

CHAPTER 24

**Classifications, Rules, and Code of
an Operational Grammar for
Mechanical Translation***

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I. PRINCIPLES AND CLASSIFICATIONS OF AN OPERATIONAL
GRAMMAR FOR MECHANICAL TRANSLATION

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Premise. The trend of research of the Italian Operational School.

A. Criticism of the Philosophical Tradition

In 1939 some Italian research students began a study of human intellectual activities. In the course of some 15 years they had reached the following main conclusions:

(1) A philosophical tradition of centuries brings us to exclude that the contents of thought be considered as activities. On the contrary, this tradition presents them as objects, and more exactly: (a) as objects of an observational type, (b) without either of the characteristics of observability.

According to this tradition all things are of themselves already existent in some place and time proper to them, and there given to passive human knowledge.

They are present in man through their "double," in the form of sensation, or experience, or representation, or concept, etc., losing at least one or the other of the characteristics of the original things to be known.

(On this critical work of the philosophical tradition, see for example, "Language and the Table of Ceccatieff," Hermann & Cie, Paris, 1951; *L'Ecole opérationnelle et la rupture de la tradition cognitive*, "Bulletin de la Société française de Philosophie," Mars-Mai, 1952-3, Librairie Armand Colin, Paris; *Consapevolizzazione dell'Osservare*, mod. 3, "Atti del Congresso di Metodologia," Ramella, Torino, 1953; *Comment ne pas philosopher*,

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"Actes du Xième Congrès international de philosophie," Vol. I, North-Holland Publishing Company, Amsterdam, 1953; Le definizioni sviate, "Atti del XVI Congresso Nazionale di Filosofia," Fratelli Bocca, Milano-Torino, 1953, by S. Ceccato.)

These "abstract" entities of the philosophers cannot be utilized either by the anatomist and physiologist, who investigate the organic base of thought, or by the technical specialist setting out to repeat them in a model. In fact, both must deal with things of observational type and with activities performed by these, as their functions.

(2) The Italian researchers were able to demonstrate that the presence of the things as objects corresponds to a possible attitude on our part, and thus is in its turn a result, and not a primary and irreducible datum. Another attitude we can adopt is to consider things as activities.

Hence those researchers were aware that it is possible to start from a neutral position, in which things are not yet considered either as objects or as activities: research could tend to one direction or the other.

They proposed to study thought and its contents in terms of operations. (That is why they gave themselves the name "Operational School.")

This operational trend cut out the classical and insoluble problem of the relations between mind and body. Both had been conceived by the philosopher as entities and collections of entities, the ones "abstract" and the others "concrete," and thus unable to show any relation between each other except that of negation. With the new trend, in fact, this relation becomes a relation between functions (activities, processes, changes of state) and organs (observational things).

Henceforth it became possible to obtain results which can be utilized either by the anatomist and physiologist, for their inspectional ends, or by the engineer, for his constructional ends.

B. The Operational Results and the Possibility of Mechanising the Relation Between Thought and Mind

In the course of their operational analyses, the researchers of the School found that all things can be reduced to four fundamental types of activity: differentiation, figuration, categorization, and correlation.

Differentiation. Differentiation can be characterized as the activity which allows us to speak, for example, of warm and cold, of light and darkness, of hard and soft, of attention and inattention, of silence and noise, of good and bad moods, etc.

This activity can be seen as the function of certain organs which change state.

In man, as organs typical of differentiation, we can indicate, for instance, the cells of the retina, to which light and darkness cor-

respond, when the cells change state, from excitement to rest; or the olfactory cells, for odour and odourlessness; or the various innervations of the limbs, to which heaviness and lightness correspond; etc.

It may be thought that differentiation is the sensation which philosophers and scientists who take up the cognitive tradition talk of. But differentiation differs from this for two reasons. No cognitive elements are involved in differentiation. That is, there is no preexistent object given to sensation, and there is no pre-existent subject ready to receive a sensation from it. Besides, the simple differentiatum, resulting from differentiation, is still completely without a location which would allow us to speak of a "redoubling" of a thing, for instance, outside and inside the human body.

The operational analysis shows how sensation arises from differentiation by the addition of a subject; where, however, neither the subject, nor the addition, have any character of imposition, because they are the results of two mental operations, which, like any operation, may or may not be carried out.

Since a differentiatum results from a change of state, every differentiatum contains both states. This is easily realized if, for example, one thinks of light, even in full daylight: because, at least for a split second, one must represent darkness to oneself. Just as in thinking of darkness, even in complete darkness, one would have to represent light to oneself. The difference between the two differentiata is constituted by the different direction of the passage between the two states; and every differentiatum will have at least one opposite. The range of a differentiating organ, however, is often much richer. For instance, the thermal range, besides "hot" and "cold," registers "tepid," which can be seen in relation to either the one or the other, or to both.

Figuration. Figuration gives us figures or forms. It can be described as a differentiation which occurs in places, different in relation to a spatial system of reference, such as our body. The shifting of the differentiation may occur either through an articulated part of the body, such as the arms, the hands, the fingers, the head, the eyes, etc., or through a complex of fixed places, among which the differentiation moves, for example, by substituting the place in which the differentiation occurs on the palm of the hand.

Let us follow this figurative activity, for example, in the case of a table, when the differentiation at stake is that of hard and soft. With differentiation the wood will be separated from the air, and by moving the arm the differentiation will be shifted until it traces the form of the table. Or let us follow this activity in the case of a coin placed on the palm of the hand, when the differentiation at stake is that of heaviness and lightness. With the differentiation the metal will be separated in the same way from the air, passing from the receptors in contact with the one, to those in

contact with the other, until the form of the coin is traced. And so on.

As has been seen in these examples, differentiation, with the addition of figuration, gives rise to perception. This explains the impression of obligatoriness, of bound-upness that accompanies it; in fact, not only does figuration, bound to the results of differentiation, follow an obligatory path, but, being in a certain sense born in couples of differentia, the perceived thing is bound by differences to what surrounds it. If, on the other hand, it is differentiation which is added to figuration, we get representation.

We speak of perception and representation as observational activities. It appears clearly that the one does not derive from the other, except contingently, in particular cases, each of which has thus a history of its own.

Categorization. Categorization gives us the mental, or logical, categories, including, for example, substance, accident, subject, object, and, or, with, also, by, state, process, point, line, surface, volume, simple, complex, number, cause, effect, determined, equal, different, time, space, singular, plural, etc.

Categorization can be described as a particular kind of differentiation which occurs at times, different in relation to a temporal system of reference, that is memory. It is to this particular kind of differentiation that we owe the states of attention, or presence, or consciousness, that is an attention not yet focalized; and of inattention, or absence, or nonconsciousness. The state of attention, of participation, we create in a person when we say: "Pay attention," "Look," etc.

The system of reference, the memory, allows a combining of states of attention by a process which recalls that of addition, but in which the order of the addenda retains its value. In fact, analysis shows how, while every consciential differentiation occurs separately, two states of attention can be resumed as one element, and enter as such into combination with other states of attention.

A few examples will illustrate this mode of combination.

If we compose a series of mental categories according to the number of states of attention contained in them, the simplest of them is made up of two states. This, then, is the most elementary of the mental categories. Let us begin our illustration from it.

The two consciential differentiations follow one another and, by virtue of the mnemonic system, to which both refer, finally appear as a unity. That is to say, in recalling addition, both $1 + 1$ and 2 will be present. This construct is what is designated by "thing," or "something," in the widest meaning of these terms, as it appears for instance in the "what" of questions, or in the German "etwas." This combination can be created, for example, by saying to a person: "Pay attention ... , here." The first state of attention, still not focalized, on meeting the second is given, so to speak, a prop, or support, which fixes it.

Three states of attention give rise to three distinct possible combinations. The three states following one another, each entering separately into combination (that is, $1 + 1 + 1$); the three states following one another, the second two entering into combination when already combined, that is the state of attention followed by the something ($1 + (1 + 1)$), which is the construct of the "objectness"; the three states following one another, the first two entering into combination when already combined, that is the something followed by the state of attention ($((1 + 1) + 1)$), which is the construct of "subjectness."

With four states of attention there are nine possible combinations, at least half of which are given no name or use.

Of the simplest combinations, according to the serial criterion, let us mention two of the most frequently used—the "singular" and the "plural." The singular is obtained by a state of attention, followed by a something, followed by a state of attention (that is, $1 + 2 + 1$); the plural is obtained by a something, followed by a state of attention, followed by a something (that is, $2 + 1 + 2$).

A question concerning the categorization organs may receive—given the present state of our anatomical and physiological knowledge—more than one answer. We can, for example, think of a number of consciencial organs, all equal to one another and interchangeable, which function according to the particular temporal order of the combinations; but we can also think of one single organ, which produces the necessary states for the combinations by means of a pulsation. This second hypothesis seems, for the moment, the more reliable, since it implies uniqueness of consciousness, and thus this uniqueness does not have to be explained.

Categorization, like figuration, can be accompanied by differentiation. From it we obtain various constructs, among which the physical things, resulting from the addition of spatial location to differentiation (so that a physical thing will always be found in one place and different from at least one other thing in another place); and we obtain the psychical things, resulting from the addition of temporal location to differentiation (so that a psychical thing will always be found at a certain moment and different from at least one other thing at another moment).

