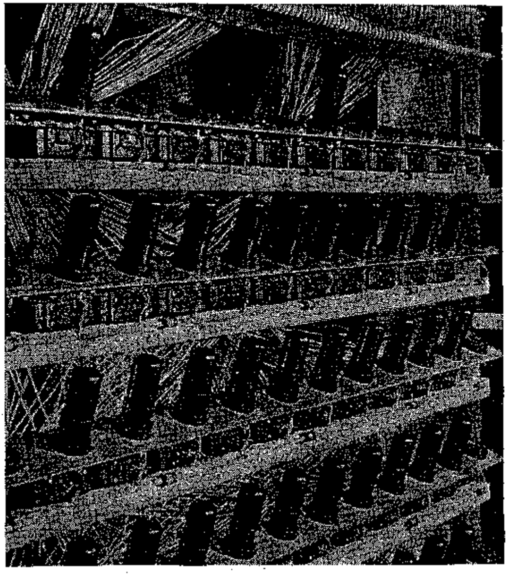


Switching Systems as Mechanized Brains

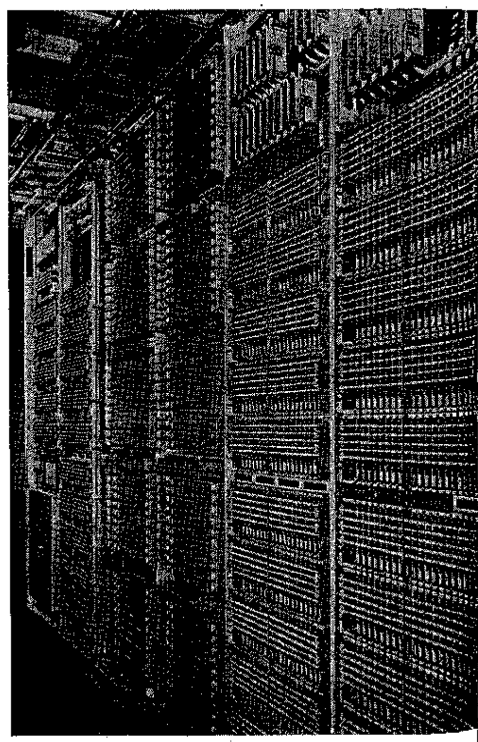
JOHN MESZAR
Switching Systems Development

Editorial Note: Common control switching circuits and the various forms of electrical computers operating on similar principles have often been referred to as electrical brains because of the distinctly rational operations they are able to carry out. To just what extent the actions of the human brain can be duplicated by electrical circuits is still a moot question. Some members of the Laboratories feel that probably no switching circuit could duplicate all the acts of the mind, while others feel that it is at least theoretically possible to design a group of electrical circuits that would duplicate many functions of the human brain. John Meszar gives here a brief outline of one position. It is intended that other views on this question will eventually be published in forthcoming issues. The question is one of such general interest that BELL LABORATORIES RECORD *feels it worthwhile to present these differing opinions although recognizing that at the present time they are opinions — not established facts.*

Can the functions of the human brain be reproduced by switching systems? This subject has been thought about lately by many people, inside and outside Bell Telephone Laboratories. It is a loose and controversial (but fascinating) subject whose ramifications quickly bring into play different interpretations of the human mental process, most of which are based — like this article — on opinions and speculations rather than facts. It is also a subject which can be discussed casually as the weather, or pursued doggedly at the risk of one's peace of mind. Best of all, one does not have to know a great deal about switching

"The Thinker," the photograph at the right, by Auguste Rodin, is published through the courtesy of The Metropolitan Museum of Art.

To establish requested connections, automatic telephone switching systems accurately link-up appropriate sections of a maze of paths.



