THE UNIVERSITY OF MICHIGAN
INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

RESEARCH FRONTIERS I

INDUSTRY AND THE HUMAN BEING IN AN AUTOMATIZED WORLD

Transcript of the Second Ann Arbor Industry-Education Symposium

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TABLE OF CONTENTS

INTRODUCTION

A rising tide of complexity is being encountered in all fields of human endeavor and one of its strongest manifestations is in industry. The human being as an industrial worker, as decision maker, as owner, as consumer, as citizen, and as observer, affects, and is affected by, the industrial process. The manager must take these interrelationships into account in his short-term, intermediate, and long-range planning and administration.

In keeping with its function of bringing frontier research within the purview of subscribers to the Program, on May 24, 1957, the Industry Program presented a one-day meeting on research related to the human being.

The researches selected for presentation are alike in that they are all being done at the University of Michigan; they all seek understanding relative to some aspect of the human being; and, in our opinion, their increasing effect on the relationship of the human being to industry will come to fruition within fifteen to twenty-five years.

The talks are pitched at the level of the highly intelligent layman, and are technical in the sense that no attempt has been made to avoid a complex concept. However, professional jargon and nomenclature have been avoided wherever possible. Moreover, they do not seek direct practicality. It will take years for much of what is described to make its impact on industry.

This record is not a publication, and has been reproduced primarily for distribution to those who attended the meeting.

Harry H. Goode

Symposium Chairman

WELCOME

Ralph A. Sawyer
Dean, School of Graduate Studies

I regret that it has been necessary to depart from the announced program and that I have to welcome you instead of Dean Brown, who cannot be here because of his health. The Industry Program has been a major interest of his for some time, and we certainly hope that he will be able to be present at the next of these sessions. The Industry Program is, as a matter of fact, also a strong interest of the Graduate School. A considerable amount of the information which is distributed through this program is the result of new research done by graduate students as doctoral dissertations in the Graduate School. The Industry Program has been helpful to these students in the publication and distribution of their dissertations.

The session this morning is a little unusual it seems to me, "Industry and the Human Being in an Automatized World." Some years ago, I heard a jingle which said, "The danged machine with its insight keen is doing our work today, thus taking the place of the human race and making us guys passe." Since I heard that jingle, the danged machine has developed a great deal in taking the place of the human race, but there are still some things that the machine can't do, and they include things that are to be discussed today. There is no substitute for the human brain in many processes of decision-making and planning; and even in some of the things that the machine does, we can still learn something from the brain. The brain is not a very large installation as you know, and yet, the machine has not licked it yet in some aspects of storage of information and of quick access to the information. We still need to find something out about how the brain does this. Today we are going to hear something about human behavior and the operations of the mind. I am sure that I do not need to tell those of you who have come here today that our Mental Health Research Institute, our Institute for Social Research, our Departments of Psychology, Sociology, Mathematics, and Speech at the University of Michigan, really have a pre-eminent position, a position of leadership in many of these aspects of human behavior that we are to hear about. I hope that you find this program profitable. I am glad to welcome you here today both on behalf of the Graduate School and of the University.

OPENING REMARKS

Harry H. Goode
Chairman of Symposium
Professor of Electrical and Industrial Engineering

I'm impressed with Dean Sawyer's remarks that we haven't yet learned to substitute for the human brain. Perhaps it is high time we did, since I notice that there is no room here for an introductory set of remarks by the chairman of this program. I hesitate to let you plunge into the middle of this set of talks without some kind of attempt to organize this discussion or at least tell you how it got to be. So at the risk of disturbing the program, I am going to take ten minutes to discuss it. Anyway, I had already prepared ten minutes of discussion, and I'm not going to let that go to waste. So, here it is.

The purpose of the Industry Program itself, I'm sure most of you are familiar with. I understand that this is to encourage communication in science and engineering between our University and Industry. The real objective is to get you to the research frontiers, so to speak, here at the University, and the Industry Program does this in several fashions: by transmission of preprints and papers about to be published which gives you somewhat early information, by discussions, word of mouth, and by this kind of a symposium.

There is a special purpose in today's meeting and this special purpose is somewhat three-fold. The first of these is again to bring you to these research frontiers in the University, and you will meet, as Dean Sawyer has told you, some of the people who are outstanding on these frontiers, who are the front-line gunners, so to speak. Secondly, we have tried to bring to you a panel for the afternoon discussion from the outside world who will comment in a knowledgeable manner on the material which will be discussed earlier in the day. A third purpose is to give you a chance to sit back and look from the long-range view and say, "Well, where is all of this leading to?"

The one thing we can guarantee is that we will have no answers for you, so don't expect any and this gets us started properly. But we think we can raise a large number of questions and this is what we will do. Since you really don't have enough problems in your daily work, we think we should provide some more material for you.

The questions as to why this subject was chosen comes next. The committee that formed this meeting was asked to consider a meeting on systems, complex systems, and we had two troubles with that. First of all, I have recently been asked to review three books on systems, one of which was really industrial engineering and dealt with things like time and motion study, to some extent computers, things of this nature. A second, concerned with operations research in both industry and war, dealt with problems of complex equipments too, and the third had nothing to do with either of these, but was concerned with philosophy, systems of philosophy and thought, things of this nature. Now, even though these are widely spread, they all carry this title "systems" and they all came to me, which shows you how confused this word is.

Secondly, it is not an accident that these are called by the same name because all stem from the same set of causes. But the fact that these look unlike means that discussing the word "system" or having a meeting on systems, is almost nebulous.

We chose instead to pick a small part of the large area covered by "Systems" and this is the impact of this rising tide of complexity on the human being himself. Here we thought that the University had a good deal to offer in the way of information about what is going on in research.

I could talk for a long time about measuring this rising complexity, but to see that it is rising against us in Greek tragedy form, one needs only consider that we have a birth rate of around, I believe, in 1955 the number I saw was 24.7 per 1000. We have a death rate of around 9.7 per 1000 which gives us an interest rate on population of about 15 per 1000. You've made calculations of this sort -- it turns out that the doubling period here is about 40-some odd years. We are somewhere in the neighborhood of 170 million. In 40 years we'll have 340 million. Around 1900 there were 75 million. This is an inexorable process; we can do nothing about this; people go on doing this kind of thing, and even if we shut off immigration, which is not such a large factor today, here it is, 340 million; we will have double the problems in this country in 40 years. So the things we see happening in the way of solution are necessary evils.

Consider the picture in regard to the areas of: transportation. with the jet liner coming into use, communication with new complexities, energy requiring nuclear power stations, extremely complex weapons for warfare, all of these things are really indicators of the same kind of thing: Complexity. Now, the interesting thing is the impact of all of these on us. If human beings are not present, then this whole process is of no interest. So really, the center and hub of the whole thing is the human being, and he comes into this picture in a lot of ways.

One of the ways he comes into this picture is as a citizen, and immediately several questions come into mind. Nuclear energy as we are using it, is this a good or bad thing for civilization? He must think about this as a citizen, he's asked to vote on things which affect the existence of these sources of power. Automation, is this a good or bad thing? Psychological motivation in advertising, is this a good or a bad thing? So that as a citizen he is faced every day with this kind of question. As a worker, the skills required of him are higher, the intricacy of living in the place where he works is greater. We have displacement of the worker and we have a transient period of unemployment and he is faced with these situations. As a consumer, he is given more leisure and he has to find out what to do with it. This is no small problem for the future.

Now, in all of these capacities, the human being is certainly affected, but in management capacity, I think, perhaps greatest of all. The manager has a number of functions, and in every one of these functions this increase in complexity is affecting his thoughts. In marketing, he is faced with new reactions of people, new groups of people. New markets bring up the question of innovation, which I understand is a major management function. The manager also has to deal with a large variety of new products, and he must consider their effect on his business. In finance, he has a new ratio in terms of the capitalization required per worker, he has a new set of factors to deal with when he talks about how much capital and how he goes about raising this capital in connection with this new technology. In sales, he deals with a new area in psychology. In productivity, he has an entirely new technology. In personnel handling, psychology has changed the picture. All of these events raise questions for the manager. Let me tell you about an old alumnus who came back to a university and was talking to a psychology professor and he said, "Professor, are your exam questions just as hard as they used to be?" And the professor said, "Yes, we're asking the same hard questions; in fact, we're asking the same questions." The old student was amazed. He said, "Well, if the exam questions are the same as they used to be, don't all the students get 100?" The professor said, "No, all the answers have changed."

And this is precisely the situation we're in and I think with this in mind, we'd like to turn to the program and examine some of the new answers to the old questions.

INTRODUCTION - Harry H. Goode

Our first speaker this morning is Dr. James G. Miller who is called "Dr." in either sense, which is a fairly unusual thing. He is a psychiatrist, a psychologist, and I understand from talking with him, somewhat of a mathematician. He has a group over at the Mental Health Research Institute. He is the director there and his group represents the most unusual collection of professions I have encountered in a long time. I talked with this group; I first came in contact with them about a year or a year and a half ago; there are a mathematical biologist, a physiologist, a psychologist, and a political scientist, of all things, collected together, examining the question of systems, and I think it is about this work that Dr. Miller will tell us today.

RESEARCH INTO THE BEHAVIOR OF HIERARCHICAL SYSTEMS

James G. Miller
Professor of Psychiatry
Mental Health Research Institute

Now that my personal, intellectual and emotional status, and that of the members of our group, have been questioned, I should like to do what I can to re-establish it by telling of the patient who entered the psychiatrist's office snapping his fingers. When the psychiatrist asked, "What are you doing that for?", the patient replied, "That's to keep the wild elephants away." Rather puzzled, the doctor said, "But there aren't any elephants loose for 7,000 miles." "Effective, isn't it?" commented the patient.

Although this story has no direct relevance to the theory I am going to outline this morning, it does point up some of the problems involved in evaluating the effectiveness of any program of action. Mr. Goode did what he could to indicate why people primarily in mental health research should be involved in as complex an activity as ours. We are deeply concerned with the problems of mental disease; we view them in some aspects as similar to physical illness, but in a good many other aspects as dissimilar. We are properly established in a medical school, yet we must be fundamentally concerned with individual and group behavior, with social process, social norms, and with what is considered acceptable and unacceptable behavior. We must also be concerned with some of the problems mentioned by Dean Sawyer - the relationship of mind to brain, new developments in the understanding of brain function. We recognize many components of the complex problem of mental health and disease, and we realize that some sort of integrated formulation is necessary.

Therefore, in the last five years our group has emphasized a primitive and highly tentative effort to bring together representatives of the disciplines concerned with human behavior, so that they can work together over a long period in an attempt to find some essence of agreement in these different fields and in the diverse schools within them. We know that the agreement will not come easily, so we attempt to define the points where we disagree and if possible set up critical experiments to help resolve these disagreements.

I am going to present to you the work we are doing in two parts. First, I shall talk about the general theoretical integration of our program. Much of it will be little better, or little worse, (according to your perspective) than metaphysics! We are working on an integrative method to bring together numerous ideas, few of them original with us, and to fit them together into a mosaic design concerning normal and abnormal behavior. Nearly every behavioral scientist would question one or more of the statements I shall make. But I am going to give you a direct, integrative statement, though even our own group would probably cavil at some of it. In the second part of my talk, I shall give you an example of the research we have been getting under way in an effort to develop general principles concerning human behavior that can be confirmed empirically. After coming together as a group in Chicago some years ago, each one presenting his own point of view concerning the nature of man, we decided there was more promise in what we now call general behavior systems theory than in any other single approach of which we were aware and, therefore, that we would make an effort for a period of time to confirm or disconfirm certain aspects of this point of view. Such theory was not original with us but began probably as far back as Lotke, a biologist; in more recent times it has been advanced in biology by Bertalonffy. It is closely related to concepts of information theory and cybernetics developed by Ashby in England and by Wiener, Weaver, and Shannon in this country. As you will see, it incorporates the notion of homeostasis, maintenance of physiological equilibria in the body, and also draws ideas from a number of social sciences.

General systems theory emphasizes similarities in a hierarchy of physical systems - the nuclear particle, the nucleus, the atom, the molecule, the crystal, the virus (here the living or behaving systems begin), the cell, organ, individual, group, and society. Above these behaving systems there are the biota (i.e., all living things and the physical environment around them), the planets, the solar system, and the galaxy. We have no concern in our program with this total range of systems. We would certainly not be competent to work on the fundamental problems involved in generalization across the whole range. We deal with the selected set of these systems which we will call for convenience "cell, organ, individual, group, and society." We are interested in the probability that predictive mathematical models (and also in some cases electronic models) can be made of these systems.

We ran into all the complications concerning the term "system" that Mr. Goode suggested. My way of dealing with them is to define "system" as a concrete entity which has a definite locus in space-time. It has certain other characteristics which will be mentioned shortly.

We recognize also that there are conceptual systems. For example, mathematical models are conceptual systems. It is possible to make conceptual systems which have no reference to anything that exists in the real world. It is also possible to make conceptual systems that are more-or-less similar or isomorphic to systems in the real world, and much of the function of behavioral science is concerned with the development of more and more precise and accurate mathematical quantitative conceptualizations of conceptual systems which refer to real systems that can be observed. Each system except the largest of all - the universe - has its environment. The system and its environment together constitute a suprasystem. For instance, the organ is composed of cells; the individual, of organs; the society, of individuals. We therefore refer to the cell as a subsystem and the individual as a suprasystem of the organ. And you can go up and down the levels in that fashion.

Now we believe that there are certain general characteristics of behaving systems. First of all, they are all living, and this makes them a very special subclass of systems. They can live only within a restricted range of pressure and temperature and hydration. Their function is fundamentally based, as L. J. Henderson pointed out, on the chemistry of the compounds of carbon and of water. Henderson wrote an imaginative book on the effects of changing the environment, describing possible life in a world where, as perhaps might be true on Mars or one of the other planets, the fundamental constituent was ammonia or methane instead of water. Behaving systems are related genetically, from the virus to the components of the society. They are also related in terms of the fact that they are composed of a specific sort of substance, protoplasm. For these reasons, it is not surprising that there should be certain similarities concerning all of them. It would be much more difficult to find generalities concerning all conceivable systems.

So some of the generalities concerning behaving systems are: (1) they are bounded regions in space-time; (2) they have relatively important inputs and outputs of energy (solid arrows in Figure 1) and of information (dotted arrows in Figure 1); (3) they maintain a stability within themselves which does not exist in the external environment. In other words, they keep a series of variables within a critical range of stability. If these stabilities were not maintained,

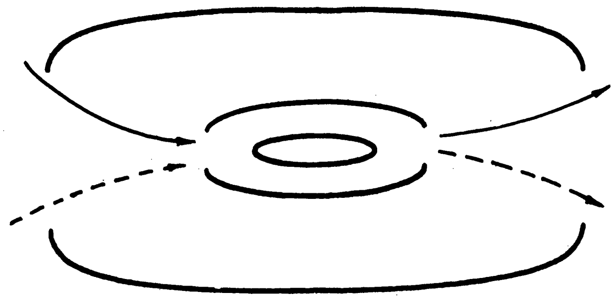


Figure 1

the boundary would disappear and the system would merge with the next larger system. For example, the living human being maintains his body temperature constant around the range of 98.6°. Within a few hours of his death, his temperature assumes the temperature of the surrounding room. The medullary thermostatic mechanism which controls temperature within the boundary in a way that it is not controlled outside, ceases to function and then the temperature fluctuates with the next larger system, of which the body is a component. So we conceive of feedbacks of various sorts - frequently information feedbacks, sometimes energy feedbacks - that maintain systems in stability.

There are negative feedbacks like a thermostat which automatically turns down the furnace when the temperature rises, and turns it up when the temperature drops. Positive feedbacks, of course, would lead to disruption or explosion of the systems.

We believe that each of these systems is composed of sub-systems of these again of sub-systems, and each of them has the function of maintaining one or more variables stable. The cardiovascular system of the body maintains blood pressure and several other functions within a range; the balance system of the brain maintains the body in certain axes in space, and so on. The principle is the same whether or not the primary function of the subsystem is to process energy, as in the digestive blood system, or whether its primary function is tc process information, as in many of the subsystems of the brain. Some subsystems are obviously more efficient than others. Some accomplish no effective purpose for the total organism, and actually may be a disadvantage to it, the classic example being the vermiform appendix. However, most subsystems are relatively efficient and tend to minimize the cost of the function they perform, the energy required to carry it out. The brain is a remarkable subsystem in that it consumes minute amounts of energy and performs complex information-processing and decision-making functions.

One of the functions of a subsystem may be as a mechanism of defense or of adjustment, to maintain an equilibrium against stress within a certain critical range. Stress may be defined as a change in the rate of input to the system of any environmental component, either energy or information, which displaces the system from equilibrium. For example, physiological studies show that there must be a certain relatively constant rate of oxygen input into the human being. If the input is inadequate, he suffers and finally dies from anoxia. If oxygen input is too high, death occurs from oxygen poisoning. Oxygen must enter within a certain range of rates, which may vary somewhat. If you are below ground, in Mammoth Cave, for example, the rate that oxygen comes in is a little faster; on the Andes at 18,000 to 19,000 feet the rate is slower. The organism has various subsystems which are mechanisms of adjustment that together maintain the level of blood oxygen even though there are marked variations in the rate of input. But if the variations go beyond a certain range, the organism cannot handle them and they become stresses that finally result in collapse of the system.

There is increasing evidence to suggest that lacks or excesses of information input may also disturb living organisms in various ways. Let me give some examples. Riesen discovered that if a chimpanzee is raised in darkness for the first three months and then permitted to live in light, he will never attain perfect vision. On the other hand, if you raise a chimpanzee for the first three months under ordinary light, then keep him in total darkness for as long as six months, he will regain his vision rapidly when brought back into daylight, returning to normal after a few hours. In other words, the maturation of the nervous system after birth requires certain inputs of sensory information into the nervous system. If that information does not come in during the first three months, at least in the chimpanzee, there is permanent structural change. It has also been demonstrated first by Hebb in Montreal and more recently by Lilly in Bethesda that deprivation of sensory information input may result in psychotic states. Lilly's method was to support himself, naked, in a large metabolic tank, about two feet below the surface, breathing through a snorkel, his eyes covered with white glass which blurred vision, his ears stoppered, and the water temperature maintained exactly at his body temperature. In two to three hours, he began to develop psychotic hallucinations. At first they were like images; then they became dreams; and then they became more and more realistic until finally he (and another subject who also volunteered for the experiment) was convinced that he was approaching a psychotic state, which possibly might be irreversible if he did not surface at once. This indicates that some sort of equilibrium is maintained by a constant flow of sensory information, and that the organism may be harmed if the flow is not maintained at a certain rate. Conversely, there probably can be an excess of information input. What we call the "tensions" of modern society, with its peptic ulcers, may well result in part from an overwhelming input of sensory information - more rapid than can be assimilated. It is certainly true that loud noise, strong light, etc., can sometimes disturb us seriously. Affection to children can be either too great in the over-protective parent, or too little in the rejecting parent, and this can affect emotional adjustment, resulting in some sort of imbalance. So it is possible to combine research findings and some of the central notions of psychiatry and psychology into a systems theory.

I have been talking almost exclusively in terms of the individual, partly because that is the primary concern of mental health research. Nevertheless, we believe that principles like those I have mentioned may also apply to the organ and to the cell. As a matter of fact, Selye in Montreal has made it clear that stresses, such as changes in the rate of input of acids injected into a dog's veins or of salt through the membrane of a cell, call into play mechanisms of defense which are mobilized by organ and cell in order to restore the essential equilibria of life. One principle in which we are interested concerns the rate of return to equilibrium after varying amounts of stress. Possibly the mechanisms of defense used and the forcefulness and speed with which they return the organism to equilibrium may have certain similar mathematical characteristics, i.e., the further away from equilibrium, the stronger these forces and the speedier the return. These processes do not increase linearly, but are stronger than linear. For instance, for 1 unit of displacement, the returning forces may be of strength 1, but for 2 units of displacement, the returning forces may be of strength 3 or perhaps 4, rather than of strength 2. We wonder if this may not be true in situations where, for instance, dissident members joining a group have to be dealt with vigorously by the group in order to restore its previous order. We wonder whether the strength of the reserves brought to the front by successful armies does not increase more quickly than the stress imposed on the army by the enemy. It would be possible to study in terms of behavior systems theory the military tactics of armies that have succeeded in maintaining their boundaries as compared with armies that have not succeeded.

There are complicated problems of measurement in comparing the strength of stresses on systems with the strength of the restoring forces. Wherever possible, we use what we call "u-units", that is, CGS units and their derivatives, the units of natural science, plus the units provided by information theory. The relationship of CGS to information units has been studied somewhat, though not in relation to behaving systems, and this is a complex question. Wherever possible we use these units rather than the more classical psychological units. In the behavioral sciences generally, the suggestion that similar units and dimensions can measure human behavior and cellular functions arouses much dissent. Frankly, for many aspects of behavior I cannot yet work out how such units can be used. On the other hand, there are situations where they clearly are useful, and since we are searching for general principles that apply quantitatively across levels, it is necessary to try to find uniform dimensions. A general theory of any sort - not only a general theory of behavior - must deal with a single set of dimensions, or it cannot be general.

The number of facts about all aspects of human behavior, coming in from many different disciplines, is increasing with rapid acceleration. No single human brain can do the reading and analysis involved in keeping current with them. We believe that unless some integrated conception is more or less generally accepted, to which newly discovered facts may be fitted in (as is true, for example, in organic chemistry), many good researches on human behavior will be lost in limbo; they will be forgotten for lack of an effective classification system. Relatively few should, in all probability, center their efforts, as we are, on a general theory. Likely to be more productive as the primary effort of behavioral scientists at present, is the development of microtheories, small theories about single aspects of behavior. Our role is discovering the relationships among such microtheories.