On the other hand, by accompanying figuration and categorization, we get, for instance, the various types of geometry (Euclidean and non-Euclidean).

All these constructions are continually being carried out, and can also be followed, providing that:

(i) we get away from the (cognitive-philosophical) attitude that leads one to look for the various categories in the observational constructs—which inevitably prevents the attention, so deviated, from being directed towards the mental activities;

(ii) we train ourselves to slow up our mental operations, and at the same time to become sensitive to them and ready to seize them.

Differentiation, figuration, and categorization, either separate or with the constructs resulting when they are put together, supply thought with its contents. But their results do not constitute thought of themselves. To render them thought, an activity characteristic of thought intervenes.

Correlation. Men think in so far as they give a temporal order to the material received from their other activities (an order which is different from that of categorization). This order is that proper to correlating. Hence we can say that thinking is correlating, opening and closing correlations. In correlating, a thing is performed in the interval of time $t_1 - t_0$, and it is maintained through the interval $t_2 - t_1$; during this interval a second thing is performed, and it is maintained through the interval $t_3 - t_2$; during this interval a third thing is performed.

Thought thus reveals a polyphonic character, which recalls a counterpoint pattern of two notes to one. The thing which becomes temporarily superimposed on the other two is the correlating element, or simply the correlator, of the correlation; the thing performed first is the first correlatum, the thing performed second is the second correlatum.

The correlator is always a mental category, whereas the correlata can be either mental categories or the results of any other type of activity.

At this point the operational students could easily realize that to designate a correlation, a linguistic expression must supply at least five indications: three for the particular things correlated; one for the function of correlator (from which one infers that the other two act as correlata); and one for the place of one of the two correlata (from which one infers the place of the other).

In a complex thought, and most of our thoughts are complex, whole correlations take the place of correlata or of correlators of others, giving rise to correlational mosaics, or correlational nets. But in any case the proposition which expresses them will be exhaustively analyzable into two orders of indications:

- (i) those giving the particular things correlated, and
- (ii) those giving the particular function absolved by each of them in constituting the correlational tissue.

C. The Construction of Models

If thought and its contents are presented in this way, that is in terms of operations, it is understandable that it is no longer an absurdity to set out to reproduce them, to make a model of them. The organs of the models can be in a material like that of the human body, or in a completely different material; but their functions, that is the activities they perform, will be the same.

The students of the Operational School were tempted by these constructions of models. And it is important to make it clear that the work was not prompted by mere exhibitionism, or by those prac-

tical ends which, once it reaches a certain level of perfection, it could serve. Construction, the engineer's design even, is the surer test to prove that the description of the operations to be carried out by the model does not contain any of those irreducibly metaphorical, or negative, or contradictory expressions which are characteristic of philosophy (as a consequence of the philosopher's cognitive attitude).

From 1954 onwards, the operational students pursued these projects and their actualization.

The most original results, and also the most effectual project, concerned the mental categories; and this was put first. In 1956 the School was able, on the occasion of the Automatism Exhibition held in Milan, to present "a mechanical model of mental operations," which illustrates the operations corresponding to 23 mental categories. (See Adamo II, "Civiltà delle Macchine," N. 3, 1956, by F. Maretti.)

Subsequently the School devoted itself to the study of a more ambitious machine, in which the whole operational chain which takes us from a perceptual situation to the speech expressing it, should be present. In this model, besides the organs for the activities already mentioned—such as differentiation, figuration, categorization, and correlation—calculators, memories, both permanent and transitory, comparators, elaborators, excitors and hinderers, etc., also appear. Here the most original and important operational results applied in the machine are those obtained from the study of relations of dependence (and interdependence):

(i) between the observational operations and the operations of mental categorization; and

(ii) between the perceptual, representational, and mental operations, on the one hand, and the opening and closing of correlations in thought, on the other, as dependences which determine the functioning of a consciousness gate, or valve, which admits certain things to the thought which is in progress, or excludes them.

The project of this machine, "which perceives and speaks," has not yet been effectuated. (See: A Mechanical Model for Brain Operations, in "Tappe nello studio del l'uomo," Feltrinelli, Milan, 1959; and also "La machine qui pense et qui parle," in "Acts of the First International Congress of Cybernetics," Namur, 1956, Gauthier-Villars, Paris, by S. Ceccato.)

MECHANICAL TRANSLATION

A. The Operational Solution

The students of the School had reached this operational awareness and were at the beginning of this "models race," when they were invited to take part in the "Third London Symposium on 'Information Theory,'" which was to be held in September 1955, contributing a paper on Mechanical Translation.

The invitation was accepted, and it prompted the School to converge on this particular problem a part of the results already achieved by the operational analyses of thought and language and to promote a completion of these in the direction of mechanical translation.

At the time of the Symposium the School was thus able to present a solution of the problem which, however rough in its outlines, was fairly advanced in principle.

The main features of this solution are as follows:

(a) Languages are not fabricated from one another, but are all built up on thought and must contain the indications to express it.

(b) These indications are conventional and appear mainly in the form of connections between the particular operations that we perform, on the one hand, and some particular sounds and scratches, on the other hand.

(c) The linguistic conventions should be analysed by studying the connections between thought and its contents, and the sounds used to express them. No study of language which keeps within the limits of the sounds of a language, or seeks the relations between the sounds of two languages (as was attempted till now, either in grammars of a single language, or in the bilingual ones, and equally in the various attempts at mechanical translation) can exhaustively analyse the linguistic conventions.

(d) Since the five essential indications for expressing each correlation are supplied in the various languages, not only through the sound material of the single words, but also through the order in which they are placed, it is impossible to translate word for word. Translation is carried out, in the human mind, and it must be carried out in the machine, at least sentence for sentence.

(e) By interpreting the five essential indications, we obtain:

- (1) the correlational constructs, which represent the structural, or logical, aspects of thought, and
- (2) the contents of these constructs.

(f) Translation takes place in passing over this correlational bridge; and, entering the bridge with one particular language, we can come out with as many languages as we like, without having to modify the entry.

B. Classifications

The operational students had now to force language to reveal all its semantical conventions.

Their attention was at once directed towards the things used as correlators.

There are various reasons for this.

First of all, while things of all kinds can act as correlata, be they mental or non-mental, correlators are exclusively mental categories, and of a particular kind. Thus, while the things used as correlata can run into millions, those used as correlators are not above a few hundreds.

Besides, the things used as correlators are more common among men, even of different civilisations, and more constant in their history, than the things used as correlata.

It was decided to begin with the individuation of the possible correlators one by one, and to characterize the correlations by means of them, without taking into account for the moment the individual features of the correlata. In this way, the correlators are dealt with as individuals, and the correlata as classes.

We give here a list of correlations distinguished by the presence in them of the particular individuated correlators. This list, as the others used below for illustrative purposes, has been compiled for the mechanical translation to and from four languages, English, Russian, Italian, and Chinese, with a range of some 500 stems, which give rise to about 2,000 English, 9,000 Russian, 4,000 Italian, and 1,000 Chinese voices, or terms. The stems have been taken from the words contained in the volume "English through Pictures," by I. A. Richard & C. M. Gibson, Pocket Books Inc., N. Y., 1957. (This work, preparatory to mechanical translation without restriction of vocabulary, obeys the terms of an engagement assumed by the Center of Cybernetics and Linguistic Activities, of the Milan University, with the European Office of the Air Research and Development Command, USAF.)

The correlations in the list are numbered for the most part in the order in which they appear in the course of the said volume, but here they are grouped according to certain affinities.

Spatial Relations:

- 6 = BY, near to, at the side of
- 7 = IN, position within limits of space; location
- 8 = ON, covering, with contact
- 9 = OFF, separation
- 11 = TO, something reaches the object, or the subject
- 14 = ПЕРЕД (in front of)
- 15 = TO, motion in the direction of
- 16 = AT, exact or approximate position, not within limits
- 17 = FROM, motion from the inside
- 22 = WHERE, motion to a place
- 24 = FROM, motion from a place
- 27 = OVER, position higher than
- 28 = UNDER, position lower than, location
- 30 = IN, position within limits of space; motion
- 31 = INTO, motion or direction to a point within
- 32 = ON (?), covering, with contact; motion of the object
- 33 = THROUGH, introducing the thing traversed with penetration, when there is an obstacle
- 41 = AT, direction of motion
- 43 = WHERE, at rest in a place
- 52 = ROUND, so as to encircle or enclose
- 54 = TO, orientation
- 59 = ON (?), covering, with contact; motion of the subject

- 60 = UNDER, position lower than, in motion
- 62 = THROUGH, introducing the thing traversed with penetration, without obstacle
- 65 = ACROSS, crossing a surface
- 67 = ACROSS, forming a cross with
- 69 = ON, position in relation with two sides
- 77 = ON, motion with direction

Temporal Relations:

- 19 = AFTER, following in time
- 36 = WHEN, at the time that; generical coincidence
- 50 = IN, inclusion within limits
- 51 = BEFORE, preceding in time
- 53 = AT, exact or approximate position; immobilizing
- 61 = FROM, starting point
- 63 = ON, during, coincidentally or contemporaneously with; the thing taken into account for the reference is an interval
- 64 = TO, arriving point
- 72 = FOR, during, in the extent of; the interval is replete
- 73 = (WHILE), coincidence with intervals on both sides

