classed as "obsessed." Yet I know of nothing which has the motivating power of an obsession to solve a problem or prove a point. Although some educators are beginning to understand and value such unique students, it is too often the case that they are expelled from school, or are at least so frustrated and repressed by the necessity to conform to the established pattern that they grow into neurotic adults and are of little value to their fellow men. . . .

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Presentation of Papers

All scientists (and indeed nonscientists too) are aware that talks at professional meetings should be concise, lucid, and held to the allotted time. All are equally aware of how short we fall of this goal. Too often talks are rambling, confused, slow in getting underway, and then rushed and garbled as the speaker runs out of time. All this could be avoided if it were required that each speaker present the chairman of his session with a magnetic tape recording of his talk for playback over the hall's public address system. The author would sit on the platform, signal for slides at the right time, and be prepared to field questions at the end. He would have adjusted his talk to the proper length at home (or else the chairman could reject it) and he would have had to listen to it himself, the salutary effect of which would be incalculable.

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Missing Links in Computer Intelligence

The paper by Ulric Neisser on "The imitation of man by machine" [*Science* **139**, 193 (18 Jan. 1963)] describes three characteristics of human thought which are absent from machine programs. I would like to add a fourth characteristic which is, perhaps, the most important one. This is the property of "consciousness," the ability to be aware of the stimuli coming to us from our sense organs, and of the thoughts circulating in our own nervous systems—and to be conscious of the fact that we are conscious.

While Neisser touches on this matter in his discussion, I believe that the property of "consciousness" is worth emphasizing.

Conceivably a computer could be programmed to give emotionlike responses, or to operate with a multiplicity of motivations. The central question here is whether a computer could be built which would be aware of its emotions, motivations, and the world around it. While this would appear to be an inconceivable feat (some would say impossible), the fact remains that our own human consciousness is, somehow, the end result of physical interactions taking place within the mechanisms of the body cells. There is no a priori reason for assuming that these operations cannot be performed by man-made circuits (although the complexity may make it impractical).

Present-day computers think unconsciously and compulsively. In the jargon of psychoanalysis, they consist entirely of superego, and are devoid of ego or id. The question of humanlike machines, translated into these terms, becomes: Can we build a computer with an ego?

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Neisser seems to believe that popular misconceptions about "thinking" machines (they are not capable of "thinking"—even in quotes) are due to a misunderstanding of the nature of human thought. Indubitably! But it is equally due to a misunderstanding of the very nature of machines and machine operation. Even the most sophisticated computing machine cannot do anything it is not programmed to do, although much of the program is now "built in" into the machine and does not have to be spelled out in detail by the programmer.

If a comma was omitted in the program, then what was intended to mean two small adjacent numbers is not two small adjacent numbers but one large number, and the machine reacts accordingly. Every machine is literal without any sense of discrimination, common sense, or humor. It is the obedient servant of man—like the disastrously obedient slaves in fairy tales of the past—and in its very obedience lies the danger, for men do not always wish as wisely and well as an omnipotent master.

Most important in Neisser's article is his brief allusion to the use of computing machines to "make social decisions." Again, the very thought of using machines to "answer" questions of human and moral values, or taste, betrays a—widespread, unfortunately—lack of understanding of the very nature of computing machines, of mathematics, and of logic. These machines are eminently suitable to implement the solution of problems in mathematics and logic for the simple reason that they are built in accordance with such laws. Every circuit is the hardware manifestation of a Boolean-algebra equation.

Therefore a machine can solve any problem that can be expressed as a mathematical equation, which means—at least, in theory (in practice, we sometimes lack proper understanding of the problem or mathematical skill to formulate it)—any problem for which a purely rational solution is possible. Social decisions must never be made on purely rational grounds. They are primarily questions of human and moral values and, let us hope, good taste.

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While Neisser avoids explicit statement of the extreme position that differences between human thought and the functional properties of modern computers are insurmountable, he clearly implies support of that position by his subtitle.

Neisser's arguments do not support a mystical or irrational view of the differences between men and machines. Instead of demonstrating any inviolable distinction between the two, he has pointed the way toward making machines more nearly "human" and hence more useful to humans.

The chief differences, Neisser states, arise from the developmental (and, one might add, even the phylogenetic, historical, and ontogenetic) origins of man. Human thinking is inseparable from other human activities and processes. It "takes place in, and contributes to, a cumulative process of growth and development. . . . The cumulation of learning is interwoven at every point with inborn maturational sequences." A machine will continue indefinitely to pursue any goal programmed into it (this is perhaps its most inhuman feature); whereas the motivations which govern human thought are complex, subtle, and changing. The computer acquires and retains information in a systematic and controllable fashion; whereas the human thinker "lives willy-nilly in an accumulating context of experiences which he cannot limit even if he would."