Though we are looking for general principles, we are equally concerned with the specific differences among these different levels. We conceive of a general principle being like $x + y = z$, of which there are an infinite number of examples. A special case of the principle, at one level, might be like $3x + 4.2y = 7.1z$. In other words, the differences among the levels and the species of individuals at these levels must be indicated in order to make a precise prediction about a specific system. So, similarity and difference are equally important in an empirical predictive science.

Now let me illustrate specifically what kind of research we are undertaking in order to find out whether there are formal identities among systems at various levels. We have conceived of 40 or 50 propositions which may apply across the levels. In most cases, we don't understand the relation of one proposition to another. One proposition with which we have dealt recently concerns input overload. It has to do with characteristics of living systems which also apply to non-living (i.e., electronic) systems. The proposition is that, for each system, if you measure input in bits of information per second, and measure output in the same units, as input increases, output also increases for a period of time, then levels off, and finally at a certain point there is a rather sudden flexion in the curve and quantitative output diminishes. (See Figure 2)

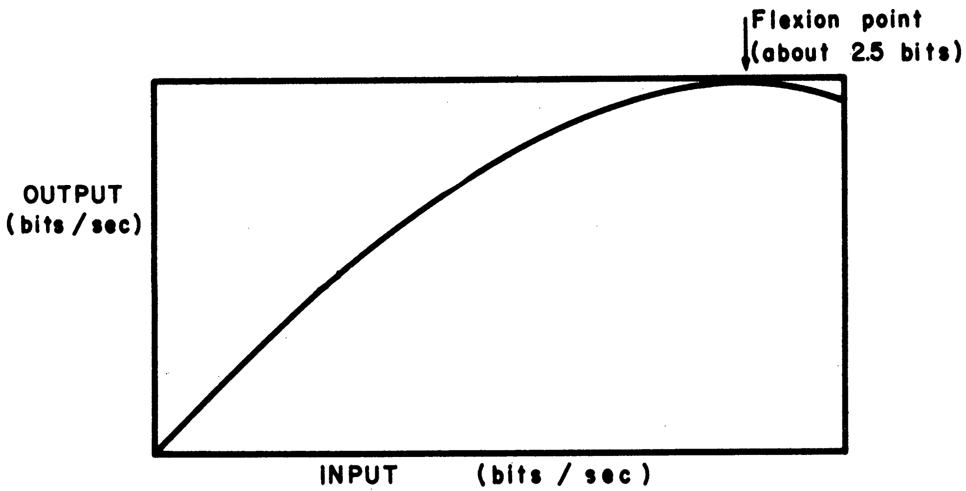


Figure 2

This was first called to our attention by an interesting article by George Miller of Cambridge, Massachusetts, on the magic number 7. He indicated that around 7 units (which incidentally represents about 2.5 bits) is the average person's channel capacity. For example, numbers between one and seven digits you can remember and repeat correctly afterwards, but you make errors when there are more than seven digits.

A similar performance characteristic has been studied by Quastler. Two years ago he reported that at Illinois he arranged to have pianists play random music (the notes were selected according to a table of random numbers). A delightful type of music similar to African folk music resulted. It was found that a curve like that in Figure 2 was characteristic of all pianists who played such music. As the rate of playing was increased, by speeding up a metronome, the rate of output increased, then it leveled off, and then, as the pianists were forced to play even faster, a confusion state was reached and output actually diminished. Quastler measured quite precisely the channel capacity of the pianists and found that in this and in other related tasks like typing, reading aloud, and mental arithmetic, a maximum capacity of 22-24 bits per second was reached, although few human beings are capable of this. He also found that the capacity could be changed by altering the possible range of choices. For example, if you had to play ADADAD, or just two notes, this would result in a different output of notes per second. This in electronics is called "altering the band-width." After Quastler's work was publicized, we learned that Jung, studying certain portions of nervous tissue, had found exactly the same thing: if more and more impulses per second are put into slabs of cortical tissue, this same sort of performance curve results. However, the breaking point is probably different at the level of the organ than at the level of the total individual. This is a fact we need to learn. We have also found that under certain circumstances single neurons may react similarly - up to a point the output rate of the cell will increase as the input increases, but then level off and ultimately decrease. With electrophysiological equipment recently available, we can study the neuron as a channel and discover its performance characteristics.

What do we plan at the levels of the individual, group, and society? Our thinking at the moment for the individual is a tracking situation, in which a subject, by moving a joy-stick control, has to keep a blip in the center of an oscilloscope as it is moved electronically, either randomly or regularly. Electronic recordings of his performance are taken and analyzed by computer methods for certain characteristics of his errors. We can also measure precisely how many bits of information per minute he can handle before increasing errors diminish the correctness of his output.

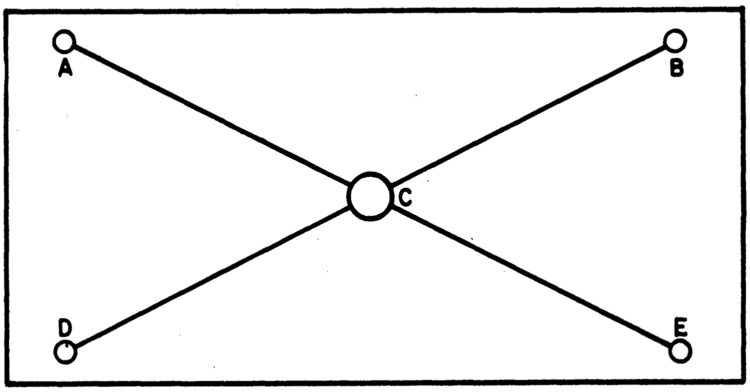


Figure 3

This situation may be extended to the group by the following procedure. (See Figure 3) A looks at one oscilloscope displaying horizontal motion; B at another oscilloscope with vertical motion. They both communicate to the captain of the team, C, by a code previously agreed to. C conceives the juncture of these two motions as a dot, and making a decision, he gives instructions for moving levers to D, who controls the lever that moves the oscilloscope blip vertically (though he never sees it), and to E, who similarly controls the lever that moves the blip horizontally. Here we have a group of five people operating as a communication system, transmitting information, and tracking. The tracking characteristics of the group may be measured in the same way as mentioned previously, with exactly the same CGS and information units.

At the level of society, we are harder pressed. There are certain communication systems large enough to be called a society - say, an army or an anti-aircraft battalion. We could perhaps study a battlefield situation, with tracking of the enemy. Certain data, recently declassified, suggest that if the rate of enemy planes coming into an area being protected by anti-aircraft increases, the number shot down will increase proportionately to a given point, after which the actual number shot down will not increase, and beyond a certain rate fewer planes will be shot down. A large social system, like an anti-aircraft defense command, operates as a channel and can be overloaded.

It is also possible to study the Post Office Department or Western Union during the Christmas rush, which is certainly an input overload.

Two final points: First, obviously other matters may be studied besides performance - the type of errors, for instance. In queuing theory, three types of inadequate or erroneous strategy for handling inputs are studied. One is queuing inputs at a boundary as they arrive to be processed. The second is non-processing, refusing to accept inputs. The third is inadequate processing - doing something, anything, in order to get on with the task. There is also a fourth mechanism of adjustment or defense against input overload, i.e., opening up other channels to carry the overload. Simple systems, such as the neuron, probably cannot do this. Complicated systems, like the human being, certainly can. They can receive information through the eyes and ears simultaneously, and consequently are able to process more inputs, just as more channels at a toll gate when opened, can handle more cars per hour. So the mechanisms of defense, and the order in which they are applied at each level of behaving systems, can be studied, and the mathematics of queuing theory applied.

We can also investigate relative economic costs of performances of channels under normal input and under input overload. A study of operators at a telephone switchboard might demonstrate the typical performance curve, but this would not measure the amount of work necessary to operate the system. Performance can be measured without paying attention to cost, but in addition the cost of performance at each level can be measured. It may well be that the cost per unit processed increases rapidly at the point performance begins to break down.

In conclusion, let me summarize. I have discussed in detail only one proposition, out of many on which we could do empirical research. We are taking living systems of different levels, and making them components of non-living physical systems, all of whose characteristics we can measure in u-units - CGS or information units. Understanding the characteristics of all the other components of the non-living system as natural science rigorously does, we can then study the transfer functions within the living human being, the living cell, or the living society in comparable units, because it is a part of the larger system. This is the general strategy which we hope will, in the end, lead to a more precise and quantitative science of behavior.

INTRODUCTION - Harry H. Goode

Our next speaker is Director of the Institute of Social Research; he is Professor of Sociology and Psychology, and I believe most of you have somewhere heard of Dr. Rensis Likert.

ORGANIZATIONAL ASPECTS OF HUMAN BEHAVIOR

Rensis Likert
Director of the Institute for Social Research
and Professor of Psychology and Sociology

American management is on the threshold of a very important break-through. The managers and supervisors who are getting the best results are employing leadership and supervisory practices that point the way to a new management theory. The work done at the Institute for Social Research during the past 10 years for a wide variety of organizations indicates that there are some important inconsistencies between the practices actually used by the most productive managers today and the basic concepts and principles of the prevailing theories of management.

Since 1947 we have been conducting a series of related studies seeking to find what kinds of organizational structure and what principles and methods of leadership and management result in the highest productivity, least absence, lowest turnover, and the greatest job satisfaction. Studies have been conducted or are under way in a wide variety of organizations. These include one or more companies in such industries as the following: public utilities, insurance, automotive, railroad, electric appliances, heavy machinery, textiles, and petroleum. Studies also have been made in government agencies. In general, the design of the studies has been to measure and examine the kinds of leadership and related variables being used by the best units in the organization in contrast to those being used by the poorest.

The managers and supervisors in American industry who are getting the highest productivity with lowest scrap loss, least absence and turnover and highest levels of motivation and employee satisfaction are deviating systematically from the practices and procedures which, according to the present management theories and systems, should get the best results.

These high producing managers and supervisors are making these deviations in their day-to-day supervisory procedures in spite of elaborately specified operating procedures prescribed by companies for all such functions as selection, training, supervision, communication, compensation, decision-making, functionalization, etc. These standard operating procedures, based as they are on the current theories of management are actually preventing the superiors and supervisors in all companies from gaining the full benefit of the changes which they are endeavoring to introduce.

Let me illustrate this point briefly. The traditional management theory, upon which companies base their day-to-day operating procedures, specifies that it is the responsibility of management to perform the following functions, drawing when needed upon specialized resources, such as the Methods Department, available within the company:

1. Break the total operation to be performed into its simple, component parts or tasks.

2. Develop the best way to perform each of the component parts.

3. Hire people with appropriate aptitudes and skills to perform each of these component tasks.

4. Train these people to do their respective tasks in the specified best way.

5. Provide supervision for these people to see that they perform their designated tasks using the specified procedure and at an acceptable rate as determined by work standards established through timing the job.

6. And, where feasible, also use incentives in the form of individual or group piece rates.

It is significant that supervisors who conceive of their job as stated in 5, above, are found more often to be in charge of <u>low</u> rather than <u>high</u> producing units. Many different studies in widely different industries and for widely different kinds of work-clerical, sales, manufacturing, etc., -- consistently show this pattern. Supervisors who are above average in being employee-centered, goal-oriented, are about three to four times more likely to be in charge of units which are above average in productivity than are the production-centered, process-oriented supervisors. If the supervisors in charge of units which rank in the top one-fourth in productivity are compared with supervisors who are in charge of the poorest one-fourth in productivity, these differences of course become greater. The chances then are about seven to one that the high productivity units will be supervised by an employee-centered supervisor. (For a description of what is meant by "employee-centered" and "production-centered", see <u>Productivity, Supervision and Morale in an Office Situation</u>. Ann Arbor: Institute for Social Research, 1950.)

Much other evidence could be cited showing that the traditional theory of management does not work as it should. For example, high producing supervisors spend more time than do low producing supervisors on many functions, such as the off-the-job problems of subordinates, which should have no relation to productivity if the current theory were correct. Similarly, high producing employees should like performance rating procedures which bring them merit increases, but they do not. High producing employees have a less favorable attitude than do low performance employees toward performance ratings which are linked to compensation.

Evidently there is an important inadequacy in our current theory of management and in the operating procedures for selection, training, supervision, etc., based on this theory. But there is also much which is very powerful about the present management theory. Scientific management, cost accounting, budgeting, and related developments are powerful concepts and tools and are responsible for the extraordinary productivity achieved in American industry. What is needed, therefore, is an extended or new management theory which fully utilizes all the resources of scientific management, cost accounting, and related processes but utilizes these resources in a fashion which overcomes the existing inadequacy.

The research findings indicate that this inadequacy is due to the failure of the current management theory to make use of all of the powerful motivational forces which function in the working situation. The current theory is based on the assumption that buying an employee's time adequately taps all of the motivational forces needed for effective functioning. Economic motives are extremely important, but as the high producing managers and supervisors consciously or unconsciously sense, tapping only these motives is not enough.

A new theory of management, therefore, is required. The basic concept of the new theory involves the full utilization of scientific management, cost accounting, etc., but in a manner which fully utilizes all of the powerful motivational forces which function in the working situation. To use this new theory in any company it will be necessary to derive operating procedures for selection, training, supervision, compensation, communication, etc., which will fit the traditions and past methods of operating of that <u>particular</u> company. A general formula for deriving these operating procedures for any particular company can be stated based upon available research findings.

Consistently, in study after study, we find that treating people as "human beings" rather than as "cogs in a machine" tends to show up as a variable highly related to the motivation of the subordinate in all levels of the organization. The extent to which the superior conveys to the subordinate a feeling of confidence in him and an interest in his on-the-job and off-the-job problems exercises a major influence upon the morale and motivation of the subordinate.

These results and similar data from other studies show that subordinates react favorably to experiences that they feel are supportive and increase their sense of importance and personal worth. Similarly, persons react unfavorably to experiences that are threatening and decrease or challenge their sense of personal worth. Each of us as an individual, as a human being, has an inborn desire for a sense of importance, of personal worth. We want appreciation, recognition, a feeling of accomplishment, and a feeling that people who are important to us believe in us and respect us. If we get this needed sense of importance and personal worth, we are positively motivated; if not, we are negatively motivated and we react unfavorably.

This general pattern of reaction appears to be universal and provides the general formula being sought for deriving operating procedures likely to yield high and cumulative motivation. The individual members of an organization will be highly motivated when the interactions between the individual and the others in the organization are of such a character that these interactions convey to the individual a feeling of support and a sense of importance and personal worth. We should try to have the interactions between the people in an organization of such a character that they convey to the individual this sense of personal worth, including, for example, a feeling of confidence in his potentialities and a realization that his abilities are being used well.

But one other factor is also very important: An individual's reaction to any situation is always a function, not of the absolute character of the interaction, but of his perception of it. It is how he sees things that counts, not objective reality. Consequently, an individual will always interpret an interaction between himself and the organization in terms of his background and culture, his experience and expectations. The pattern of supervision that might be effective with a railroad's maintenance-of-way crew, for example, would not be suitable in an office full of young women! A subordinate tends also to expect his superior to behave in ways consistent with the personality of the superior. All of this means that a subordinate will react in terms of the subordinate's background, experience, and expectations. <u>It is essential, therefore, that each interaction be of such a character that there will be a maximum probability that the subordinate will, in the light of his experience and expectations, feel that the experience is supportive and contributes to his sense of personal worth.</u> This is the general formula that can be used to derive operating procedures for applying the new theory in any particular situation.

Some crude partial applications of the new theory have been made by changing only one or a few operating procedures. These experiments were started before the new theory had been clearly developed. Nevertheless, these partial applications are yielding impressive results, such as 15% to 25% increases in productivity accompanied by increases in interest in work, increased concern about doing it well and more favorable attitudes toward supervisors and managers. In other studies substantial saving in indirect costs have been achieved amounting to as much as $1000 per employee in two different companies. In another company absences were reduced resulting in a saving in one year of over 65,000 man-hours of paid time.

These results indicate that a full application of the new theory, which would involve changing all of the operating procedures in a company in an integrated and coordinated manner, would yield a substantial increase in performance and reduction in costs. Changing only a few of the operating procedures produces a situation where the remaining old operating procedures cause unfavorable impacts on the new procedures. These unfavorable impacts limit the improvement which would otherwise be derived from the new procedures.

The new theory involves a more complex managerial system than the present theory. To use it fully and effectively will necessitate greater learning and skill than is now the case and will also require greater emotional maturity and greater confidence and trust on the part of the members of the organization than at present. Operating under the new theory, however, will help the members of the organization to develop greater emotional maturity and similar characteristics. Like other forms of organizations, the new management system will develop the kinds of persons required for its effective functioning.

Any attempts to apply the new theory in a company should proceed slowly and experimentally and with adequate motivational measurements to guide all phases of its introduction. Obviously, any attempt to make an over-all application of the new theory in a particular plant should be viewed as experimental and treated in the same manner as all new pilot projects and plants. The initial trials are almost certain to encounter the kinds of mistakes or "bugs" that pilot plants are set up to study and eliminate before large-scale applications are made. Small-scale pilot projects should, therefore, be made before a large-scale over-all application is attempted.

It will involve much hard work and time for a company to shift all of its operating procedures so that they represent a full and effective application of the new theory. The larger the organization, the greater will be the problems involved and the greater will be the time required to shift successfully to the new theory. The rewards, however, will be great. Increased productivity, decreased costs, better quality products, greater employee satisfaction, and similar results would benefit all concerned: management, employees, customers, and stockholders.

The Institute for Social Research would like to work with a few companies to learn how best to apply the new theory. We are looking for a few particularly well-managed companies who have the faith and courage to tackle this new way of running a business.

I have tried briefly to summarize some of the exciting and promising developments which I believe are coming from research on human behavior and motivation. I hope that I have been able to convey to you the importance and promise of this research even though I have had to deal with it rapidly and briefly.

INTRODUCTION - Harry H. Goode

Our next speaker on Psychological Models of Human Preference is Dr. Clyde H. Coombs, who is Professor of Psychology and a co-editor of the volume, Decision Processes, which made a fair stir in the information theory and decision process world.

PSYCHOLOGICAL MODELS OF HUMAN BEHAVIOR

Clyde H. Coombs
Professor of Psychology

The problem that I am going to talk about is the problem of how a group arrives at a decision, when the group consists of a number of individuals, and the individuals have different preferences for the various alternatives which the group faces. The source of the material, the kind of things I'll be talking about, comes from political science, economics, mathematics, and psychology. It's a hodge-podge and melting pot of all of these fields. The kind of problem is the one which arises in a legislature; for example, where from a whole range of alternatives one is to be selected and is to be made into law. It is the kind of problem you have in a jury which needs to make a decision of culpability or amount of damages, for example. I was trying to explain to my fourteen year old son last week what it was I was going to talk about today and I told him, "Take a family - father, mother and several children - and they want to go to a movie that night. There are several movies in the town and each member of the family had his order of preferences amongst these various movies. The family wants to go as a unit and arrive at a group decision - a decision which in some sense would best represent what the various members of the family prefer." And he says, "Oh, I get it. Everybody decides to go to a movie they don't like."

There are many possibilities for a group decision function. The father can decide - this is a dictatorship. Authority of some sort, law, custom, religious codes, all of these are essentially mechanisms for arriving at decisions. Now, I'm going to be interested here only in one general class of these kinds of decision functions - in particular, what we call concensus. This is the general problem of amalgamating the individual preferences in a group, a democratic kind of process. So the situation we are talking about is a group. It can be a club, family, legislature, a nation, whatever, and they're faced with a set of alternatives and these alternatives are to be ordered for the group as a whole. The various members of the group have different orderings representing their ordered preferences amongst these alternatives. The problem is how to amalgamate the individual preference orderings into a single ordering which in some sense will best represent all the various individuals.

Now, there are two obvious solutions which we are compelled to reject. The first is that of averaging the individual preferences for each alternative. This must be rejected because, for one thing, it requires that we be able to measure how much an individual prefers each alternative, and secondly, that the scale on which we measure how much each individual likes each alternative be the identical scale for the different individuals. In the language of economics, this is known as a problem of interpersonally comparable utility. Essentially, I've got a painting up here and we want to know whether you like it more than I like it. You'll pay twenty dollars for it, I'll pay ten dollars for it. Does that mean you like it more than I or that your value for twenty dollars is less perhaps than my value for ten dollars? We begin to make assumptions of this sort which would permit us to arrive at a decision that you like that painting more than I. Which one of us would care to jump into the river for it? Well, you like to swim in colder weather than I do -- that kind of thing -- we don't know. It would be hard to decide in a precise quantitative sense which one of us liked a painting more. Pareto was the first to abandon this notion of interpersonally comparable utility and there has been a great deal of literature in mathematics and economics since on both sides of the problem. We are going to take the position that no satisfactory interpersonally comparable utility can yet be determined.

So we shall look at a second obvious alternative for solving this problem, one which does not require measuring utility with numbers. This would be a method, let us call it, of majority decision. We might have every individual rank order the alternatives; for every pair of alternatives he says which one he prefers, and then for every pair let us take the majority decision. An illustration will show what's wrong with this method. Suppose we have three alternatives and suppose for simplicity's sake we have just three individuals in a group. So, one individual rank orders the three alternatives, A, B, and C. A second individual rank orders the alternatives B, C, and A. The third individual rank orders the alternatives C, A, and B, from first to last in preference. So we look at the alternatives A and B and we see that two-thirds of the individuals prefer A to B and we see that two-thirds of the individuals prefer B to C, and we see that two-thirds of the individuals prefer C to A. So we go right around in a circle. We have a set of what we call intransitive-paired comparisons and this, as a decision mechanism, is not desirable because it does not arrive at a decision.

