

The Impact of Cybernetics Ideas on Psychology

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The impact of cybernetic ideas in psychology has been in the area of the mind-body problem, on theories of the nervous system and on social-ethical problems arising as consequences of automated technology.

Thomas Kuhn, in book, *The Structure of Scientific Revolutions* [1], defines a scientific revolution as radical reconstruction of the conceptual framework within which scientific investigations are conducted. By definition, therefore, a scientific revolution is either a consequence or a forerunner of profound changes in outlook. It is sometimes the one, sometimes the other. For example, the scientific formulation of celestial mechanics (the mathematical physics paradigm) was established already by Newton in his *Principia*, but the "philosophical system", in which the paradigm was clearly enunciated, was formulated a century later by Kant. On the other hand, the conceptual systems produced, say, by Marx and Freud, although their *philosophical* impacts were enormous, have so far stimulated very little genuine scientific work rooted in these conceptualizations. I would venture to say, however, that scientific revolutions will eventually sprout from both of these frameworks of thought.

In the case of the cybernetic revolution, both the scientific and the philosophical formulations appeared practically simultaneously. The man with whose name cybernetics is most frequently associated was responsible for both. As a scientist, Norbert Wiener forged the mathematical tools for describing and investigating intricate systems of information processing and control. As a philosopher, he pointed out the epistemological and the ethical implications of the conceptualizations suggested by cybernetics. Both the scientific and the philosophical aspects of cybernetics have a relevance for psychology, inasmuch as psychology today has both scientific and philosophical (e.g., epistemological and ethical) components.

The epistemological component of the philosophy rooted in cybernetics is concerned, in its narrow sense, with the mind-matter dichotomy, clearly of central interest in philosophical psychology. The ethical component is concerned with the

impact on society of the Second Industrial Revolution, clearly relevant to social psychology.

By way of approaching our subject, let us first examine the impact of cybernetics on thinking in the biological sciences. Leverage for the development of the philosophy of biology was provided for a long time by the standing dispute between the "vitalists" and the "mechanists". The mechanists maintained that all life processes could be explained by the operation of "physical and chemical laws", either those already known or those to be discovered. The vitalists maintained that such laws could never be adequate by account for life processes, and that consequently a special principle (a "vital force" or something of this sort) has to be postulated in any biological theory. As long as the dispute was conducted on the purely philosophical level, there was little likelihood that much good would come of it. By "good" I do not necessarily mean a conciliation of the opponents. A conflict of ideas has "good" results, in my opinion, if new ideas emerge from it. The Hegelian idealized thesis-antithesis-synthesis cycle is a prototype of fruitful intellectual conflict. Such a process is discernible in the mechanist-vitalist controversy, largely because some of the vitalists were empirically-oriented scientists and so were able to formulate their arguments as specific challenges to the mechanist position.

For example, it was argued at one time that the so-called "organic" compounds could be synthesized only within a living organism. Failure to synthesize such compounds in the laboratory was, therefore, evidence for the vitalist view. The synthesis of urea by Wöhler in 1828 demolished this argument, but not the vitalist position. The vitalists could still maintain that living organisms derived energy from sources not traceable to either kinetic or potential energy stores, as the mechanists understood these forms of energy. With the discovery of the mechanical equivalent of heat, this argument, too, collapsed.

Thereupon the vitalists retreated to another position. For example, H. Driesch, a prominent vitalist in the beginning of the century, maintained that the development of the embryo was governed by the so-called "principle of equifinality", which supposedly enabled the embryo to assume its "goal" of becoming the organism that it was destined to become, despite interventions. To demonstrate this principle Driesch cut a sea urchin embryo (in a very early stage of development) and showed that both halves developed into complete sea urchins. Driesch argued that if the development were guided by "purely mechanical" laws, the two halves would develop as two halves. The fact that they did not was due, in Driesch's opinion, to the fact that biological processes, unlike mechanical ones, are governed by "goals" or "purposes".

Of course, Driesch's argument can be easily refuted. He used the term "mechanical" in its colloquial, not its scientific sense. In common usage a "mechanical" performance is a "mindless" one, governed by rigid rules unaffected by changed conditions. A mechanical process, as it is understood in physics, is a deterministic one, to be sure, but the determining factors are the initial conditions. Typically a mechanical process is expressed as a solution of a differential equation which involves a whole family

of time courses. The *particular* time course which obtains is determined by the boundary conditions together with the differential equation. Now clearly, the two separated halves of Driesch's sea urchin were not in the same initial condition (configuration) as the two unseparated halves of an intact embryo. Therefore there was no reason to suppose, even assuming a purely mechanical process, that the two separated halves would follow the same time course as the two joined halves.