Additive Relations:

- 02 = SUBJECT-DEVELOPMENT, a thing is followed in its history
- 03 = SUBSTANCE-ACCIDENT, a thing is put into relation with a characteristic; without temporal indication
- 04 = APPPOSITION ("", OF), a thing is put into relation with a parenthetic thing
- 05 = DEVELOPMENT-MODALITY, an activity is qualified
- 25 = DEVELOPMENT-OBJECT, an activity is applied to an object
- 46 = PREDICATIVE, of subject
- 48 = PREDICATIVE, of object
- 55 = AMOUNT/DEFAULT (OF), quantity which is present or absent
- 76 = GENERIC DELIMITATION (IN, AT, OF, WITH, ON)
- 80 = DEVELOPMENT-OBJECT, a performed act is applied to an object

Resuming Relations (relations which take up again):

- 38 = THAT, WHICH, WHO, WHERE, WHY, WHEN

Relations of Dependence:

- 18 = TO, the dative case, without passage of an observational thing—there is no interval of space or time to be traversed as constitutive element
- 35 = AFTER, in pursuit or quest of
- 37 = WITH, by means of
- 39 = FOR, with a view to
- 40 = BY, through the action of
- 44 = FROM, derivation
- 56 = FOR, reciprocal dependence

- 66 = OF, transformation
- 68 = THROUGH, introducing the thing traversed as an agent
- 74 = BY, source and author
- 75 = BECAUSE, for the reason that
- 78 = 為, for-to
- 79 = FOR-OF, purposive specification

Inclusion Relations:

- 01 = CLASS-SPECIMEN
- 42 = :, illustration
- 57 = GENDER-SPECIES
- 58 = IDENTIFICATION

Relations of Presence-Absence:

- 12 = AND, connecting
- 20 = , , listing
- 21 = WITH, company
- 23 = BUT, contrary tendency
- 26 = BETWEEN, insertion between two elements
- 29 = OR, alternative
- 34 = OF, partitive

Comparison Relations:

- 45 = LIKE, resemblance between two things which maintain their individuality
- 47 = THAN, introducing the second member of comparison of inequality
- 49 = AS, as ... as, introducing both members of comparison of equality

Order Relations:

- 81 = AFTER, following in order

The individuation of the particular correlators allows:

- (a) an examination of the acceptability of the correlata, as classes, in relation to the correlators. This acceptability depends on two main conditions: (1) the content of the correlatum, and (2) the position of the word designating the correlatum, in relation to the position of the word designating the correlator;
- (b) a choice of the particular correlator required, in the case of a text in which the word designating it is polysemantic.

Let us give some illustrations of the test of acceptability as to the content, in the cases (a) and (b) respectively.

Take the correlator "between" (code number 26), in the expression "the river is between the hill and the town." A rule for the correlation N. 26 requires the second correlatum to be a plural. Here, by classifying the things as singular and plural, what is designated by "hill," as singular, will not be acceptable as second correlatum of that correlation, but only what is designated by the whole expression "the hill and the town," which is a plural.

Take the Italian expressions "andare a Milano" and "stare a Milano" or the corresponding French expressions "aller à Milan" and "demeurer à Milan." The Italian "a" and the French "à" are

very polysemantic words which, among other things, designate both motion towards and location, corresponding to two correlators which are designated in English by two distinct words, "to" and "at." It must then be decided which of the two correlations is the one indicated. Here a classification of the activities into motion and location activities serves for this.

The examination of the correlata for their content is carried out according to criteria which, although of general bearing, are still chosen to master the restricted vocabulary being dealt with. These criteria are:

- constituent elements: differentiata, figures, mental categories, and their compounds
- dependences
- space, and its specifications
- time, and its specifications
- aspects (specification of the activity in relation to time in general)
- number
- engagements to give preference to a certain correlational function, or to exclude it
- constituent correlations: subject-development, non-subject-development, principal subject-development, subordinate subject-development
- open or closed constructs

The two examples given for acceptance illustrate: the first, the criterion of number; the second, the criterion of space.

Of course, each of the classes which result from the application of the above criteria is in its turn variously divided.

We give here, to illustrate this point, the list of these subclasses for the item "space":

- | | | |
|---------------|--------------------------|------------------------------------|
| —space | —movement | —moving away from
or separating |
| —closed space | —spontaneous movement | —crossing |
| —contact | —generated movement | —crossing on the
surface |
| —distance | —movement with direction | —crossing with
penetration |
| —open space | —moving near | —crossing with
obstacle |
| —state | —moving away from | —crossing without
obstacle |
| —orientation | —separation | —passing beyond |

The correlators too, although they are considered as individuals, are grouped into three classes:

- those accepting only sentences (subject-development) as correlata
- those accepting only isolated terms or locutions (non-subject-development)
- those accepting both types of correlata.

So far we have examined the acceptability of the correlata considering their content. As to their acceptability considering the position taken up by the words which designate the particular correlators in relation to the position taken up by the words which designate their possible correlata, this concerns:

- the order of the words at input
- if they are next or distant from one another, and
- if, where they are distant, the words between them can or cannot be skipped.

For instance, in the proposition "I pull the rope, strong as I am," "strong as I am," can and must be correlated with "I," in the appositional correlation, although the two expressions are separated by the words "pull the rope." On the contrary, in "Men and horses, tired as they are," the correlation cannot be carried out with "men" only, because the conjunction "and" cannot be skipped.

In constituting a correlation many languages also lay down criteria of alienability. These do not concern so much the content of the things put into correlation, or the order of the words which express them, as certain forms given to the sound material. Here we come to the agreement and its rules.

For the four languages in question, it has been sufficient to examine in this connection:

- | | | |
|---------|---------|-------|
| —case | —number | —mood |
| —gender | —person | |

Let us give as an example the two expressions: "The waves of the sea, which mourns ... ," and "The waves of the sea, which mourn" A rule for the correlation of subject-development (code number 02) requires the agreement in number between the subject and the verb, which compels us to interpret the expressions in two different ways, giving rise to two different correlational nets.

We have already made mention of the polysemanticity both of some words and of their position in relation to one another. And we have also seen how the classifications previously introduced can in part eliminate it.

But the criteria used are not always sufficient to exclude that, by starting from one and the same expression, one can arrive at more than one equally acceptable and allowable constructs.

In studying this difficulty, the students of the School had only to follow a well-known line. They took into account:

(i) The frequency with which the meanings of a polysemantic word appear, either in absolute form, or in relation to certain subjects or types of discourse, that is the presence or absence of certain words in the context of the polysemantic word;

(ii) the pertinence of notions among one another.

A 'propos of frequency, in everyday speech one will give preference, for instance, first to the literal meaning of a word, and then to its figurative, metaphorical meaning.

As to the pertinence of the notions among one another, the students took an interest, not only in the normal concomitance of of certain notions, but also in the contradictions and truisms which sometimes arise from a certain interpretation of an expression, and which must be discarded if there is an alternative interpretation.

The Italian language is a very fertile field for these studies on polysemanticity, particularly because it has taken over from Latin a great freedom in placing words. The very simple example which follows, taken from Italian, can illustrate what kinds of classifications are necessary to resolve certain cases of polysemanticity, and how they supply the machine with a cultural patrimony.

Take the proposition "La carne mangia il lupo." In Italian, as in English, French, etc., to designate the function as subject and as object of a development, the place of the words indicating them is used: before and after the verb respectively. But Italian does not always observe this order strictly. And so we get our proposition "La carne mangia il lupo" (which translated word by word, as it stands, gives us "The meat eats the wolf"), where, however, any Italian would translate without hesitation taking the wolf as the subject and the meat as the object of "eats." We get the same from the machine if we classify the various things into animate things and their activities, and inanimate things and their activities. Eating, an activity of an animate thing, if it is not taken metaphorically, will pertain to the wolf, an animate thing, and not to the meat, an inanimate thing. If, however, the proposition were "The sheep eats the wolf," the above classification would not be sufficient, because both wolf and sheep are animate things. We should have to add another classification, which distinguishes between carnivorous and herbivorous animals, and between their activities with the objects of them. Thus the interpretation would again be that the wolf eats the sheep. But if the proposition were "The puppy eats the wolf," this classification would not be sufficient either. We should have to add to it a further division into wild and tame animals, together with what happens when they meet each other, namely of their mutual behaviour.

What we have said about the classifications illustrates the matrix reproduced here. (see Fig. 1) This matrix accompanies every word. A further four orders of classifications appear in the matrix; and we shall now proceed to speak of these.

But in the first place, we must define what is meant here by "word." A word is one or more than one scratch isolated from

INPUT	SKILLS		TELEPHONE		ACCEPTANCE		AGREEMENT		POSSESSANTICITY			NORMINAL SPHERE	INDIVIDUALITY					OUTPUT														
	P	I	P	I	C	G	N	P	H	N	P		F	Fu	A	T	M		C													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
I-																																
C-																																
R-																																
C-																																
S-																																
.																																
.																																
.																																

FIGURE 1.

other scratches by an interval or an apostrophe. A matrix registers one word with this criterion.

But thus one word not always gives us indications which allow us to individuate one particular thing to be put into correlation, or one correlational function.

