Sebastian Konstantinovič Šaumjan

CYBERNETICS AND LANGUAGE

I. THE CONCEPT OF THE MACHINE IN CYBERNETICS

The well-known German mathematician D. Hilbert wrote: "A nation in isolation cannot progress unless neighboring nations are also progressing, the interests of the different states require not only that order should reign within each of them but also that the relationship between these states should be correctly maintained; the same is true in the case of the different sciences."[1]

These words of D. Hilbert, written many years ago and in which he stresses the prime importance of the interdependence of the sciences, take on a special significance at the present time when cybernetics, which is developing at an increasingly fast rate, makes it possible to discover profound analogies with far-reaching implications, between spheres of knowledge which *a priori* are unrelated.

The definition of the subject of cybernetics is as follows:

There exist three principal types of machine:

Translated by Paul Grigorieff and K. Norton-Smith.

[1] D. Hilbert, "Axiomatisches Denken," *Gesammelte Abhandlungen,* III, Berlin, 1935, p. 146.

https://doi.org/10.1177/039219216501305108 Published online by Cambridge University Press

1. Machines which transform one type of energy into another (e. g. steam engines, gas turbines);

2. Machines which modify the nature and the situation of the objects which are produced (e.g. textile machinery, metal-working machinery, transport);

3. Machines which transform one type of information into another (machines capable of use in exploiting the results of scientific and technical research, or for automatic translation between different languages, etc.).

This latter type of machine is one of the subjects of cybernetics research but it must be stressed that this science concerns itself with such machines only as representative of highly abstract systems and not in their concrete form. "Cybernetics is the study of different systems of whatever nature capable of receiving, storing and exploiting information and using it for purposes of control and adjustment."[2]

The concept of a machine as an abstract system transforming information is the fundamental notion providing a bridge between sciences which, at first sight, seem to be little related, such as neuro-physiology, biology, psychology, economics, linguistics or pedagogy. To quote a remark of Prof. A. E. Kobrinsky: "Cybernetics is a science in which the physiologist shows the engineer how to construct a robot whilst the engineer teaches the physiologist the structure of the nervous system. One might also add that they both teach the economist the regularity of economic structures."[3]

Let us examine in detail the concept of the machine in cybernetics. W. Ashby writes:

> Many a book has borne the title "Theory of machines," but it usually contains information about *mechanical* things, about levers and cogs. Cybernetics, too, is a "theory of machines," but it treats, not things but *ways of behaving*. It does not ask "what *is* this thing?" but "*what does it do?*" Thus it is very interesting in such a statement as "this variable is undergoing a simple harmonic oscillation," and is much less concerned

[2] A. N. Kolmogoroff, Preface to the Russian translation W. Ross Ashby's *An Introduction to Cybernetics*, 1959, p. 8.

[3] A. A. Feldbaum, "The Process of Teaching for Men and Robots," in *Cybernétique—Mentalité—Vie*, 1964, p. 421.

with whether the variable is the position of a point on a wheel, or a potential in an electric circuit. It is thus essentially functional and behaviouristic...

Cybernetics stands to the real machine—electronic, mechanical, neural or economic—much as geometry stands to a real object in our terrestrial space. There was a time when "geometry" meant such relationships as could be demonstrated on three-dimensional diagrams. The forms provided by the earth—animal, vegetable, and mineral—were larger in number and richer in properties than could be provided by elementary geometry. In those days a form which was suggested by geometry but which could not be demonstrated in ordinary space was suspect of inacceptable. Ordinary space *dominated* geometry.

Today the position is quite different. Geometry exists in its own right, and by its own strength. It can now treat accurately and coherently a range of forms and spaces that far exceeds anything that terrestrial space can provide. Today it is geometry that contains the terrestrial forms, and not vice-versa, for the terrestrial forms are merely special cases in an all-embracing geometry.

The gain achieved by geometry's development hardly needs to be pointed out. Geometry now acts as a framework on which all terrestrial forms can find their natural place, with the relations between the various forms readily appreciable. With increased understanding goes a correspondingly increased power of control.