A somewhat more sophisticated argument of the vitalists concerns the supposed violation of the Second Law of Thermodynamics by living organisms. Supposedly the Second Law predicts a continual increase of entropy, that is of "disorder", in physical systems. Living organisms, however, as they become "organized" in their development from the fertilized egg, become "less disordered" as it were. Only with the onset of death does the process of disintegration and eventual dedifferentiation from the environment set in. This apparent circumvention of the Second Law of Thermodynamics by living organisms has been at times stated as an argument supporting the vitalist view. The fallacy of this argument is the failure to keep in mind that the increase in entropy is a necessary process only in systems isolated from their environment. Every living organism, however, is an "open" system, in constant exchange of matter and energy with its environment. It can be easily shown that in such systems there can well be a decrease of entropy (at the expense of entropy increase in the environment). If a living system is made closed, i.e., if all exchanges of matter and energy between it and the environment are cut off, it will soon die, and then, of course, will suffer an increase of entropy.

The vitalists have held out longest on the matter of "purposeful or intelligent behavior", which, they have maintained, can be observed as a genuine manifestation only in living creatures. Automatic control technology developed during World War II (for which Wiener's ideas were largely responsible) blurred the difference between living and non-living systems with reference to "purposeful" or "intelligent" behavior. This technology was concerned with developing two types of devices, namely servo-mechanisms and automata. A servo-mechanism is a device which, to an observer ignorant of its principles of operation, appears "purposeful", at times even "intelligent". To talk about purposeful behavior, we must specify what we expect from behavior of this sort. Clearly, some "goal" must be specified as part of such expectations. The pursuit of a pre-set goal is accomplished in the servo-mechanism by a system of so-called feed-back loops. Through the feed-back loop, changes produced in the environment, or in the system itself, by its outputs are fed back as inputs to the system. In this way, the *discrepancy* between performance and goal becomes a stimulus, and the system can be made to approach the goal by reacting so as to decrease the discrepancy.

During World War II, the feedback principle was applied in the construction of missiles which actively "pursued" their targets. There is ample evidence of such feedback loops in nervous systems of living organisms. It is quite likely that the typically purposeful, goal-seeking behavior of organisms is a consequence of the

operation of servo-mechanisms not unlike the artifacts introduced by the new technology.

In this way, the specific challenges posed by the vitalists to the mechanists were met. The history of vitalism has been one long retreat. However, the so-called mechanist position also changed radically in the process. The mechanists had to abandon the simple clockwork models of organisms. Nor did a book-keeping of energy inputs and outputs suffice to explain the living process. With the advent of cybernetics, a new element was brought into the concept of the automaton as a model of the living organism, namely that of information processing. This leads us to the broad epistemological implication of cybernetics, namely a new concept of the mind-body problem.

The legacy of Descartes introduced the dichotomy explicitly into European philosophy, and it has dominated this philosophy ever since. "Physical" and "mental", "objective" and "subjective" were explicitly or tacitly assumed to be mutually exclusive categories. A controversy over the "primacy" of the one or the other (the materialist-idealist confrontation), conducted on the metaphysical level with its concomitant political commitments, was for a long time, in my opinion, an obstacle to progress in epistemology.

The germinating idea that a link between the subjective and the objective might be rigorously established in a scientific context appeared clearly in the parable of Maxwell's Demon. In the middle of the last century, Maxwell, Claudius, and Boltzman established the connection between thermodynamics and statistical mechanics. Gross thermodynamic laws were revealed as statistical consequences of molecular motion, governed by mechanical laws. In particular, the Second Law of Thermodynamics, according to which the entropy of an isolated system could only increase with time, was shown to be a reflection of the fact that such a system tends toward the most "probable" distribution of the positions and the velocities of the particules that compose it. In this connection, Maxwell conjectured that a "demon" i.e., a being with senses so sharp that he can distinguish the velocities of individual molecules, could lower the entropy of an isolated system (of which he is a part) by a sequence of "decisions".

