10

JPRS: 16,716 OTS

17 December 1962

AN ELECTRONIC CONVERSATIONALIST

by Ye. Saparina

- USSR -

U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
JOINT PUBLICATIONS RESEARCH SERVICE
Building T-30
Ohio Drive and Independence Avenue, S.W.
Washington 25, D. C.

Price: $1.60

FOREWORD

This publication was prepared under contract for the Joint Publications Research Service, an organization established to service the translation and foreign-language research needs of the various federal government departments.

The contents of this material in no way represent the policies, views, or attitudes of the U. S. Government, or of the parties to any distribution arrangements.

PROCUREMENT OF JPRS REPORTS

All JPRS reports are listed in Monthly Catalog of U. S. Government Publications, available for $4.50 ($6.00 foreign) per year (including an annual index) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C.

Scientific and technical reports may be obtained from: Sales and Distribution Section, Office of Technical Services, Washington 25, D. C. These reports and their prices are listed in the Office of Technical Services semimonthly publication, Technical Translations, available at $12.00 per year from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Photocopies of any JPRS report are available (price upon request) from: Photoduplication Service, Library of Congress, Washington 25, D. C.

JPRS: 16,716

AN ELECTRONIC CONVERSATIONALIST

(And the machine replied ...)

-USSR-

[Following is the translation of an article by Ye. Separina in the Russian-language periodical Znaniye-Sila (Knowledge is Power), No 10, October 1962, pages 29-32.]

"I asked:
'Were you glad when it rained this afternoon?'
It replied:
'No, I prefer sunshine'.

'In hot weather, people have to bathe at least once a day', I noted.

'Yes, I was really sweating it out in the heat today' came the reply.

'When Christmas comes, we'll be in for some cold weather', I added weightily, attempting to keep up the conversation.

'Cold weather?' my friend responded, 'Yes, it usually is cold in December'.

'It's a clear day today', I said, sticking to my line. 'How long do you think it will last?'

'Allow me not to lie' my friend replied, thrown off balance by my contradictory remarks. 'How can rainy weather be clear weather?'"

This conversation is reported to have taken place in Toronto between the Canadian scientist Berkeley and an electronic computer. The computer memory was fed three hundred English words and taught to carry on a simple conversation.

An electronic conversationalist! So much is being written about all this today that we unavoidably get the impression that machines will really begin talking any day now. But in order to have a conversation between a human being and a machine, it must be taught to speak. Before it can speak, however, it must be endowed with hearing. And not by means of a simple microphone, but through an electronic ear capable not only of hearing sounds but of differentiating different sounds and the syllables and words which they make up, i.e., of hearing and understanding speech.

The differences in pronunciation between the letters "a" and "e", "n" and "r" -- this narrowly specialized problem which formerly interested only linguists and teachers of foreign languages -- is now acquiring "industrial" importance.

Speech sounds are combined in unusual pairs, "cut up" into pieces, "taken apart" into tens of component parts, and subjected to hundreds of no less unusual experiments. It is not by accident therefore that laboratories where this work is going on are called experimental phonetics laboratories. Laboratories of this type are now set up in Moscow, Leningrad, and Tbilisi.

If you have a chance, you certainly should visit one of them.

You will be shown three-dimensional pictures of vowels and consonants and even entire words. The sound of a word on such a picture is not recorded by notes on a staff. They are represented in models similar to relief maps of mountain ranges or icebergs.

On other pictures you will see color representations of different voices. The intensity and pitch of sounds in the pronunciation of syllables and words are indicated by the brightness and hue of colored spots.

In the speech laboratory you will see the most varied devices for recording sounds and special mechanisms for their cutting and splicing. Among other equipment is a special sound spectrograph. In passing through it, speech sounds are broken up into a number of "lines" of differing height and amplitude. These lines form a sound spectrum similar to the seven-color rainbow produced by the spectral resolution of white light.

Here you will become acquainted with an unusual "separator" which separtes out not cream from milk, but any part of a sound recorded on magnetic tape, all the way down to a "piece" of a sound lasting 3-4 hundredths of a second.