What actually happens is that:

(a) sometimes a word designates a whole thing to be correlated, or a whole correlational function, together with a part of another.

This is common, for example, in German, Italian, French, etc., in the case of the articulated preposition, which unites a preposition and an article into just one word.

A word of this type must be split up in order to send the indications contained in it to different sides: the preposition to the correlator, and the article to be blended with the following word. Thus a word of this type must correspond to two separate matrices; and in its direct matrix a column will contain the indications for splitting it up. Therefore we say, for every word, in the "splitting" column, whether: the word can be used as a whole; the word must be split up; or the word can, as a polysemantic, appear in both forms. (This third possibility is shown, for instance, by the Italian "colla," which corresponds both to "con la," = "with the," and to "colla," = "paste.")

(b) sometimes a word designates only a part of a thing to be correlated, or only a part of a correlational function.

This is common, for example, in the compound forms of verbs, in nearly all languages, and it is extremely frequent in all kinds of compounds with Chinese ideograms. It is clear, for instance, that "was" and "has been," or "more true" and "truer," have the same correlational value.

Words of this type must be blended; and the "blending" column will contain three orders of indications:

First order

- the word does not blend
- the word blends
- the word blends and does not blend.

Second order (type of compound we get)

- correlating element
- verb
- adverb
- etc.

Third order (position of the words)

- the word blends with a preceding one
- the word blends with a following one
- the word blends with another preceding and next to it
- the word blends with another preceding and removed from it
- etc.

The last two orders of classification in the matrix are the "notional sphere" and the "individuation"; both, and particularly the

second, concern an examination of the words, which is carried out, keeping in mind the output more than the input text.

In the notional sphere are indicated relations and things in these relations, which reflect our cognitions. (Of course, this happens within the limits of our list of words, and the possibilities of this vocabulary have been still more restricted to no more than five relations for each word.)

Some examples will illustrate the content and bearing of the notional sphere.

When the input language is in one aspect poorer than the output language, and so presents an alternative in the latter, the machine must take a choice. This occurs for instance when the input language, as Latin or Russian, has no articles, whereas they exist in the output language, as English or Italian, and with two or more different meanings, among which the choice must be made. In English and Italian there are two kinds of article, definite and indefinite, which designate things opposed from various aspects. For example, the definite article, "the," designates things already known and so individuated, and the indefinite article, "a," designates things presented for the first time and so not individuated. In this case, we proceed to examine whether the thing spoken of in the text has already been mentioned or whether it appear there for the first time. But it does not always happen that the thing is previously named directly, sometimes it is named indirectly, through other things which imply it, following one or the other relation, logical or causal. In such a situation, the machine could never make the necessary decision, if it does not know of these implications. Take for translation into English the Latin proposition "Librum lego et scriptorem laudo," or its Russian equivalent "Я ЧЮ КНИГУ И ХВАЛЮ ПИСАТЕЛЯ." Before the word "writer," which translates "scriptorem," or "ПИСАТЕЛЬ," we must put the definite, and not the indefinite, article, because the writer has already been referred to by the word "book" ("liber," "КНИГА"), as its author. The machine will know this if we have supplied its notional sphere with the indication that book and writer can be in the relation of product and producer respectively (code number 74).

In other cases the notional sphere serves to remove polyseman- ticity. Take for example, for translation into English the Italian proposition "Aprire l'ombrello sulla testa." In Italian, "su" designates both contact and position above at a distance, which English, richer on this point, designates by two different words, "on" and "over" respectively. To make a correct choice, the machine must have head and umbrella in the notional sphere, with the indication of their "over" relationship (code number 27).

Thus the notional sphere represents the highest level of culture provided by the machine; its intelligence, if this is understood to mean "to find relations."

Individuation intervenes in modifying the thought corresponding to the output language, when it does not coincide with the thought corresponding to the input language.

Here we come on a problem which has only been touched in passing when speaking of the decisions we have to take if the output language is richer than the input language; and this is certainly a problem which involves a much wider field of analysis and awareness.

To focus the problem let us give a brief indication of its origin.

Men operate on the results of their activities in two ways, even before language comes into the picture. They can group the results of their activity by addition, or by correlating them in the structures of thought.

Everyone makes use of both possibilities, according to the type and number of things to be grouped; but sometimes, though starting from the very same things, we find that both ways are followed, and this gives rise to two distinct expressions in the same language.

For example, English gives us both "to run" and "to move quickly," where the temporal qualification (the speed) is added, in the first case by addition, and in the second by the development-modality correlation. In English we also find both these ways followed in "to redden" and in "to make red," where in the first case a single word designates the addition both of development and transitivity, which are two mental categories, and of the differentiatum "red," which constitutes their content; while in the second case only the two mental categories are added and present in a single word, but the differentiatum appears separately, in a word of its own and correlated with the two mental categories as a kind of object of these.

Generally, grouping by addition gives rise to single words, and grouping by correlation gives rise to expressions. And generally, we group by addition the operations which are most frequently performed all at once. For instance, we are very often straight away interested in the fact that things are singular or plural; and so these mental categories are grouped by addition to the operations which constitute these things, and they are designated by a sound blended with the sounds which designate them. But here too the exception is not lacking. For instance, Chinese designates the singular with a separate ideogram.

If, however, the qualifications of movement (as we have seen in our example) are grouped either by addition or by correlation, and correspondingly designated, perhaps no language designates just movement, keeping the results of the various activities which concur to constitute this notion separate, and then grouping them by correlation (which would give rise for instance to the expression "the same thing first in one and then in another place").

The differences in grouping—which interest us most here, given the four languages we are dealing with—concern above all the aspects of verbs (criterion 27), that is certain qualities of the actions in relation to the temporal framework which constitutes their term of reference.

Action is examined:

- in its duration
- in its instantaneousness
- in its being about to
- in its beginning
- in its proceeding
- in its ending
- in its uniqueness
- in its repetition
- in its giving rise to consequences
- in its absence of consequences

This is done because these aspects of verbs often appear with designations which unequivocally indicate the variety of the ways followed in grouping.

Other outstanding differences of grouping concern the moods of verbs (criterion 29), particularly when we pass from the designation of a unitary situation (indicative mood) to the designation of the various pluralistic situations, that is, which contain one or more alternatives. For example:

- Simple alternative (one of the meanings of subjunctive)
- will to remove the alternative (imperative)
- hoping or wishing to remove the alternative (optative)
- dependent alternative (conditional)
- solicited alternative (interrogative)
- etc.

The individuation criteria are:

- | | | |
|---------|-----------|---------------------------|
| —number | —function | —mood |
| —person | —aspect | —other characteristics of |
| —voice | —tense | content |

The rules for the modification of the correlational nets are based above all, as has been said, on the classifications resulting from these criteria. We avail ourselves of them to substitute both the particular things correlated, and a whole correlational construct.

FINAL CONSIDERATIONS

The rapid survey of the criteria of classification suggests some considerations.

We have developed in these classifications the procedure already in use among the grammarians from ancient times: of reining in the rank, disorderly variety with which words appear in a language, so that we find the flower-beds of a garden where vegetation has grown wild. The ten or so grammatical categories, or parts of speech of the traditional grammar, have even in this preliminary work become the 81 correlations distinct in their corre-

lating elements, with the possibility of ordering their correlata into 162 classes.

Is this the right road? Can we, by proceeding in this direction, bring our work to completion, reaching a mastery of the language such as to permit a machine to take the place of a man, even before going on to translation, in understanding a speech?

The importance of our operational approach seems now to consist, still more than in the results in translation, in the insufficiencies it allows us to point out in itself.

We must keep in mind that men group the results of their activities in two ways, by addition and by correlation, and that in grouping, people speaking different languages quite often effectuate different distribution, following patterns by now settled in these languages. Then it is easy to realize that in translating we are continually passing over what results from the distributive branching, going back to a stage in which our activities are freed from grouping. Of course, the links among them, of addition and correlation, have immediately to be put back, otherwise no thought would be constituted and no language formulated. But our operational material, at least for a moment, was inevitably present to us in a pre-distributory and non-differentiated form.

In consideration of this, our procedure appears to have been restricted in at least two ways:

(a) by starting from, not the isolated elementary activities, but the results of the groupings, namely the sums of the additions, and the correlations;

(b) by individuating the particular correlators, not among the general correlating possibilities, but among the particular correlating exigencies of a limited vocabulary of four particular languages.

There is another linguistic awareness that the operational approach to mechanical translation has supplied us.

We are now perfectly aware that languages are created to serve our purposes only by counting on a sedimented cultural background, to which they are complementary and that must be always present to make a linguistic situation comprehensible. By themselves languages are not sufficient to give rise to such a background, nor do they contain it.

Many classifications effectuated for reasons of polysemanticity, and the whole notional sphere, tend to bring to the machine at least fragments of our culture and experiences.

But these classifications also start from a too-far-advanced grouping situation.

And so our next step is now clear: to break down any operational construct into its smallest component parts, reaching a limit much more proper to the thousands of years of our biological, than to the hundreds of years of our cultural history.

The operational analysis, mentioned at the beginning of this report, assures us of this possibility, and that the restrictions of the moment will be overcome.

This step will also allow us to face with complete success the problem of mechanical summarizing, in which the cultural factor has much more weight than in translating.