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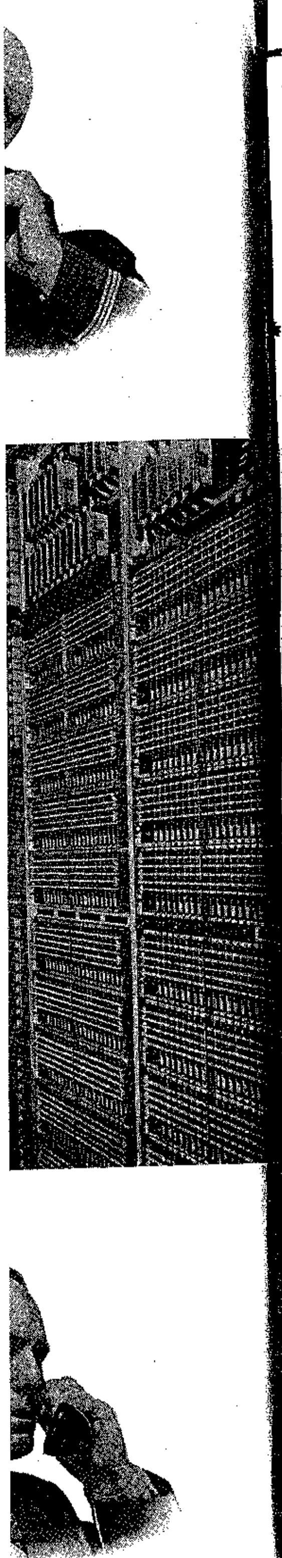

systems to feel the equal of experts in appraising them as mechanized brains.

Let us be a little more explicit about the subject. As is well known, the most fundamental characteristics of the switching art – the characteristic responsible even for the name of the art – is its use of the "switch," an elementary two-valued (open or close) device, and corresponding two-valued (on or off) signals. Based on these elementary devices and signals, switching systems have been conceived and brought into existence which can receive a lot of information, and manipulate it automatically through a sequence of internal steps until some predetermined final objective is accomplished. To telephone engineers, the best known example of such a system is, of course, the common-control dial telephone switching system which receives from thousands of subscribers information specifying the telephone they want to be connected with, and which accurately links up the appropriate sections of a maze of paths to establish these requested connections. Outside of the telephone field, it is the automatic digital computing systems, such as the ENIAC, UNIVAC, and ORDVAC, that receive the most attention as switching systems of truly significant capabilities. With appropriate instructions they can, for instance, calculate the trajectory of a gun shell faster than the shell can fly it.

From the standpoint of this article, the chief item of interest about any of these systems is that in accomplishing the over-all objective of the system, its component circuits perform such functions as: counting, remembering, selecting, deciding, translating, locating, and calculation – functions that strongly imply operations commonly associated with human mental effort. This then brings up the natural question: Are such implications justified and significant, or are they simply the result of poetic license in the use of words by switching people? In other words, do switching circuits truly reproduce certain processes of the human mind or, like costume jewelry, are they but superficial imitations that do not stand critical examination? The question becomes even more appropriate in the light of the limited knowledge that neurophysiologists are acquiring of the human brain's own internal processes, which seems to indicate that – like a switching system – the brain also accomplishes its functions by internal rearrangements of its superlative network of two-valued elements, the neurons.

Before anyone gets the impression that this article is going to be a dissertation on "machines that think," that anticipation will be disposed of forthwith. The subject of "thinking machines" receives more than its just share of attention in articles of those writers who extract the last ounce of speculative excitement out of it. One such article in a respectable weekly magazine, for instance, noted that during the post-war peaks of telephone traffic certain crossbar central offices misbehaved in a manner that baffled the engineers. Since a working crossbar office depends on the dynamic interplay of thousands of relays, such a situation was not surprising to those of us who have often been puzzled by the misbehavior of a single complicated switching circuit during laboratory tests. The subtle implication conveyed by the article, however, was that such systems therefore have characteristics akin to capricious will. In fact it is not doing much injustice to the article to infer that some day Telephone Companies might decide to hire psychoanalysts to help switchmen maintain crossbar central offices. Such views about machines that think and act according to their thoughts are intuitively repugnant to most of us.

It is appreciated that this assertion is subject to quick retort along the lines that intuitive feelings can be wrong. There was a time, for instance, when it was also against common sense to admit that the earth is round, not flat, and that it is wandering as a speck in the universe, rather than being its center. Ancient, deep-rooted concepts are not readily changed even if ultimately they prove to be wrong. However, on mechanical thinking we can buttress our intuition by tangible, factual supports. We know that an automatic system is but hardware, shaped of steel, and copper, and glass, and other dead materials. Such materials can move, expand, and contract in response to forces; some can be magnetized; some can transmit electrical energy and so on; but these properties do not even remotely resemble the ability to think, which is the highest, most exclusive endowment of the living human mind. Design engineers who have brought into existence such outstanding examples of automatic systems as our modern common-control central-office systems know best how prosaic is the hardware employed, and how common-place are the details that make such systems tick.