Here you will here the familiar voices of radio announcers and birdsongs, opera melodies and the squeaky voice of Buratino [Pinocchio], normal words, and a leapfrog jumble of sounds produced by running the tape backwards... In other words, if you have an opportunity, do visit one of these laboratories. You won't regret it.

When your surprise over what you have seen and heard has worn off a bit, you will begin to understand the purpose behind it all.

Curious things have been discovered by students of live human speech. The spectra of Russian vowels, for example, revealed many "superfluous" parts. If the vowels are slightly "truncated", we continue to recognize them. This means that we speak with a large excess of sound, while the "useful information", using the expression of the cyberneticists, is conveyed by only a small part of them.

Moreover, as soon as the sound "a" was shortened somewhat, it came to resemble something between "a" and "e". And in such a way the sound was introduced into sentences in place of all true "a's" and true "e's". But our ear was still able to distinguish which sound belonged where, despite the fact that each letter in a word was pronounced quite differently than when spoken separately.

On another occasion, a correctly sounded "o" was recorded on tape. Then the tape was played in reverse. Suddenly everyone heard something like two sounds which merged into one -- "e" and "u".

It is quite clear that both components were present on the first occasion on the ordinary recording. But they were not perceived separately. Why was this? The researchers decided that this was because the ear accustomed to Russian speech in which the vowel "o" is pronounced like a single, inseparable sound does not distinguish its component sounds.

And, in a reverse way, our brain often adds on something which the actual physical sounds forming a word really lack.

One of the experiments carried out was to record and play back for the experiment participants a number of meaningless sound combinations corresponding to a word made up of four syllables. Then the word itself was reproduced: "na-ka-pa-la". Although it was pronounced without any expression and with equal emphasis on each syllable, the listeners nevertheless placed the accent in their minds. In an analogous combination of meaningless sounds, the accent was not placed by the listeners.

Thus it turns out that an accent really absent in a chain of sounds is actually imparted to it in our minds.

This is confirmed by yet another example. The word "na-lo-ma-la" was also pronounced without accent. All of the syllables had exactly the same physical properties -- frequency, loudness, and duration. Nevertheless, Russian students clearly heard an accent on the third syllably, while non-Russians heard nothing.

As you see, the study of how we hear speech has revealed many heretofore unknown purely psychological peculiarities which greatly complicate the creation of an "electronic ear".

But a machine must be able not only to hear words, but to pronounce them itself. This means that in addition to the ear, we must create a model of the throat, larynx, etc., and not simply construct individual artificial organs. After all, our purpose was to create not a "speaking" or "listening" machine, but a sort of electronic conversationalist capable of carrying on a conversation on some individual topic (at least as a beginning).

This means that it must be equipped with something like an artificial organ of speech which could itself place accents and differentiate between "o" and "e", even if these are similar in sounds in different words, etc.

This in turn requires that we find out how our own speech center works.

Find out? But don't we know already?

Signals of Signals

"Patient M., 52 years old, right-handed, literate, entered the Institute on 23 August with a complaint of impaired vision..." I read in the history of the ailment. "Some days ago, hanging up a picture in his home, he felt a sharp pain, lay down, closed his eyes, and on getting up and looking out the window found that the houses across the street seemed strangely flat. In going to work could hardly recognize surrounding objects. Streetcars and autos had a toylike aspect. Passed by the sidestreet in which he was supposed to turn and barely managed to reach the next intersection. Could not recognize fellow workers. Delivered to hospital..."

Skipping several lines of figures in the clinical report and pass on to the neurologist's conclusion:

"Patient's state unchanged. Continued failure to recognize relatives and friends, though clearly distinguishes their faces. Discovers who is standing next to him by indirect clues -- headgear, voice.... Looks at himself in the mirror and does not recognize himself. In looking at pictures, examines and describes individua.. details, but does not understand the picture as a whole.

"Diagnosis: visual agnosia". And a marginal note: "Apparent damage to 19th and 39th cortical areas".

Isn't this a strange ailment? We could assume that the patient was suffering from damage to the visual portion of the brain. But this is not the case. Areas 17 and 18 are quite normal. For some reason, the damage lies in cortical areas 19 and 39 which apparently have no direct bearing on sight.