One of the requirements we are going to have for a decision mechanism is that it's got to take the preference orderings of the individuals and amalgamate them into a simple order because it's got to decide which is preferred. It can't leave you in a trap like this. This is known as the paradox of voting which was first pointed out in 1882. Now, this mechanism is used in deliberative bodies where a range of alternatives comes up for decision in a succession of pair-wise comparisons. And the thing is that you can get any decision you want if you start right. You present the pair of alternatives, A and B, and you see that A is preferred and B is rejected, so you put A up against C, and when you put A up against C, you end up with C as the final choice. On the other hand, you can start with B and C and you'll see very quickly that you end up with A as your final choice, and it's perfectly obvious that if you start with A and C you'll end up with B as your final choice. I am sure that every successful politician is at least intuitively aware of this mechanism.

With these methods inadequate as decision mechanisms one might ask if any method could exist based solely on what we'll call ordinal utility. This is what we are calling ordinal utility, there are no numbers associated with how much the individuals like the alternatives; it's just a rank order of their preferences, from most utility to least for an individual. And the question is can any method exist which can take the ordinal utilities and arrive at, in general, in all cases, a social utility. Kenneth Arrow, an economist, wrote a monograph in 1951 in which he proved mathematically that none could exist, given certain reasonable kinds of assumptions, like weighting the individuals equally, and so on. If you weight the individuals unequally you could weight them all zero but one, give him the whole weight and you have a solution. But that's trivial, that's an autocratic solution. So, what we are interested in, what he was interested in, is whether a decision mechanism could exist which would do things like weight the individuals equally, weight each vote equally. One individual prefers A over B, another prefers B over A, etc., can one combine these in some manner and always get a social utility? Kenneth Arrow showed that no method of voting, neither plurality voting, proportional representation, etc., will remove this paradox.

This is where I got interested in the problem because we have a model for measuring and analyzing the preferences of individuals, which measures preferences on what we call an ordered-metric scale. This is a scale, a type of measuring system, which is something stronger, something more than an ordinal scale but something less than numerical measurement. What you get in particular is that you can measure the alternatives on an ordinal scale and in addition, differences can also be ordered. So that you could say that in addition the difference in utility between alternatives A and B is greater or less than the difference in utility between alternatives B and C.

I'll just say a few words about this as background to what I want to go to next. The manner in which we arrive at this. Consider a very simple unrealistic situation where your alternatives just differ on say one dimension, one attribute, whatever it is, amount of damages, or whatever might be appropriate, and conceive that we have the individuals in the group, the members of the group, distributed over this continuum, each individual represented by a point on the continuum, representing how much that individual likes that attribute, his ideal, let's call it. That's his preferred position on what we call the J-scale. These could be candidates for office, going, say, from liberal to conservative and this is a voter, representing just the kind of a candidate he'd like most to vote for. Now, if we took an individual like that and asked him what he preferred amongst a given pair of alternatives, like A and B, we make the assumption that he will prefer that candidate who most nearly represents his ideal, so that this individual, this voter I've drawn here, would prefer B to A and A to C, A to D, and so on. We have a set of paired comparisons and it would end up in a rank order; in fact, in this simple instance, you could represent this voter by a scale like this, for terminology let me call it an I-scale so I can talk about them. The individual's I-scale - his preference - can be represented by a line in which he is a point at the end of it and each of the alternatives is a point on this line, representing how far away the alternative is from him. It's as if you took this J-scale where he was and picked it up like a piece of string and folded it and got the order of the alternatives on this piece of string going away from him. This is the individual's preference scale. It is perfectly obvious that the different individuals, all of them here, would be picking up this scale, folding it, and giving you their preference ranking.

The J-Scale

This scale represents a continuum, from minimum to maximum, of one attribute. A, B, C, D, are candidates ranked on this attribute. The first voter's ideal is closest to B, next closest to A, etc.

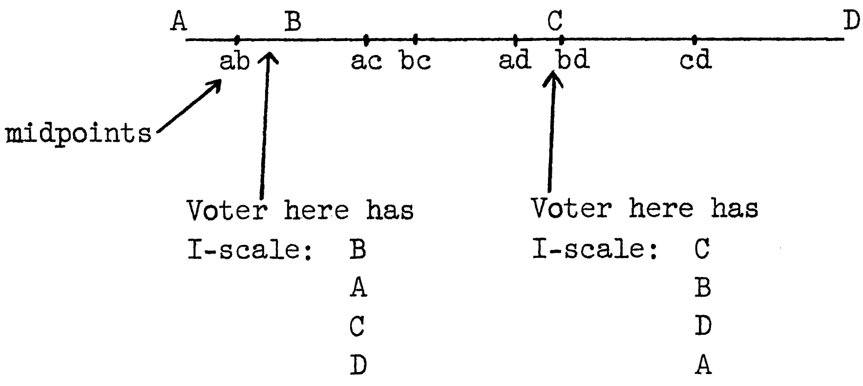


Figure 1

Now, consider all the individuals who were, say, at the end to the left of the midpoint between alternatives A and B (see Figure 1). All of those individuals, no matter where they were, would have the rank order preference A, B, C, D. It is perfectly clear. So let's write that one down. We would have a set of people who would say A, B, C, D for their ordering of preferences. Now consider an individual just on the other side of this midpoint between alternatives A and B. Such an individual would have a preference ordering on A and B of B over A, because he is now nearer to B than he is to A but with respect to the other alternatives he is the same as the first person and he would have an ordering B, A, C, D. We'll call A, B, C, D the first I-scale and this the second (B, A, C, D). Such an individual would have a preference ordering then B, A, C, D. Other individuals in this second interval would also have this same ordering, B, A, C, D, until we got to the next midpoint which would be the midpoint between alternatives A and C. All the individuals in this second interval here would have the same rank ordering, B, A, C, D, until we got to individuals on the right side of that midpoint. These individuals would now reverse their ordering on A and C and we would have individuals whose I-scale was B, C, A, D, and this would be our third I-scale. Then we would get to the midpoint, B, C; all the individuals in here would say B, C, A, D, until we cross the midpoint, B, C, and we would now get into the fourth interval which is bounded on the right by the midpoint, A, D, and all the individuals in this fourth interval would reverse on B, C, and would give you the rank ordering C, B, A, D. And you can see how you can go on and altogether you would expect to get seven different I-scales, seven different ones generated by the six midpoints.

Now, let me compare that with this example

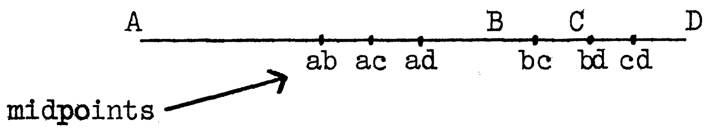


Figure 2

Now, let me compare that with this example where stimulus A is here, B is here, and C is here, and D is here. Suppose it were like this. There would now be people who were down here giving A, B, C, D just as before, no different from Figure 1. We would cross this first midpoint beginning the second interval, the first midpoint is always between alternatives A and B, the first two alternatives. The second midpoint is always between the first and the third, so this would be A,C midpoint, and the people in this second interval, between A, B and A, C midpoints, would do exactly the same thing as in the previous case. So here we would have a set of I-scales A, B, C, D - B, A, C, D - and then you cross A, C into the third interval and you get B, C, A, D. The first three I-scales there would be just the same as the first three in the previous case. But now see what happens. What is the next midpoint that we cross as we go down this scale? (Figure 2) Knowing the simple order A, B, C, D, tells us that A, B midpoint comes first, A, C comes next, but it doesn't tell us what comes third. We see that it could be the midpoint between alternatives B and C or it could be the midpoint between alternatives A and D. Now, in this instance, Figure 2, I tried to draw this so that the midpoint for alternatives A and D comes next. If that were the case, then we cross that midpoint to go to the fourth I-scale and we would get the I-scale B, C, D, A. Something quite different from the case in Figure 1, and the thing that generates this, obviously, depends upon whether the distance between the two alternatives A and B is greater or less than the distance between these two alternatives C and D. If alternative A in Figure 2 could be moved to the right this A, D midpoint would move with it and would at some point, when the distance $\overline{CD}$ became greater than the distance $\overline{AB}$, be on the other side of the B, C midpoint and this fourth I-scale would be different. So this is your data.

You get a set of rank ordered preferences and when they satisfy the necessary conditions you can recover this J-scale at the level of what I call an ordered-metric scale in that the alternatives are ordered and you have metric information at the level of order relations on metric, that one distance is greater or less than another distance. This expands into a great variety of things; we won't pursue that; it's enough to give the flavor of the kind of thing we are talking about. From people's rank ordered preferences we can get metric information at an ordinal level.

Now, ideally, what we would like to do would be to take (to arrive at our social utility, our group decision) the measure of every alternative here representing how much the individual likes it -- you see where it is in preference ordering -- take a measure of that utility that the individual has for that alternative, average that over all the individuals, and end up finally with a scale down here which gives us the one end that had the most preferred down to the least at the other end -- just averaging these preference magnitudes over the different individuals and this would give us an average preference scale which in some sense would represent the group as a whole. The trouble is, of course, as we said before, that we don't have numerical measures of how much the individual likes each alternative. We merely know that he prefers, say, B to C and prefers it to A -- we don't know how much he prefers it. We have this ranking, we don't have these numerical measures but ideally if we had those numerical measures we would average them and we would have a scale which in some sense represented the group as a whole.

Now, we can look at this in this way. Wherever an individual is on the scale and wherever an alternative is on the scale, if there were an alternative right where the individual is, he'd be just as happy as he could be. He would be satisfied, maximally satisfied. And as we move to an alternative which is further and further removed from his ideal position his satisfaction diminishes. This is the assumption in this model: that when he says he prefers one to another, it means that it is nearer to him than the other. So, what we have is a distance here going away from him. Now, the measure of the individual's preference, then, for a stimulus, would be the numerical measures on the I-scale which would represent the distances; for each individual we would have a measure of the distance the alternative was from his ideal position. This is what we would like to average so that we would then get for each alternative its average distance from all the individuals in the group. Then we would pick as the one which was first choice for the group that one which on the average was nearest everybody but because we don't have these numbers we can't average them.

There is a theorem in mathematical statistics which says that if you take the points in a distribution and take the distance that every point is from some origin, some arbitrary point in a distribution, and you average the distances that all the points are from this point in the distribution, that average value will be a minimum if this point, the origin, is at the median, the median being the middle point of the distribution, and with some more simple conditions satisfied as you move away from that median point, the average distance of all the points from this origin gets larger and larger. Well, it is a very simple step from this to the clear conclusion that the alternative which will be at the highest end of this scale will be that alternative which is nearest the median point in this distribution, which is the median individual. And, as you move away from that median individual, alternatives get larger and larger mean distance away from the individuals -- which immediately says that if we could find the median individual (we've got frequencies on each of the I-scales), if we found the median individual in this distribution of I-scales, his rank order of preferences would be the same rank order as we would have gotten if we knew the numerical values and averaged them and just got the rank order from that. So what we can have here is a social utility, a social choice function, which would be the same rank order as if we had actually measured the various utilities for the alternatives and averaged those over the various individuals.

Let's consider -- it is interesting to interpret this, to think of what kind of a decision function this is. This is the kind you might like or might not like. So we look at this again. Let's say that from where an individual is (his ideal), to where an alternative is, that distance is a measure of dissatisfaction. Let's call it dis-utility. He is maximally satisfied where he is and as you move away, his utility goes down. Whatever that distance is, if it's zero, it's zero dis-utility where he is, and as you move away you have increasing dis-utility.

What we would have arrived at here, then, by taking the median individual's rank order, the first alternative would be the one which on the average was nearest all the individuals so it would have the least dis-utility and the dis-utility would increase as you went on this scale from the median individual. So I call this kind of a social utility a least-disliked social utility. This would be the kind of a society you would have if the individuals in the society had this kind of a mechanism as a choice mechanism. It would be one which would be minimizing dissatisfaction.

It's interesting to point out that this would be something different, probably, from a decision mechanism which arrived at a most preferred. I don't know what this would be; it is not defined. But suppose you had a range of alternatives facing a group and suppose the group's ideals were asymmetrically distributed on the J-scale. That's the way the members of the group were. What kind of a social choice or decision should the group make? There's a heavy weight toward one end of the scale but they're spread all over and this is typical of a group. If everybody agreed, we wouldn't have any problem. We are assuming they don't agree and that's why we're interested in it. Well, you might want to say that perhaps in some sense some point down here, near the modal point, is most preferred. I don't know quite how you want to define it but something down there would probably be most preferred. This mechanism would say down here, the median, should be the social choice. It would be a type of mechanism which is essentially a kind of compromise mechanism, one in which no particular sub-group would dominate and decide for the group as a whole, but rather all would participate and there would be a final choice which minimized the total dissatisfaction in the group. Any other choice would increase the total dissatisfaction. It would or might make a few people more happy and a lot of people less happy.

It's interesting to think of this in terms of some of the conventional methods that we have for group decision making, things like the Hare system of voting, averaging rank orders, and so on. I think it's not particularly difficult to show if you have rank orders, 1, 2, 3, 4, and you average rank orders, you can see that that's an approximation to this kind of a solution and the Hare system of voting is another illustration of an approximation to a social choice function, decision function, which minimizes dissatisfaction and arrives at a least dis-liked.

I don't know how it is in the organizations that you belong to but in the American Psychological Association when we elect a president we use essentially the Hare system for selecting our president and the president we arrive at then among the various candidates is not in some sense the most preferred but the one that's least disliked. Nasty way to look at things.

If I bring this back to the subject of this conference on the human being in an automatized world we would say something like probably someday one of your companies would be constructing little family computers and the members of the family would step up to the computer and say, "I like it C, B, D, A." And each member of the family would do this; the computer then would go through the process of unfolding, find out what the latent attribute was, where the median individual was and put back on a little tape to the family, "Go to Movie B."

INTRODUCTION - Harry H. Goode

The next paper is under the joint authorship of Professor Herbert Paper of Near Eastern Studies and Professor Gordon E. Peterson of the Speech Department. Professor Paper will give you the paper and will talk on "Information and Human Language."

INFORMATION AND HUMAN LANGUAGE

Herbert H. Paper
Assistant Professor of Near Eastern Studies

Gordon E. Peterson
Professor of Speech

Today the development of complex automatic control systems is an accomplished fact. The techniques of feedback and servo-system design are well developed and have found many important applications. The time has come when instruments are being developed to perform many complex operations previously requiring a human operator, and interests in automation are developing rapidly. We have learned that machines can do, sometimes even better or more reliably, some of the things that man has been doing with his hands.

But can machines do what man has done with his mind? Here again, we have found that computers can do, sometimes better, or more reliably, and certainly faster, some of the things which man has previously done with his brain. Can computers be designed and programmed to learn some of the complicated things that man can learn? and solve some of the complicated problems which he can solve? We now believe that they can, but we are only at the threshold of the development of systems which can simulate the more complex operations of the human mind - at the threshold of the development of automata in the broad sense of the term.

These electronic brains must have inputs and outputs suited to the environment in which they work; they must have some equivalent of man's sensory and motor systems; they must be able to deal with the delicate and refined variations in optical and acoustical patterns to which man can respond.

But most important and most difficult of all, these systems must be able to deal with language - not merely with simple, discrete codes, but with the enormously complex code known as human language. For automata must operate and serve within human cultures where both spoken and written languages dominate much of man's existence. The cultural and technological development which we know and take for granted is inconceivable without a long heritage of written records. It would be difficult to estimate the amount of our national effort which is devoted to the transmission and storage of spoken and written language (libraries, secretaries, telegraph, printing, telephone, recording, etc.). Even in those cultures that are primitive from a technological point of view we find highly developed systems of spoken language all of which are amenable to being converted to written forms. And following the work of Benjamin

Lee Whorf and others, there is some evidence that language in part dominates our beliefs, our attitudes, and our thought processes.

This report is primarily concerned with the nature of the language processes and with the problems involved in human language automation.

In order to identify these various processes, let us examine Slide 1. At the center of this figure is shown a very crude schematic of the primary sensory and motor mechanisms involved in language for one individual (individual number 2). At the left the two E's stand for an eye and ear, B is for brain, and the H and M are for the motor mechanisms, hand and mouth. What one says, he also hears, of course, and what he does with his hands he may see. These feedback paths are shown by dashed lines in the figure; they are of very great importance in human behavior, including language production. The importance of the oral-aural feedback path has been illustrated by having an individual speak into a magnetic tape recorder while wearing earphones which return his speech to his ears with the delay of the record-reproduce process. The result is often a violent disturbance of the speech production. It has been shown that this disturbance on the average is at a maximum in the range of 0.02 second, which is obviously related to the delay time around the closed loop through the Brain.

At the left in the figure are indicated the motor mechanisms of primary interest in communication for individual number 1, and at the right of the figure are indicated the sensory mechanisms of primary interest for individual number 3. We may consider individual number 1 as the initiator of the message and individual number 3 as the recipient of the message.

Individual number 2 can perform some very interesting functions when interposed in the communications path as shown in the diagram. If individual number 1 initiates the message in the spoken form, individual number 2 may repeat it in the spoken form; more importantly, he may transform the speech signal, which is composed essentially of continuous parameters, into an orthographic (or printed) discrete code. In a similar manner, he may copy an orthographic signal created by individual number 1, or he may transform it into continuous speech.

Machines which could perform these two language transformations (speech-to-orthography and orthography-to-speech) would have many important applications. Extensive research is now in progress on the basic problems involved in each of these transformations and various preliminary instruments have been constructed. It does not seem unreasonable to anticipate that practical devices may be developed within the next one or two decades.

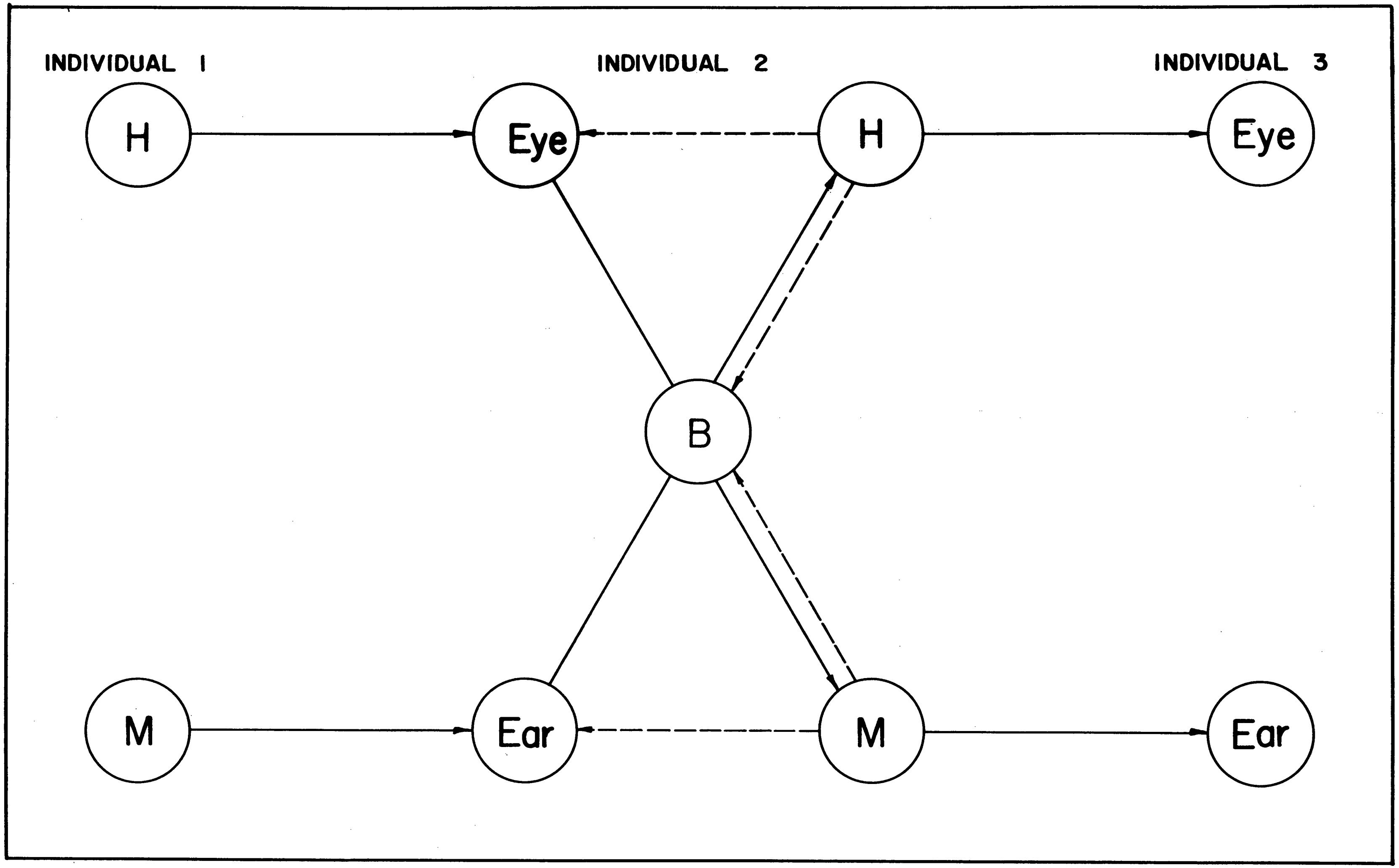


Figure 1

A communications diagram for three individuals.

E - Eye and Ear
B - Brain
H - Hand
M - Mouth

Let us consider the basic nature of the pathways indicated in Slide 1. It is obvious that they differ tremendously in nature and complexity. It was not until Shannon developed a fundamental theory of information that we had a means of comparing the capacity of these channels. In this theory, information about a system is defined in terms of the number of possible physical states of the system. The quantity of information involved in the occurrence of some one state, as the appearance of a specific symbol within a given code, is defined in terms of the number of binary choices necessary to select the symbol.

Under uniform conditions of transmission and reception, an efficient code is one having all states equally probable and independent of each other in occurrence. None of the components of speech, however, are equally probable. The wave forms, the individual speech sounds, the syllables and words all have certain individual frequencies of occurrence and they are influenced by what precedes and what follows. The difference between the amount of information transmitted if all conditions of the code were equally probable and the information transmitted when the code has more complex statistical properties may be defined as the redundancy. There are many ways in which to illustrate this redundancy; the method we have chosen involves an electronic gate which turns the speech off 50% of the time. This process is illustrated in Slide 2. In the top pattern is shown a continuous speech signal; in the second pattern is shown the gate function; and in the third pattern is shown the interrupted speech.

