consistent way. However, these variations are extremely small compared with those found along other dimensions of behavior. The fastest and slowest drinkers in the present sample differed by less than 1 lick per second, on the average, and individual variability was of the same order of magnitude (*4*).

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Some Moral and Technical Consequences of Automation—A Refutation

Abstract. The machine is not a threat to mankind, as some people think. The machine does not possess a will, and its so-called "conclusions" are only the logical consequences of its input, as revealed by the mechanistic functioning of an inanimate assemblage of mechanical and electrical parts.

In an article entitled "Some moral and technical consequences of automation" (*1*), Norbert Wiener has stated some conclusions with which I disagree. Wiener seems to believe that machines *can* possess originality and that they *are* a threat to mankind. In ascribing a contrary opinion to the man in the street—to wit, "that nothing can come out of the machine which has not been put into it"—he overlooks or ignores the fact that there is a long history of the acceptance of this more reassuring view by scientific workers in the field, from the time of Charles Babbage to the present (*2*). Apparently Wiener shares some of the lack of understanding which he ascribes to the public, at least to the extent that he reads implications into some of the recent work which the workers themselves deny.

It is my conviction that machines cannot possess originality in the sense implied by Wiener and that they cannot transcend man's intelligence. I agree with Wiener in his thesis that "machines can and do transcend some of the limitations of their designers, and that in doing so they may be both effective and dangerous." The modern automobile travels faster than its designer can run, it is effective, and the records of highway fatalities attest to the dangerous consequences. However, a perusal of Wiener's article reveals that much more than this is meant, and it is to this extension of the thesis that I wish to take exception.

Wiener's reference to the "Sorcerer's Apprentice," and to the many tales based on the assumption that the agencies of magic are literal-minded, might almost lead one to think that he attributes magic to the machine. He most certainly seems to imply an equality between man and the machine when he states "disastrous results are to be expected not merely in the world of fairy tales but in the real world wherever two agencies essentially foreign to each other are coupled in the attempt to achieve a common purpose." In relationships between man and a machine the machine is an agency, but only an agency of man, entirely subservient to man and to his will. Of course, no one will deny that "we had better be quite sure that the purpose put into the machine is the purpose which we really desire and not merely a colorful imitation of it." If we want our house to be at 70°F when we get up in the morning, we had better set the thermostat at 70° and not at 32°. But once the thermostat is set at 70° we can go to sleep without fear that the genie in the furnace controls might, for some reason of his own, decide that 32° was a better figure. In exactly the same way and to the same degree we must anticipate our own inability to interfere when we instruct a modern digital computer (which works faster than we do) and when we instruct a thermostat (which works while we sleep).

Wiener's analogy between a machine and a human slave is also quite misleading. He is right in his assertion that "complete subservience and complete intelligence do not go together" in a human slave with human emotions and needs and with a will of his own. To ascribe human attributes to a machine simply because the machine can simulate some forms of human behavior is, obviously, a fallacious form of reasoning.

A machine is not a genie, it does not work by magic, it does not possess a will, and, Wiener to the contrary, nothing comes out which has not been put in, barring, of course, an infrequent case of malfunctioning. Programming techniques which we now employ to instruct the modern digital computer so as to make it into a learning machine *do not* "remove from the mind of the designer and operator an effective understanding of many of the stages by which the machine comes to its conclusions." Since the machine does not have a mind of its own, the "conclusions" are not "its." The so-called "conclusions" are only the logical consequences of the input program and input data, as revealed by the mechanistic functioning of an inanimate assemblage of mechanical and electrical parts. The "intentions" which the machine seems to manifest are the intentions of the human programmer, as specified in advance, or they are subsidiary intentions derived from these, following rules specified by the programmer. We can even anticipate higher levels of abstraction, just as Wiener does, in which the program will not only modify the subsidiary intentions but will also modify the rules which are used in their derivation, or in which it will modify the ways in which it modifies the rules, and so on, or even in which one machine will design and construct a second machine with enhanced capabilities. However, and this is important, the machine *will not* and *cannot* do any of these things until it has been instructed as to how to proceed. There is (and logically there must always remain) a complete hiatus between (i) any ultimate extension and elaboration in this process of carrying out man's wishes and (ii) the development within the machine of a will of its own. To believe otherwise is either to believe in magic or to believe that the existence of man's will is an illusion and that man's actions are as mechanical as the machine's. Perhaps Wiener's article and my rebuttal have both been mechanistically determined, but this I refuse to believe.

An apparent exception to these conclusions might be claimed for projected machines of the so-called "neural net" type. These machines were not mentioned by Wiener, and, unfortunately, they cannot be adequately discussed in the space available here. Briefly, however, one envisions a collection of simple devices which, individually, simulate the neurons of an animal's nervous system and which are interconnected by some random process simulating the organization of the nervous system. It is maintained by many serious workers that such nets can be made to exhibit purposeful activity by instruction and training with reward-and-punishment routines similar to those used with young animals. Since the internal connections would be unknown, the precise behavior of the nets would be unpredictable and, therefore, potentially dangerous. At the present time, the largest nets that can be constructed are nearer in size to the nervous system of a flatworm than to the brain of man and so hardly constitute a threat. If practical machines of this type become a reality we will have to take a much closer look at their implications than either Wiener or I have been able to do.