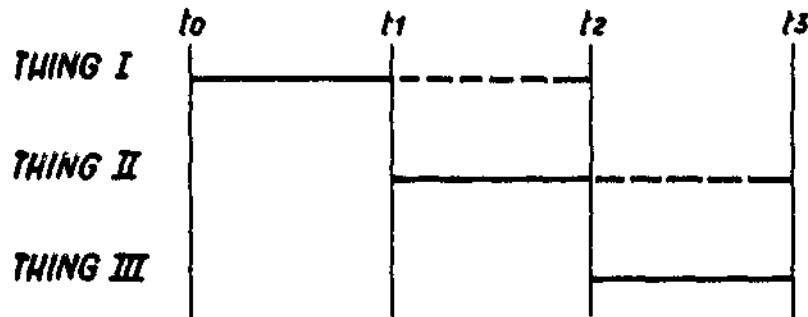
Only the more detailed the analysis, the longer and more painstaking must be the work of the researcher.

II. HOW TO REPRESENT AND RULE CORRELATING

by E. Maretti

THE CORRELATION

Correlating is a special kind of operation which assigns a specific temporal order to three things. Namely:

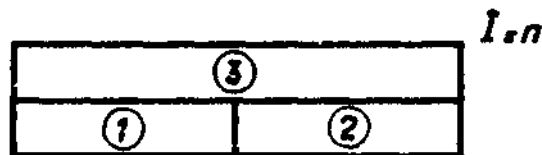


By virtue of this temporal order, thing I becomes the first correlatum, thing II becomes the correlator, thing III becomes the second correlatum.

Correlation is the result of the operation of correlating. When it is analysed in its structure, it appears constituted by three things in a reciprocal temporal relationship, one of them (the first correlatum) is present in the interval of time $t_1 - t_0$ and lasts through the interval $t_2 - t_1$, the second (the correlator) is present in the interval of time $t_2 - t_1$, and lasts through the interval $t_3 - t_2$, the third (the second correlatum) is present in the interval $t_3 - t_2$.

Representation of the Correlation

The correlation is represented insofar as its form is concerned by the following structure:



the three rectangles of which correspond to the three elements of the correlation, and it is designated by an index number $I = n$, which characterizes the particular type of correlation in question.

This representation has proved extremely useful since its intuitive aspects are a guide to the linguist in his analytical work.

Note—The index numbers given here are those of the code adopted for the classification of the correlations by the research group of the Center of Cybernetics and Linguistic Activities of Milan University.

This type of representation of the correlation is called "correlational form."

Classification of the Correlation

The correlations have been classified according to their particular correlators (index numbers $I = n$).

The index number $I = 00$, which does not specify what the correlator is, has been introduced among the index numbers I , characteristic of the specific correlations. This solution is adopted whenever the indications provided by the word or expression are still insufficient to individuate it; this individuation will be obtained from a combination of an index number $I = 00$ with another, be it $I = n$ or be it $I = 00$, according to specific rules.

Note—We consider as specific correlations the correlational forms indexed $I \neq 00$, general those indexed $I = 00$.

Contents of the Correlation

The correlational form receives its contents from the particular things that occupy the places in the three rectangles; as we have said before, the index number which designates it corresponds to the particular thing, which acts as correlator.

The first correlatum occupies the place indicated by 1.

The second correlatum occupies the place indicated by 2.

The correlator occupies the place indicated by 3.

Designation of the Correlation

To designate a correlation (that is the three particular things which are contained in it and their functions) at least 5 indications are required:

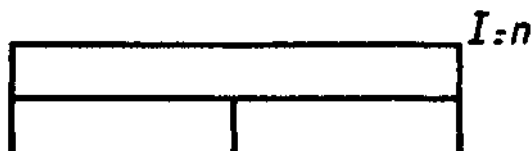
- (a) three that designate the three particular things correlated,
- (b) one that designates the thing used as correlator,
- (c) one that designates the place (first or second) of one of the correlata.

In fact, when the correlator is designated, it can be inferred that, the other two things are the correlata, and on the designation of the place of one of the correlata the place of the other can be inferred.

If the indications inferred were all expressed explicitly, they would amount to 8:

- (a) three for the particular things correlated,
- (b) three for the functions absolved by them in constituting the correlation (one for the correlator, two for the correlata),
- (c) two for the places occupied by the two correlata.

Given the correlational form,



the 5 indications necessary and sufficient to designate it can be given by 5 specific sounds or scratches (which in their turn may appear alone or with some special blendings).

Note—From now on we shall speak exclusively of sounds; it will be understood that in so doing we refer to both the commoner forms of linguistic expression, sounds and scratches.

These sounds do not always coincide materially with what are normally called "words." From the point of view of interest here, by "word" we mean everything that comes under the head "INPUT" in the matrices.

This noncoincidence occurs because two or more words sometimes indicate only one of the things correlated or a correlational function of these, in the same way as a single word sometimes indicates two or more correlated things, or correlational functions of these, and sometimes both things and functions.

Hence to constitute the correlation starting from speech, it is necessary first of all to know if each word is to be used: (1) as a single and exhaust if whole, (2) after being split up, and (3) after being blended.

These indications can be partially given by the order of the sounds.

Not all languages follow this economical criterion by which a correlation can be designated by 5 indications; nor those that do, without exception. Sometimes one or more of the indications which can be inferred are provided explicitly.

Usually, at least in modern western languages, the correlation is designated by two or three isolated words and the order of these.

Sature and Free Correlations

A correlational form is said to be saturate when its three places, or rectangles, are occupied.

A correlational form is said to be free when at least one of its places is empty.

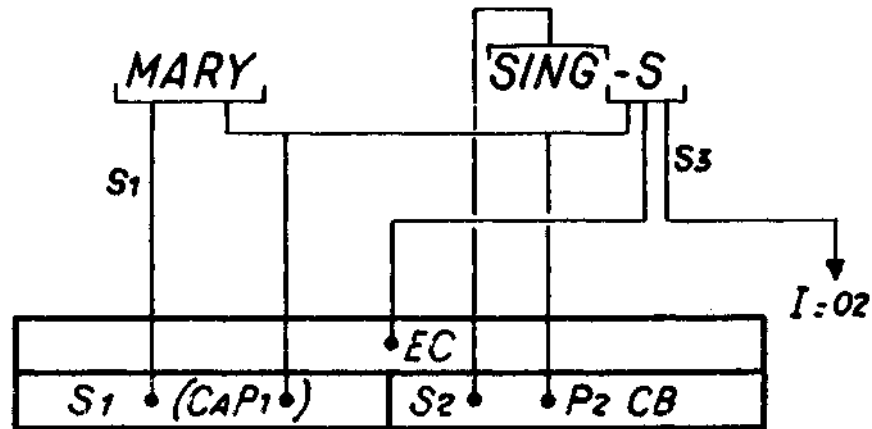
Note—From now on the following abbreviations will be used: C. F. for "correlational form," S. C. F. for "saturate correlational form," and F. C. F. for "free correlational form."

In most cases single words supply only part of the indications necessary to indicate the three things which saturate a C. F.; hence single words give rise to F. C. F.

Note—The following symbols are used to distinguish the 8 indications which designate the things and their functions in a C. F.: S₁, S₂, S₃ for the particular contents, C_a, C_b, for the functions of correlata, EC for the function of the correlator, and P₁, P₂ for the places occupied by the correlata.

Examples (for a better understanding of these examples see also p. 721):

Example 1.



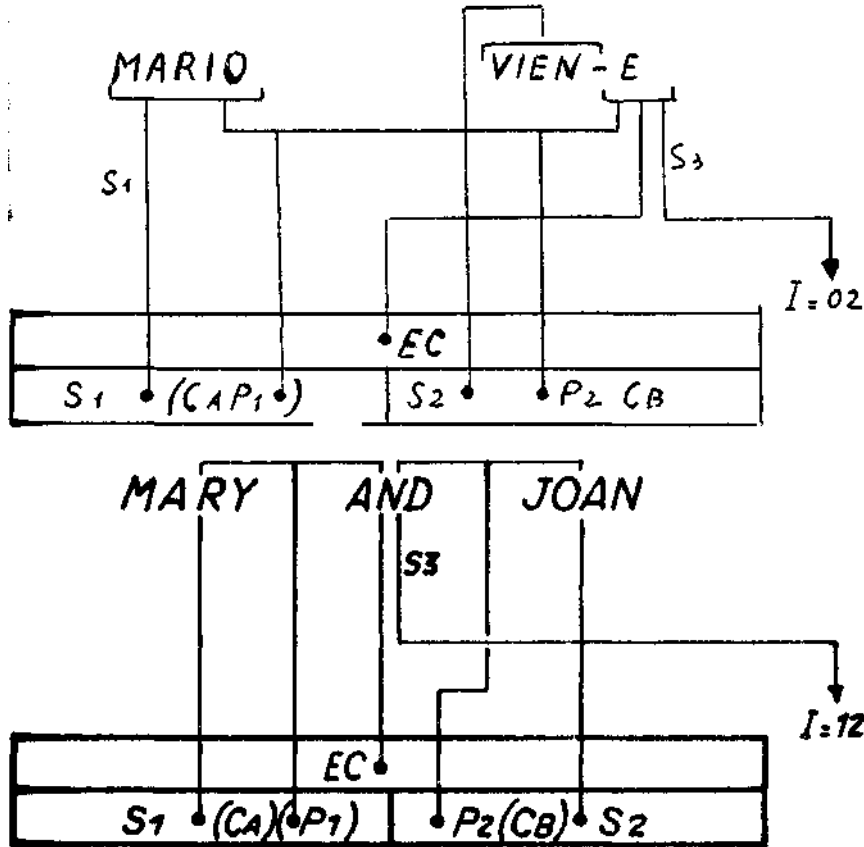
The three particular things correlated here are:

Mary	S ₁	
sings	S ₂	
the subject-development correlation	S ₃	(I = 02)

This particular subject-development correlation is designated by the sound "s", because of its position in relation to the sound "sing." Also the correlator EC and the second correlatum are designated by the sound "s," because of its position in relation to the sound "sing." The first correlatum is designated by the sound "Mary," because of its position in relation to the sound "sings" (C_b and P₁). (The last indication is not strictly necessary; but in this case it becomes opportune insofar as the word "sings" might also indicate the development-object correlation (I = 25), owing to the transitivity of the verb "to sing." The necessary indications are: S₁, S₂, S₃, EC, P₂; the redundant ones, C_a, C_b, P₁.)