Specifically, the demon could operate a gate in a partition between two chambers, admitting the faster moving molecules to only one of the chambers and the slower moving ones only to the other. As a consequence, the temperature of the first chamber would be raised at the expense of the temperature of the second. Thereby the Second Law of Thermodynamics would be circumvented, because the total entropy of the system would be decreased in this process without compensating increases elsewhere. In other words, it appeared to Maxwell that by exercise of "intelligence" one could circumvent a "law of nature".

Now in the framework of the mind-body dichotomy, there is nothing remarkable in this conclusion. If a "physical law" is seen as a description of how nature operates "if left to itself", we see a circumvention of "physical law" every time we "exercise

volition" to intervene in the course of events. In this context we see ourselves (our "minds") as "outside nature". If, however, a physical law is regarded as governing the behavior of all matter and no "agents" outside of the world of matter are postulated to exist, then Maxwell's Demon ought not exist even as a figment of the imagination. In other words, a law of nature ought not be circumvented even in a *Gedankenexperiment* involving a *deus ex machina*. We have in Maxwell's Demon a re-statement of the vitalist view, indeed in a very much stronger form than formerly, since the possibility of violating the Second Law of Thermodynamics is offered in an *isolated* system, provided only that such a system contains an "intelligent", i.e., presumably a living being. If the vitalist view is to be refuted once again, Maxwell's Demon must be exorcised.

The Demon was exorcised for the first time, I believe, by Leo Szilard in 1929 "Über die Entropieverminderung in einem thermodynamischen System bei Eingriffen intelligenter Wesen" [2]). The gist of Szilard's argument was that, in *making his decisions*, Maxwell's Demon must suffer increments of entropy at least equal to the decrements that he effects in the thermodynamic system by his selective treatment of the molecules. Later L. Brillouin came to the same conclusion by a different line of reasoning.

Here, then, is a link between the concept of "intelligent decision", i.e., information processing, and a purely physical concept of entropy. It remained for Norbert Wiener to call attention to the remarkable isomorphy between the mathematical expression for entropy derived in statistical mechanics and that of "Quantity of information" as the concept is understood by communication engineers. That this isomorphy is not merely an accident of mathematical formalism but points to a profound relation "in nature" appears from the information-entropy conversion formula. Namely, associated with the act of using one bit of information in order to effect a change, there is an entropic cost of $\log_2 2 \times 1,38 \times 10^{-16}$ ergs/degree.

This conversion formula is analogous to that of Joule which exhibits the heat equivalent of an erg of work. Just as the mechanical equivalent of heat revealed the profound connection between two seemingly unrelated aspects of matter, so did the entropic equivalent of information. The latter relation is, perhaps, of even greater philosophical significance, because in the mind-matter dichotomy "information" appeared as clearly an aspect of "mind", not of "matter".

These, then, were briefly the impacts of cybernetic ideas on scientific-philosophical problems relevant to psychology. Let us now see how the development of psychological science in recent decades has mirrored these impacts.

The application of the feedback principle in theoretical psychology appears already several years before the specific formulation of cybernetics, namely, in the so called "law of effect". The discovery of the conditioned reflex by Pavlov instigated the construction of physiological models of learning, envisaged as systematic changes in patterns of responses to repeated stimuli. The central postulate is that a particular response mediated by a particular stimulus depends on the path taken by the nervous

impulses resulting from the stimulus. The path, in turn, depends on the ability of the impulse to pass across the synaptic connections from one neuron to the next. Accordingly a conditioned response is assumed to arise as a consequence of the facilitation of the path leading to that response. The additional postulate embodied in the "law of effect" is that the change in the environment resulting from a particular response itself becomes a stimulus as a result of which certain paths become facilitated and others inhibited. This is, of course, an application of the feedback principle in the construction of a learning theory without reference to mentalistic concepts.

The concept of "the quantity of information" has been applied in the study of reaction times. It is interesting to note that this area of inquiry is perhaps the oldest area in experimental psychology, which itself is nearly one hundred years old. The particular experimental situation of interest was one where *choice* reaction time occurs. The subject is asked to respond differentially to each of a given number of stimuli. It has been known for a long time that if the stimuli are presented at random and equiprobably, the reaction time can be expressed as a constant (the basic, probably physiological reaction time) plus a quantity proportional to the logarithm of the number of stimuli. Since the latter is a measure of the a priori uncertainty of the stimulus (i.e., of the amount of information a stimulus conveys) it is intriguing to think of the choice reaction time as the time required to "process the information". After the formulation of the mathematical theory of information by C. E. Shannon [3], where the quantity of information was related not only to the number of possible signals but also to their probabilities of occurrence and to their statistical interdependence, the possibilities of testing the information-testing hypothesis were greatly expanded. For now one could vary the number of possible stimuli, their probabilities of occurrence, and their degree of interdependence while keeping the average uncertainty per stimulus constant. If the information-processing hypothesis is correct, then the average reaction time should depend only on this average uncertainty and not on the way this uncertainty was composed of the various probabilities.