Cybernetics is similar in its relation to the actual machine. It takes as its subject-matter the domain of "all possible machines," and is only secondarily interested if informed that some of them have not yet been made, either by Man or by Nature. What cybernetics offers is a framework on which all individual machines may be ordered, related and understood.[4]

Machines, considered as abstract systems, serve as models for the objects analysed. As such, cybernetic machines represent mathematical images considered as hypotheses for the internal structure of the objects studied. Usually the idea of a model is linked to some material, illustrative image—for example, at one stage in the development of physics the solar system was regarded as a model of the structure of the atom. But this notion of illustration can be extended to abstract, symbolic systems; such systems are called perfect models to distinguish them from material models, i. e. material images of the objects studied.

[4] W. Ross Ashby, *An Introduction to Cybernetics*, London, 1964, pp. 1-2.

Cybernetic machines therefore represent abstract and symbolic systems used as perfect models of the objects analysed.

The necessity to find models occurs wherever the interior structure of the object studied is not accessible for direct observation. In cybernetics such objects are called "black boxes." This term is borrowed from electricity where it is often necessary to define the contents of a sealed box having an input and output. By applying different influences to the input and then observing the result of these influences at the output the engineer can reach a conclusion on the contents of the box. In cybernetics, when examining an object as a black box, the input will be represented by the operation carried out on the object by the experimenter, and the output by observations of the results of these operations.[5]

Every model represents a particular idealization of the object studied. This is equally true of cybernetic machines.

> Cybernetics is indifferent to the criticism that some of the machines it considers are not represented among the machines found among us. In this it follows the path already followed with obvious success by mathematical physics. This science has long given prominence to the study of systems that are well known to be non-existent—springs without mass, particles that have mass but no volume, gases that behave perfectly, and so on. To say that these entities do not exist is true; but their non-existence does not mean that mathematical physics is mere fantasy; nor does it make the physicist throw away his treatise on the Theory of the Massless Spring, for this theory is invaluable to him in his practical work. The fact is that the massless spring, though it has no physical representation, has certain properties that make it of the highest importance to him if he is to understand a system even as simple as a watch.[6]

The concept of the cybernetic machine as a model of the object under study is applicable to linguistics. On the basis of a general representation of abstract cybernetic machines it is possible to analyse the grammar of any language as a logical machine transforming one aspect of an item of linguistic information into another.

[5] A special chapter is devoted to the idea of the "black box" in W. Ross Ashby, *op. cit.*, pp. 86-117.

[6] W. Ross Ashby, *op. cit.*, p. 2.

The application in linguistics of the concept of cybernetic machine has led to the creation of a new domain in this science: the theory of generative grammar. In the following paragraphs we shall examine a number of important characteristics of this new domain in linguistics together with its theoretical and practical significance.

II. GRAMMAR—A LOGICAL MACHINE

The grammars examined as logical machines will be called "generative grammars." In each three constituent features can be distinguished:

1. An assortment of elementary grammatical subjects from which complex grammatical subjects can be produced.
2. An assortment of operations which when applied to simple grammatical subjects provide a means for generating complex subjects.
3. An assortment of structural characteristics attributed to each grammatical subject produced (thus forming a hierarchy of complex subjects produced).

To illustrate this, the generative structure can be compared to "Meccano" in which there are also three constituent items:

1. An assortment of basic elements from which particular objects are constructed.
2. Instructions indicating the operations necessary to construct these objects from the basic elements.
3. Diagrams or structural descriptions of the objects to be constructed.

In generative grammars considered as logical machines, at the input we find information on the definitive number of elementary grammatical subjects and on the rules for generating complex grammatical subjects, at the output the complex grammatical subjects required.

As an example of generative grammar I will cite the one which I use in the miniaturised artificial language which I have constructed and which I shall call "M Language." It is worth noting in passing that the construction of such languages is of great interest since with their aid it becomes possible to distinguish clearly the various fundamental properties of natural languages. Their construction represents in linguistics a mental experiment analogous to those in physics or other abstract empirical sciences.

"M Language" is composed of three groups of expressions which we shall call K1, K2 and K3.

1. The following expressions belonging to category K1: *a*, *ab*, *abb*, *abbb*, *abbbb*, *abbbbb*, etc. contain a single symbol *a* and "n" times the symbol *b* placed on the right of *a*; "n" can be equal to zero as the first expression shows.