The operator functions as a highly intelligent and versatile switching system.

This answer to the basic question looks—and is — arbitrary. If the question of mechanized thinking could be disposed of that easily, this article would stop right here; in fact it would not even have been started. There is much more to the subject. Just what do we mean by thinking? What operations of the human mind come under this term? Let's discuss a few elementary examples that may confirm the doubts of those not sure of the answer, and may create doubt in those who feel they know the answer.

Someone requests the Laboratories' telephone operator for a connection to extension 752. The operator makes a busy-test, receives an indication that the extension is in use, and therefore refuses to comply with the request. In so doing, did she use her head? She certainly did and her supervisor would unhesitatingly agree. Testing for and respecting a busy line, however, is also one of the simplest accomplishments of an automatic switching system.

At the switchboard of a manual exchange, the operator receives a call for line No. 4700. She promptly locates the jack terminating this line, and is set to make a busy-test. However, she notices a distinctive mark at this jack, indicating that 4700 is a line to a Private Branch Exchange, which is served by a multiplicity of adjacent lines, all usable when 4700 is called. If the first of these lines is busy, therefore, she does not turn down the request for connection. Instead, she hunts in an orderly manner for an idle line in the 4700 group. Did the operator go through some mental process in this short sequence of actions? One would be reluctant to say no. However, locating the physical termination of a subscriber line, noticing that it's a PBX line, and hunting for an idle one in the group, is one of the many features of dial telephone system circuits.

Mr. X is with a group of people in a particular Conference Room. One of us wants to talk to him and so asks the operator to ring this Conference Room. She consults her records and finds that she has to ring extension 131. In translating the room number into a telephone extension number, did the operator do any mental work? There seems no doubt she did. However, that is exactly what the crossbar system translator does when it translates a subscriber equip-

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A conventional problem in telephone message accounting may involve the following charging plan: initial conversation interval of five minutes chargeable at three message units; overtime conversation intervals of two minutes, each chargeable at one message unit; a very short (say six seconds) deductible allowance on all messages. Now, an operator's ticket shows that a certain telephone conversation started at 58.6 minutes after 2:00 P.M. and ended at 25.8 minutes after 3:00 P.M. If the message-rater of the accounting center bills the customer fifteen message units, did she do any thinking in arriving at this answer? Not many will deny it. However, that is exactly what one of the automatic message accounting machines accomplishes.

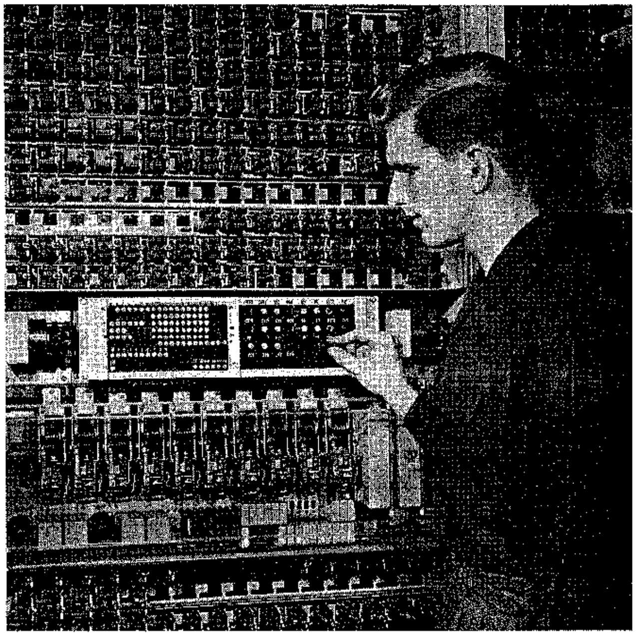
A grade-school student is given the following problem:

$$574968 \times 759826$$

After some minutes of calculations on paper (with indications of erasures, perhaps) he comes up with the correct answer. In doing this problem, did he go through a process of thinking? Most everbody will unhesitatingly – and perhaps unwarily – answer yes. Some would even compliment themselves silently for good mental performance if they went through all the steps of the problem in a number of minutes and obtained the correct answer. However, a digital computer will also give the correct answer and do so in a split second.