Early experiments in this area, particularly those of Hyman, Hick, and other workers in England gave encouraging results. However, it seems to be the unpleasant role of the mathematician to show that the equations derived from one model can also be derived from other models, or at least equations can be derived which, although mathematically not identical, give the same or even better fits to the data. The first such attack on the information-processing theory was launched, if I remember correctly, by L. S. Christie and R. D. Luce [4] (who, incidentally also demolished the famous Weber-Fechner Law on purely mathematical grounds), and I confess I have also contributed to this "destructive" work. Quite recently Sylvan Kornblum [5] of the University of Michigan showed by very carefully designed experiments that in the context of 2, 4, and 8 stimuli, the reaction time to each stimulus separately examined, depends not on its uncertainty in the information-theoretic sense but rather on whether it was preceded by itself or by another stimulus, thus suggesting

that delays are due to changing the neural pathways rather than to some formal information-processing operation.

It happens not infrequently that a too ready and too enthusiastic acceptance of new striking developments and, above all, their all too often facile and superficial application are bound to lead to disappointments. Nevertheless a constructive effect of the informational-theoretical approach to experimental psychology has remained. The ideas did stimulate new lines of investigation and the revisions that were bound to follow the disappointments have served to make both experimental and mathematical psychologists more critical and more discriminating with the result that the maturation of psychology has been advanced.

A discussion of the impact of cybernetics on psychology must, of course, include an account of the influence of automaton (or computer) technology on the thinking of psychologists concerned with the analyses of thought processes. Perhaps the first explicit formulation of this aspect of the cybernetic point of view in psychology was in the paper of McCulloch and Pitts entitled "A Logical Calculus of the Ideas Immanent in Nervous Activity" [6]. The principal result of that paper is a formal proof of the proposition that "arbitrarily complex" behavior patterns can be simulated by an automaton, provided only that the pattern can be described with sufficient precision. The key concept in this proposition is that of "arbitrary complexity". A measure of this complexity is the "degree of conditionality of a response" to a stimulus. The degree of conditionality, in turn, refers to the circumstances that must be taken into account to determine the response. Typically, these circumstances are related to the past history of the responding system, which, in turn, were determined by stimuli impinging on it. Hence an automaton can in principle be designed which refers to its "memory". The elements comprising the automaton correspond to what amount to operations by means of logical constants, such as "or" (inclusive and exclusive), "and", "if . . . , then", "not", etc. The automaton can carry out the operations required to follow directions of the following sort: "If so, then do this, unless that obtains, in which case proceed as follows: . . . But if at such and such at time thus and so has occurred, then use the following procedure . . . etc." Such directions (essentially strategies, as defined in game theory) are clearly a prototype of reasoning used in making decisions, supposedly a function of "rational thought". In this light, an automaton performing logical operations can be viewed as a "thinking machine".

Discussions of the analogy between computers and brains have been characterized by more emotional involvement than is usual in scientific discussions. The publicity attending the building and operation of high speed computers with the usual exploitation of sensational angles did not help the situation. The nickname "giant brains" calls to mind the eerie climate of science fiction, especially the nowadays frequently occurring theme of the sinister use of power conferred by scientific knowledge. Thus, it is easy to lose sight of the scientifically and philosophically important questions which ought to be asked in connection with these new views on the nature

of formal thinking. It serves little purpose to ask the questions in "folk language", like "Does the computer think?". Folk language tends to take it for granted that words have clear meanings, just because they are very commonly used. As long as the meanings lead to no contradiction, no apparent misunderstandings arise thereby. In the design of a technical language such an assumption cannot be made. Words must have an operational meaning if questions involving them can ever be answered. Although the usefulness of the word "to think" cannot be disputed (since it carries a rich intuitive meaning), it cannot be used without further qualification in a scientific discussion of "thought". For example if, as is common in folk language, one associates "consciousness" with thought, then the question "Does the computer think?" is not answerable. This should not be surprising, because even the question "Does my brother think?" is not answerable in this context. There simply is no way of verifying the consciousness of another. Of course an overwhelming majority of us (all excluding the solipsists) will agree that my brother and, for that matter, any human being has a "consciousness" and "thinks". And this conviction has important practical social consequences, but it is a conviction qualitatively different from one which declares that the atomic weight of carbon is 12.