2. Expressions belonging to the group K2 are: *c*, *ca*, *cab*, *caa*, *caaa*, *caababb*, *cabbabbba*, *cabbbbaaa*, etc. They contain a single symbol *c* and "n" expressions of category K1 placed on the right of *c*, again with the possibility of "n" being nil.

3. Expressions of group K3 are: *ac*, *abc*, *abbc*, *abbbc*, *abbbbc*, *abbbbbc*, *aca*, *acab*, *abcabb*, *abbbca*, *acabbb*, etc.—i. e. they comprise an expression of group K1 and one of group K2.

The grammar of "M Language" represents a logical machine which supplies the expressions within the groups K1, K2, and K3. The sources used by this machine are:

1) The information concerning the definitive number of elementary grammatical subjects such as the symbols *a*, *b*, *c*;

2) The information concerning the rules for generating expressions in group K1, K2, K3 from these symbols.

These rules are formulated as follows:

1. The expression *a* belongs to category K1.

2. If the expression α belongs to category K1, αb belongs to category K1.

3. The expression *c* belongs to category K2.

4. If the expression α belongs to K2 and β to K1, the expression $\alpha\beta$ belongs to K2.

5. If the expression α belongs to group K1 and β to K2, the expression $\alpha\beta$ belongs to K3.

Our grammar generates the expressions of "M Language" and at the same time provides a structural characteristic for each of its expressions. These characteristics can be represented in the form of diagrams which are normally called "trees."

That for the expression *abbcab* can be presented in the form of the following tree:

$$\begin{array}{lccl}
\text{N}^\circ\ 2 & \underline{a \qquad b} & \underline{a \qquad\qquad\qquad b} & \text{N}^\circ\ 2\\
\text{N}^\circ\ 2 & \underline{ab \qquad b} & \underline{c \qquad\qquad\qquad ab} & \text{N}^\circ\ 4\\
 & abb & cab & \\
 & \multicolumn{2}{c}{\underline{\qquad\qquad\qquad\qquad\qquad\qquad}} & \text{N}^\circ\ 5\\
 & \multicolumn{2}{c}{abbcab} &
\end{array}$$

Each expression in this diagram is called a "point" of the tree. The expression *abbcab* is called "root" of the tree. The rule numbers are indicated opposite the horizontal lines and the application of the particular rule to the point above the line generates the expression below it. If we enumerate the points of the tree from top to bottom and left to right the process of generation is as follows:

1. By rule n° 2 points *a* and *b* on the left become point *ab.*
2. By rule n° 2 points *ab* and *b* become point *abb.*
3. By rule n° 2 points *a* and *b* on the right become point *ab.*
4. By rule n° 4 points *c* and *ab* become point *cab.*
5. By rule n° 5 points *abb* and *cab* become the root point *abbcab.*

Let us consider now the interpretation of these expressions in "M language." The symbols *a*, *b* and *c* are the equivalents respectively of *substantives*, *adjectives* and *verbs.*

The group K1 is analogous to nominative phrases; in reality each substantive, in the present instance the expression *a*, is a nominative phrase, just as a substantive accompanied by any number of adjectives which qualify it (*ab*, *abb*, *abbb*, etc) represents a nominative phrase.

The group K2 is the equivalent of a group formed with a verb. In reality any intransitive verb, in our example the expression *c*, is a verbal phrase, just as a transitive verb accompanied by a certain number of nominative phrases (*ca*, *cab*, *caa*, *caabbabba*, etc.) represents a verbal phrase.

The group K3 is the equivalent of propositions linking together nominative and verbal phrases. An expression such as *ac*, *abc*, *abbc*, *abbbc*, *abbbbc* is the equivalent of a proposition

https://doi.org/10.1177/039219216501305108 Published online by Cambridge University Press

containing an intransitive verb whilst an expression such as *aca*, *acab*, *abcabb*, *abbbca*, *acabbb* is equivalent to a proposition containing a transitive verb.

