at night on scientific papers, things which he had postponed until he would be through with his term at the Commission. He now started to work systematically on the manuscript for the Silliman Lectures; most of what is written in the following pages was produced in those days of uncertainty and waiting. In late November the next blow came: several lesions were found on his spine, and he developed serious difficulties in walking. From then on, everything went from bad to worse, though still there was some hope left that with treatment and care the fatal illness might be arrested, for a while at least.

By January 1956 Johnny was confined to a wheelchair, but still he attended meetings, was wheeled into his office, and continued working on the manuscript for the lecture. Clearly his strength was waning from day to day; all trips and speaking engagements had to be canceled one by one, with this single exception—the Silliman Lectures. There was some hope that with X-ray treatments the spine might be, at least temporarily, sufficiently strengthened by late March to permit his traveling to New Haven and fulfilling this one obliga-

tion that meant so very much to him. Even so, the Silliman Lecture Committee had to be asked further to reduce the lectures to one or two at the most, for the strain of a whole week of lecturing would have been dangerous in his weakened condition. By March, however, all false hopes were gone, and there was no longer any question of Johnny being able to travel anywhere. Again Yale University, as helpful and understanding as ever, did not cancel the lectures, but suggested that if the manuscript could be delivered, someone else would read it for him. In spite of many efforts, Johnny could not finish writing his planned lectures in time; as a matter of tragic fate he could never finish writing them at all.

In early April Johnny was admitted to Walter Reed Hospital; he never left the hospital grounds again until his death on February 8, 1957. The unfinished manuscript of the Silliman Lectures went with him to the hospital, where he made a few more attempts to work on it; but by then the illness had definitely gained the upper hand, and even Johnny's exceptional mind could not overcome the weariness of the body.

I should like to be permitted to express my deep gratitude to the Silliman Lecture Committee, to Yale University, and to the Yale University Press, all of which have been so helpful and kind during the last, sad years of Johnny's life and now honor his memory by admitting his unfinished and fragmentary manuscript to the series of the Silliman Lectures Publications.

KLARA VON NEUMANN

Washington, D.C., September 1957

Contents

Since I am neither a neurologist nor a psychiatrist, but a mathematician, the work that follows requires some explanation and justification. It is an approach toward the understanding of the nervous system from the mathematician's point of view. However, this statement must immediately be qualified in both of its essential parts.

First, it is an overstatement to describe what I am attempting here as an "approach toward the understanding"; it is merely a somewhat systematized set of speculations as to how such an approach ought to be made. That is, I am trying to guess which of the—mathematically guided—lines of attack seem, from the hazy distance in which we see most of them, a priori promising, and which ones have the opposite appearance. I will also offer some rationalizations of these guesses.

Second, the "mathematician's point of view," as I would like to have it understood in this context, carries a distribution of emphases that differs from the usual one: apart from the stress on the general mathematical techniques, the logical and the statistical aspects will be in the foreground. Furthermore, logics and statistics should be primarily, although not exclusively, viewed as the basic tools

of "information theory." Also, that body of experience which has grown up around the planning, evaluating, and coding of complicated logical and mathematical automata will be the focus of much of this information theory. The most typical, but not the only, such automata are, of course, the large electronic computing machines.

Let me note, in passing, that it would be very satisfactory if one could talk about a "theory" of such automata. Regrettably, what at this moment exists—and to what I must appeal—can as yet be described only as an imperfectly articulated and hardly formalized "body of experience."

Lastly, my main aim is actually to bring out a rather different aspect of the matter. I suspect that a deeper mathematical study of the nervous system —"mathematical" in the sense outlined above— will affect our understanding of the aspects of mathematics itself that are involved. In fact, it may alter the way in which we look on mathematics and logics proper. I will try to explain my reasons for this belief later.