In our illustrative diagrams, the brackets indicate that the designation is superfluous.

Example 2.



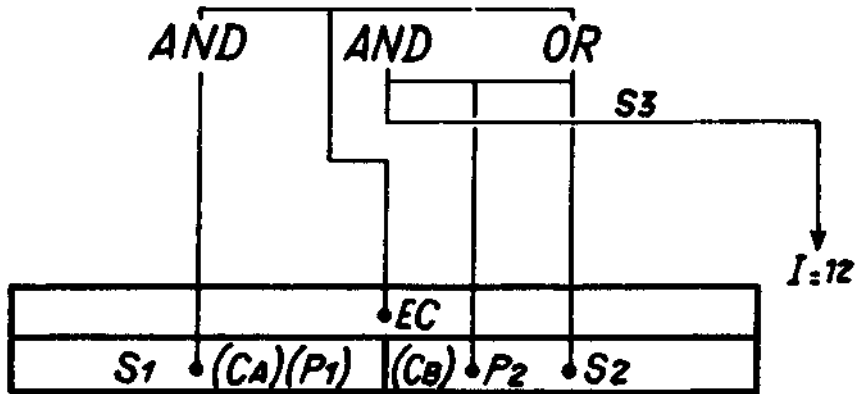
In this Italian example, "Mario" can be placed before or after "viene," at will, as the verb is only intransitive and hence can indicate explicitly only the subject-development correlation ($I = 02$), and not that of development-object ($I = 25$).

The three particular things are:

Mary	S_1	
Joan	S_2	
The copulative correlation "and"	S_3	($I = 12$)

The correlator EC is designated by the sound "and," which is the only one of these three words that can act as a correlator. In fact "Mary" and "Joan" can only act as correlata. The first correlatum is designated by the sound "Mary," because of its position in relation to the sound "and," and equally the second correlatum, "Joan."

In example 3, the only sound that could designate a correlator was "and," and hence the function of correlata assigned to the other sounds could already be inferred from the strength of this. In this example:



the sounds "Mary" and "Joan" are substituted by the sounds "and" and "or," which, unlike the former, can also designate correlators, hence all three of the sounds can designate correlators. Then the respective positions of the three sounds, "and," "and," and "or," become significant.

Correlational Forms Corresponding to Single Words

The possible C. F.'s, free or sature, corresponding to single words, are as follows:

(a) a single word supplies all 8 indications and hence corresponds to a S. C. F.,

(b) a single word explicitly supplies an indication concerning the particular thing to be correlated (S_3), and, insofar as it is used in one of its three possible functions as a constituent of a correlation, it also supplies the indication of being a correlator (EC). In this case, 2 of the 8 indications (S_3 and EC) are given.

(c) a single word explicitly supplies an indication concerning the particular thing to be correlated (S_3), and, insofar as it is used in one of its three functions as a constituent of a correlation, it also supplies the indication of being first or second correlatum (S_1, P_1, C_a or S_2, P_2, C_b). In this case, 4 of the 8 indications (S_3, S_1, P_1, C_a or S_3, S_2, P_2, C_b) are given.

(d) a single word explicitly supplies two indications concerning the particular contents (S_1, S_3 or S_2, S_3) and three indications concerning the functions that they absolve in the correlation (EC, C_a, P_1 or EC, C_b, P_2). In this case, 5 of the 8 indications (S_1, S_3, EC, C_a, P_1 or S_2, S_3, EC, C_b, P_2) are given.

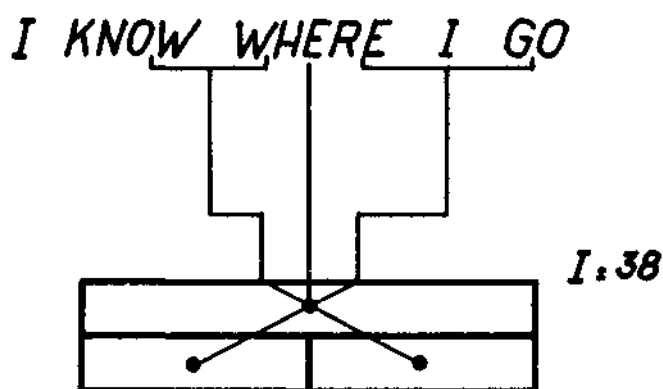
Very often, however, the single words indicate more than one C. F. In this case, only the input of other words of the proposition

determines which of these C. F.'s must be maintained and which rejected; sometimes more than one C. F. is maintained. The rejected C. F.'s appear as anticipations not justified.

Note—These possibilities are characteristic of western languages. Chinese, for example, with a single isolated ideogram, can supply the indication of a correlational function, without indicating what particular content absolves it. This is indicated by another ideogram. Consequently agreement between Chinese and these structures can in these cases only be obtained by blending two ideograms.

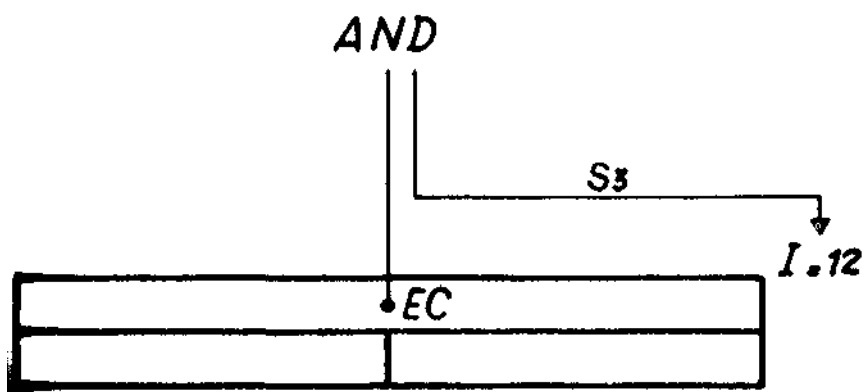
Examples:

Case A

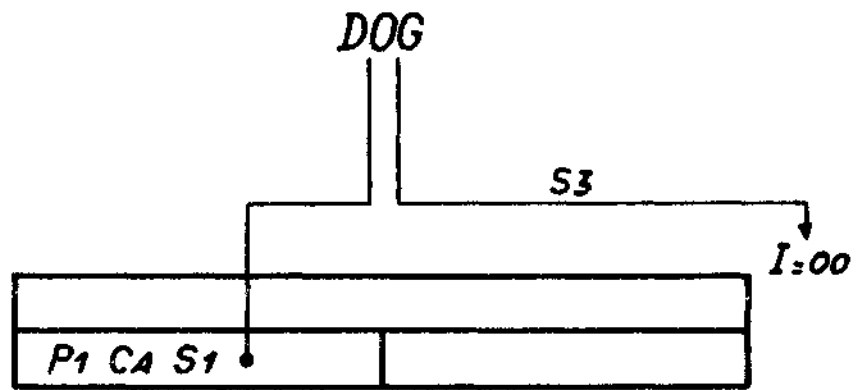
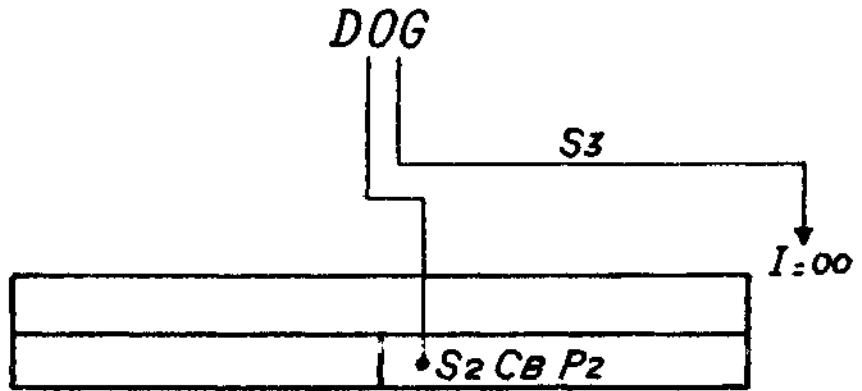


The 8 indications are given by the sound "where," because of its relation to other sounds of the proposition, which makes the thing named by "where" the object both of "know" and of "go," the two objects correlated by the resuming relation (I = 38).