One final matter requires some clarification—a matter having to do with Wiener's concluding remarks to the effect that "We must always exert the full strength of our imagination to examine where the full use of our new modalities may lead us." This certainly makes good sense if we assume that Wiener means for us to include the full use of our intelligence as well as of our imagination. However, coming as it did at the end of an article which raised the spectre of man's domination by a "learning machine," this statement casts an unwarranted shadow over the learning machine and, specifically, over the modern digital computer. I would be remiss were I to close without setting the record straight in this regard.

First a word about the capabilities of the digital computer. Although I have maintained that "nothing comes out that has not gone in," this does not mean that the output does not possess value over and beyond the value to us of the input data. The utility of the computer resides in the speed and accuracy with which the computer provides the desired transformations of the input data from a form which man may not be able to use directly to one which is of direct utility. In principle, a man with a pencil and a piece of paper could always arrive at the same result. In practice, it might take so long to perform the calculation that the answer would no longer be of value, and, indeed, the answer might never be obtained because of man's faculty for making mistakes. Because of the very large disparity in speeds (of the order of 100,000 to 1), on a computer we can complete calculations which are of immense economic value with great precision and with a reliability which inspires confidence, and all this in time intervals which conform to the demands of real-life situations. The magnitude of the tasks and the speed with which they are performed are truly breath-taking, and they do tend to impress the casual observer as being a form of magic, particularly when he is unacquainted with the many, many hours of human thought which have gone into both the design of the machine and, more particularly, into the writing of the program which specifies the machine's detailed behavior.

Most uses of the computer can be explained in terms of simulation. When one computes the breaking strength of an airplane wing under conditions of turbulence, one is, in effect, simulating the behavior of an actual airplane wing which is subjected to unusual stresses, all this without danger to a human pilot, and, indeed, without ever having to build the airplane in the first place. The checker-playing program on the I.B.M. 704, to which Wiener referred, actually simulates a human checker player, and the machine learns by accumulating data from its playing experience and by using some of the logical processes which might be employed by a person under similar circumstances. The specific logical processes used are, of course, those which were specified in advance by the human programmer. In these, and in many other situations, the great speed of the computer enables us to test the outcome resulting from a variety of choices of initial actions and so to choose the course with the highest payoff before the march of human events forces us to take some inadequately considered action. This ability to look into the future, as it were, by simulation on a computer is already being widely used, and as time goes on it is sure to find application in more and more aspects of our daily lives.

Finally, as to the portents for good or evil which are contained in the use of this truly remarkable machine—most, if not all, of man's inventions are instrumentalities which may be employed by both saints and sinners. One can make a case, as one of my associates has jokingly done, for the thesis that the typewriter is an invention of the devil, since its use in the nations' war offices has made wars more horrible, and because it has enslaved the flower of our young womanhood. On the whole, however, most of us concede that the typewriter, as a labor-saving device, has been a boon, not a curse. The digital computer is something more than merely another labor-saving device, since it augments man's brain rather than his brawn, and since it allows him to look into the future. If we believe, as most scientists do, that it is to our advantage to increase the rate at which we can acquire knowledge, then we can hardly do otherwise than to assert that the modern digital computer is a modality whose value is overwhelmingly on the side of the good. I rest my case with this assertion.

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31 May 1960

Spring Peak of Strontium-90 Fallout

Abstract. An increasing trend of Sr^{90} concentration in rain observed at Fayetteville, Ark., after November 1959, indicates that the seasonal and global movements of stratospheric air masses, such as described by Brewer (*1*) and Dobson (*2*), play an important role in causing the spring peaks of the Sr^{90} fallout.

To explain the vertical distributions of water vapor and ozone in the atmosphere, Brewer (*1*), in 1949, and Dobson (*2*), in 1956, proposed a model of global movement of the air masses. According to this model, there is a cold pool of air in the stratosphere over the winter pole during the late winter months, and it carries ozone-rich air to the lower levels in early spring. It was further suggested by Dobson that, if there is such a slow sinking of air in the middle latitudes from the stratosphere to the troposphere, it must be balanced elsewhere by a reverse current from the troposphere to the stratosphere.

Stewart *et al.* (*3*), in 1957, explained the spring peaks in the rate of stratospheric Sr^{90} fallout on the basis of the Brewer-Dobson model, and Burton *et al.* (*4*) reported that the Po^{210}/Pb^{210} ratios in the samples of air filter and rain can also be explained on the basis of the global circulation model of air masses. Kuroda (*5*) observed the 1958 spring peak of the stratospheric Sr^{90} fallout, and Fry *et al.* (*6*) pointed out the fact that the Sr^{89} concentrations in rain and snow remained fairly constant during the winter and spring months of 1958–59, despite the fact that this nuclide decays with a half-life of 51 days. They explained this as due to a marked increase in the rate of transfer of the fission products from the stratosphere to the troposphere in early spring months.

An alternate explanation for the spring peak of the rate of stratospheric fallout was proposed by Martell (*7*) in 1959, and this view was later sup-