And you youself had the chance to observe that the patient sees everything and is able to distinguish objects. This means that the portion of the brain responsible for simple visual perception and the neighboring portions which perform more complex visual analysis are operating normally. The damage is to certain higher brain functions, those which enable us to recognize familiar objects and people by their external appearance.

The 19th area is located at the edge of the visual portion of the cortex. It can have a relation to vision. But what does the 39th area have to do with it?

I read the new case history.

It turns out that many variants of such a disease are possible. Sometimes the patient recognizes objects quite well by sight, but cannot distinguish them aurally. For example, to identify a car by the sound of its horn, or a clock by its ticking. Among other damage, one of the peripheral areas of the aural zone is impaired, and once again the mysterious 39th area.

In another case, a person who adequately identifies objects by appearance and sound fails to identify by touch what he is holding in his hand -- a key or a pencil. I look at the end of the description of the case. Here it is again: damage to parietal portion of the cortex responsible for the sense of touch, and once again the 39th cortical area.

It is interesting to know where this area is located. Leafing over the atlas of the brain, I find a map showing all of the more than fifty areas... At the junction of the occipital (visual), temporal (aural), and parietal (tactile) zones, I find the number 39. The area taken up by this universally-important section of the brain is fairly large.

"Area 39 and neighboring area 40 are to be found only in the human brain", I am told. "These areas developed later than the rest. They are responsible for man's higher capabilities -- cognition and working activity. It was they which developed in the process of work..."

In the work process, speech developed as a means of communication of work experience and thoughts. This could not but produce the corresponding changes in brain structure.

"In the developing animal kingdom, at the human phase there took place an unusual developmental addition to the mechanisms of nervous activity", wrote I.P. Pavlov. "To the animal, reality is perceptible almost exclusively through stimuli and their traces in the large hemispheres directly entering the special cells of visual, aural, and other receptor mechanisms of the organism.

"This is the primary signalling system of reality which we have in common with the animals. But words created a secondary, peculiarly human, system for signalling reality. Words are signals of primary signals..."

The secondary signal system makes possible speech communication among humans; it serves as the basis of the higher psychic activity of the brain. The conditioned stimulus here is the word in all of its forms -- pronounced, heard, and seen. The brain must be able to distinguish a word in any of its guises, and even prior to its enunciation must construct it mentally, or even an entire sentence.

It was once thought that the brain contained a "collection" of images of external objects. Then the secondary signalling system would have to be conceived in a fairly primitive way. Words were names of objects, so that it would be sufficient to project all of the elements of the primary signal system onto the secondary one to obtain yet another collection in which each objective image in the primary system would bear a one-to-one correspondence with its name in the secondary system. But what do such words in the secondary system as "again","without", "after all", and "or" represent? Where are the numerous grammatical variants of words such as "you are thinking", "he is thinking", "they will be thinking", etc.? And what about such signals as "wave function", "correlation", "differential"?

Now it has become clear that although the relations between the primary and secondary signal systems do exist and are indeed very close, they do not fall into such a primitive geometric scheme. How is the secondary signal system present in the brain? In other words, what is the structure of our speech center?

Having become firmly convinced that all brain functions are more or less closely related to definite portions of the brain, I wanted to know where this notorious speech center was to be found?

It turned out that there is no such center in the brain. There are individual portions scattered all over the cortex which are related to speech in some way or other. There is a motor speech center, an aural speech center, and a visual speech center. Each of them is related to the recognition of one of three verbal guises -- visual, aural, and enunciatory. In oral and written expression as well as in reading aloud or silently, the most varied portions of the speech center come into play. This becomes very clear when one of them fails to function. Various speech defects are called by a common term -- aphasia. They are being studied at the Neurology Institute by the well-known aphasiologist Esfir' Solomonovna Beyn.

When Words Fail to Come Off the Tongue

Doctor Beyn was receiving her new patients that morning.

"Sit next to me and listen attentively to all my questions". Esfir' Solomonovna offered me a chair and went to fetch her patient.