So much for elementary examples of human mental operations which are reproduced exactly by switching circuits. A whole series of other examples could be readily cited. None of these examples is impressive by itself, but a switching system may include a great many such simple features, and the resultant versatility of the system, its composite competence to perform a relatively complex series of mental operations, may therefore be truly remarkable. Thus the question: What is thinking? is very much in order. Is mental effort the same as thinking?

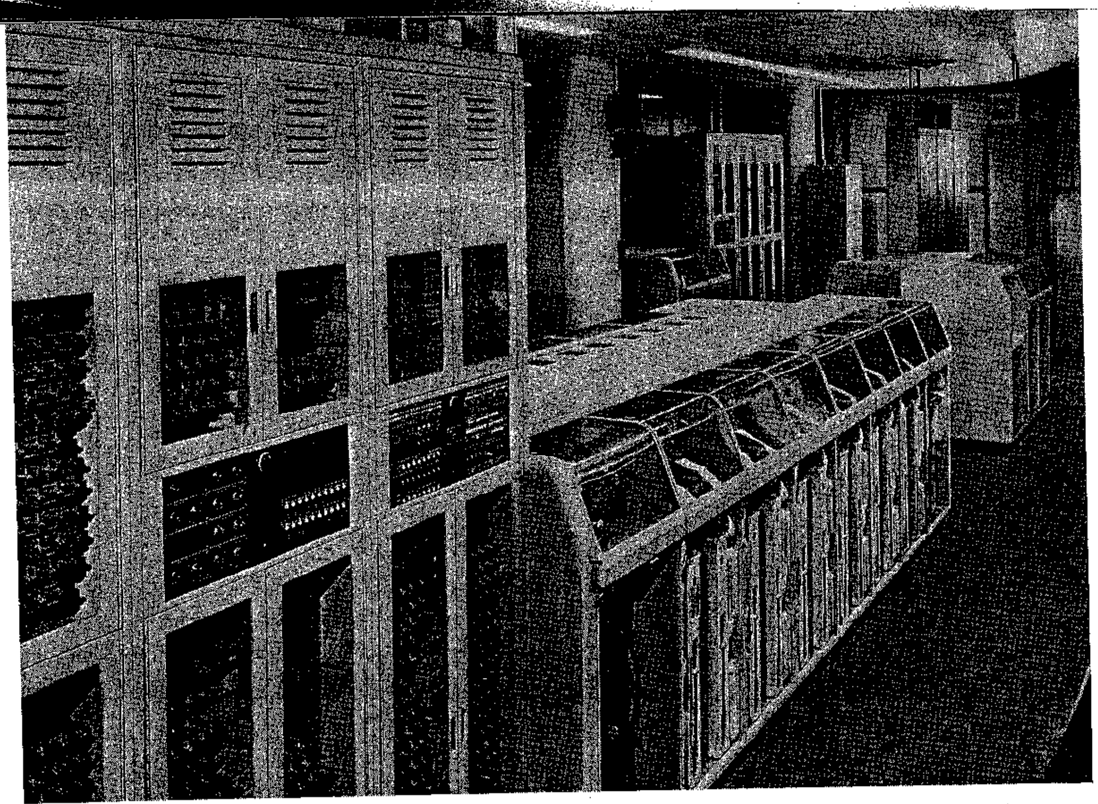
If we do not want to be trapped into admitting that automatic systems think, we can give only one answer to the question. We do not think every time we use our head. Much of our mental effort consists of recalling facts stored in our minds (the multiplication table, for example), and manipulating such information in accordance with a set of rigid rules, also stored in our minds. The facts and the rules of manipulation have been implanted in our minds some time or other as part of our training, and are treated as inviolate, unalterable. Mathematical computations – be they simple or intricate – are typical examples of this type of mental effort. The simple multiplication problem used above



A switching system is a physical structure of relays, tubes, wires, etc., combined with a wealth of stored information.

could be given to a thousand individuals and they would all use the same mentally stored information, and follow an identical pattern of procedure step by step. Deviations in the procedure, if any, simply represent optional rules.