The real question is whether or not these differences are so fundamental as to rule out forever the possibility of our building some day a machine that can make rational and useful social decisions. . . .

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Ulric Neisser's article brings to mind a remark I was privileged to hear from J. von Neumann during an informal talk on computers given at the Institute for Advanced Study at Princeton, in 1948. A woman in the audience started raising the canonical question, "But, of course, a mere machine can't really *think*, can it?" For a while he tried to put it off with a good-natured gesture, but she persisted. So he turned to his tormentor and said: "Look here. You insist that there is something a machine cannot do. If you will tell me precisely what it is that a machine cannot do, then I can always make a machine which will do just that."

The full import of this remark may have been lost on the person to whom it was directed, but to others in the audience it answered, in a sudden flash of understanding, many half-formulated questions. There is no limitation at all inherent in the machine; the only limitations on making "machines which think" are our own limitations in not knowing exactly what "thinking" consists of.

Von Neumann's remark applies equally well to all of the alleged differences pointed out by Neisser. I suggest that his arguments, far from establishing any "deep difference between the thinking of men and machines," describes only the present state of ignorance of psychologists concerning what growth, emotion, motivation, creativity, and so forth really are.

This does not mean, as Neisser implies, that it would be desirable to incorporate all these features into machines of the future. For most applications of machines, this would amount to a deliberately built-in unreliability. I could hardly disagree more strongly with the implications of the remark, "If machines really thought as men do, there would be no more reason to fear them than to fear men." It is just the fact that machines do not get confused by emotional factors, do not pursue hidden motives opposed to ours, do not get bored with a lengthy problem, that makes them far safer agents than men for carrying out certain tasks. What we have most to fear in the world today is not machines which lack these "human" features, but men who, unfortunately, have them.

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My paper was not concerned with the inherent limitations, if any, of machines. I attempted to describe the differences between existing or contemplated computer programs on the one hand, and human thinking on the other. It is true that human thought processes are not well understood, but this seems irrelevant to the accuracy of my description. Jaynes' opinion that emotion and growth are deplorable sources of unreliability seems equally irrelevant.

I would like to comment directly on the remark attributed to von Neumann. It is not necessarily true that a program can be written to carry out any well-specified task. The following counter-examples are due to Oliver G. Selfridge:

The speaker may be asked to make a machine to defeat Botvinnik at chess, or to select the painting (from 100 in a contest) which will be awarded first prize by the judges. He will be unable to make such machines at present, and equally unable to give formal proof that he can ever succeed in doing so. (We do have promising leads for the first of these problems, but success cannot be guaranteed.)

If it be replied that these tasks are not specified "precisely," one may enquire what further precision is required. It will probably appear that the underlying idea of a precise definition is rather like a computer program. In that case the assertion reduces to "If you will tell me how to program a task, I can always do so."

Even the last statement may not be right. It is possible that some tasks, including the simulation of human thought, are so complex that the specification would take a full lifetime to write, and the resulting program 1000 years to de-bug. There is no way of knowing in advance; we must find out by experimenting.

Dogmatic assertions of the omnipotence of computers tend to stir up a multiplicity of, often unpleasant, reactions in the reader. They do not have the supposedly compensating advantage of being true.

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Self-Stimulation Experiments

Your publication of papers by Margules and Olds [*Science* **135**, 374 (1962)] and by Hoebel and Teitelbaum [*Science* **135**, 375 (1962)] leads me to propose the following physiological explanation of the association which they describe between mechanisms for self-stimulation and for feeding in the lateral hypothalamus. It is my opinion that in a self-stimulation experiment the negative feedback loops of normal feeding mechanisms are replaced by an artificially constructed loop having a positive sign.

Under natural conditions, an activation of the lateral hypothalamus induces or facilitates feeding behavior. Included in the many possible varieties of such behavior is bar pressing—one of the responses which lateral hypothalamic activity will induce for feeding. Ordinarily such behavior induced by the lateral hypothalamus leads to ingestion of food, and this leads in turn to a number of physiological changes which inhibit further intake of food and suppress the activity of the lateral hypothalamus. But when, as in a self-stimulation experiment, the bar pressing leads not to food ingestion but to electrical stimulation of the lateral hypothalamus, then that part of the brain can only become still more active. Consequently the animal is that much more likely to press the bar again, and every further press enhances the chances of more presses. Induced to press the bar in the first place by a naturally occurring activation of its lateral hypothalamus, the animal receives for its press only a recurrent stimulation into the region which originated the bar pressing.

This distinction between a normal, negative feedback loop and an artificial, positive loop avoids the paradox mentioned by Olds [*Physiol. Rev.* **42**,