To speak of thinking in the scientific context, we must define thinking operationally, for example, by specifying what a machine must be able to do in order that we may concede to it the faculty of "thought". It is noteworthy that today such criteria (put by people who do not wish to concede thought to machines) are far more demanding than in former years. This only shows that people have a tendency to hang on to the conviction that "thought" is something reserved for human beings or at least for "higher animals". In the days before computers, one might have demanded complex mathematical operations as evidence of "thinking". Today when such operations performed by computers have become commonplace, they no longer suffice as evidence. A generation ago a competent chess playing automaton was probably unthinkable. Even after such automata were built, it was argued that they could never surpass their makers, since it was the makers that programmed them with the principles of decisions. Aside from the fact that in memory capacity and in speed of calculations the computer far surpasses the human being, there is nothing that in principle prevents the computer from becoming "creative", that is, from stumbling upon new strategic principles *unknown* to its creator and so surpassing him. To make this possible, one need only provide the computer with the *principles* of search ("heuristics"), not necessarily with the *results* of the search.

Those that would deny "genuine thought" to the machine today (and I suppose I ought to include myself among them) must go much farther afield in their demands of what the computer should "demonstrate" to give evidence of "creative thought". For example, let the input to such a computer be everything that was written in physics prior to 1905 and let it come up with the Special Theory of Relativity. Or, in the field of artistic endeavor, let the input be all the sensory inputs that have impinged on Shakespeare or Michelangelo or Bach, and let the computer come up with

a Hamlet, a Moses, or a B minor Mass. These examples are obviously contrived so as to deny the faculty of creative thought to the computer. (One is reminded of the standard fairy tale theme where the hero is given an "impossible" task to accomplish.)

There is, however, a simpler and more instructive way to see the enormous gap which still separates human thought from computerized "thought". Consider the parlor game known as Twenty Questions. The game is played as follows. One of the company thinks of something, which may be as far fetched as he likes — a person, an event, an idea, or any combination of them, real or imaginary, possible or impossible. The others try to guess what it is by asking Twenty Questions, each to be answered by yes or no. Let us see what it would take to design a computer to play such a game. To make it easier for the computer, we shall restrict the ideas to those that can be expressed in a phrase of not more than 100 letters, and we shall allow the computer 600 questions. Let the idea to be guessed be "the egg from which came goose, from which came the quill, with which Chaucer began to write Canterbury Tales".

From a certain point of view, the design of a computer that will succeed every time is extremely easy. Since each letter of a 26 letter alphabet contains less than 5 bits of information, the computer can guess each successive letter of the describing phrase in five questions or fewer. After guessing a letter, the computer displays the sequence guessed and asks "Is this it?" If it is, the game is over, if not, the computer goes on to guess the next letter. In this way no more than 600 questions will ever be required. Of course, this is not the way human beings play the game, for there would be absolutely no point in playing it so. Human players must confine themselves to "meaningful" questions, i.e., to categories chosen among the categories that we actually make in thinking about the world. The usual initial questions are Real? Material? Does it exist now? Has it once existed? Has it existed in the Eastern Hemisphere? Before 1500? etc. To be sure, all these categories can be included in the program of the computer, together with the rules for making the next dichotomy depending on the answer given. Still I doubt very much whether a computer can be programmed which would "zero in" on the egg from which came the goose from which Chaucer's quill was taken, as well as on *any other idea* that may spring up in the human mind.

If this conjecture is correct, why is it so? The phrase can be guessed by a machine if the universe from which the building blocks for the construction of the guess are taken, is strictly circumscribed, in our example, the alphabet. In all probability, the phrase cannot be guessed by a simply specified algorithm, if the universe is coextensive with the concepts which we can *potentially* form. In one case, we can completely specify the *rules* of sequential selection (i.e., the algorithm); in the other we cannot.