After several moments, they came in together. The Doctor seated the patient in front of her and began relating the case history. The patient entered the Institute several days ago; prior to that day she was being carefully examined by the clinicians. All analyses were carried out and relatives questioned as to the events leading up to the patient's loss of speech.

Today Esfir' Solomonovna planned to determine the structure of speech defects and to find out the extent of speech impairment.

"Well, let's get acquainted Zoya Petrovna", she said, looking deeply into the patient's vacant eyes. "I'm going to treat you now... So, tell me what happened?"

The woman made some attempt at a reply, but with no success. She reached into her pocket for a handkerchief.

"Alright, alright", the Doctor gently patted her on the knee, "but what are we to do? We have to get out of this situation somehow. But to help you I must talk to you. Tell me, what's the name of the doctor in charge of your case?"

"Mm... ma Ni... kola.."

"So, very well". Paying no attention to the patient's anxiety, the Doctor continued to pose questions. "What's the number of your ward? Are your comfortable there? Are you alright here?"

After listening to the unrelated fragments of words, she made a note in her file.

"The first step in the investigation are the answers to questions, the check of word sounding and the functioning of the motor speech center", said the Doctor softly turning to me.

"Now tell me, Zoya Petrovna, which sentence is right in its meaning", she turned to the patient once again, "'The earth is lit by the Sun' or ' the Sun is lit by the earth'?'

While the patient was thinking, tortuously contorting her brow, Doctor Beyn slowly and clearly repeated both sentences.

She received no reply.

"Myabe the patient simply doesn't know the answer?" I asked quietly.

"No", Esfir' Solomonovna replied quietly, "she is suffering from an impairment of understanding of certain grammatical structures. Let us take an analogous case -- function..."

"Try to tell me which is right: 'The hunter shot the bear' or 'The bear shot the hunter'?"

Once again a vacant stare showing lack of understanding.

"You see? Look ..." she offered the patient a book and a pencil. "Zoya Petrovna, please put the pencil on the book. Put the pencil ON the book", she repeated, emphasizing the preposition. And seeing how the patient helplessly shifted the objects from place to place, once again repeated softly over and over, "...pencil ON the book".

After several attempts, the patient succeeding in doing what was asked.

"And now, please put the pencil UNDER the book..."

Once again, unsuccessful attempts ending with a nearly accidental proper gesture.

The Doctor recorded the results of the session in her notebook and proceeded.

"Zoya Petrovna, write down on this piece of paper what I dictate to you".

Awkwardly, as if for the first time in her life, the patient took up the pencil. The first letters, although crooked and shaky, could nevertheless be made out. Then the patient's hand slipped without finishing, dropping the pencil.

I hurried to pick it up...

"Please don't", Esfir' Solomonovna said wearily. "She won't be able to write anyway. By all indications, the patient has lost the ability of written speech".

"Listen to what I'm going to tell you", she said to her patient: "you will soon be able to speak, that's a promise; but it's going to take some hard work and I will need your cooperation. I can't do it alone... Will you help? Good, so that's settled..."

When the patient left, I asked dubiously:

"Is she really going to speak?"

"Yes, in one and a half months she'll be speaking again... it's a mild case", Esfir' Solomonovna replied as she rose to fetch the next patient.

I spent the whole day at the Neurology Institute examining the wards, looking at patients returning from their speech lessons happy with their first successes, as well as those still unable to leave their beds and whose disorders had not yet begun to be corrected. From all of these extremely varied speech impairments I gradually began to see what a complex and intricate mosaic of inhibited and excited portions of the brain lay at the basis of articulated and meaningful speech.

When this pattern is disrupted, the integrated process falls apart and we clearly see the component parts of that marvellous property of the human psyche called speech.

How the "Speech Center" Works

In the speech process, the two cerebral hemispheres play different roles. As is known, the left hemisphere is more highly developed in man. For this reason, incidentally, our right hand which is controlled by the left hemisphere is stronger and more dextrous, after all -- this is the hand we write with. If the left hemisphere is damaged, speech and writing are impaired more seriously.