The reader has probably noticed that our logical machine is capable of generating expressions of a variety of lengths, whereas in real languages they would be limited; thus generally speaking a substantive can only be accompanied by two or three qualifying adjectives, a transitive verb can normally govern only two or three objects. However, it is important not to confuse the internal nature of real languages with the empirical limitations imposed on their functioning by the external factors of communication. In theory any phrase in a real language can be as long as one wishes; any substantive can be accompanied by any number of qualifying adjectives and a transitive verb can govern any number of objects. The fact that in practice the length of phrases is limited in real languages depends not on the internal nature of these languages, but on the composition of the information transmitted in the communication process and on the greater or lesser memory capacity of the speaker and the listener, who have difficulty in retaining very long phrases. The logical machine described above which generates the artificial miniaturised "M Language" reflects precisely this aspect of the problem.

To conclude this example it would be of use to enlarge on the term "generation" which does not mean that generative grammar shapes the behavior of the speaker who synthesizes propositions in the language. In reality it remains neutral as regards the viewpoints of both speaker and listener. Special algorithms of automatic synthesis and language analysis must be constructed from generative grammars in order to be able to shape the linguistic behavior of speaker and listener. Although the construction of these algorithms must be based on that of generative grammars and in addition it is indispensable to take account of them when creating generative grammars, it must be remembered that we are in the presence of different spheres of research on language in general. The difference between the theory of generative grammars and that of algorithms can be compared to the difference between mathematical logic and the mathematics of numbers.

III. PRESENT STATE OF THE THEORY OF GENERATIVE GRAMMARS

The first study of these grammars appeared in 1956 in an article by N. Chomsky dealing with three models describing language: a model comprising a finite number of situations, one for the direct components and a transformation model.[7]

I shall not dwell upon the first two models which, as Chomsky showed very convincingly, cannot serve as equivalent means in research on real languages. Instead I shall concentrate upon the third model proposed by Chomsky.

The transformation grammar of Chomsky is a generative grammar composed of three parts: 1) the systems of rules for the direct components, 2) the systems of rules for transformations, 3) the morphological rules for phonemes.

In this transformation grammar the generation of propositions takes place as follows: this grammar, considered as a logical machine of a definite type, has at its input the symbol "S" which represents the proposition as an overall, undivided element. By a series of successive operations this symbol is transformed in accordance with the rules for its direct components into a final chain. The whole formed by such chains provides the kernel of a language and this kernel contains simple active narrative propositions called kernel propositions. New chains arise thanks to the application of the transformation rules for their direct components. The final chains thus obtained are recorded at the output into chains of morphological phonemes in accordance with the special rules for phonemes.

This is the general outline of the transformation grammar,[8] which, as is well known, originated from a critical analysis of the direct components model in descriptive linguistics. In this grammar the direct components model is examined only as one particular model included in the general grammatical model. Thus transformation grammar can be regarded to some extent

[7] N. Chomsky, "Three Models for the Description of Language," I.R.E. *Transactions on Information Theory,* 1956, Vol. 1, T-2, n. 3.

[8] A detailed description of transformation grammar can be found in the article by N. Chomsky already quoted and in a book by the same author, *Syntactic Structures,* The Hague, 1957.

as the later development of descriptive linguistics. It represents a considerable step forward by comparison with the models of descriptive linguistics, but the fact that it was born precisely on the territory of descriptive linguistics and with no connection with the other tendencies in structural linguistics can be detected in transformation grammar, as it appears in the work of N. Chomsky, R. Liza etc., in the sense that it is distinctly exclusive in character; it concerns only the syntagmatic axis of the language and ignores the paradigmatic axis. Just as the interdependence of these two axes, in other words the interdependence of syntactic constructions and of the classes of morphemes and words, constitutes the pivot of language structure, the basis of any grammar must be a construction taking account of them also. Because descriptive linguistics are constructed entirely upon the syntagmatic axis, their exclusive tendencies are transmitted to transformation grammar to the extent that the latter depends from their domain.