A similar problem is raised in the modern theory of syntactic structure [7]. Almost all children learn to speak their native tongues so that they are recognized as native speakers. This means that they make utterances recognized by other native speakers

as acceptable utterances (sentences) in the language (or dialect). Suppose now we wish to construct an automaton that will do the same. What shall we have to "teach" it? Listing *all* possible utterances is out of the question. Indeed the essence of having learned a language is revealed in the speaker's ability to make *new* utterances which he has in all probability never heard before, but which are nevertheless "acceptable". Evidently, not a listing is required but a set of rules for constructing such utterances — an algorithm.

Now the rules we see in grammars are useless for this purpose. The rules mention terms like noun, verb, preposition, subject, predicate, gender, number, etc. These terms are defined with reference to other equally abstract terms: nouns with reference to "names of persons, places, or things" (is "wisdom" a place, a person or a thing?), verbs with reference to "actions" (is "to consist of" an action?). Definitions of prepositions, conjunctions, and articles are even more vague. To see this, try to define words like "the" or "if". The rules and definitions we find in grammars are at best hints that can be utilized by an adult mind in studying a foreign language (by comparing with his own) or in bringing his own utterances closer to the usage peculiar to a particular social class. (Thus to "improve one's English" means to learn to speak or write more like the people on the higher rungs of the social ladder.) But these rules are useless for teaching an automaton to generate acceptable utterances of its own, even if we do not ask that the utterances be related to each other by a continuity of meaning.

Specific and *exhaustive* rules of syntax evidently have not been discovered by the linguists.

There remains, however, the possibility of teaching an automaton to make acceptable utterances in the same way that a chess playing automaton is taught to play acceptable chess — by getting it to select "heuristics" which lead to a greater proportion of "acceptable" utterances. But there is a fundamental difference. Whereas the chess automaton could register each game as "won" or "lost", according to explicit objective criteria, there seems to be no such criteria for an acceptable utterance. A machine may be taught to produce acceptable sentences through a feedback loop *including a human speaker* (who will make the decision "acceptable" or "unacceptable"); but if this is done, it is the man who teaches the machine. The machine does not teach itself.

If only the machine could be taught to *recognize* an acceptable utterance, it could teach itself to make one. This brings us to the problem of recognition, a problem of foremost importance in psychology and one on which cybernetics could shed considerable light.

The problem of pattern recognition in automata is, as one would expect, much more difficult than the problem of goal-directed action. For in the latter, goals can be specified, but not in the former. We do not know explicit criteria for "good" classification (except in very special instances) and so cannot build them into Gestalt-recognizing machines.

Perhaps the most fundamental recognition problem is that of meaning recognition. A meaning-recognizing machine should be able to apply *general* rules to decide whether two given sentences do or do not say the same thing. Some of these rules may be simple grammatical transformation rules and so seem in principle mechanizable.

“Peter hit Paul” and “Paul was hit by Peter” say approximately the same thing, and the identity of meaning is attributable to the grammatical transformation rule from active to passive verb form. There are also very simple semantic transformation rules. “Peter is taller than Paul” and “Paul is shorter than Peter” say virtually the same thing, as can be determined by the application of a simple semantic rule. But what is the transformation rule which enables any bright ten-year-old to recognize that “Every rose has thorns” and “There are no unmixed blessings” say approximately the same thing?

Here we have gone beyond grammar and beyond formal semantics. We have entered the area of *symbolic* transformations, a jungle, which depth psychologists have been valiantly attempting to chart. Psychoanalysis, for example, is an attempt to understand the working of the human mind by discovering the rules of symbolic transformation, according to which early childhood experiences are imbedded as the components of the adult personality.

Whatever the merits of a particular postulational system of such transformations (e.g., the Freudian system relies heavily on sexual and proto-sexual experience as the source of the transformation rules), the importance of such an attempt cannot be over-estimated. For they strike at the frontier: the manifestations of the human mind that still defy rigorous analysis.

These, then, are the current problems, related to the problem of understanding the mind (the fundamental problem of psychology): creative thought; recognition of situations, particularly of meaning; the role of symbolic transformations in personality formation and in behavior. In arriving at these problems, we believe, we have arrived at the frontier, separating the aspects of mind which we have understood from those which still elude our understanding. Cybernetics has played a large role in displaying this problem with a degree of clarity not hitherto attainable. The frontier is further out today than it was even well within our memory. Therefore it appears that those who maintain that mind is in principle unanalyzable in scientific terms have been retreating, just as the vitalists have been retreating in biology. But the complementary “advance” can continue only if the frontier is always kept in mind. As some aspects of mind are “explained away”, we must immediately focus on others, which are sure to appear, like the retreating horizon. The hard-line anti-mechanists perform a useful function to the extent that they present the cybernetician with ever new challenges (problems not yet solved) as they insist that “the mind is not a machine”.