In the speech which you are to hear the interruption rate is 50 times per second, and the speech is on just one-half of each period. This speech is not 50% intelligible, however, but is easily understood. In tests with isolated monosyllables, subjects can understand over 90% of the words under these conditions of switching.

It seems that human language is a code which operates with a redundancy of about 50%. It must not be concluded from this fact, however, that human languages are inefficient. We might better conclude that large amounts of redundancy are essential to effective communication under the great variety of complex conditions to which human languages is subjected. It is not improbable that human language involves a practical balance between needed redundancy and the desire for minimum time and effort in communication under relatively favorable conditions.

The linguist finds that he can analyze human language into an interrelated set of basic components on various levels. Every human language has a unique set of these basic components. The relationships of these components within each language are often exceedingly complex.

Let us start with an acoustical analysis of speech into its various properties. The analyses of the sentence shown in Slide 3 were made with a sound spectrograph which is a signal analyzer now commonly used in the study of speech. The spectrogram at the bottom of the figure

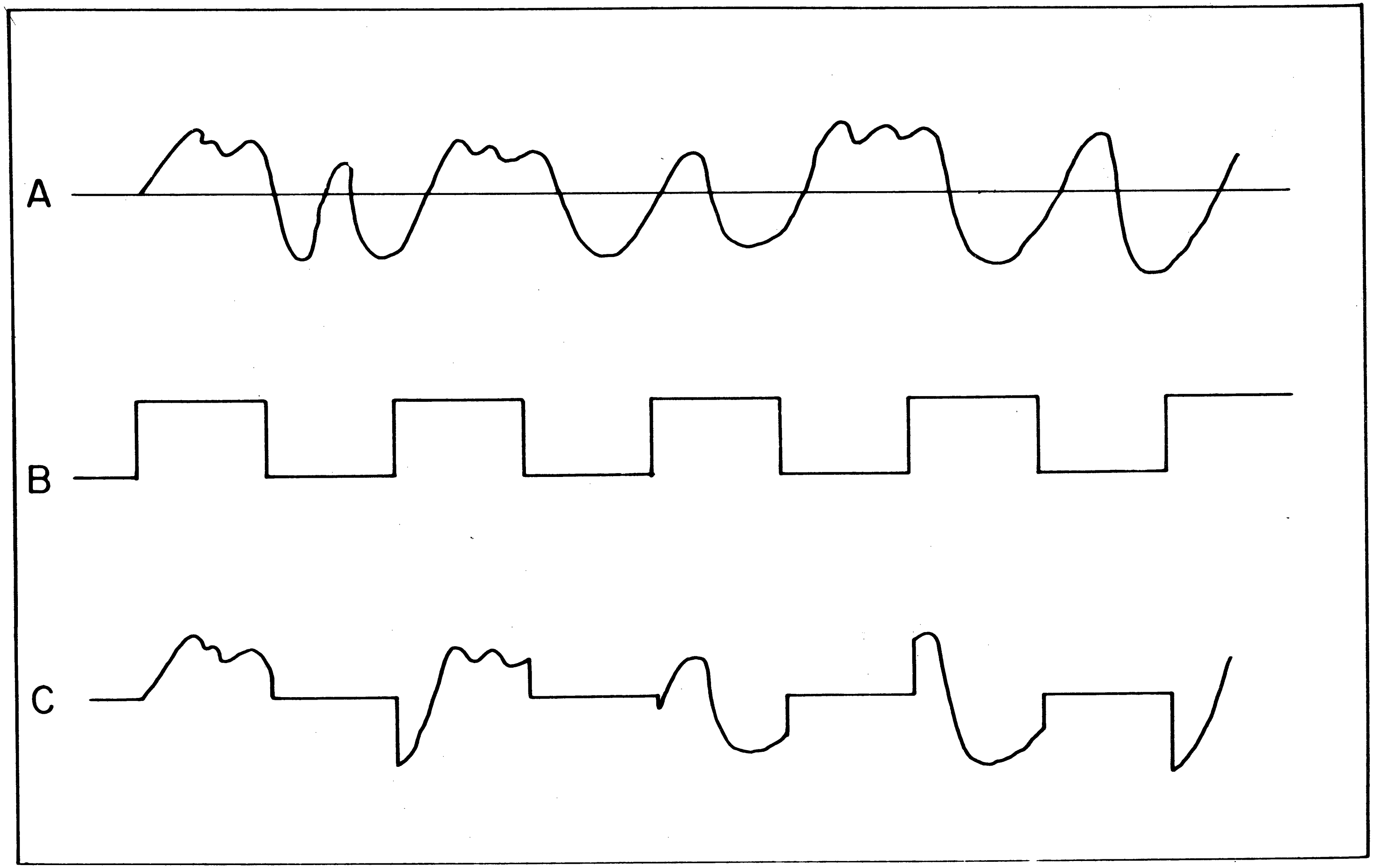


Figure 2

Interrupted speech.

A. Continuous speech wave
B. Gate function
C. Interrupted speech wave

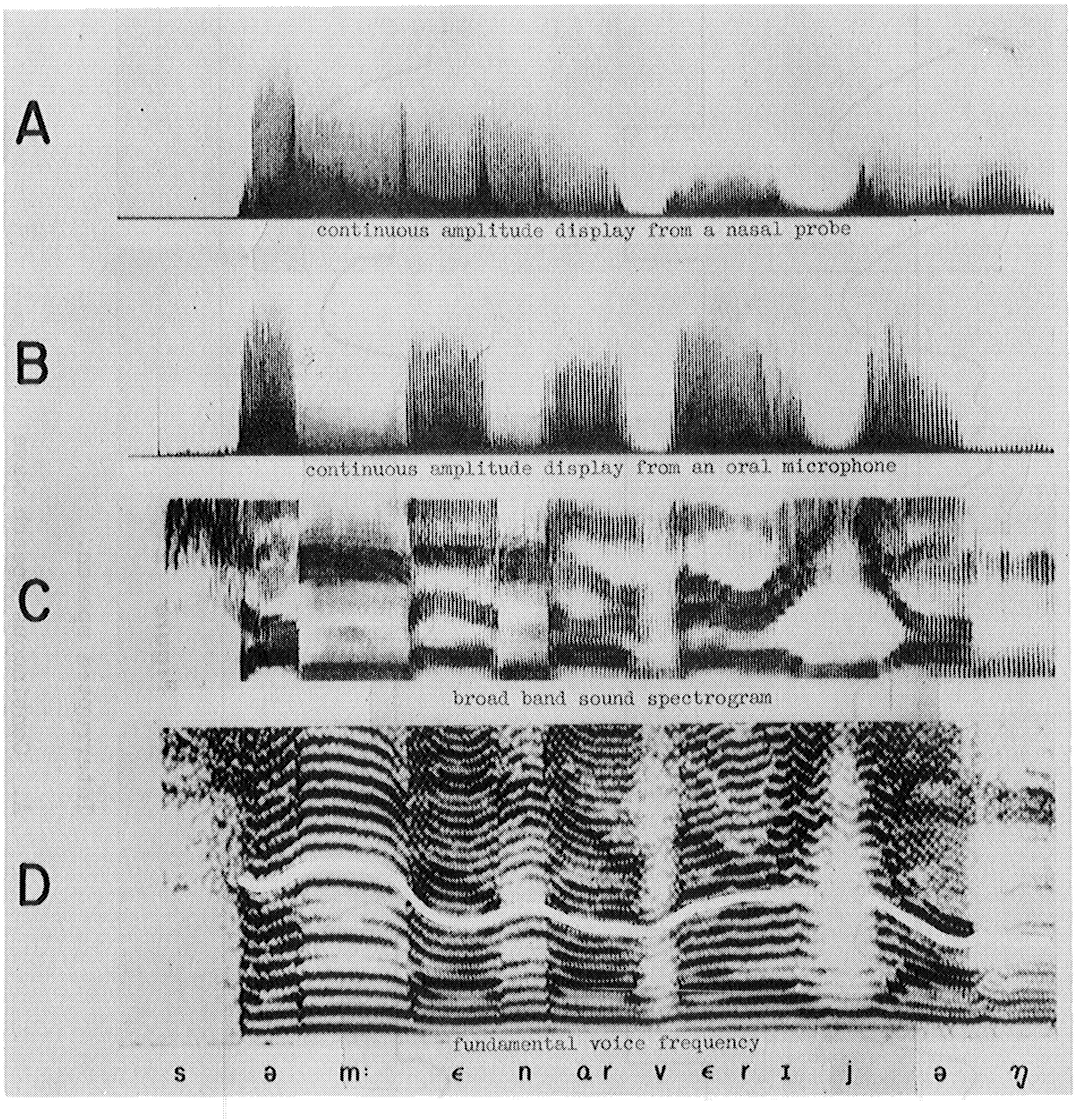


Figure 3

Spectrographic analysis of the sentence: "Some men are very young."

is constructed with a narrow analyzing filter so that the individual harmonics of the voice are displayed. The trace of the tenth harmonic shows the pattern of the fundamental voice frequency. It is the graph of this frequency which primarily depicts our perception of vocal pitch. The next, somewhat more complicated, pattern of random striations, gaps, and heavy black bands is a sound spectrogram with a vertical scale of frequency from zero to approximately 3500 cycles per second. Time is shown along the horizontal axis for each of these four patterns, and in the slide it extends for about two seconds. This spectrum analysis primarily reflects the articulatory movements for the vowels and consonants of spoken English. The third pattern from the bottom, on the same time scale, shows an overall amplitude trace of the speech. The vertical scale here is approximately linear, so that this pattern is essentially what one would see on a cathode-ray oscilloscope with a slow sweep and the lower half of the wave inverted and superimposed on the upper half. The top pattern is a similar amplitude representation from a probe tube microphone placed in the nose as the sentence was spoken.

It will be noted at once that there are essentially no discrete acoustical sounds in speech. The continuously changing characteristics of most of the patterns in Slide 3 are very conspicuous. In order to indicate further the continuous nature of speech, Slide 4 was prepared. In this slide are shown broadband sound spectrograms, along with corresponding traces from narrow band sound spectrograms for the fundamental voice frequency. In the upper spectrogram, analysis of a normal utterance is shown with time along the horizontal axis and frequency on the vertical axis. For the lower spectrogram, discrete sounds which represented the isolated elements of the continuous speech were recorded individually. As the speaker produced the isolated segments he listened to the normal utterance and attempted to imitate the phonetic qualities and the vocal pitches which he heard. The isolated elements were then connected together to form a continuous tape and the result can be heard in the following recording.

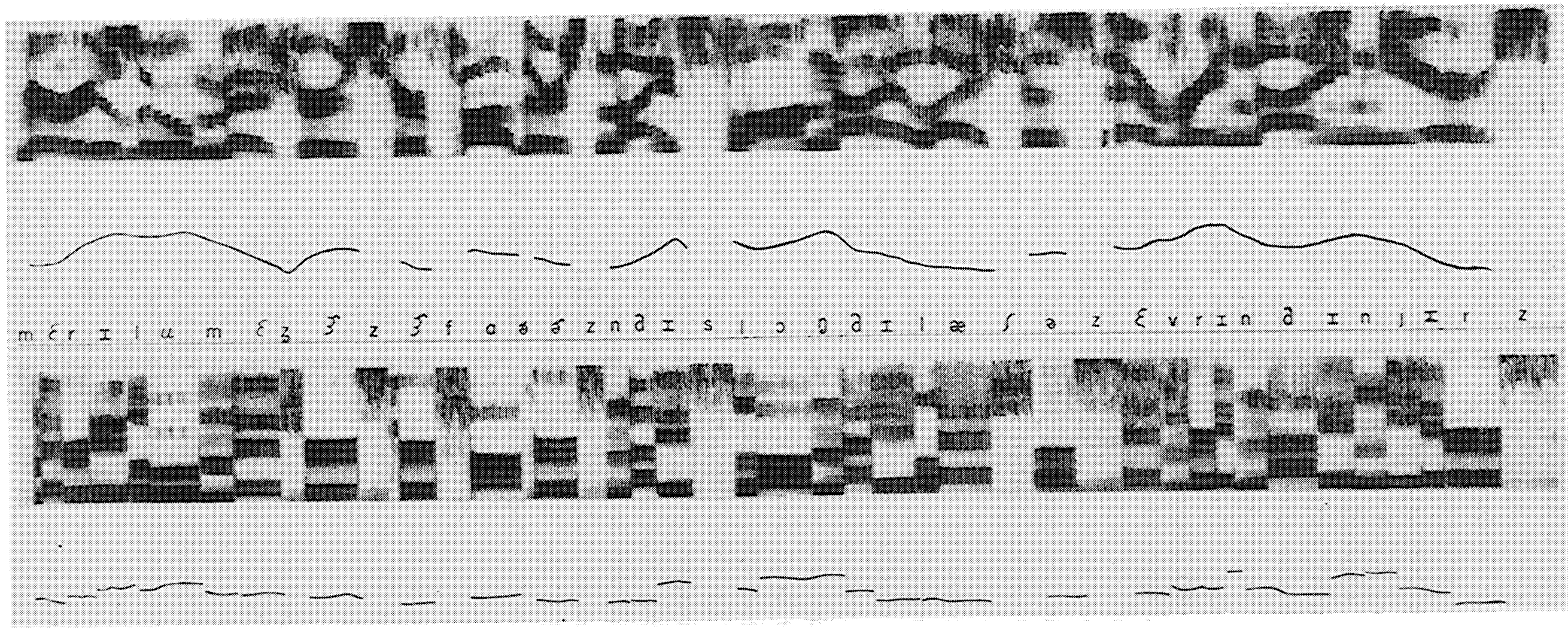
When we compare the dynamic nature of the upper pattern with the broken or blocked-like patterns in the lower figure, it is not surprising that the synthesized utterance is not highly intelligible.

Speech synthesizers have been constructed, however, which make it possible to insert the dynamic or moving aspects of the speech pattern. Such a synthesizer was constructed by Walter Lawrence of the Signals Research and Development Establishment of Christchurch, England. The magnetic tape recording was made of the output of this instrument.

In listening to continuous speech, the linguist is able to analyze it into a complicated discrete code. A suggestion of how the variables of Slide 3 constribute to this code is given in Slide 5. In

Upper spectrogram: Broad band sound spectrogram of normal speed.

Upper trace: Fundamental voice frequency of the same utterance.



Lower spectrogram: Broad band sound spectrogram of synthesized speech.

Lower trace: Fundamental voice frequency of the synthesized speech.

Figure 4

The continuous nature of speech illustrated with the sentence: "Mary Lou measures her father's nice long eyelashes every nine years."

this figure three levels of oral language structure are indicated. At the left are represented the physiological mechanisms of speech, as previously referred to in Slide 1. The fact that the deaf can lipread, or that we often understand better when watching the speaker's face is ample evidence that a listener may derive information from a direct observation of the positions and movements of the vocal apparatus as well as from its acoustical transformation. In the center of Slide 6 are indicated the basic linguistic elements of language. The recognition of the nature of these elements has been one of the greatest advances in the analysis of language structure. They may be defined as mutually contrastive classes of speech signals. Within a given class the individual signals do not contrast. The individual occurrences of these signals are effected by what precedes and by what follows, however, so that the elements of the class are environmentally conditioned. The signals are classified differently, of course, in different languages. The basic elements are sometimes popularly called "speech sounds"; in the terminology of the linguist they are called "phonemes".

A phoneme may be considered as a class of signals within some interval (t_2-t_1) which is contrasted in human judgment with other signals over an interval of similar duration within a particular language.

It should be noted that the phoneme does not have meaning in the sense that words and sentences do. At these higher levels, the linguist finds more basic patterns of morphology and syntax. These structures also involve mutually contrastive classes, but these more complex patterns have a semantic significance associated with them. Slide 6 should not be interpreted as showing a sequence from the production to the perception of speech. The components of phonemes and morphemes are as much characteristics of the encoder as of the decoder; otherwise no communication would occur. Rather the figure shows different properties of the code and degrees of generalization or abstraction. (In general, second order relationships are not indicated in the figure.)

The acoustical signal is essentially continuous over short intervals of time. At the level of the phoneme, the linguist employs discrete notations. In the production and interpretation of speech the phonemes are combined to form the meaning-bearing symbols of language. Both the phonemes and the morphenes may be identified as classes of environmentally conditioned, non-contrastive elements. By environmentally conditioned, we mean primarily that the components are affected by other components preceding and following in time. By non-contrastive, we mean that functionally they serve the same purpose and elicit the same human reaction.

In the communications diagram of Slide 1, individual number 2 cannot only convert the form of the message, but he can also translate

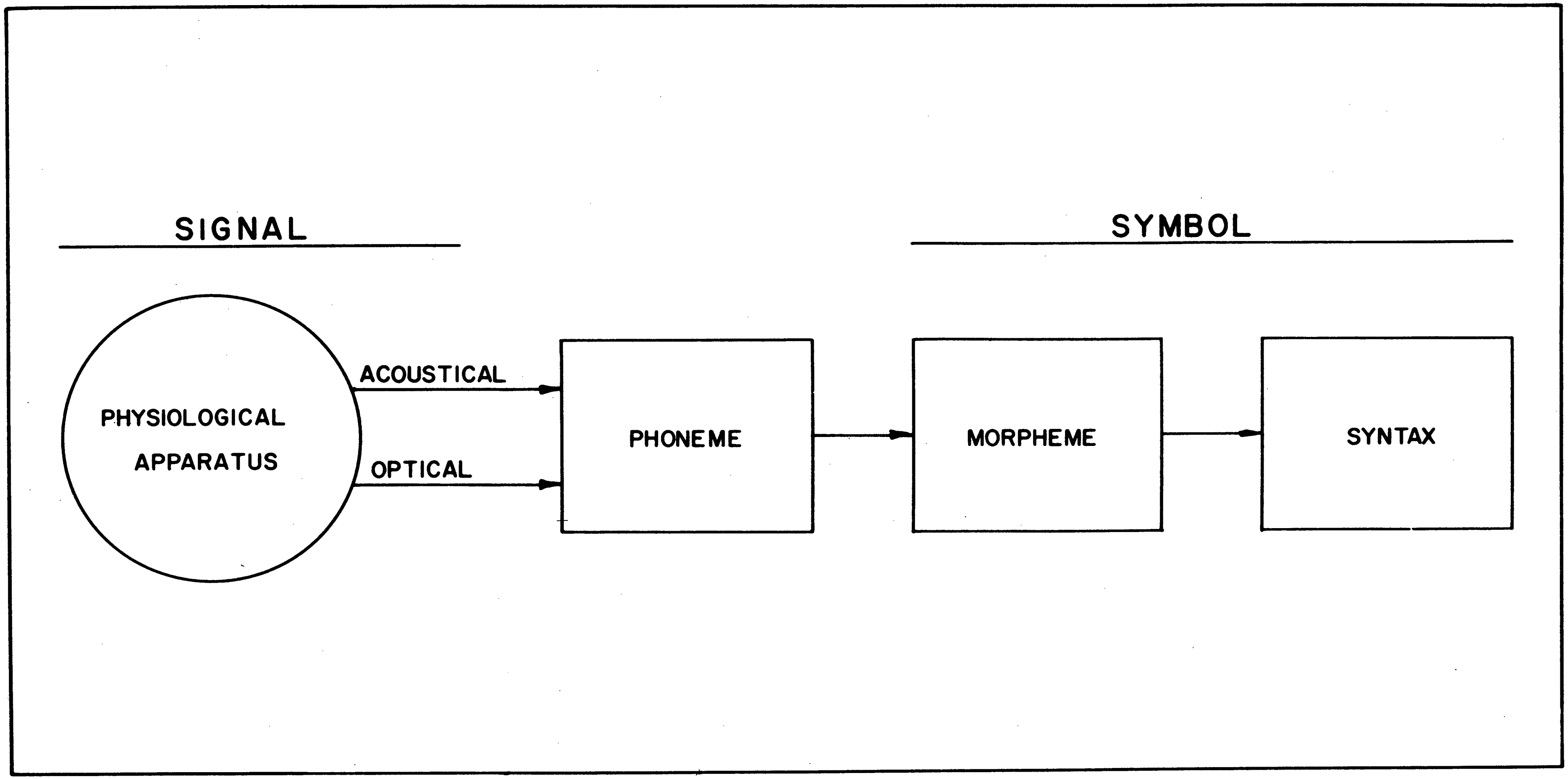


Figure 5

The basic structure of spoken language.