There is also another difficulty in transformation grammar. The transformation rules for this grammar are so constructed that the two principal degrees of abstraction in the language are confused: that of internal syntactic relations and that of linguistic resources which serve to express these relations. Using the terminology of Ferdinand de Saussure one can say that two totally different levels are mingled in transformation grammar: that of language and that of the word. Let us take a concrete example. In a proposition the relation between the subject and the object is part of the internal syntactic relations. In certain languages such as French or English the linguistic procedure which expresses this is the order of the words; in other language: a model comprising a finite number of situations, cases. Neither word order nor inflection are, properly speaking, part of the internal syntactic relations of the language; they serve merely as linguistic means for expressing these relations. However, special rules exist in transformation grammar concerning the order of words and these rules rank equally with the transformation rules dealing with internal syntactic relations. By reason of its logical structure, transformation grammar belongs to those systems called concatenate, based on the principle of the linear disposition of the elements.[9] In reality the internal syntactic relations of language are totally independent of the external linear principle which has its place at the level of the word. It is for this reason that it is unlikely that models belonging by their logical structure to concatenate systems can be considered as equally valuable instruments for exploring the innermost recesses of language structure.

Taking into account the necessity to make a clear distinction between internal syntactic relations and the linguistic means which serve to express these relations, I propose to introduce into generative grammar the concepts of genotype and phenotype. Linguistic genotypes are syntactic objects considered independently from the linguistic means used to express them. Linguistic phenotypes are the external forms in which the genotypes are clothed. The sum total of linguistic genotypes composes precisely, in the spirit of F. de Saussure, the nature of the language.

The terms "genotype" and "phenotype" have been borrowed from biology where the external appearance of the individual in relation to certain traits is a phenotype whilst the genotype is the genetic make-up of the organism.

Organisms may display the same phenotypes but different genotypes or, on the contrary, the same genotypes but different phenotypes.

In accordance with the distinction between linguistic genotypes and phenotypes I propose to consider two degrees in the examination of a language: that of phenotypes and that of genotypes.[10]

The problem of the construction of transformation grammar is very ingenious in view of the fundamental limitation of the genotype and phenotype degrees of abstraction and of the correlation of the syntactic and paradigmatic axes. I took the

[9] The term "concatenation" means the operation of linking together symbols in a particular linear sequence.

[10] S. K. Šaumjan, "Transformation of Information in the Learning Process and the Double Degree Theory of Structural Linguistics," *Report of the Proceedings of the Conference on the Treatment of Information, Mechanical Translation and Automatic Reading of Texts*, Moscow, 1961.

first step in this direction at the Conference (Moscow, November 29 to December 2, 1961) organized by my department of structural linguistics in the Institute of Russian of the USSR Academy of Sciences. At this Conference, devoted to the problems of methods of transformation, I proposed a new model which I called "applied generation model"[11] which has the following characteristics.

Unlike the transformation model and other known aspects of generation models belonging by reason of their logical structure to concatenate (linear) systems, the applied generation model represents a new type of generation model related by its logical structure to non-linear systems of abstract objects, i. e to systems in which the relation between the abstract objects is fixed independently of their linguistic expression.[12]

The sole operation in an applied generation model in order to form abstract objects is a binary operation called "application." In general, application can be defined as follows: "If X and Y are abstract objects, XY must also be so." This definition calls for the following explanation: just as X and Y are abstract objects, so the link between them is also abstract, in other words independent of the linear disposition of the symbols which designate these objects; thus whether we arrange the given symbols in the opposite order or one below the other, in

[11] S. K. Šaumjan, "Transformation Grammar and Theory of the Classes of Words," *Report of the Proceedings of the Conference on the Treatment of Information, Mechanical Translation and Automatic Reading of Texts*, Moscow, 1961. The later stages in the development of applied generation models are illustrated in the following works: 1) S. K. Šaumjan, "Linguistic Generation Model Based on the Two Degree Principle," *Problems in the Knowledge of Languages*, 1963; 2) S. K. Šaumjan and P. A. Soboleff, *Applied Generation Model and Calculation of Transformation in the Russian Language*, Moscow, 1963; 3) S. K. Šaumjan, "Transformation Grammar and Applied Generation Model," collection *Methods of Transformation in Structural Linguistics*, Moscow, 1964. The complete description of the applied generation model can be found in my book, *Structural Linguistics*, in course of publication in the "Science" ("Naouka") series. I am also preparing in collaboration with P. A. Soboleff a systematic description of the Russian language on the basis of the applied generation model.