Mathematical computations are, however, not the only acts falling into the category of "non-thinking mental effort." Any problem, any situation which demands the exercise of rigorous logic, where the procedure and the final outcome is inherent in

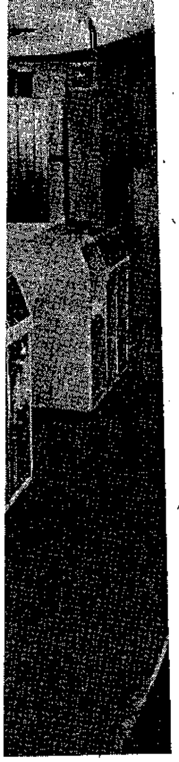


Machines are taking over many areas of mental effort. Above, one of the machines of the automatic message accounting system.

the statement of the initial conditions, where the "if . . . . . then" relationship holds, is of the same type. Solving such problems, taking appropriate action in such situations is mental effort, but it is not thinking. Each new problem and situation of this type calls simply for the reuse of the same stored facts and the application of the same rigorous rules of procedure to a set of new variables to arrive at a new but inherent conclusion. The facts and the rules can be implanted into human minds by training, or they can be incorporated into automatic systems by design. For a given set of initial variables they will both go through identical steps and arrive at the same answer.

Now the theme of this article has emerged. It is an emphasis on the necessity of divorcing certain mental operations from the concept of thinking, and thus pave the way for ready acceptance of the viewpoint that automatic systems can accomplish many of the functions of the human brain. From this viewpoint, it is not the physical structure of relays and tubes of an automatic system that functions as the brain. The mechanical brain is the combination of that structure with all the information it possesses. Such a loaded structure, in certain areas of mental effort, may even outperform the human brain. In those areas, therefore, the analogy between switching circuits and the human mind is not that of imitation versus genuine jewelry, but that of artificial crystals grown by the Western Electric Company versus natural crystals mined in South America. Performance, uniformity, and price are actually in favor of the artificial ones.

Divorcing thinking from what we regard at the present time as routine, logical mental operations is not enough. As time goes on, it will be more and more essential to cultivate a completely undogmatic and open-minded attitude for the concept of thinking. Perhaps the most flexible concept is that any mental process which can be adequately reproduced by automatic systems is not thinking. There are several basic virtues in this flexible concept. First, it avoids the extremely difficult, if not impossible task, of defining positively what thinking is, by stating what is not thinking.



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Second, it is easy to apply and results in straightforward conclusions. Once a machine performs a certain type of mental operation, that operation is not thinking. Third, it makes full allowance for the increasingly versatile automatic systems of the future, which are unquestionably coming and which will force an accelerated shrinkage in the area of mental effort to which the term "thinking" remains applicable. It is well to recognize that in time this shrinkage may become very extensive as switching systems come into existence to perform more and more spectacular feats of logic, such as automatic weather predicting, automatic language translating, etc.

We are faced with a basic dilemma; we are forced either to admit the possibility of mechanized thinking, or to restrict increasingly our concept of thinking. However, as is apparent from this article, many of us do not find it hard to make the choice. The choice is to reject the possibility of mechanized thinking but to admit readily the necessity for an orderly declassification of many areas of mental effort from the high level of thinking. Machines will take over such areas, whether we like it or not.

This declassification of wide areas of mental effort should not dismay any one of us. It is not an important gain for those who are sure that even as machines have displaced muscles, they will also take over the functions of the "brain." Neither is it a real loss for those who feel that there is something hallowed about all functions of the human mind. What we are giving up to the machines — some of us gladly, others reluctantly — are the uninteresting flat lands of routine mental chores, tasks that have to be performed according to rigorous rules. The areas we are holding unchallenged are the dominating heights of creative mental effort, which comprise the ability to speculate, to invent, to imagine, to philosophize, to dream better ways for tomorrow than exist today. These are the mental activities for which rigorous rules cannot be formulated — they constitute real thinking, whose mechanization most of us cannot conceive.

THE AUTHOR: John Meszar was graduated from Cooper Union in 1927 with a B.S. degree in E.E. He has been employed by the Laboratories since 1922 when he began work as a technical assistant working on the testing of toll switching circuits. In 1942, after several years as a supervising engineer in toll switching circuit design work, he became an instructor in the Laboratories' School for War Training. Following the war, he returned to circuit design supervision and devoted much of his time to AMA. Since June, 1952, he has been Director of Switching Systems Development II. In 1951 the American Institute of Electrical Engineers awarded him first prize for the best paper in the communication division presented during 1950.