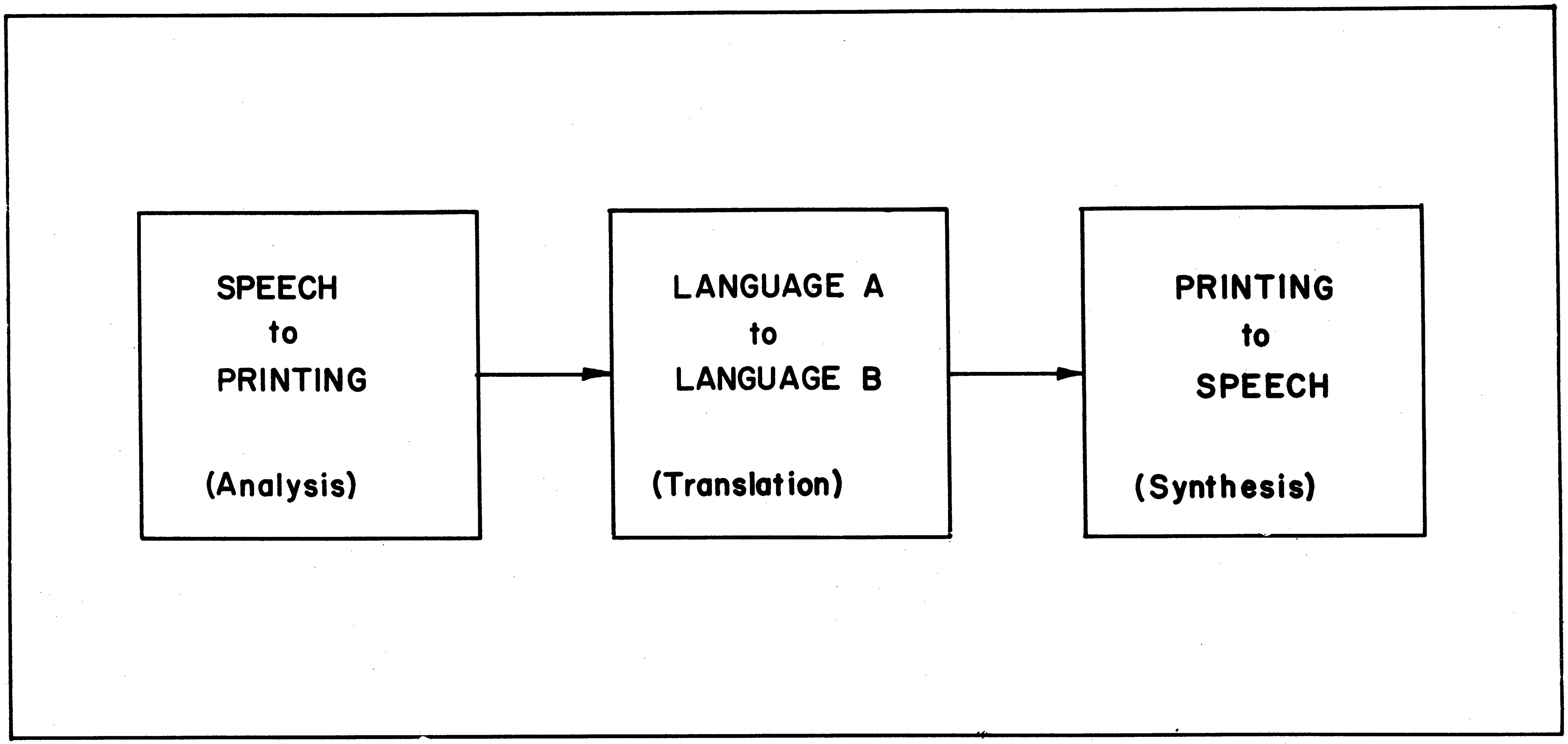


Figure 6

The processes of oral-aural mechanical translation.

it into another language. He can also both translate and transform, so that a message which is initiated in either the spoken or the written form may be transmitted in a different language in either the spoken or written form.

Work in language tranlation by machine has thus far been concerned primarily with printed forms. A complete oral-aural translating machine from one language to another is much more formidable. The basic operations are indicated in Slide 6. Essentially, three basic highly complex processes would be involved; first, the conversion from spoken input to printed output; second, a mechanical translation from the printed output of step 1 (which now becomes the input for step 2) to a printed output in a different language; and third, the synthesis of speech from the printed form of the new language. We will leave to the imagination a time schedule for the development of such complete linguistic automata.

At the present time research is in progress by several groups throughout the United States and Europe on mechanical translation. There are three basic methods under investigation.

1. The first method is essentially empirical in nature. With this method a very limited text is translated from one language to another, and the detailed procedures for making the conversion are recorded. As new text is gradually added, the expressed procedures are modified and expanded accordingly. In this way one might expect eventually to arrive at a stage where it would be unnecessary to add further procedures for converting from one language to another.

2. The second general approach involves the use of an intermediate or special language of some type into which and from which all translations are made. This method would reduce the number of translation systems necessary when it is desired to have several languages mutually convertible.

3. The third general method involves more restricted materials. The theory which underlies this method considers human language to be closely related to culture in the sense of the anthropologist. Each language is considered to present a special cultural analysis of the physical world and of human relationships. In addition each language has its own structural form. Thus the mapping of one language into another is considered to be a very complicated process and direct matching of linguistic structures for any particular pair of languages is considered most effective. Relationships between the cultures and relationships between the two linguistic structures are studied and rules for the conversion of one to the other are derived. It should be noted that there is a special complexity to language translation -- for not only must the two linguistic

structures be described, but also the distribution or occurrence of each element (as a word) within the structure must be determined and stored so that it can be properly translated.

Let us summarize briefly: In the automatic conversion of speech to orthography, we are primarily concerned with the transformation of the relatively continuous parameters of speech to the discrete components of written language. The simplest transformation is the conversion from the speech signal to the basic discrete linguistic elements: phonemes and morphemes. Complex computing apparatus would be required to convert these to conventional orthography; letters, words, and punctuation marks. Thus far progress in automatic speech recognition and in machine translation is in a very preliminary stage. At present there have been approximately four different instruments constructed which are able to recognize a limited number of phonemes and syllables or words.

Linguists are at present engaged in the laborious task of analyzing certain languages in very great detail so that computer programs may be prepared for their translation. In the process of learning to program machines for linguistic research, it is expected that much detailed information about language structures will be developed.

We may conclude by saying that much theoretical development and basic research is in progress which will contribute to language automation. It appears that we may have to look very far into the future, however, to find automata that can follow complex spoken instructions. It does not appear that we will ever be relieved of the necessity of learning languages and of knowing -- as human beings -- how to use these languages effectively. We see at least no immediate threat that machines will be dictating the instructions for man to follow!

INTRODUCTION - Harry H. Goode

The next paper was prepared by W. P. Tanner, a research psychologist, and T. G. Birdsall, a research mathematician. These gentlemen have for some time been working in our Engineering Research Institute, doing research on the human's ability to detect and recognize signals. This paper is entitled "Signal Detection", and will be presented by Mr. Birdsall.

SIGNAL DETECTION

Theodore Birdsall
Associate Research Mathematician

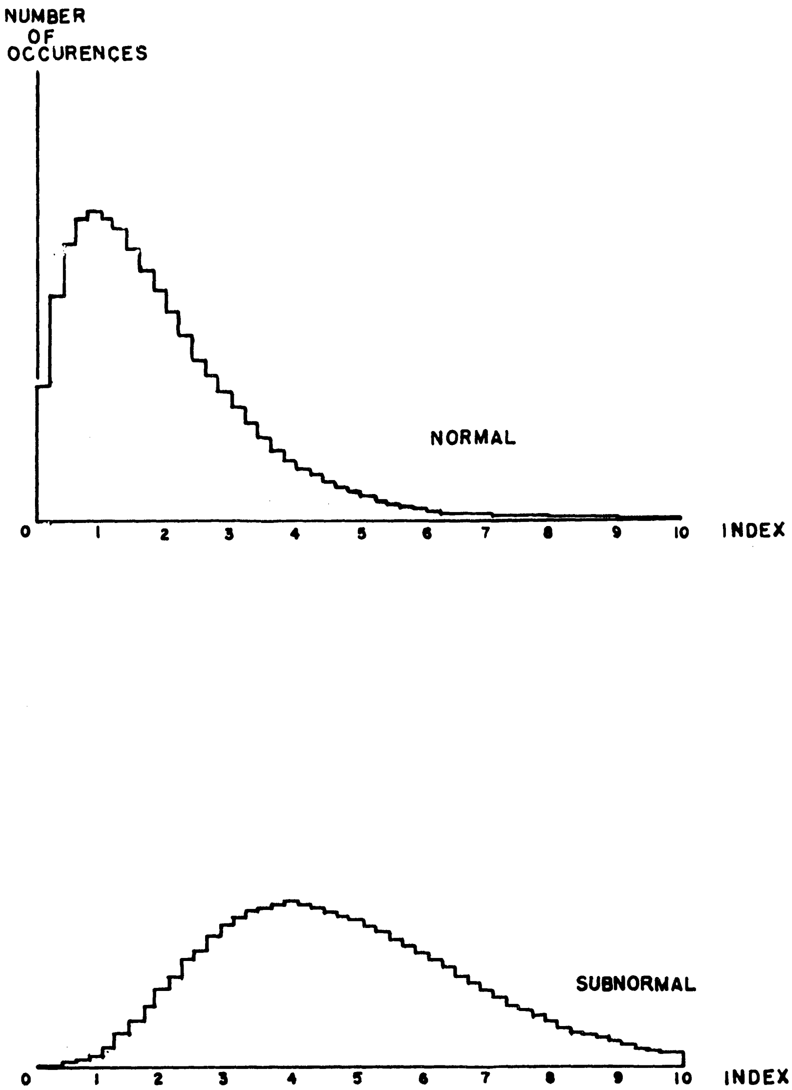
Wilson P. Tanner, Jr.
Associate Research Psychologist

I. Decision

I would like to clarify and expand on the title of this talk, "Signal Detection." The experimental work has been primarily devoted to the detection of signals, either small signals, or somewhat larger signals in added noise. The detection of a signal is actually the decision by a human observer that a specific auditory or visual signal was or was not present. Hence the theoretical work that is the framework and guide to this experimental work is decision theory.

To establish a firmer common ground with you, I would like to discuss a simple decision process that is done consciously. The example is one from quality control. Suppose that a certain quality control laboratory takes a sample of fifteen parts produced by an automatic machine; the parts are taken back to the laboratory and compared to a standard. The control group repeats this process periodically, in order to determine whether the machine is due to break down or put faulty parts into the production system in the near future. If the sample of fifteen parts deviate sufficiently from standard, a maintenance crew will be alerted to check the machine more thoroughly. The quality control group uses a test that they have experience with and they arrive at an index, or a number, based on the fifteen units tested.

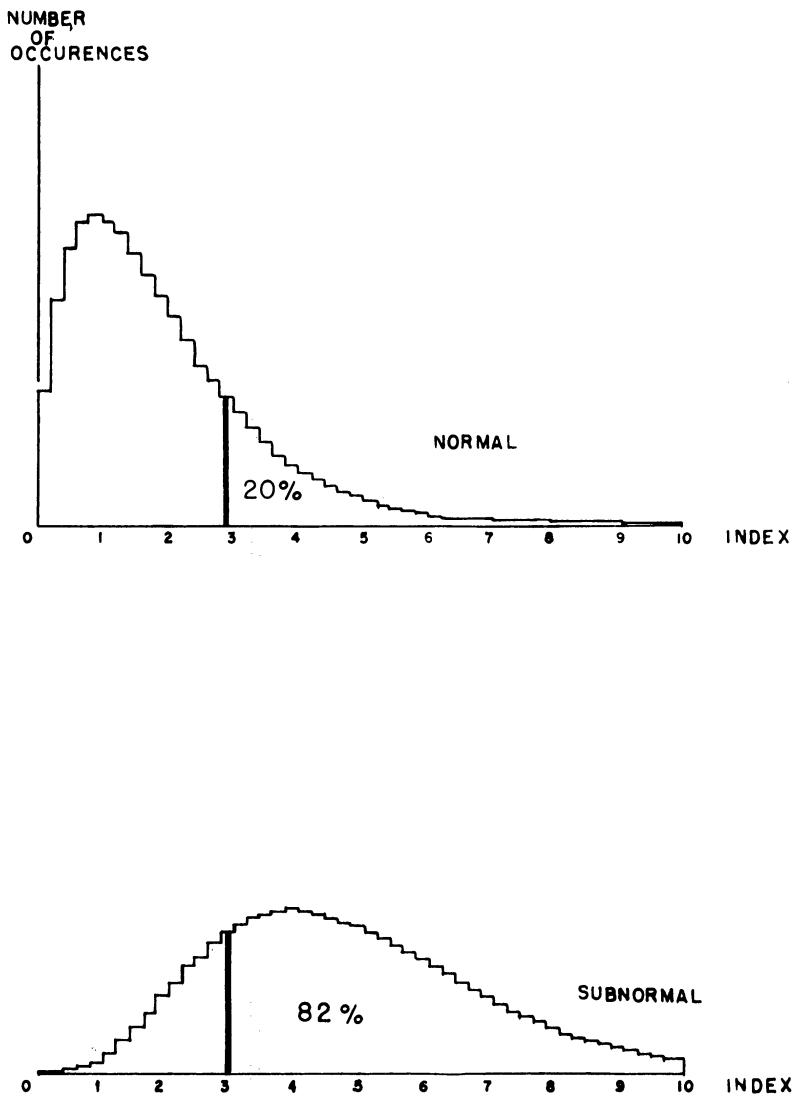
On slide one are shown two bar graphs; the upper shows the relative frequency of occurrence in the past of different indexes that have been given to machines that were normal and were not in need of overhaul or repair. The index numbers vary quite a bit, for the test is very complex. The important thing is that this curve is the distribution of relative frequency of occurrences of different indexes when the machines were normal. The lower curve is a similar distribution of indexes recorded from machines which have required repair soon after sample lots were taken. For these sub-normal machines the index is generally higher, although in individual cases the index may be quite low.



Slide 1

The action that the quality control group has to take is not simply to report the index, but to reach a decision: to alert the maintenance crew, interrupt production, check the machines, or not to alert the crew. In my hypothetical example, this index I have been discussing is assumed to be the most sensitive index of the condition of the machine-higher indexes generally meaning sub-normal machines. A consistent basis for a decision is "to draw the line" through some critical value of the index. Any sample lot leading to a higher index will cause the maintenance crew to be alerted for that machine.

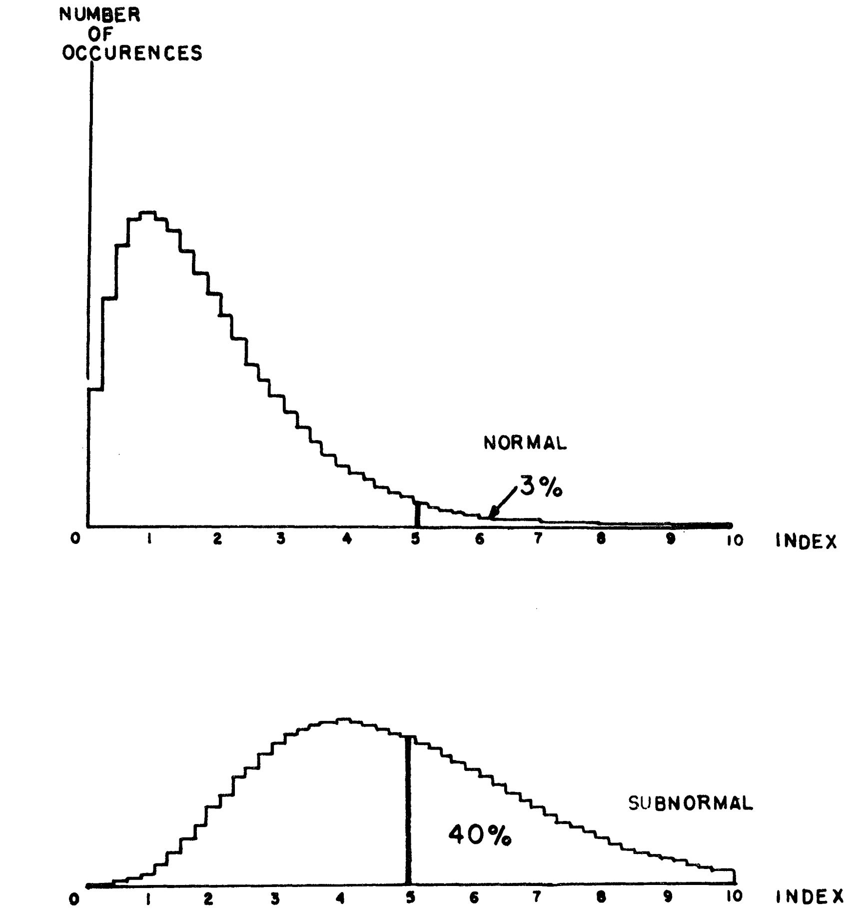
This is illustrated in slide two. A critical index of 3 is shown. Eighty-two percent of the indexes from sub-normal machines fall above index 3, and so it can be expected that eighty-two percent of the time sub-normal machines will be called to the attention of the maintenance crews <u>before</u> these machines have broken down or have produced



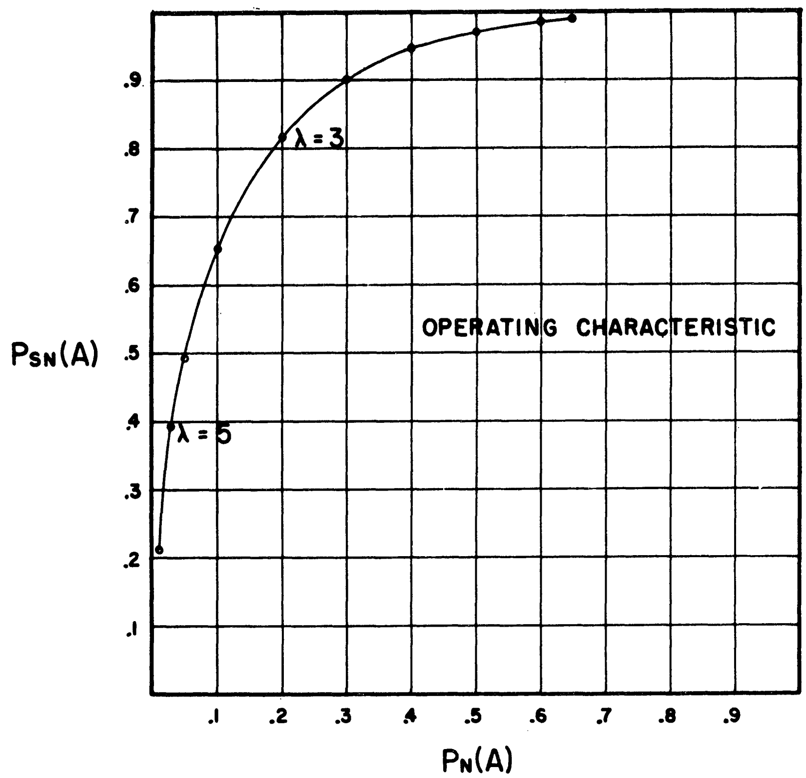
Slide 2

faulty parts. On the other hand, twenty percent of the time a normal machine is tested, a crew will also be alerted, these false alerts adding extra cost and no savings.

If the critical index is raised to reduce this value of twenty percent of false alerts to some more reasonable figure, the result is shown in slide three. The index has been raised to 5. The maintenance crew is now alerted only three percent of the time when the machine is normal. When the machine is sub-normal they are alerted forty percent of the time. This forty percent compares to eighty-two percent in the previous case. So it is seen that in this quality control where there is a spread, a distribution, or a smearing out of the basis for decision, a compromise must be reached. This relation is totally summarized in the fourth slide.



Slide 3



Detection of a Subnormal Product

Slide 4

Relative probabilities or relative frequencies are plotted against each other in this slide. This is called an "ROC" curve or "Receiver Operating Characteristic." (The name is not used in quality control, but is taken from its use in signal detection in the reception and detection of signals.) Slides two and three are each a point on this curve. The eighty-two percent alerts when the machine was sub-normal is plotted above the twenty percent alerts on normal machines. The somewhat lower forty percent alerts on sub-normal machines are plotted above the point three percent false alerts which corresponded to it. Each point on the curve represents a different possible critical index in which to "draw the line" between alerts and non-alerts. The operating characteristic summarizes all these possible critical indexes. Using this, knowing values and cost that will result from correct or false decisions, and a knowledge of the relative frequency of sub-normal machines in this plant in the past, the quality control group can choose the best critical value. As an aside, they will actually look at the slope of the receiver operating characteristic, to determine the point at which the cost of added false alerts will just off-set the savings from the corresponding amount of additional correct alerts.

This has been an example of a conscious decision process. I would like to emphasize several points. In this situation of quality control, the basis for decision was not clean-cut, but was distributed. A clean-cut decision was reached by choosing a specific critical index. The performance of this whole decision process is summed up by the receiver operating characteristic for the detection of sub-normal machines.

I would like to conclude this example by considering another member of this company, who wishes to understand and evaluate the effectiveness of the quality control group without studying in detail their basis for decision. He keeps track of the test that they use to arrive at the index, and the way that they choose the critical index and also keeps records of the actual decisions, whether they proved to be right or wrong, and the net value of this process of detecting sub-normal machines.

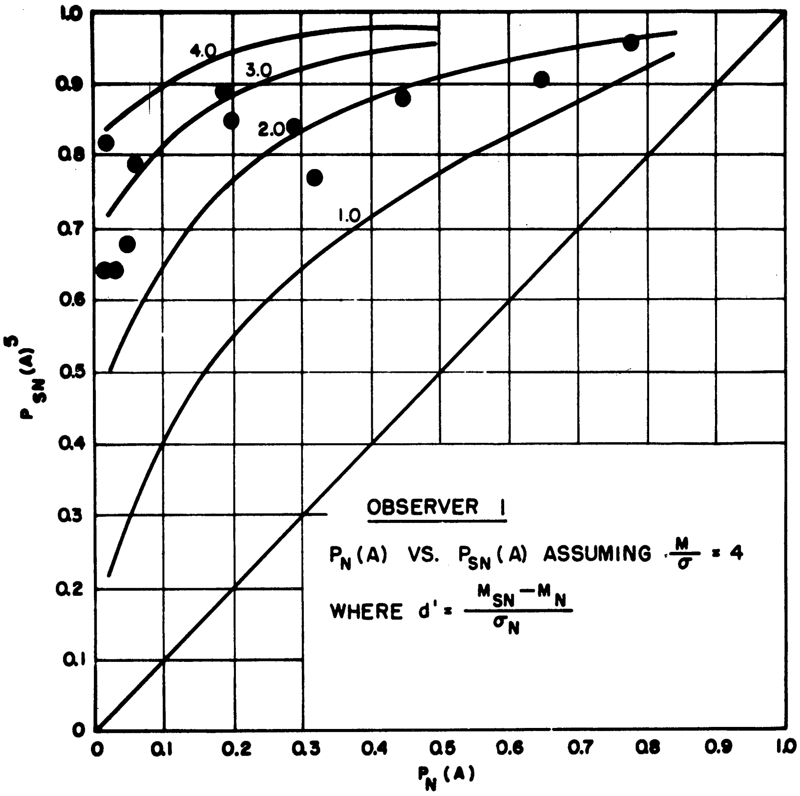
By observing repeated decisions, he can observe: the relative number of sub-normal machines detected, and the relative number of false alerts arrived at from a single operating point. As the costs of maintenance or the necessity of detection change, he can observe the shift in the operating point, and obtain a picture of the entire operating characteristic. Secondly, he can determine if the changes in operating point were the proper ones to meet the changing savings and costs. Lastly, if a better or best set of tests is devised forming an improved basis for decision, by comparing operating characteristics he can determine the efficiency of the old basis for decision compared to the new basis.