As detailed knowledge of the physico-biological basis of our mental apparatus increases, the questions concerning the nature of mind will become less charged

with affect and anxiety. Perhaps in due time our title as beings endowed with a mind will come to mean considerably less to us than it does today, just as occupying the center of creation has come to mean considerably less to men as they have acquired appreciation of the vastness and grandeur of the cosmos.

In conclusion, I should like to say something about the ethical implications of cybernetics, or (which I believe to be the same thing) about the relevance of cybernetics to macrosocial psychology. These implications were pointed out by Norbert Wiener in his book *The Human Use of Human Beings* [8], which deals with the automation revolution, the so-called Second Industrial Revolution. Its main thesis is the responsibility of society in utilizing properly the freedom which automation can confer on man. Automation can liberate man from routine mental toil in the same way that energy-harnessing technology liberated him from physical toil in the technologically advanced countries. However, the deeply ingrained habits of viewing human beings as instruments in the pursuit of self interest persist in the ruling elites. The evil inherent in the degradation of human beings to "instruments", whether in the pursuit of wealth or of power, is not confined to the traditional social manifestations of "exploitation", such as slavery, the labor market, cannon fodder, and the like. The social problems raised in the first decades of industrialization were so obviously consequences of economic deprivation of population masses that in the eyes of social critics, from those days on, economic exploitation usually remained the prototype of every form of exploitation of man by man; and all social evils were thought to derive from it. Today we know that exploitation can take on many forms and need not stem from "appropriating the fruits of others' labor". We can easily envisage a society in which no one is economically deprived, all physical labor and even all routine mental work having been long delegated to servo-mechanical slaves. Yet we can well imagine the members of such a society reduced to instruments in the service of a newly-evolved super-organism, *Status bellagerens*, the war-waging state.

This new quasi-species is endowed with a quasi-physiology. It processes raw materials into products which "nourish its cells". It possesses a complex "nervous system" which coordinates the action of its various organs (the institutions). Its "psychology", however, is utterly foreign to everything we call human. It even lacks anything comparable to the psyche of a typical mammal; for example, it affects rooted in sexual activity and its consequences. It has only one appetite — the acquisition of unlimited power. It regards everything outside of itself only as (a) prey, (b) threat, (c) an instrumentality for increasing its own power. The modern warfare state is the realization of the age-old nightmare, the Golem come to life. This super-organism is the theme of Norbert Wiener's last book, published posthumously, *God and Golem, Inc.* [9].

It is interesting to trace parallels between the technology of an era and man's conception of the world. When the only known machines were tools and clockworks, the universe was conceived in the science of the day as a vast clock, and animals were sometimes conceived as mechanical dolls (Descartes). With the advent of heat

engines, transformation of energy came into the focus of attention, and physiology, the most advanced of the biological sciences, became concerned primarily with the associated problems. As telecommunication developed, the nervous system received increasing attention as the seat of "the mind". In our age of computers, models of the nervous system became increasingly more sophisticated. Information-processing (both in psychology and in embryology) now receives most intense scrutiny. There is no denying that this progressive change of conception represents an intellectual maturation. Nevertheless, as the automaton model of the organism becomes more and more realistic, the danger increases of "remaining stuck" with the latest version of the mechanistic view.

It is with great apprehension that I raise this issue. My thinking being rooted in the scientific rather than in the philosophical or the theological tradition, I suspect that the charges of sterility and semantic emptiness leveled at most of the conceptions of man offered by philosophers and theologians are largely true. Thinkers unencumbered by scientific criteria of meaningfulness and truth have been trying for many centuries to come to grips with "essences", to little avail. Nor am I inclined to give much credence to the idea, persistently defended by the vitalists, that life is a sort of Holy Ghost. Nevertheless, I reject categorically the idea that "information processing" and wisdom are identical, or even related. Therefore I am deeply suspicious of the sort of cost-accounting pedantry that passes for "rationality" in the conduct of public affairs, the sort of mentality satirized by a sign said to adorn one of the offices of the Rand Corporation — "Don't Think — Compute!"