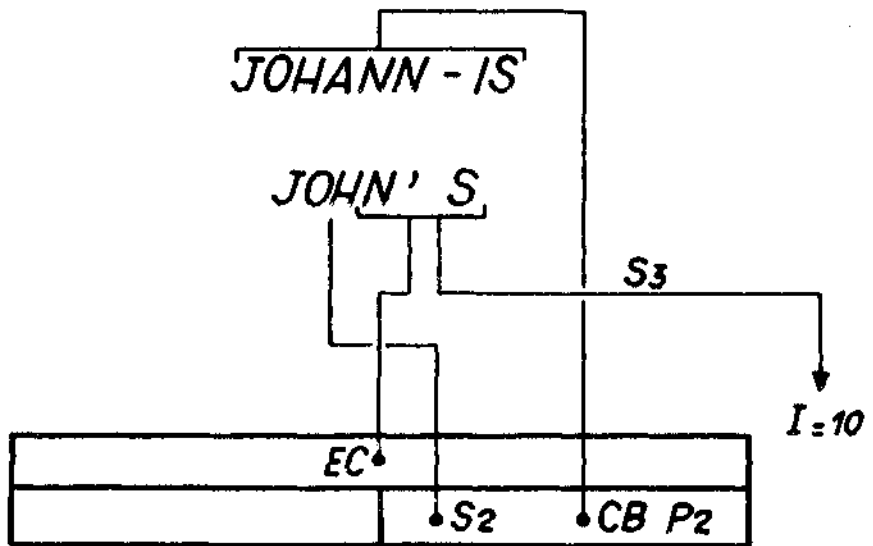
case B



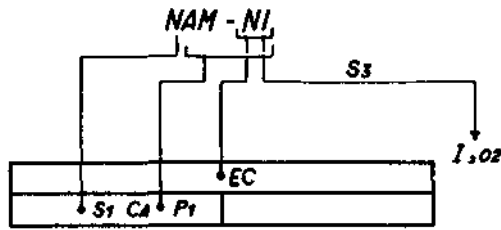
Case C



Case D, 1



Case D,2



In the last example, from the Galla language, the nominative, which acts as a subject taking a verb, is obtained with the ending "-n," or "-ni," distinguishing it from the nominative used in the absolute as a predicate, which has no case forms.

The indication of the particular correlation, merged with that of the first correlatum, appears in a speech habit now quite widespread in America, where "of" often becomes an "a," blended with the sound indicating this correlatum: for instance "sort of chairs" = sorta chairs."

Simplified Representations

Let us now indicate the C. F.'s (S or F) corresponding to the single words, by means of geometrical structures—analogueous to those described above—in which the occupied places are indicated by a dot within each rectangle.

Every dot synthesizes two or three indications.

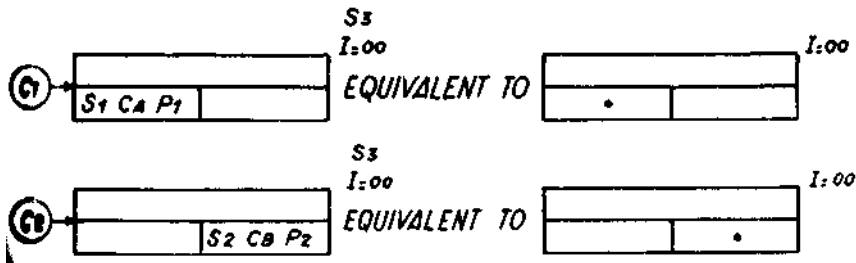
Case A (8 indications):



Case B (2 indications):

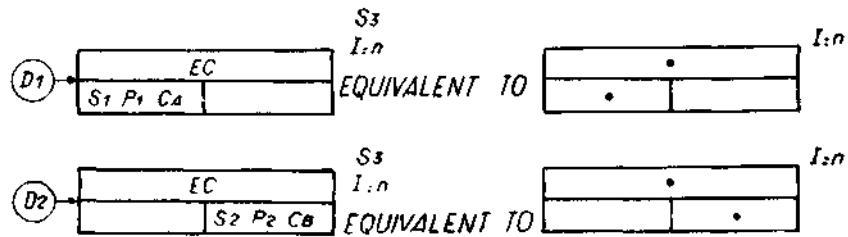


Case C (4 indications):



In this case we have two different F. C. F.'s. Since we have to choose the place of the correlatum from two places, this choice provides a further indication, which limits the original indication. To obtain this indication, the F. C. F. must be presented in both its alternatives.

Case D (5 indications):



Functions Designated by Words

Single words have already been considered in relation to the number of indications that each of them supplied to the C. F. (F. or S.). Single words can also be considered in relation to the function that they absorb in constituting the C. F. (F. or S.).

These functions can be divided into two types:

- A. Simple functions, which are
 - 0 = correlator,
 - 1 = first correlatum,
 - 2 = second correlatum;
- B. Complex functions, which are
 - 3 = correlator and first correlatum,
 - 4 = correlator and second correlatum,
 - 5 = correlator, first and second correlatum.

The functions 0, 1, 2, 3, 4 give rise to F. C. F.; the function 5 gives rise to S. C. F.

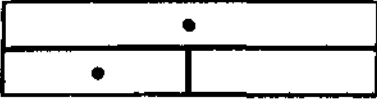




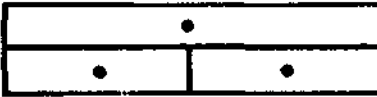

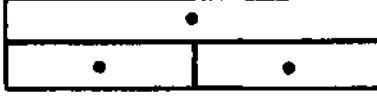
The correlational possibilities of a single word will be indicated by 2 code numbers:

- (a) the first, referring to the particular features of the correlation (index number $I = n$);
- (b) the second, referring to the particular features of the saturation received by a C. F., that is to say, its function in the C. F.

How Correlational forms are Combined

We speak of "combining" to indicate the operation or operations carried out on F. C. F.'s to obtain other free or sature C. F.'s, within the limits of a S. C. F.

The results of combining the F. C. F.'s are as follows:

1. 0 + 1		$I = n$
2. 0 + 2		$I = n$
8. 0 + 3		$I = n$
4. 0 + 4		$I = n$
5. 0 + 5 (No)		
6; 1 + 2		$I = n$
7. 1 + 3 (No)		
8. 1 + 4		$I = n$
9. 1 + 5 (No)		
10. 2 + 3		$I = n$
11. 2 + 4 (No)		
12. 2 + 5 (No)		
18. 3 + 4		$I = n$
14. 3 + 5 (No)		
15. 4 + 5 (No)		

(The combinations followed by "No" are excluded.)

In combining the 6 C. F.'s the combinations resulting from: (a) a C. F. combined with itself, and (b) the same C. F.'s combinations in inverse order, have not been taken into account.

These results of combining are obtained by using the following rules:

Rule A. The correlata must occupy different places;

Rule B. The correlators must have the same index number I, or one of them must have the index number $I = 00$;

Rule C. From the combination of two C. F.'s, with index number $I = 00$, there emerge one or more S. C. F.'s (code number 5) with particular index number I.

THE CORRELATIONAL NET

By assigning a particular temporal order to the correlations, we obtain a correlation net. This temporal order is the same as that already seen for the correlation. In this case, however, instead of one or more of the three things to be correlated, we have at least one whole correlation.

The correlational net is composed of two or more C. F.'s, of which at least one is sature.

A correlational net may be sature or free.

Sature are the correlational nets in which all C. F.'s are sature; free are those in which at least one C. F. is free.

The Construction of the Correlational Net

We speak of "composing" to indicate the operation, or operations, carried out on S. C. F.'s or F. C. F.'s to form a correlational net. This terminology distinguishes composing, from which the correlational net is obtained, from combining, which gives us the single C. F.'s. (As will be seen, a rule is based on this distinction.)

When we speak without specifying if combining or composing is involved, we use the word "to couple,"

The results of coupling are called "correlational constructs."

These constructs may be sature or free.

The free correlational constructs are of two kinds:

(a) primary, which are made up of one C. F. only.

(b) secondary, which are made up of more than one C. F., of which at least one is sature.

The composition is carried out in two ways:

(a) by insertion,

(b) by superimposing.

We get insertion when a F. C. F. is partly or wholly saturated. We get superimposing when two S. C. F.'s are composed by means of some content they have in common.

The composition by superimposing comes about since certain things can absolve more than one correlational function. For instance, in one proposition a thing acts both as the subject in relation to a verb and as a noun in relation to an adjective.