Speech is first of all the reproduction of words and individual sounds which make them up. The main role in this process is played by the rear section of the lower frontal convolution -- areas 44 and 45. Here is the motor speech center whose impairment oral speech impossible. The patient loses the ability to pronounce words although he hears and understands them quite well. If this portion of the brain is only slightly affected, words come out with difficulty.

It is the same in such cases with the writing of words, i.e., the analysis of hand motions and the related motions of the head and eyes.

When we learn to write, we mentally build up a plan of motion as a result of which the representation of the letter is formed. This plan, as all work skills, is formed with the participation of area 40. If it is damaged, the patient likewise loses the ability to write, but for another reason -- his loss of the hand manipulation plan.

Oral speech, just as the work skills which it accompanies, is also built up according to a definite plan. After each action which produces a sound there follows the analysis of the results of this action in the aural speech center somewhat in the nature of an internal playthrough. This is followed by the construction of the next sound. Such a check of the word structuring plan is performed by the front part of area 22.

If this part is impaired, the word cannot be formed, although some of its components are pronounced correctly.

If there is a disruption of the link between the motor and aural centers, speech becomes incorrect: word syllables are juxtaposed ("mosavar" instead of "samovar"), extra letters are sounded, etc.

Area 22 is located in the temporal region. Both 22 and the neighboring 21st area constitute the aural speech center. This is where perception of oral speech takes place. Upon damage to this part of the brain, the patient ceases to recognize words he hears, just as with damage to the visual center he loses the ability to understand written words. Between the aural and visual speech centers are intermediate areas -- 37 and the familiar 39. With damage to the former, the patient first of all loses the ability to name well known objects. When shown a knife he is likely to say "the thing which cuts", a glass is "the thing to drink from", a comb is "the thing to fix the hair with".

The names of objects are "forgotten" not only when area 37 is damaged, but also upon impairment of the coordinated functioning of various speech centers or the motion of neural processes from the primary signal system into the secondary one.

Similarly, the recognition of written words and their combinations is based not only on the improper functioning of the 39th area as the "recognition center" in general. Very frequently it is the result of the disruption of time links between the visual, aural, and motor speech centers. (In reading, we mentally transform the visual representation of words into internal unsounded speech. The aural and motor speech centers must also be operative in order for us to be able to do this).

Our consciousness reflects not simply pictures of the outside world; we apprehend the essence of phenomena and their dependence on such entities as space and time. Speech must convey the peculiar interrelationships of objects and phenomena in time and space. This is done by means of grammatical structure -- word endings and special auxiliary words -- prepositions, conjunctions, etc.

With damage to area 46 in the frontal region, man cannot structure his speech with grammatical correctness, i.e., he cannot represent the relations between objects in time and space by means of language.

In listening to others speak or reading a book, we must be able to analyze sentences from the same standpoint. This becomes impossible upon disruption of areas 37, 39, and 40. The patient cannot tell the difference between the expressions "the father of the son" and "the son of the father" (or, as you recall, "the Sun is lit by the earth").

The time sequence in the declarative sentence: "I went for a walk after work" is taken by the patient in the sequence of word occurrence, i.e., first "went for a walk" and then "finished work". In response to draw a cross under a circle (or to place a pencil on a book), he will first draw the cross and then place a circle under it, performing the command in the order of word occurrence, etc.

You can see from all this the complexity of the secondary signal system in our brains. In all of the interrelationships of individual speech centers and the visual, aural, and other centers of the primary system scientists as yet see no clear-cut pattern. Nothing analogous to all this exists in the field of cybernetics.

But the fact that at the basis of the psychic higher brain activity there lies the transmission of signals, albeit more complex ones, of the second order as it were, allows us to study it from the standpoint of information theory, just as the functioning of the nervous system in general.

This mathematical discipline studies the processes of information transmission along the most varied lines of communication. These include not only technical devices such as the telephone, telegraph, or radio, but also the "living telegraph" -- our organism.

After all, the nerves and even the bloodstream convey information. These information messages enter the brain which processes them and responds by emitting new signal commands. Information enters the secondary signal system in a similar way.

The Optimum "Communications System"

Let us assume that a man is asked to arrange a thoroughly shuffled deck of cards by suits. Or let us say and experienced typist is asked to press down on the required key upon hearing any letter from a random selection of letters.