In our work with the human observer we cannot determine his basis for decision directly. We therefore followed the same three steps of the outside observer of the quality control group: First, determine the operating characteristic for human observers for many types of simple signals. Secondly, determine the ability of the human to shift his operation to his own advantage in the face of changing values and costs. Thirdly, in situations where a best basis for decision can be determined mathematically, determine the efficiency of the human as compared to the best.

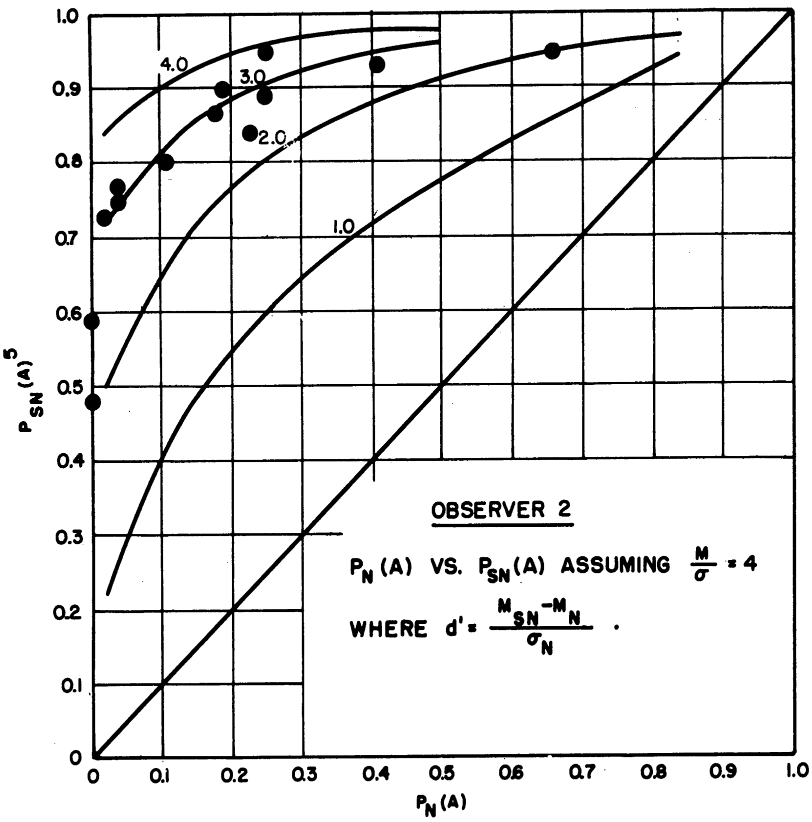
II. The Receiver Operating Characteristic as a Description of Human Performance

I would like to turn now to the experimental work where the receiver operating characteristic is used as a description of human performance. This first series of experimental work that I will briefly describe were vision experiments where a signal is a short flash of light on a uniform white background. These experiments were to determine what the relation was between false alerts and correct detection and how the human observer made use of this relation. It should be remembered of course that the observers in these experiments were not informed of the desire of the experimenter to determine such a relation, but were motivated in several different ways which I will explain in a moment. The first experiment was to instruct the observers to report whether they saw or heard a signal as the case may be without further explanation of how they were to do this. This established a single point on the operating characteristic curve for each observer. The observers were then encouraged by instruction to answer more frequently or to answer less frequently, and they did indeed, and when they answered less frequently they answered both less frequently when there was no signal and less frequently when there was a signal, as would be expected. In this way several points were determined for each observer.

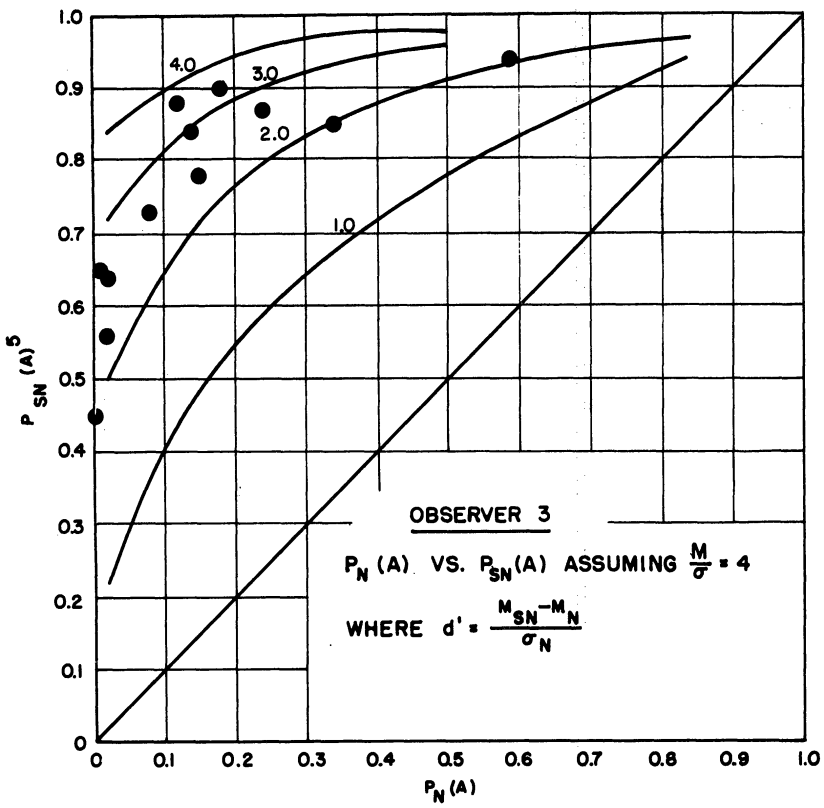
The next four slides each show about a dozen operating points; each slide is for a different observer. The solid curves marked 1, 2, 3, and 4 refer to theoretical operating characteristics. These slides are used because they will show the range of conclusions that can be drawn. Slide 5, for the first observer, shows considerable scatter in the data, and none of the curves drawn show a good fit. Thus this observer was not using a basis for decision like that implied by the curves, and was probably not using a consistent basis for decision throughout the experiment. (The data was collected two hours a day for 3 to 6 days.) Slide 6 shows a much different picture, with less scatter and a good fit to the curve labeled "3". Thus the second observer could be described as having the operating characteristic labeled "3". The third observer, slide 7, shows about the same degree of scatter, but is not fit well by the theoretical curves, while the fourth observer, slide 8, scatters about the curve labeled "2".



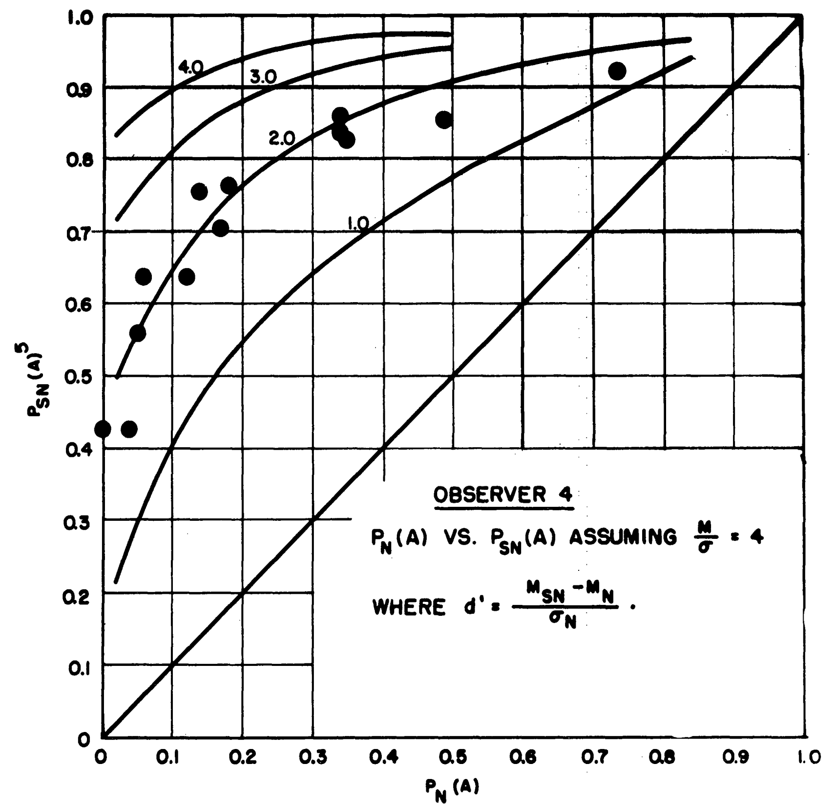
Slide 5



Slide 6

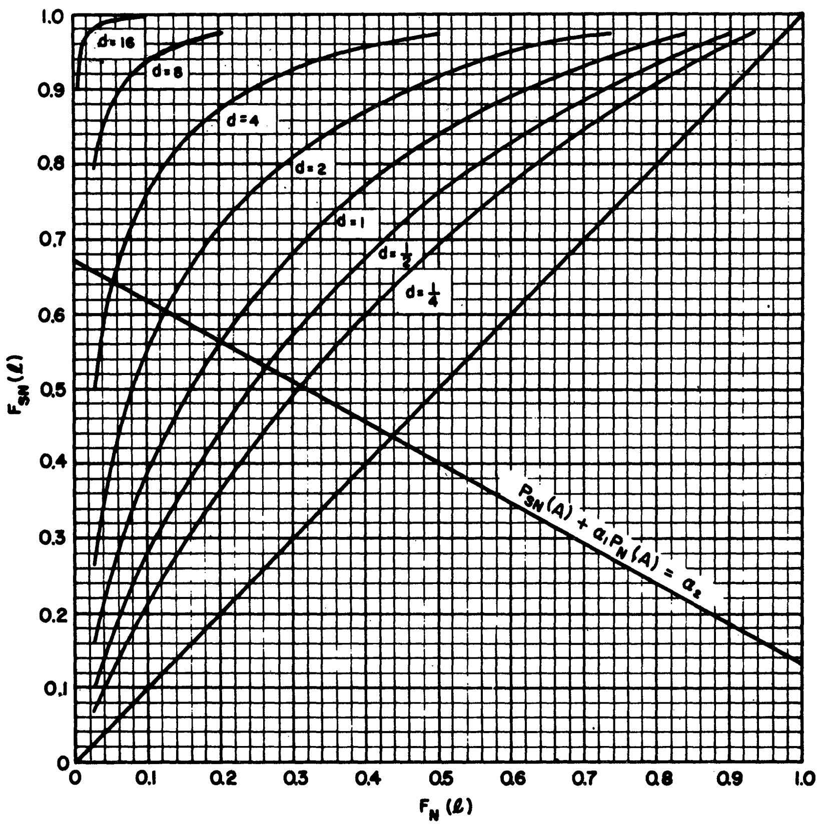


Slide 7



Slide 8

I do not have any of the auditory receiver operating characteristics on slides. The detection job of the observer in audition is to detect the presence of a pulse of a known frequency, such as 1000 cycles per second, in a background of wide noise. The operating characteristics for trained observers show less scatter than in vision, and fit the normal operating characteristic curve of slide 9 so closely that only the index on the curve is recorded and used in subsequent slides.



RECEIVER OPERATING CHARACTERISTIC.
WITH GAME SOLUTION FOR $a_1 = .53$, $a_2 = .67$
($\ell n\ \ell$ IS A NORMAL DEVIATE WITH $\sigma_N^2 = \sigma_{SN}^2$, $(M_{SN} - M_N)^2 = d\ \sigma_N^2$)

Slide 9

Now it has been established that the human observer in two types of simple detection tasks can be said to be operating along a curved operating characteristic. It was desirable to determine if he could use this ability to vary in frequency of response to his own profit. To this end, the observers were set up on a bonus or incentive system. The observers were told the relative frequency of occurrence of the signals in the test, for example there will be a signal in twenty-five percent of the presentation, or more commonly there will be a signal in half of the presentation. In addition, he was told the monetary bonus for the two different correct responses, no response when there was no signal and a detection response when there was a signal. For example a detection of a signal might be worth three cents, while a correct response when there was no signal would be worth one cent. It was customary in these experiments for simplicity to weight the errors zero. Since the experimenter knew the observer's operating characteristic which he had displayed in the previous experiment, he could determine from the characteristic what would be the most profitable operating point for the observer, and how much bonus he could expect to make. The maximum bonus that could be made by each observer was compared with the actual bonus that he received for that experiment. The results can be summarized rather simply. The observers tended very much in the direction that they should have gone in order to obtain a maximum bonus. They would not operate exactly on the expected point, but their bonus was within five percent of the maximum bonus that the observer could earn.

In summary it can be said that in the detection of simple visual and auditory signals most human observers had consistent receiver operating characteristic curves, that they could move the operating point, and do so for their own profit.

III. The Efficiency of the Human Observer in Situations in which an Optimum Exists

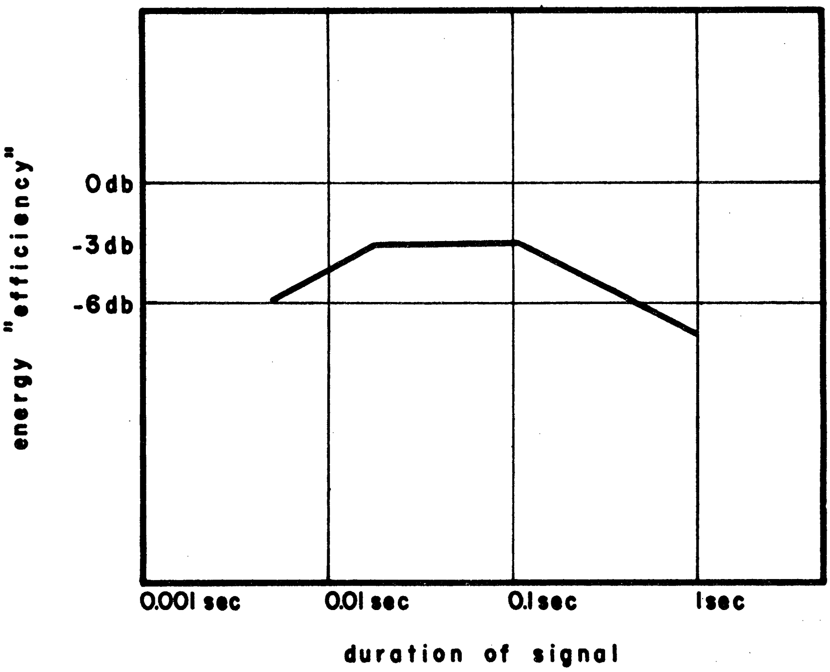
We are all familiar with the versatility of the human. In the detection experiments the human showed his versatility by detecting a variety of visual and auditory signals, and adjusting his operating point as values and costs changed. We would like to study the degree to which the human can specialize in detection. We are in a position to do this when we, the experimenters, know a best basis for decision, and thus know the optimum receiver operating characteristic.

Of the multitude of experiments which were run, three can be singled out as pointing out the direction of the work. In all of the experiments the signal was auditory, a 1000 cycle note 1/10 of a second long, in a background of rather loud uniform noise. The conditions under which this signal was presented were such and under such control that each presentation of the signal was exactly like each other presentation of the signal, except for the changing noise at each particular moment. That is, the parameters of the signal were held under very tight control; the frequency, the amplitude, and even the phase of onset of the signal were held constant. After the observer's performance was evaluated the amount of energy was computed that would be required to get the same performance if the observer had been a mathematically optimum being. The ratio of the actual energy presented to the human to this minimum necessary energy is called the efficiency of the human being. We work in an engineering environment, and it is customary to compute power or energy efficiencies, and to state these in decibels. In decibels the efficiencies of the observers in this particular experiment ranged from a little less than 3 db down to 6 db down. An exceptionally good observer has come to within 1.5 db of optimum performance when the signal is held within these constraints.

The emphasis is placed upon the discovery of such high efficiencies for the following reasons. Suppose an optimum receiver is designed and its performance calculated when there is uncertainty about the precise parameters of the signal; for instance, if the frequency is only known to within a few percent, if the phase, the exact starting time of the signal, is not exactly determined to within a factor of 1/2, or if some additional noise other than that presented by the equipment to the earphones actually exists in the receiver. The efficiency calculated for such a device will be the same or less than that calculated for our observers. Thus it is concluded that in the experiments, the human has shown a high degree of specialization, and has obtained a relatively unexpected high efficiency.

The second experiment that I would like to mention is the type that was run only once and can be run only once because we had to trick the observers. Very simply, they were trained on a 1000 cycle tone 1/10 of a second long although they had worked at other frequencies too. In this particular experiment they were informed that the frequency would be 1000 cycles; it was not, it was set 300 cycles off at 1300 cycles. They had had experience at this frequency, but they were not expecting this frequency. In a run of fifty trials all of the observers missed the signal and all of the observers reported that they believed that the oscillator had been turned down or off; none of the observers suggested that the frequencies had been changed, or that they heard anything at any other frequencies but ignored it consciously because they were not looking for it. Thus, high efficiencies were obtained when the signal was what was expected, and no efficiency was obtained when the signal was not the frequency, pitch, that was expected.

I would like to mention one class of experiments and show a slide with the results which more or less typifies these experiments. The third experiment was the study of the ability of the human to adjust to the precise duration of a signal. The signal was auditory, a 1000 cycle tone. In slide 9 we see a plot of the efficiency on the ordinate as a function of the duration of signal on the axis. The experiment was run so that the energy of the signal was held constant, which meant that the optimum or maximum detectability of the signals was constant. We can see that there was a middle range of durations for which the efficiencies of the observer was constant and maximum, and that for very short and for very long duration signals the efficiency dropped off. Although this shows the data for only one observer, four observers actually took part in the experiment, and each of the observers showed a



Slide 10

similar region of matching or constant efficiency, and fall-off regions on either side of this. The exact zones where the efficiencies were constant varied somewhat from observer to observer. This center zone is the zone in which the observer can best use duration information.

The present experiments have been designed to determine signals for which human observers are highly efficient detectors, to determine what types and how much information the observer can utilize as a specialized detector, and what types of information he cannot use. The natural types of information - frequency of the signal, duration of the signal, the exact starting time of the signal, and the number of different signals to be looking for at one time - are being investigated. The signals are becoming more complex, beginning studies in audio patterning and speech.

PANEL SESSION

In this session, representatives of research, education, the press, and industry present some of their ideas concerning the possible impact on society by the developing theories and practices outlined in the preceding talks. Following these talks is a record of discussion between the audience and panelists, and closing remarks by the panel chairman.

CHARLES E. ODEGAARD

Chairman of Panel Session
Dean of the College of Literature, Science,
and the Arts and Professor of History

I was just speaking with Harry Goode about the order in which the names appear in print in your program. I told him I wasn't quite certain whether his analysis was a sample of mythmaking or whether it was a rational incidence from a rational procedure that led to the list of names appearing the way they do in your program. I called attention to the fact that the order of the program indicates, with reference to the panel, that there will be representatives of research, education, the press, and industry. The only trouble I find with this inference is that I think our panel, the gentlemen on my left and my right really represent double- and triple-threat men, so that these categories are a little fuzzy and not quite accurate as a result. I think I shall, however, introduce the members of the panel to you all in a lump, as it were, so that once they begin to talk, their comments will be a continuum until they pass out into the general audience here. On my right is Dr. Earl P. Stevenson, a graduate of Wesleyan University in Connecticut who went to M. I. T. for graduate studies in Chemistry, taking his master's degree there. He then proceeded into research work, becoming the director of research, then a number of years ago, the president, and last year the chairman of the board of Arthur D. Little, Inc. In the course of a long career with Arthur D. Little, he has had an extensive career in research and industry. He has had at the same time a very considerable interest in education. He is now president of the board of trustees of Wesleyan University and has served as visitor or consultant to the Lowell Institute and to Tulane University. I think he could slip in under the rug as an educator as well as a research man. In addition he has been associated with a great many scientific societies in this country.

Mr. Sherwin on my extreme left graduated from Wheaton College in Illinois and then he took his Ph.D. in physics at the University of Chicago. During the war years he was active in the research program conducted by the Radiation Laboratory of M. I. T. Subsequently in 1946, he went to the University of Illinois where he became professor of physics in 1951. In addition to all the miscellaneous and numerous things that a professor of physics does, he also served as director of various important research projects which have been located at the University of

Illinois. In 1954 he served as Chief Scientist of the Air Force, and last year he received the Air Force Association Award for his work in the contributions of science to air power. His current interests vary from nuclear physics, coherent radar systems, to signal detection particularly in human hearing which takes us back to a variety of topics which have been discussed today.

On my left, in our category representing journalism, is Mr. Harold Buchbinder, who graduated from Cornell University with both a bachelor's and master's degree. He has engaged in various kinds of industrial research and taught at Northeastern University and at the City College of New York. More recently, he has acquired a journalistic interest in science and engineering. He has been editor of "Design News" and was the first editor of "Research and Engineering" and is interested in the publishing field covering research, development, and design, and the management of these aspects of industry.