[12] The detailed characteristics of non-linear logical systems of abstract objects, in the terminology of H. B. Curry 'O Systems', are given in the book by this author *Foundations of Mathematical Logic*, New York, 1963.

each case the combination of these symbols will indicate the same abstract link between the same abstract objects.

In the applied model the generation process is discrete in character, taking place in two steps. The first occurs at the genotype level: here are found perfect objects analogous to words and propositions. The second stage consists of establishing the systematic rules of correspondence between these objects at genotype level and the concrete objects at phenotype level, i. e. the real words and the propositions of any real language.

The generation mechanism of the application model which constructs perfect objects operates independently of the rules for correspondence. Perfect objects do not contain within themselves grammatical categories, which can exist only at the level of a concrete language. Tense, case, mood, person, number, gender, etc. belong to these categories which are encountered only at the phenotype level. Thus a certain number of perfect objects generated by the application model represents an ideal language which I shall call the genotype language. The latter can be considered as a "yardstick" language in typological research.

In this language two sorts of perfect linguistic objects can be distinguished: words and "word complexes." The application model incorporates two generation mechanisms corresponding to these two sorts of object, called word generator and complex generator. The former models the relations between the different linguistic units considered on the paradigmatic axis of the language, whilst the latter models the relations between linguistic units on the syntactic axis of the language.

It has been stated above that application represents the sole operation for generating objects in the application model. Although this operation is entirely adequate for the generation of objects of any degree of complexity and on this account it is not essential to make use of transformations, there is nevertheless a valid reason which leads us not to reject transformations when using the application model. It is precisely the fact that transformations make it possible to establish the essential invariability relationships between propositions; for in fact invariability represents the pivot of syntactic structure in particular and of linguistic structure in general. Of course, it is possible to obtain two propositions separately by means of the operation of application: "The boy writes the letter" and "The letter is written by the boy," but transformation makes it possible to go beyond the invariability relationships between the two propositions and to show that the first can be transferred into the second. The discovery of invariability relationships makes it possible to explore the fundamental laws of language structure and thus increases the explanatory power of the application model.

It should be noted that the concept of transformation in the application model differs entirely from that of transformation grammar. In order to make this distinction evident, I shall make use of the analogy in the history of the concept of the phoneme in which two fundamental stages can be distinguished. In the first the phoneme was treated as a primary, initial unit in the phonological system; this was the situation prior to the experiments of N. S. Troubetzkoy and R. Jakobson. In the second stage the phoneme was no longer a primary concept but was replaced by the notion of phonological opposition. Nowadays the phoneme is regarded as forming part of phonological opposition, i. e. as a concept defined by that of phonological opposition. The latter led to a real revolution in the history of phonology, which at present has been transferred from a theory of phonemes to a theory of phonological oppositions. The system of differential elements successfully developed by R. Jakobson and his school, represents nothing else than the system of binary phonological oppositions which are considered as primary elements in relation to the phoneme.

The problem of the transformation concept presents a similar aspect. In numerous works on transformation grammar, transformation is considered as a primary notion. On the basis of this interpretation of the concept of transformation these latter are taken in isolation in atomistic fashion; the transformations are intended as a list and do not form a true system which could be presented in the form of a calculation of transformations.

In the applied generation model the primary notion is that of the field of transformation and not the transformation itself; this field is intended as a system of special operators which

I shall call "relators." As regards the concept of transformation it is no longer primary but represents only an element of the field of transformation or the notion resulting from that field. Just as phonology was transformed from the theory of phonemes to the theory of phonological oppositions after the introduction of the latter, so must transformation grammar change from the theory of transformations to that of transformation fields after the introduction of these fields.

Thanks to the fact that in the application model transformations are considered as elements of the transformation field, it is possible to go beyond the atomistic manner of treating transformations which is used in existing works on the grammar of transformation and on the basis of which transformations are intended as a list.

In the application model we are dealing with the calculation of transformations within the field and not a list of isolated transformations. This calculation makes it possible to obtain all the types of transformation for any sort of phrase.

In the Department of Structural Linguistics which I head in the USSR Academy of Sciences, as well as in other scientific centers, important experiments have already been carried out on different languages in order to verify the adequacy of the applied generation model in the description of concrete languages. One of the results of these experiments is precisely the new structural description of the Russian language already mentioned above.