If "rational behavior" is defined as the effective pursuit of a preset goal, then the servo-mechanism, in pursuing the course most likely to realize its goal, is exhibiting "rational behavior". This rationality, however, is meaningfully defined *only* with reference to the objective. In human affairs it is senseless to define rationality in this way. For, since human history will presumably go on, we must think of objectives as means for attaining future goals. This is precisely what is not done in the formulation of objectives by sovereign states in the pursuit of their "national interests". "National interests" become ends in themselves or, in the case of predatory powerthirsty states, they are selfenhancing goals: appetite for power is insatiable.

If goals are evil or stupid, "rationality" in the pursuit of such goals is a threat; first and obviously, because "rational" means are likely to be effective; second, because the use of "rational" means enhances the self-esteem of the policy-makers and their entourage of scientific advisers and consultants to the point of rendering the policy-makers impervious to ideas outside their immediate scope of comprehension. This is the stance that C. Wright Mills dubbed "crackpot realism".

Certainly the cyberneticians are not to be blamed for this sorry state of affairs. Nor is it even true (as some are inclined to believe) that important public policy decisions are guided in technique-worshipping societies by computer print-outs. Nevertheless, in assessing the achievements of cybernetics, we must not shut our

eyes on the perversions and distortions to which every great idea at least temporarily falls victim. So it was with cybernetics. It suggested "automation of thought", and the idea has been seized upon as a rationalization of dehumanized decision-making by those who have long ago substituted computing for thinking.

The man who contributed most to the development of cybernetics had the same misgivings concerning its impact on technologically advanced societies.

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REFERENCES

- [1] T. Kuhn: *The Structure of Scientific Revolutions*. The University of Chicago Press, 1962.
- [2] L. Szilard: Über die Entropieverminderung in einem thermodynamischen System bei Eingriffen intelligenter Wesen. *Zeitschrift für Physik* 53, (1927), 840—856.
- [3] C. E. Shannon and W. Weaver: *The Mathematical Theory of Communication*. The University of Illinois Press, Urbana 1949.
- [4] L. S. Christie and R. D. Luce: Decision structure and time relations in simple choice behavior. *Bulletin of Mathematical Biophysics* 18 (1956), 89—112.
- [5] S. Kornblum: Serial-choice reaction time: Inadequacies of the information hypothesis. *Science* 159 (1968), 432—434.
- [6] W. S. McCulloch and W. Pitts: A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics* 5 (1943), 115—133.
- [7] N. Chomsky: *Syntactic Structures*. Mouton, 's-Gravenhage 1957.
- [8] N. Wiener: *The Human Use of Human Beings*. Houghton Mifflin, Boston 1950.
- [9] N. Wiener: *God and Golem, Inc.* M.I.T. Press, Cambridge, Mass. 1964.
- [10] A. Rapoport: An Essay on Mind. *General Systems* 7 (1962), 85—101.

VÝTAH

Vliv ideí kybernetiky na psychologii

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Vliv kybernetiky na psychologii byl nejzřejmější v oblasti dichotomie podstaty myšlení a v teorii nervového systému. Vitalistické pojetí nemateriálního myšlení, ovládání rozumového a účelového chování živých bytostí, spočívalo na předpokladu nemožnosti vysvětlování takového chování „mechanickými“ termíny. Při rozšiřování analýzy fyzikálního systému na systémy, ovládané homeostázou a zpětnovazebním řízením, ukázala kybernetika, že taková vysvětlení jsou možná. Tímto pokrokem techniky, založené na kybernetických principech zpracování informace, byly vytvořeny teorie nervového systému, ze kterých je patrné, že chování libovolného stupně složitosti by mohlo být simulováno zařízeními s umělými „nervovými systémy“.

založenými na principech logického kalkulu (počítače a samočinně se organizující automaty). Samozřejmě, problém „myšlení“ se ve světle těchto teorií neztratil. Byl pouze přesunut do vyšších úrovní analýzy. Speciálně zabývání se jazyky, používanými při programování v počítačích, položilo do ohníka zájmu některé velmi komplikované otázky týkající se psychologických aspektů jazyka.

Automatizace vyvolala nové sociální problémy a tím i nové přístupy k sociální filosofii a etice. Zvláště otázky týkající se osudu člověka ve společnosti s úplně automatizovanou technikou přešly z oblasti ryzí spekulace do oblasti bezprostředních praktických úvah.

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