On my immediate right is Mr. Robert Lewis. He graduated from the Columbia School of Business Administration in accounting, and became an officer of various industrial firms; in 1945 he became a consulting management engineer with Sanderson and Porter and remained with them until 1949. Those of us who are residents of Ann Arbor are very glad that he came here in 1950 as president of Argus Cameras, and while we wish Argus Cameras and Sylvania Electric all kinds of good things, we rather regret that the merger of Argus is taking Mr. Lewis away from Ann Arbor as a local resident to New York as Vice President, Director, and Assistant to the President of Sylvania Electric Products. This is just by way of a local citizen's comment of sorrow at the departure of Mr. Lewis from our circle here in Ann Arbor, but we're very happy to have him with us today.

We shall next turn to the individual members of the panel for their comments on the conference up to this point. Each of the members of the panel will make a presentation and then it will be my function to try to draw all of you into the total panel to deal with what we have heard today. If I can use some of the figures of speech I have been hearing in the course of the day, I hope that the noise we have heard will turn into signals which can be bandied about here with all kinds of information flowing back and forth within this entire group.

EARL P. STEVENSON

Chairman,
Arthur D. Little, Inc.

Dr. Odegaard, Ladies and Gentlemen:

In making a beginning, I feel almost as if I were opening the conference because I think the speakers this morning very studiously refrained from discussing the title of our symposium. We've had some very interesting papers relative to the new techniques that are evolving in certain fields of the social sciences and I suppose the challenge to us here on the panel is to now see what these may mean in terms of our particular interests as we face the problems of an increasingly automatized world. I think I'm almost the first one to use the title today - automatized world - so I may not even pronounce it right.

The brochure of this meeting has given the purpose of our conference and those who so far have spoken have not used the term "human engineering" of which we hear a great deal today. Possibly we have avoided the use of this term because human engineering means different things to different people, and I myself have been among those who have been greatly confused by it - particularly confused when I recently saw a marriage counselor advertising his activities as those of human engineering. The word "engineering" itself is open to some ambiguity. We come to accept words as being symbolic of accurate things, but I believe engineering also means different things to different people. Included in our organization is an engineering group and I would like to rather carefully state what I understand to be embraced by the term engineering. We mean by engineering "the design of a process or a machine that can be operated and maintained with available or teachable skills while meeting prescribed standards of performance and production." Now I cite that because such a definition does not ignore the operator. We here today are considering the operator more than the machine.

In many ways the automobile idealizes this concept of engineering. Yet the automobile of today is quite a different machine than it was yesterday. Man has proven to be adaptable, in other words, to the mechanical operating requirements of the automobile as these have changed. But now let us depart from the field of engineering and look at this from the human side, and ask ourselves it it is not a social error to build automobiles without at the same time devising traffic regulations which drivers will abide by. (I'm a little sensitive to that since I have to report to the Registrar of Motor Vehicles on my return to Boston, for having ignored one of our thousand and one minor traffic requirements.) Now research on the use of the automobile, on the machine itself, on the individual's reactions as well as on the machine's characteristics, which engineers are predominantly concerned with, is obviously demanded as we face an increasingly mechanized world.

Today I wanted to note two aspects of the impact of the introduction of automatic equipment - especially computing equipment - into existing organizations. These two issues, I think, deserve more attention than they have so far received. The first of these might be stated as "dethroning" or "deskilling" supervisory and managerial personnel. We've heard a great deal about both today. Are we going to dethrone and deskill, or at least radically change, the requirements of the manager and the supervisor? Because supervising an automatic machine, I think you would agree, requires an entirely different kind of skill than supervising one hundred workers. Team maintenance, such as we have in research or engineering, I think, requires considerably different skills from the problem of machine maintenance. The computer, for example, demands that the office manager possess some knowledge of engineering and mathematics. This will come as a great shock to some office managers. And that the scientist and the engineer must in turn adapt themselves to the capabilities of the new machines. Those of you who operate research departments and engineering divisions, I think, are sympathetic with me in the fact that this in itself is a problem. Also management in turn is confronted with a threat, a threat to minor and major empires, a threat to the skills on which careers have been built. We pay today a high price to managers in certain capacities because they are called upon to make decisions which can be derived only through the accumulated experience of many years. Are we going to short-cut that process?

The other aspect of this problem - I said there were two - that I would like to speak of, is its relation to the organizational structure of large corporations, such as all of us are familiar with. In recent years, the inability of small top-management groups to handle the vast quantities of information required for decision-making in a large organization has led to this policy of de-centralization. Large corporations have, in this process, come to depend on the development of a common set of values and understanding among their managerial personnel so that one manager can propagate himself into a hundred managers. In several ways, automation militates against successful de-centralization, because in its essence it is a centripetal and not a centrifugal force. This is most noticeable in the application of large computing machines which are commonly installed at the corporate headquarters. The temptation then becomes strong to use them for controlling field operations, rather than servicing field operations. And then again, of course, the automatic factory which we have some excellent examples of today, is demanding less need for local autonomy. There is a greater temptation to control it from some central point. These are matters which require continuing attention.

Now, it is the privilege of those on this panel, I believe, Mr. Moderator, to raise questions without providing the answers. We demand the same privileges as some of the other speakers on the program. Yet I believe we must provide some of the answers to the questions which I am about to raise to meet our social responsibility for the further development of a highly industrialized and highly civilized society. We face some of these problems now. Managerial skills of the present type will apparently have to be relied upon very largely. As we are told in our brochure of this conference, we cannot expect any immediate help. Again to quote from the brochure, "the researches selected are alike in that they are all being done at the University of Michigan; they all seek understanding relative to some aspect of the human being, and, in our opinion, their increasing effect on the relationship of the human being to industry will come to fruition within fifteen to twenty-five years."

Well, within this time, I can certainly hazard a guess that the principles of this new science, if we wish to call it such, will already be well established in industry. Most inventions anticipate a scientific explanation, and I could give examples. Yet when the explanation does come and comprehensive scientific understandings are achieved, the way is always open to greater technological advances. I would therefore not wish to have my remarks construed as disparaging these efforts.

We need new techniques; but the gap between the two approaches disclosed at this conference and the needs of industry, the demands of human engineering must be bridged. In the meantime, we can expect some charlatans to flourish. In terms of scientific progress and engineering I think you will agree, that fifteen to twenty-five years is a very long time indeed. For one thing, we must accomplish a smooth transition from a condition in which that half of the population which is not very educatable - roughly those of the low average IQ's - are mostly employed in the simple task of production, to a condition in which they are mostly employed in the service trades. For the other half, increasing automation may mean a shorter work week. But the work week of the manager and the professional worker has become longer in recent years and the pace promises to become even more hectic. That one segment of our population is beginning to have time on its hands does not mean that all of us are going to have more leisure. I think many will probably have less. It simply means that there is an imbalance between the manager with his sixty-hour work week, the service station operator with his seventy-hour work week, and the automobile worker with his projected thirty-two hour work week.

The most difficult problems posed by this expanding technology will not be technical ones. There will be problems of supplying sufficient wisdom in leadership. More thought must also be given to the proper use of leisure time, how to invest the time so as to promote tranquility of mind and satisfaction, rather than merely spending it in ways that can lead only to frustration. The second major transition that we will have to accomplish - I'll speak of only very briefly - and that is the maturing of our industrial public relations, because the machine is going to aggravate in some ways the problems of industrial relations.

Finally, I want to conclude with this note. I think we can all take pride and feel optimistic about these developments in automation. We need have no apologies; we need have no too great apprehensions. Man is an efficient source of wisdom, an inefficient source of energy; automation puts the emphasis in the right place where man is the controller rather than a motor.

CHALMERS W. SHERWIN

Professor of Physics
University of Illinois

It's my personal conviction that the impact on society of data processing, handling of information, etc. is going to be bigger probably than any other single thing. In the long run, I believe that it will have more influence on how things go than nuclear energy, for example. We always have to have a source of energy and we'll find it somehow, but the dimensions opened up by information handling are very great. Think for example of the teaching business which I work at, for reasons that I sometimes don't understand. Think about the last great invention that was applied to teaching, namely, the book. And since 1450, nobody has seriously applied any great degree of technology to teaching. Teachers today worry about their low position on the totem pole in society, and I think that their productivity per man hour is in proportion to what they deserve. The amount of output per man has not changed in the last fifty years, at least as far as I can see. If you go into a class in a university today, and compare what was going on in the 1900's, you will find that they're teaching a lot of new information that's been collected, but the methods of teaching and the means of transplanting this information to the students is no different than it was in the 1900's. The professor had a high collar in the 1900's and a low collar in 1957. I believe that the teaching process whether it be in school or industry is headed for a big technological revolution.

In the teaching business you need a machine that doesn't just sit there and talk _at_ people like movies or television, although those have not been exploited yet anywhere near their capacity. The thing you need is a machine that talks back. You need two-way communication, and this is perfectly feasible if one just puts his mind to it, and I think that is going to come. And when that does come, half of the teaching in the country will be done by drill machines in which the students sit and the machine gives them exercises, they respond, it grades them; it's a back and forth operation. The amount of engineering that goes into planning a program for a one-semester course in French or physics is going to be like something you put into engineering for the production line in an aircraft factory, but once that is worked out, then that machine and that program is going to teach a million students before the programming is changed. We just haven't begun to think boldly in terms of automatic processing in any area, and teaching is one of the areas in which I feel there lies a great future.

I believe that written language translators (going from typed or printed material into a language translation machine and out) have a great future. The future is there because of the explosive advance in data storage facility and the new methods of very high capacity storage and very fast access time. Even if you don't know quite what to do with such a facility, you get so much capacity for handling information, that you'll get something out of a translating machine that looks pretty good. I'm very optimistic about language translation.

I wanted to make a few comments about man as a signal detector, which I noticed invoked quite a bit of discussion. This is a very exciting field. I've done some work in this field myself which is one of the reasons I'm interested. You all realize your ability not to hear your wife call you to supper when you don't want to. You have a built-in filter system like the man who was expecting a 1000-cycle note and never heard the 1300-cycle note. The ability of people to pick up signals that they're interested in is very pronounced. Think about the street urchin and the woodsman who each in his environment is really a terrific signal detector. The street urchin, for example, will hear a coin clink on the sidewalk three blocks away, amid any sort of noise you could name. The woodsman would never notice it. Now you reverse their roles and put the street urchin and the woodsman out into the woods, and the woodsman knows the signals that to him are the source of his survival. The street urchin would of course be completely oblivious to them.

This question struck me for the first time today. Why should the human detection system be so mathematically predictable? Why should it really be very close to optimum detection as Mr. Birdsall has described? I suspect that if we really understand the human detection system, we'll find it's a lot closer to optimum than the 3 DB that Mr. Birdsall was talking about. In any case, it's plenty close, and the question is, why? It occurred to me that the only reason for this must be evolutionary. The animals that called too many false alarms didn't live to propagate, because they were too cautious. Those that were insensitive to the signals and missed them, didn't either. Take the case of a rabbit, for example. A rabbit has to live and he has to worry about hawks and dogs and things like that. If the rabbit constantly sees danger from every fleeting shadow, he will never have a chance to feed and to grow and to mate. On the other hand, if he does not hear the slight noise of the wings of a hawk or hear the dog or pick up the tiny odor of detection which signals danger, and avoid it, then again he won't live to propagate. So, it's clear that the animal is in a competitive environment, and this means he must be an optimum signal-detector. There is a price for a false alarm and there is a price for a signal miss. And the people or animals who pay either price too often just don't live to propagate.

The ability of the human being to adjust to the price of false alarms is really ingenious; it's really impressive. I don't know if you ever looked at the statistics, but consider cars passing on a highway. It turns out that the chances are about 100,000,000 to 1 that cars will pass each other safely head on, on an ordinary highway. And that's a tremendous number, 100,000,000 to 1. It's so big, we can't realize what it is. And, of course, if you stop to think about it, the price of a false alarm in this case, the price of an error, is extremely high, and you have therefore produced the ability to make enormously reliable decisions, in the face of a very great cost. As you drive down the highway, every ten seconds you have to decide whether you'll live or die, and a person will make in the order of 10^8 successful decisions before they make one mistake, and the reason is that they know very well that the price is extremely high. Therefore, they avoid making false decisions, they avoid making mistakes, avoid listening to the wrong signal or doing something wrong because they know that the price is so high.

Going one more level up in the hierarchy of systems Dr. Miller was discussing, the thing that intrigues me now, and which to me is the number one question for society, is whether the people have successfully realized the price of modern war. Will the people who make up the national governments make a false decision in initiating war as infrequently as they should? In the past, war was not really so costly particularly for those that won. Thus the decision to start a war has often been a great temptation. Now today, it looks as if you could easily prove that the cost is extremely high for both sides, win or lose. And the question to me is, will the social system shift its threshold for provocation of a war to a very high level, so that practically nothing will make them precipitate a war. Consider again human behavior with automobiles; the average driver today makes 100,000,000 proper decisions before he gets killed through his own error or someone else's error. If this could be projected to the groups of people making decisions in countries, and it was as obvious to them what would happen to the country as it is to you if you make a head-on collision with a car, then they would make 100,000,000 successful decisions against war before they would deliberately precipitate one. By the way, this takes 300,000 years at one decision a day before they would accidentally decide to fight, instead of not fight.

I believe that human beings are very flexible; they range over decades and decades of decision threshold ranges. These experiments in hearing indicate this basic ability in people. The more we understand of this enormous flexibility, and the more we can measure it, the safer we're going to be in adjusting to the modern world.

HAROLD G. BUCHBINDER

Executive Vice President
Benwill Publishing Corporation

One of the functions of a journalist is to watch for important trends and then to get more information to determine what various individuals in the field feel about the developing trend. There is one particular trend that stood out rather sharply when I first looked at the program and as I listened to the papers presented. This trend - one which I believe will increase in the next five or ten years - is a more important working relationship between the social sciences and the engineering sciences.

Back in 1945 I lived with a group of student psychiatrists and psychologists; here are some of the terms they used in discussing human behavior: "anxiety states", "phobias", "manic and depressive states", "obsessions", "compulsions", "paranoid delusions", "schizophrenic processes", "aberrations", "sublimations". They got a little closer to the field in which I was operating when they came up with expressions such as "perception change in detail" which was called "differentiation". That was a familiar term that I could latch on to because I had performed an operation called "differentiation" and it was a question of whether my differentiation on x^2 was equivalent to the differentiation of an individual in perceiving small changes in detail. And then of course, the perception of change in pattern was called "integration" and there again, was something I was fairly familiar with, because I had performed an operation called "integration". In some cases, when attempting to understand what was going on, I would ask questions such as "what are you measuring? How do you know that you measured what you set out to measure?" (These were the questions we always asked ourselves in the laboratory. We didn't know whether some of the answers we were getting were inherent with the test equipment we were using, inherent within ourselves, or actually in the particular equipment under test.) This was called a mechanistic point of view; it was frankly looked down upon somewhat; human behavior would never be expressed in C.G.S. units.

As a matter of fact, at the particular time, the field of psychiatry and psychology, as I knew it, from the four or five men that shared my particular apartment on campus, were more functionally oriented than organically oriented. I put emphasis on these two words, because these were the terms they used. The idea of controlling human behavior and suppressing aberrations chemically by means of injections was frowned upon in those days. Today, I hear those same people discussing the possibility that some human behavior may be susceptible to chemical treatment rather than to a functional treatment such as psychoanalysis. Thus there seems to be a significant and discernible change; the pendulum is swinging in the other direction.

Full consideration and investigation of concepts which lie at both ends of the pendulum have contributed to a forward progress. I think we're reaching an era in which there will be more and more of an attempt to define and study human behavior in terms of the systems put forth by Professors Miller and Coombs. This is the trend that impresses me. I have a copy of a paper published by an engineer and scientist at General Electric Company and also papers published by Coombs and Miller. I selected several paragraphs from this technical paper which is called "Hazardous Environmental Factors and Effects Related to High Supersonic Speed Bomber Defense Problems." I also abstracted several paragraphs from Miller and Coombs and showed these to several of my psychological and psychiatric friends and also to several scientific and engineering friends. There were three paragraphs from each paper, from each discipline. I asked the readers to determine whether the paragraphs were written by the same men and whether the material was understandable. All writers were describing behavior in terms of systems and subsystems; they discussed general behavior theory. I am sure that there were fine differences in use of the terms (components, systems, environment, pressures) and as a matter of fact, I think that in one of the papers the term "explosion" was used which misled the individuals to whom I made this small test into thinking this paragraph came from a scientific or engineering paper. This small test proved that picking these paragraphs out of context made it completely impossible to determine what was being said by a psychiatrist studying human behavior or what was being said by a scientist discussing the behavior of a particular subsystem of hardware within a larger system of hardware. The important fact is that from now on, more and more emphasis will probably be placed on attempting to evaluate human behavior and engineering hardware in terms of parallel sets of terms or a parallel theory.

Let me give you a quick example. Fifteen years ago, the subject of servo-mechanisms as I knew it then was essentially an engineering science. Today it is not considered an engineering science, it's considered an engineering practice. The science is called engineering cybernetics. This is a method of approach, a rational system of solving problems in guidance and control - no gadgets are mentioned - only occasionally, the writer might mention something physical or specific to tie some of the equations down to hard cold facts and also to help some of the individuals working in the field. This is called an engineering science, i.e., engineering cybernetics, the entire theory of control and guidance as expressed mathematically, in general form with specific types of solutions to specific types of theoretical problems. Servo-mechanisms is now looked upon as an engineering practice. This really deals with the hardware, the valves, the pneumatics, the hydraulics, the electronic circuitry, and it uses as part of its approach to the design of a particular servo-mechanism system, the theory coming from what is now called engineering cybernetics. I think that what we heard today may possibly form the basis for a "science of behavior" regardless of whether it is applied to human or non-human (technical) systems. What is now defined as psychoanalytic theory may well become the "practice" or applied portion of a general theory on the "science of human behavior." The correlation between the two systems will undoubtedly grow.

Such growth is extremely important to us for survival purposes. The control systems, the guidance systems that we have in equipment, are by far today much superior to our understanding of human systems. Not that we want control systems in humans, but we do want some guidance - at least the guidance of learning activities, for example, would be extremely important. There are undoubtedly some good things that can come from this approach. For example, the types of decisions that managers have to make today can be extremely stress-producing. The input to this human system can get so wild, that the manager breaks down. Today, feeding many of his problems into computing machines helps him to postpone a coronary or an ulcer by at least ten or fifteen years.

There are large problems involved in the correlation of the study of human behavior and the study of the behavior of mechanical-electronic systems. Many false starts will occur - not only in this field of endeavor but also in reporting these developments. An analogy that comes to mind is that when a completely automatic system for packaging and making cigarettes came out, the first company that used this machine advertised their product with the slogan: "Untouched by Human Hands". It didn't take the New Yorker magazine very long to come out with a cartoon. Underneath the picture was the phrase "Untouched by Human Hands"; the picture showed an assembly line on which monkeys or chimpanzees were rolling cigarettes and licking cigarette paper.

This serves as an example of a journalistic approach. When you attend a meeting like this, you can come out with some beautiful headlines that cause the man who presented the paper to go around for the next ten years explaining, "But that's not what I meant". But the problems of communication between the social scientists studying human behavior and the engineers attempting to control and guide the mechanical systems will be solved. Another factor which indicates that this trend is increasing is that more psychiatrists and psychologists are in classified work. They are not working in hospitals on patients; they are working at engineering installations. The heads of human engineering sections today are more apt to be psychiatrists or psychologists rather than engineers. Years ago, industry learned that if you wanted something designed more efficiently you put the electronic designer with the mechanical designer, so that together they could produce what each could not produce alone. This system of design, development and research extended such that teams are now composed of electronic and mechanical engineers, chemists, physicists, and mathematicians. It appears that the day has finally come when we are now inviting psychiatrists and psychologists to join this group. And I hope it isn't too late.

I'd like to close on one comment. I started with the fact that as journalists we have to read a good number of the papers presented at various meetings. We can't attend all these meetings, but we get the various societies to send us these papers and we scan them in an effort to pick out those that we think have really important facts and figures. One of the papers I read about four or five months ago was presented, I believe, by Trevor Gardner, now with Hycon Manufacturing. He mentioned a term that I have heard for the first time, "mega-death", and explained it by pointing out that in Julius Caesar's time, the cost of killing a man was twenty-five cents, during the Civil War it was something like $1000 or $2000; during World War I, it was $20,000 per man; during World War II it was something like $65,000 per man. Now, we're almost back to Caesar's time. I think it's something like $2.82, if we release an atomic bomb. The problem is, to what extent do these technical developments affect human behavior, to what extent does human behavior affect the technical developments? This is the question the answer to which I don't know. But I am certainly hopeful that the fact that we are now inviting and supporting work in the psychiatric and social sciences in terms of attempting to understand human behavior will certainly bring us to the day where we need not worry about how much it takes to protect a man, much less what it takes to put one away.

ROBERT E. LEWIS

Vice President and Assistant to the President
Sylvania Electric Products, Inc.

I just wanted to say that I have an interesting experiment in signal detection if you want to come up to my home sometime. If you go to the back stairs and the front stairs and shout at the top of your lungs, "Who's on dishes tonight ", you get a remarkable silence. But if later in the evening, you take an ice cream dish and just gently tap it with a spoon, you can hear them coming from all stairways.