It is interesting to note that the transformation calculation of the applied generation model has proved to be an effective instrument in specifically semantic research.[13]

R. Jakobson writes: "Linguistics and communications theory for some time tended to consider any interest given to 'signification' as semantic noise and to remove semantics from the framework of verbal communications. Currently linguistics are however showing a tendency to introduce 'signification' once

[13] Preliminary information on this research is given in the reports of S. K. Šaumjan and P. A. Soboleff, "The Applied Generation Model and the Automatic Obtainment of Semantic Classes and Subclasses," *Problems of Formalisation of Semantics—Summary of the Reports of the Scientific Conference*, Moscow, 1964.

more into the sphere of their research, so making use of the highly instructive experience of this provisional rejection... They are progressively finding ways leading towards the search for the relationship between the general signification and the contexts, taken as a specific linguistic object very different from the ontological problems of the reference."[14]

It is to be hoped from the results of the first experiments that the transformation calculation of the application model will confer a definite interest on the semantic aspect of linguistic research.

In conclusion it would be of use to spend some time on the significance of the theory of generative grammars. As stated above, they must serve as a basis for the construction of the algorithms of automatic synthesis and of word analysis. By means of this construction the theory of generative grammars is brought into contact with important domains of practical application such as the creation of mechanical languages for automatic translating machines, or the verbal control of machines and production objects, etc. The prospects for application of the theory of generative grammars to the practical domains of cybernetics, linked with the automation of the processes of mental work, are enormous, but this is a special subject which I shall pass over for the moment. I think, on the other hand, that it is interesting to take into consideration the philosophical import of the theory of generative grammars.

From the philosophical point of view it presents a triple interest:

1. Above all, the problem of the construction of generative grammars is in direct relation with the fundamental problem around which cybernetics is formed, which is the problem of correlation between the possibilities of human thought and the machines which transform information. This problem concerns the domain of the modulation of human thought in the universal calculating machine.[15]

[14] R. Jakobson, "Linguistic and Communication Theory," *Proceedings of Symposia in Applied Mathematics*, vol. XII, 1961, p. 250-251.

[15] A. A. Liapounoff, "Concerning the General Problems of Cybernetics," *The Problems of Cybernetics*, 1958, 1st ed.; A. Turing, *Can the Machine Think?* (translated from English, Moscow, 1960).

Since language is closely related to thought the following question must be asked concerning the grammar of natural languages: what are the limits of modulation in these languages? In other words: what are the possibilities for presenting these languages in the form of grammatical systems? From a mathematical point of view the problem posed is formulated as that of the possibility of resolving formal grammatical systems. On this subject the recent book by Bar-Hillel is of great interest. He puts forward the idea that for formal grammatical systems which serve as equivalent models in natural languages there can probably be no procedure for resolution, although there is as yet no mathematical proof.[16]

It should be noted that the problem of resolving formal grammatical systems is as important in the practical as in the philosophical sense of the word to the extent that it is related to the practical problem of the limits of formalization of the operations of mechanical and automatic translation.

2. The creation of generative grammars makes it possible to reproduce on a new level the traditional problem of the relationships between language and thought. It now becomes possible to model this relationship in a machine on the basis of systematic research into the correlation between models of grammars of natural languages and abstract, informational mechanical languages. It is to be hoped that valuable results will be achieved in this direction, throwing light on one of the most profound and difficult of philosophical problems.

3. The problem of the construction of generative grammars is directly related to philosophical problems of a general nature concerning the formation of concepts and the construction of theories in the empirical sciences. At the heart of these philosophical problems is to be found that of the relation between the principal degrees of abstraction: degrees of observation and degrees of construction. Structural linguistics is an empirical science. Therefore as in physics or other empirical sciences, in structural linguistics fundamental importance is attached to the systematic search for the relations between on the one hand models

[16] Bar-Hillel, "Decision Procedure in Natural Languages," *Logic and Analysis*, new series, 2nd year, January 1959.

belonging to the degree of construction and on the other original models belonging to the degree of observation. Cybernetic models of grammar in order to be effective must be related to their original models—the natural languages—by the system of rules of correspondence. The systematic exploitation of these rules represents one of the most important aspects of structural linguistics and is of primordial interest.