In both cases the person must mentally analyze the nature of the signal and select the proper response reaction. The time required to understand what is happening and to properly respond to the stimulus is taken up by the brain in processing the information on the type of signal received.

Already in the 1880's psychologists had established that this time increases evenly as the number of signals is increased. This shows that the time required for the processing of the received information is proportional to its quantity. In other words, the brain operates like a communications system with an optimal regime, i.e., the most rationally adjusted system.

Experiments which help confirm this are devised in such a way that they simulate the process of information transfer along technical communications lines. Here man is included in the overall scheme of the transmission chain. This is why it is possible to study the peculiarities of human information processing and to determine its differences from technical communications systems.

I once had an opportunity to take part in such an experiment myself...

It happened rather unexpectedly. I visited the psychology department of Moscow University in order to find out something about modern psychological research.

The room which I was invited to enter bore little resemblance to the "humanities" laboratory I had come to expect. The tables were covered with apparatus, bits of wire were lying on the floor, and there were the familiar oscilloscopes, rheostats, and blinker lights. In the corner of the room was a windowless cabin lined with metal plates.

The laboratory heads, associates of Professor A.N. Leont'yev opened the small, thick door to the cabin:"please get in and take a seat at the table".

On the small table there were just two objects -- something like telegraph keys which had to be depressed with the right or left hand upon the flashing of signal lights. The signal display was mounted on the wall opposite the table. There was nothing else to distract one's attention.

During the experiment the door was tightly shut, cutting off the subject from the outside world. This was much like the silence chamber in which astronauts undergo tests lasting many days.

Here, however, the voluntary isolation was of much shorter duration. And no wonder: here the object of the tests was not to determine the ability to withstand silence but the ability to respond to an intricate set of signals prepared in advance by the psychologists. It would be impossible to take more than an hour of such concentrated work.

It was not always a simple matter of depressing the right key; more often , the response required to a certain signal would be to say out loud some words, or more correctly, certain specially devised sound combinations. Let us say the upper light flashes: you must say quickly: "ben". If the lower one flashes, you say "mas" into the microphone, etc.

The researcher conducting the experiment is sitting outside. He doesn't see you, but merely hears your voice. He communicates with you by means of predetermined signals.

The probability of any given signal varies from experiment to experiment. The experimenter knows this, but the subject does not. He worries about just one thing: to respond to the signal correctly, i.e., mentally select the proper action. And the scientist, since he knows exactly which signals were given and in what sequence, is able to determine the dependence between reaction time and the amount of information contained in a given signal and consequently received by the brain.

The British psychologist Hick, one of the first to carry out such experiments, established that the rate of information processing by our brain is five bits per second on an average. But he used just a few signals emitted at equal intervals. He judged the results only according to the subject's physical or verbal response, without taking into account reaction time.

But signals can be given at varying intervals rather than at a constant rate. In other words, it is not enough to take into account the average information from ten signals; it is necessary to know how much information each individual signal contains.

Nor are the signals equivalent to one another. Let us say an operator of an automated production process is observing instrument readings. In this case an infrequent unusual signal might require the most active response or even active intervention. Can an alarm signal for example be processed as fast as an ordinary signal: temperature -- 600°, pressure -- 2 atmospheres? It is clear that the brain must not simply respond to signals but to pick out the important ones, i.e., select and analyze both important and unimportant signals.

The psychologists at Moscow University are engaged in the study of these purely human peculiarities of information processing.

One of two signals was given an emergency significance. The subject in the experimental chamber was told that a particularly fast reaction was required to the emergency signal. If the reaction time to the emergency signal was longer than the one specified, the signal system would "break down" (the operator inconspicuously shut off the instruments). The experiment would end and not be credited.

Such a differentiation of signals had an immediate effect on the results. The subject was prepared at all times for the appearance of an emergency signal. And when it did appear, the brain responded in the fastest possible time.

The rate of porcessing of important information increased rapidly.

It turns out that the meaning of the signal makes a difference to the subject. He stimulates the reception of information by the brain and raises the efficiency of the process. But according to information theory the meaning of the transferred information is irrelevant. The only thing which matters is the number of"letters" used in the message.