Mr. Buchbinder was making a comment about the times of Caesar. This room has a remarkable resemblance to a Roman amphitheatre, and I feel very much like a Christian that has just been dragged into the pit. I'm not a psychologist, a psychiatrist, an engineer, a physicist, or any combination thereof. And several months ago, when somebody suggested that perhaps I might take part in this Industry-Education program, I just put it down on my calendar and completely forgot it. It sounded perfectly rational to me. And then they sent me some material which I put in a safe place, and coming home from New York on the plane the other day, I decided I ought to get it out and look at it. I'll say one thing, I read it. But was I surprised, because about three-quarters of it, I couldn't make head or tail of, and some of it I could get a little bit from; but I did stick to it. I happen to be in a field and have been for many years, which I suppose you'd loosely call management. The longer you're in management, the less of a specialist you become, and the more superficial you become in many areas. This is a very vexing thing, because there is a great deal of satisfaction, that most of you people enjoy, in being specialists. Today is to me a new high in drawing a complete distinction from one end of the spectrum to the other, in my superficiality in many subjects and the very high degree of specialization that you people represent. You people are blazing a trail in research. Such leadership must be given by an institution and a group like this because in the daily impact of business, the necessity for making money and staying in business, keeping the stockholders off your back, just doesn't permit this kind of forward thinking by business itself. I think the important thing for people in management is an awareness, an ability to detach themselves occasionally and get a feeling of where you people are going and to try to get some sense of the values of where it may lead.

And then, within our own organization, get a person that can be a connecting link. The program speaks of industry and the human being in an automatized world. From the point of view of industry, automation brings up a great many challenges. You spoke of one, Dr. Stevenson, the management concept. Management, when there existed a lesser degree of automation or mechanization, was one thing. Today it's another. The challenges, for example, of data processing. Automation emphasizes other areas, such as financing. Having a mechanized plant is an entirely different economic problem from having a plant that's extremely flexible. Under the old order, if production went up or down or there was a change of pace, the equipment was usually adaptable. You could lay people off or take them on. You could change your tooling. But now, when you shoot the works and have the type of automation that is conceived in some of this forward thinking, you get a very high degree of inflexibility. You must know what you're doing, and it takes a large investment. If things don't go well, you can't lay off a machine. You suffer the depreciation and the overhead continuously. This is a serious challenge, from the point of view of business.

From the point of view of the human being, and the impact it has in that area, I happen to be an optimist. I hear a great many negative and alarming things said about mechanization and what automation will do to people. I believe it's having exactly the opposite effect. I think that automation is raising the entire level; I think the very fact of people being associated with automated equipment changes their perspective. For example, I was in one of our plants last week and happened to be talking to a girl who formerly was on a line where she was doing a repeat operation all day long. Now she is on mechanical equipment where she can see the entire product being made, from the feeding in of the raw material right to the final packaging. So instead of being one of many girls where she didn't have any real conception, and probably very little interest, of her part in it, she suddenly could see the whole scope of what was going on. She made it clear, and this was spontaneous on her part, that she enjoyed her new role immensely. In fact, I wonder if there isn't some kind of a feeling of superiority when a person realizes that he is controlling a machine by pushing a button; that he can make these things happen wherebefore he was a cog in a wheel. I think a good parallel which is very easily understandable is road building. Going back several generations a road project would consist of hundreds of men and a modest amount of equipment; most of them had shovels. A man with a shovel just heaving dirt certainly can have very little basic interest in the goal, or the job, or get any lift from it. In fact, he can't really conceive of what's going on, because he's probably in one spot for months at a time. You go out now and see a road project and it is moving right along with practically everybody being some kind of a specialist. So I believe that automation is bringing with it a lift in human reaction instead of the opposite as so many people fear. With automation we need more specialists and more skilled maintenance people. The increased leisure from shorter working hours brings up the problem of what to do with it. This problem will solve itself. I feel that there's no question but what it makes a bright future. Rather than go on, I would rather see if we don't have some discussion at this point.

DISCUSSION

DEAN C. C. ODEGAARD: Now, gentlemen, we'd like to widen this circle out. Before letting the panel start arguing among themselves, I'd like to get a question or comment from the group in the larger circle here.

QUESTION: (TO DR. SHERWIN) Do you imply, I believe, that the human mind has been improving with time? Now my question is, is this really true, do we have anybody today, for example, who is comparable to Socrates or Newton or anyone like that? Can we show any real improvement basically?

PROFESSOR C.W. SHERWIN: Well, maybe I didn't make myself quite clear. By improvement I mean in the sense to survive. A species must be a very effective signal-detector to make a balance between the errors of two sorts; the missing of a signal, or calling a false alarm when there isn't anything there, and that has forced us to a sort of optimum signal-detection which has probably not changed the ability of the human being to act this way - is unchanged for generations, I would say. If you could test Socrates or his contemporaries, you would find that they would respond to signal fluctuations I'm sure just like we do, because that's all built in from a long process from very far back. As far as total intelligence is concerned, I don't know, but I'd be willing to stack up some of the people like Von Neumann or Einstein or somebody like this against any of the ancients, as far as intellectual power goes. I think that they're fully equal, although this is a very hard thing to prove.

QUESTION: They're equal, but not necessarily superior.

SHERWIN: Well, you can't really answer a question like that in a way. They're clearly the same kind; they stand way way out among other people, no doubt about that. It's a question you can't really answer because you can't measure them under the same standard.

ODEGAARD: Any other questions or comments?

QUESTION: I would just like to reiterate a comment that Dr. Stevenson made, name any human trait and half of the people are going to be below average. There will be an awful lot of people who will be left out when automation is more fully developed. Only certain kinds of people can adapt to this change; not everybody taken off the assembly line will be able to control automation.

DR. E.P. STEVENSON: I think that has great social significance; we've got to do something about it.

PROFESSOR R. LIKERT: The balancing force is the number of people going into service industries. Look at the manpower used in service industries and in manufacturing and other kinds of activities. We have got a steady increase in the proportion of people used in the service industries. There is no reason to suspect that automation can be applied to medicine and technical assistance and to all the specialty and service operations.

STEVENSON: I agree, Dr. Likert, that is the trend. I have recently had occasion to study the figures on the kind of industry in New England as a social unit. Now New England is an interesting little laboratory for this. The trend has been going on for at least twenty years and very definitely the larger percentage of the population are going into service trades. I simply think that automation is going to hasten this, and that instead of following one curve, we're going to follow a curve with a greater exponential factor of some kind.

ODEGAARD: I was going to ask in connection with what Professor Likert just said if it isn't also true of automation that while you use less brute force with it you increase the number of sub-professional jobs so that under a variety of experts required to keep this automation of industry going you have sub-experts, and lesser experts, and still lesser experts. As a consequence, you're pulling men off more manual operations into a variety of kinds of service trades that support the scientific and engineering aspect of automation.

REMARK FROM FLOOR: But automation can remove a lot of jobs from clerical workers in banks, for example. So that it works both ways.

MR. R.
LEWIS: There's another observation that I think one might make along this line which is directly opposed to the proposition we make. That if we are to have the steady progress and improvement in the standard of living, we can't achieve it without automation. We're going to be undermanned; we're going to have constant over-employment, not unemployment. We need automation to keep up with the progress.

PROFESSOR
H.H. GOODE: Dean Odegaard, could I pick up Dr. Likert's point about the automation in medicine. Dr. Miller, didn't I read something recently -- about an experiment being carried on in differential diagnosis by means of a computer? With the recording of a large number of symptoms and diseases in storage, and the attempt to pick up at least the rarer diseases with this kind of manipulation?

PROFESSOR
J.G. MILLER: I have heard something about that but can't remember any details. I do know, however, of a testing device which was developed by Dr. Horace Rimoldi to aid in selecting specialists in internal medicine, an examination device for use by the American Board of Internal Medicine. It was a large cardboard containing four columns of slots. In the first column of slots there were a series of cards, half of each showing above the slot and half hidden in a pocket. The first column contained cards, which when drawn from the slots each revealed two or three sentences of history about a patient. The second column would have a series of cards bearing physical findings. The top half of one of these cards might perhaps read, "auscultation of the chest" or "palpitation of the chest." Then the relevant information was underneath on the parts of the cards in the slots. The third column of cards contained laboratory findings, e.g., red blood cells, white blood cells, etc. The fourth contained diagnoses visible on the upper halfs; the lower halfs said "Incorrect" except one, which said "Correct".

The examinee would pull out the first history card, read the history, then secure the laboratory or physical findings he wished, putting the cards down in the order in which he took them out. Finally, when he thought he could make a diagnosis, he would take out the appropriate diagnosis card and see whether it was correct. If it was not, he would continue in the same fashion until he arrived at the correct diagnosis.

This examination was validated not only against the logical progression to the solution but also against one hundred of the country's best diagnosticians, who did not always appear to approach the diagnosis logically. They would approach it in terms of other considerations. For example, suppose the diagnosis were actinomycosis, and this were not an easily treatable condition, and furthermore did not involve as much danger for other persons contacted by the patient as tuberculosis. Even though the chances are ninety-nine that the diagnosis is actinomycosis to one that it is tuberculosis, a good diagnostician would not rule out tuberculosis, first because here is something that is not only treatable, but against which it is necessary to protect others.

This particular sequential logical reasoning process is like that tested by our electronic logical analysis device, the PSI apparatus, except that it does not include any content knowledge, as of medicine.

It is clear that quantitative analysis in chemistry, diagnosis of electronic circuits by radar technicians, or the tracking down of motor trouble by mechanics have fundamentally the same logical structure, and that all these could be approached mathematically.

Incidentally I might mention an electronic gadget for quantitative analysis which is being exhibited by a company. Apparently you just insert a chemical solution into the machine and it automatically works out the logical steps to the final analysis.

QUESTION: I would like to know if automation is necessarily the optimum of industrial conditions. Sometimes automated industries come into competition with non-automated industries in the market place, and sometimes automation can come out second best.

GOODE: I would like to get a definition of "second best". In what sense: What measure?

REPLY FROM QUESTIONER: If you catch a man with a highly automated plant and make him shut down long enough, he has to go bankrupt. You can take over his market.

GOODE: But this is a kind of local situation, isn't it? This is a question of beating him at the moment which is certainly true while one is in transit. But if, for example, you were to attempt to produce cigarettes by manual means today, I think you'd have a little difficulty competing in the market. I think that probably it's true that while cigarette machines were coming into being, you could beat somebody who was in the process of putting the machines into operation, but if the population figures I was talking about this morning hold any point at all, and if our indices of productivity as a function of increased mechanization and automation, if you like the word, are any indication at all, we had better learn to live with this. We will have lost the race if we haven't increased our productivity so that we can keep track of this increase in population.

STEVENSON: Well, this discussion leads me to this question. We may have two problems here. Are we talking about automatic equipment or automatized equipment? To me these are two different things. A cigarette machine with which I am quite familiar, is an automatic machine. But you can turn to a plant that manufactures radios, I believe, for automobiles. It feeds in all the components, but it adjusts itself, there are elements built into it, so that when errors develop, it corrects them. In other words, there is something of the human function in it. Now there isn't in the cigarette machine; all you've done there is to mechanize a sequence of human tasks.

GOODE: One function of the human being; the one he performs with his fingers?

STEVENSON: That's right. It's the equivalent.

GOODE: In the other case we've mechanized the one he performs with his brain.

STEVENSON: That's the difference.

GOODE: But I was using the cigarette machine as an example of history. That is, I needed something to use as a comparison.

STEVENSON: But, I would like to know if there isn't this difference here in the minds of the audience, the automatic machine and the automatized plant.

SHERWIN: I'd like to mention that there are a lot of experiments going on in automatically controlled general purpose equipment, such as milling machines and such things which operate sequentially on data which is punched into a system of cards or tape. The same machines can do many different things in sequence with nobody handling them. The same thing is true in electronic parts manufacture and assembling. A number of companies are working very hard on the type of machine that can be set up to perform new operations simply by adjusting the tooling, and feeding in electronically the proper sequence of instructions.

MR. H.G. BUCHBINDER It seems conceivable that machines can be made to perform every function that involves work of a kind that the individual does only because he needs these things, because he needs these necessities of life. As a matter of fact, wasn't it Francis Bacon in "Utopia" who wrote of men on a voyage discovering a South Sea Island which was glorified not because of its bread-fruit and grass skirts, but because it supported an institution devoted wholly to scientific research and development. If we automatized a large number of production processes, reducing our struggle for necessities, it might possibly bring us to this kind of existence with one exception -- instead of just lolling around on the beach, looking at the moon and the sun, we could spend much of our time investigating our environment in greater detail. You would have modern up-to-date equipment with which to do it so that you could expand creatively in any direction that you wanted to.

LEWIS: I think it might be a good time to recall that the success of our economy is that it's a competitive economy, and the devil takes the hindmost. And in connection with the subject that you speak of, Frank, is somebody who takes the risk and loses. Well, that's just part of daily activity in business. And it happens in many other ways that are parallel. Why, it's going on all the time. Somebody builds a plant, and never mind whether its highly automatized or not, and he misjudges the market, so he goes out of business. This is happening every day of the week. I recall that during the war, for example, we had a tremendous building program and it was quite common at that time to wonder what on earth we were going to do with all the plants when the war was over? And I was one of them who wondered also. Finally, I gained a sense of perspective as to what was happening. We were getting more modern facilities all the time, and when business let up a little bit, the marginal plants at the bottom would have to go. All this was for the good of the economy and the general public. If you happened to be one of those marginal plants, of course, you were a dead pigeon. But that's one of the things that you have to look for. The remarkable thing is that all during the Second World War, I think our total building program was about 28 billion dollars when everyone wondered what we were going to do with it. Look what we've done since. We've beat that total program every year, and this year, I think the estimate is about 37 billion dollars for capital outlay and we're still adding to it. So it's just one of the risks of getting out of bed in the morning.

STEVENSON: I'd like to put a comment in here. What you say bears on one of the points that I tried to make, which was to express concern about those who are going to succeed in management positions, and how the managers are going to survive. Because my observation to date is that automation does not relieve but increases managerial strains. For one reason, there is the greater inflexibility in the commitment of money. I could cite for instance where a plant, highly engineered, had to operate at 85 percent of capacity to be profitable. Whereas without such extensive mechanization there could be greater leeway. Labor cost is somewhat flexible, but now the cost is primarily in fixed overhead. And this really develops peptic ulcers in those who are forced to live with these additional risks.

LEWIS: Well, I say, that this word automation is sometimes taken in an exaggerated context. The minute you use it everybody sees everything working automatically with nobody around. It's a relative situation. As a matter of fact, in the electronics industry you'll find different companies have different degrees of automation on the same products, and both of them are making a living. They just don't believe in the same degree, so it isn't hot or cold, or black or white, necessarily.

BUCHBINDER: I think that the automation today is going through the same period that the plastics industry went through twenty or twenty-five years ago. When this new thing called "plastics" first came out, it was too readily accepted and applied to too many products. It just didn't work in many applications. Consequently, it got itself a very black name. It took the plastic industry about twenty years to recover. The same phenomena started to occur in the automation industry. I think there was a terrific amount of resentment and antagonism generated amongst a good section of the engineering field when all of a sudden, we got a lot of papers on automation. A magazine called "Automation" came out. As a matter of fact, three magazines came out almost simultaneously, each one taking a different approach: "Control Engineering","Automatic Control", and "Automation". These three magazines came out within several months of each other. The reaction was swift. A lot of engineers began to deride the fact that a lot of things that we had had around for years were now classified under the heading of "automation" There's no question but that a lot of people particularly in the machine tool field began to overlook the needs of the small man who needed cheaper, more efficient machines that could be run by hand. The small operator simply didn't have the kind of capital investment to go ahead with the design and manufacture of automatic machinery which would have less flexibility in terms of product change. I recall one machine tool user who gave a particularly bitter talk about the fact that he and his associates were being completely neglected and completely overlooked by these trends in the machine tool industry. Unquestionably, in the future, there will be a lot of things that will be attempted to be automated too soon or perhaps a lot of misapplications will be made. But I think that gradually the industry will stabilize. But I still think that we have a long, long way to go before automation is a closed book. As a matter of fact, undoubtedly in 5, 10, 15, or perhaps even in 2 years, some other concepts may come up which will completely eclipse the concept of automation, I don't know.

GOODE: I'd like to pick up Dr. Stevenson's point. I think we are interested in the problems created for management by this expanding technology, expanding population, etc. This point about requiring 85 percent occupancy of a production process is an important one. I think that we all recognize rather easily the fact that if a machine operates with peaks and troughs, it will produce at a lower average level than if it operates at the same level all the time. The manager's job up until now has been, I think, like any servo-designer, to make sure that he matched the input with demand, so that he's there with a minimum amount when he was in a trough and was there with a maximum amount when he was in a peak. But, I think that society is demanding that he find out how to operate at a relatively smoothed out and fixed level. And in order to do that, he must not change the machine but he must go to the source of demand and arrange it so that it is orderly. In order to do this, since this is a rather complicated process of having the demand itself governed by the people who are actually operating the machine, he must do something about making this rather smooth also. I would underline your remarks one hundredfold that the problems of management have gone up a thousand times over what they were in this situation, and I think it is important that management recognize this.

ODEGAARD: I'm interested in two kinds of language I've been hearing for the last few minutes. Mr. Stevenson has talked about ulcers and Harry Goode has talked about productivity, and yet this is all part of management, apparently, as we've been discussing it. I heard Mr. Buchbinder's comments with interest when he talked about the terminology which now makes it appear that you can't tell the difference between a psychologist, a mathematician, and an engineer. He hoped that the psychologist had gotten into the mix soon enough; I'm not quite sure soon enough for what. Whether it's to prevent the cataclysm or to do something about it, I do not know, but at least you're glad, Mr. Buchbinder, that psychologists are there and you implied that you wished they'd been there sooner. I have to come out in the open here and say that I'm even farther off from this subject than you are, Mr. Lewis, because I'm a medieval historian. But I'm still trying to get an education, so I'm enjoying this very much. And I have been impressed with this business of terminology in my own position which calls for dealing with people in chemistry, and physics, and fine arts, and anthropology, and sociology, and literature, and so on. So that I hear a lot of kinds of words. You heard the story this morning about the returning alumnus who spoke to his professor and asked about the course and found that the same questions were being asked, but was told that the students could be fooled because the answers were different. I would like to suggest that sometimes the answers are not as different as they sound. What has happened is that many answers, if you analyze them, are still reasonably consistent, but the language in which they are expressed is different. Now, don't mistake me, I'm not suggesting that this means that nothing has been learned, I do think it means that observations that may be profound and fairly persistent have a certain transcience if they're not continuously reinterpreted into the context which changes in time and space. And that old saw may be a vivifying truth when it's interpreted in the language which is required in order to set it into a new context. I remember hearing a paper by Professor Likert about eight or nine years ago, I think, given out in California, before he and I became colleagues; it was a report on a portion of the work which the Institute for Social Research was doing here in productivity. I remember that certain conclusions, it seemed to me, were beginning to be implicit in the results he was presenting to us and I wrote on the paper napkin (this was a luncheon talk) two texts that occurred to me from the Bible. I'm not trying to suggest the superiority of the Bible to the Institute for Social Research, because I'm certain that if those texts had been used in connection with management in industry, no one would have paid any attention to them. They represented, if you will, a crude observation and in a strange idiom with reference to human behavior but which has a certain durability. This conclusion emerged in the context of the studies of the Institute for Social Research in a way which probably would mean that human behavior would be influenced as it would not have been influenced if somebody had pulled out these two passages from the Bible. Now I suspect that part of the process of human culture is a continuing re-interpretation of some good ideas that have emerged in the past. I was particularly interested in Dr. Miller's presentation of the general systems theory because when we mix up people as we have them mixed up in this room, a tremendous effort has to be devoted to turning strange terminology, this noise, into concepts that can be used across a variety of disciplinary frontiers. The difficulty of acquiring a language which can be used for interpretation is really enormous. When you think of the investment which has been made in the last century especially in specialized analysis of various aspects of the human scene in which we all live, you realize that what we've been hearing, this kind of effort of interpretation across frontiers, is a continuing and primary need of our own time. We have met here for a discussion on "Industry and the Human Being in an Automatized World". In analyzing many of these papers, it has seemed as though we were looking at the human being to try to analyze the human being as a machine, human engineering in that sense. How has evolution engineered the human being so that he functions in this particular way? We have had some very interesting analyses presented to us today of the human being as conceived of as a machine. At the same time, we noticed a certain shrinking away from certain problems. I think you did this, Dr. Coombs, when you would indicate preferences of individuals but did not move to the second stage of working on the why of the preferences. We then touched the problem of describing not only how man works, but also an even more complex affair, what he works for, and what he works for in different cultures. Those same people that can reach up and pull down a banana in the South Sea Islands can go through the most ungodly amount of work to no purpose at all, from the point of view of productivity in any sense that's being used here today. Yet in some sense this consumption of energy must be productive to them or they wouldn't do it. A lot of these natives that go through tribal dances of one sort or another for example aren't producing so far as one can see anything visible. They're just expending an enormous amount of energy, but it's productive of something that's important to them. And so, I would suggest that in this process of bringing the mathematician and the engineer and the psychologist together, one can add still another link to this chain. I'm not suggesting that we should have attempted it today; there is not only how man works, the problem we have considered today - there is also a problem in looking at what he does with whatever it is he has to work with. He produces various kinds of things. These may be goods, or dances, or paintings. There is one thing I learned during the war in connection with watching Navy crews aboard ship. I had come into the service with a nice professorial notion that nobody really liked to work. I suppose I was just reading in my own prejudices. But I became struck by the existence of a substantial number of men for whom work, i.e., various kinds of physical labor, was sheer joy. Under certain circumstances, they would seem to me to beat their brains out in the repetitive mechanical jobs where apparently the mere motion, for example, seemed to be in itself a reward. I suggest that one of the things we'd better not do is to separate work too far from life, because I suspect that one of the meanings of Professor Likert's presentation is that this business of motivation can include a lot of things besides producing material return. A lot of this motivation is associated I think with returns that have to do with repetitive things the human being likes to do. Sometimes you wonder if God knows why they like to do it, but they do it. I'm merely suggesting then that there is still another dimension of this discussion of productivity which could be thrown in, not to confuse the issue, Harry, but just to suggest that when we get the problem of communication across this collection of disciplines licked, then perhaps there is still another jump to make. Perhaps when we make that we'll get closer to talking about leisure and ulcers, the phrases which were used, I noticed, earlier, by Dr. Stevenson.