In technical communications systems this is indeed the case. But our brain operates on a different principle: important messages are conveyed to the hands, feet, or the speech apparatus much more rapidly than ordinary messages. This once more indicates the difference between the living brain and the most perfect automaton.

Our brain also reacts differently to rapid and infrequent signals. It turns out that man either consciously or unconsciously in the course of experience masters the principle of signal structure probabilities -- the regularity of their appearance. Apparently, it mentally constructs a model of the complex of signals devised by the experimenter. On this basis, it looks ahead and guesses at future events. Now the person expects the forthcoming signals. Because of this, the reaction time to an unexpected signal grows smaller than might otherwise be the case.

Of course, this is not done without some expense to the time required for the response to frequent signals. Nonetheless, such an internal restructuring of the organism is beneficial to it.

If the brain did not adapt to expectation, the reaction time would be distributed in another way: the response to infrequent signals would be slower than the response to frequent ones. Thus, the brain would have to react according to the classic laws of information theory.

How Much Information Do We Hold?

From these experimetns it follows that the rate of information processing differs in each case. However, it is much higher than the "average" value. If we take twenty-five rather than five bits of information per second (as was supposed by Hick) this would be a closer figure in the selection situation. As regards the "capacity" of the brain in general, it is hard to quote a single figure. Various "communications channels" of the organism have differing capacities.

In order to represent this more clearly, we might recall that the television set standing in your room passes one misslion bits of information per second. This about the amount of information our eyes can send on to the brain.

Computers "digest" a thousand times less information, just like our other "communications channel", the sense of touch.

The radio and telephone are thousnads of times less powerful. They are roughly equivalent to our hearing organs in their "technical specifications". In the brain itself, information is processed twice as slowly as by telegraph equipment, which handles one hundred information units per second.

Everything which the brain perceives remains in our consciousness, as was shown by the German psychologist Helmer Frank, for a period of ten seconds. This is clearly apparent from the following example: a gong is sounded, and you continue about your business without listening. If you become aware of it after it has struck five times, you are still able to say how many times it sounded -- the first five are still retained in the brain.

This led Frank to compare our active memory which retains arising images in the consciousness, echoes of signals, with a short-memory device, in contrast to the archive of memory, where information is retained indefinitely.

He calculated the approximate capacity of our short-range memory. First of all, he had to determine the lower threshold of the brain's "carrying capacity". For this purpose, he asked students to write down everything they saw on a scree, where a series of letters appeared at an interval of a tenth of a second.

It seemed that if one increased the projection time, it might be expected that twice the information would be retained in twice the time. Actually, this was not so. Each second would allow the retention of 16 units of additional information; such is the lower threshold of human consciousness.

Since we retain not less than 16 information units per second, our short-range memory -- the "short-term accumulator", as Frank called it, contains about 160 information units.

Of this number, only 0.7 of a unit enters the long-range memory. In other words, 1/25 of what we perceive is stored in the memory. (And a similar amount each second is lost by our brain, giving way to new information).

A part of the information goes into rendering meaningful that which we perceive. Let us say that 8 units are expended on the information about the stimulus itself: then the remaining eight are used for recognizing the meaning of the word if this was what the screen revealed.

Many researchers are of the opinion that of the 16 units only one half are taken in by the brain, while the remaining eight are used to call up the appropriate information from the memory.

However that may be, it is clear that the amount of information simultaneously passed by the brain is very small.

But even this small flow is enough to actuate the entire huge program of our action and thought.

As we see, cybernetics actively aids in the investigation of the secondary signal system and human psychology in general. However, cybernetics itself is in a poorer state: the newly-discovered facts about human speech apperception and information processing not only do not simplify the tasks of engineers who intend to produce talking machines, but on the contrary complicate them somewhat.

Now we can be sure that we are merely scratching the surface. If we want machines to really understand speech and be able to speak themselves, we must equip them with something in the nature of the human secondary signal system. In other words, we must create a model of human psychic activity.

10,106
CSO: 1?72-S

-END-