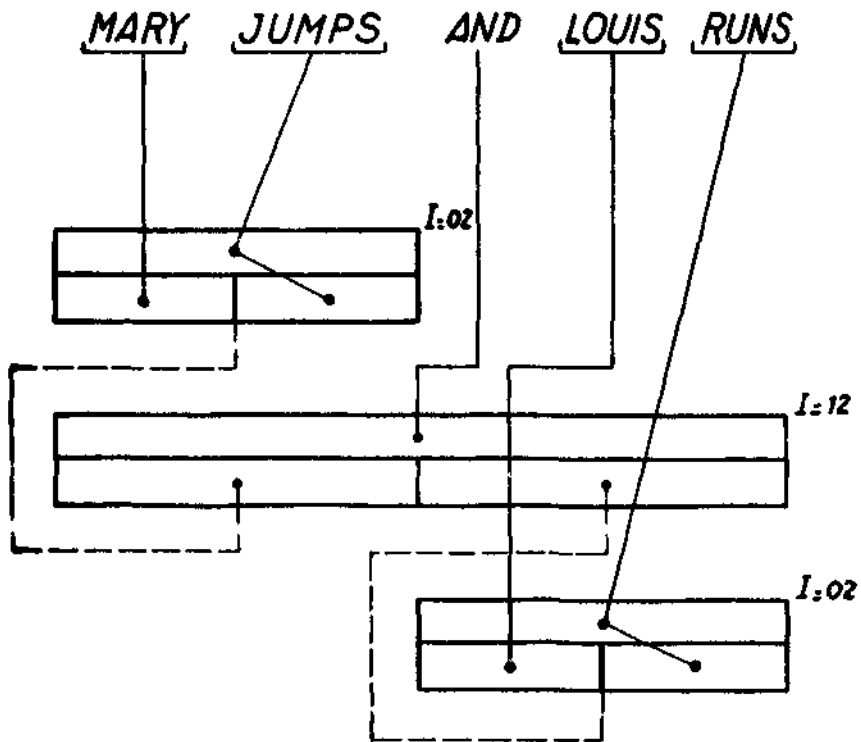
The rules for composing are as follows:

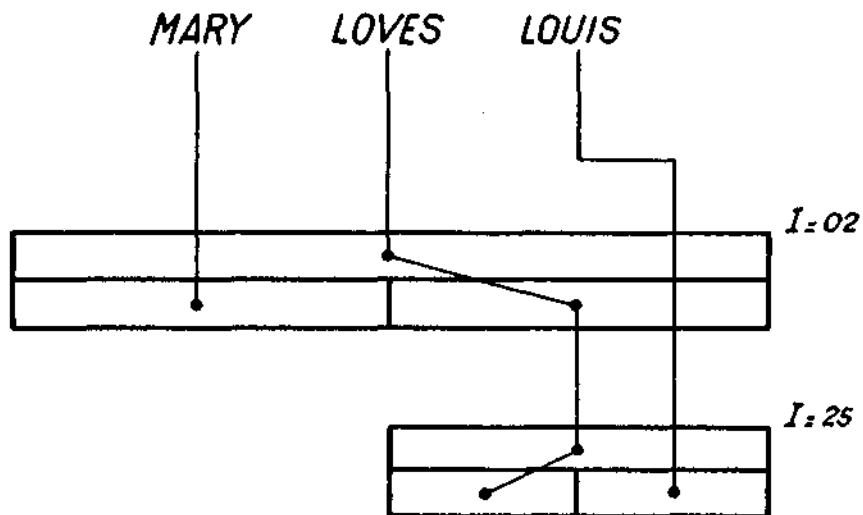
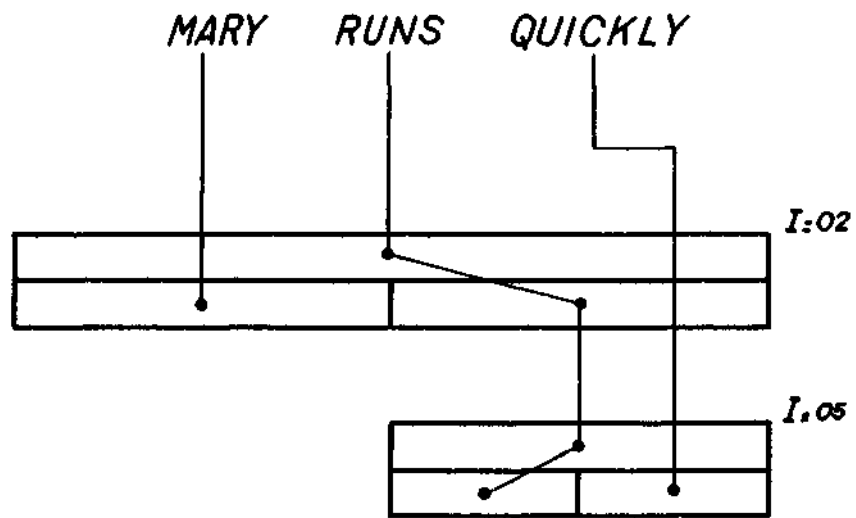
Rule A. Two S. C. F.'s may be composed only when they have a common content (composition by superimposing).

Rule B. When the C. F.'s are free and at least one of them secondary, the composition may be carried out only if there is a particular correlator (composition by insertion).

Of course, composition by insertion takes place in accordance with the rules already given for combining.

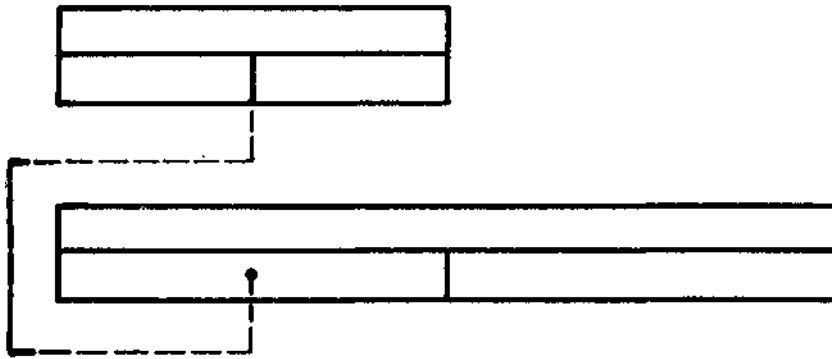
Examples:



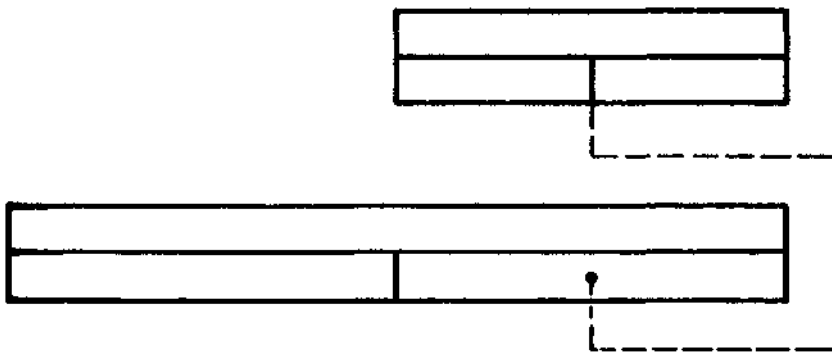


In composing by superimposition the reciprocal position of the C. F.'s is established by "arrangement rules."

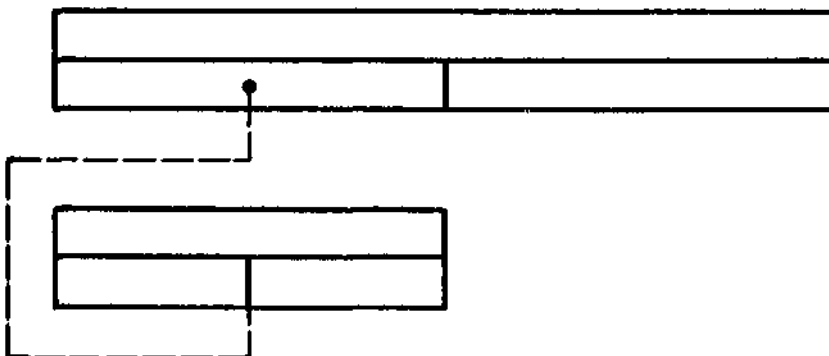
The ways of setting out two C. F.'s are as follows:



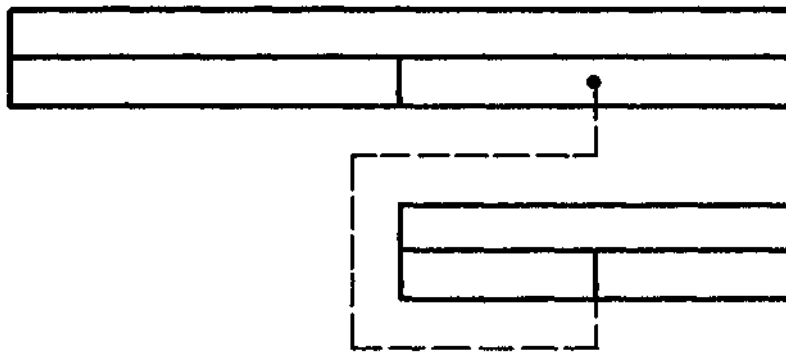
2.



3.



4.



The arrangement is decided, in each separate case, by the particular features of the S. C. F.'s which are superimposed.

Recording and Deleting Results of the Correlational Operations

The operations of combining and composing will be called "correlational operations."

The recording and deleting rules are as follows:

Rule A. After every correlational operation, with resulting constructs are registered together with the constructs which have not been utilized.

Rule B. The constructs, which have been utilized, are deleted.

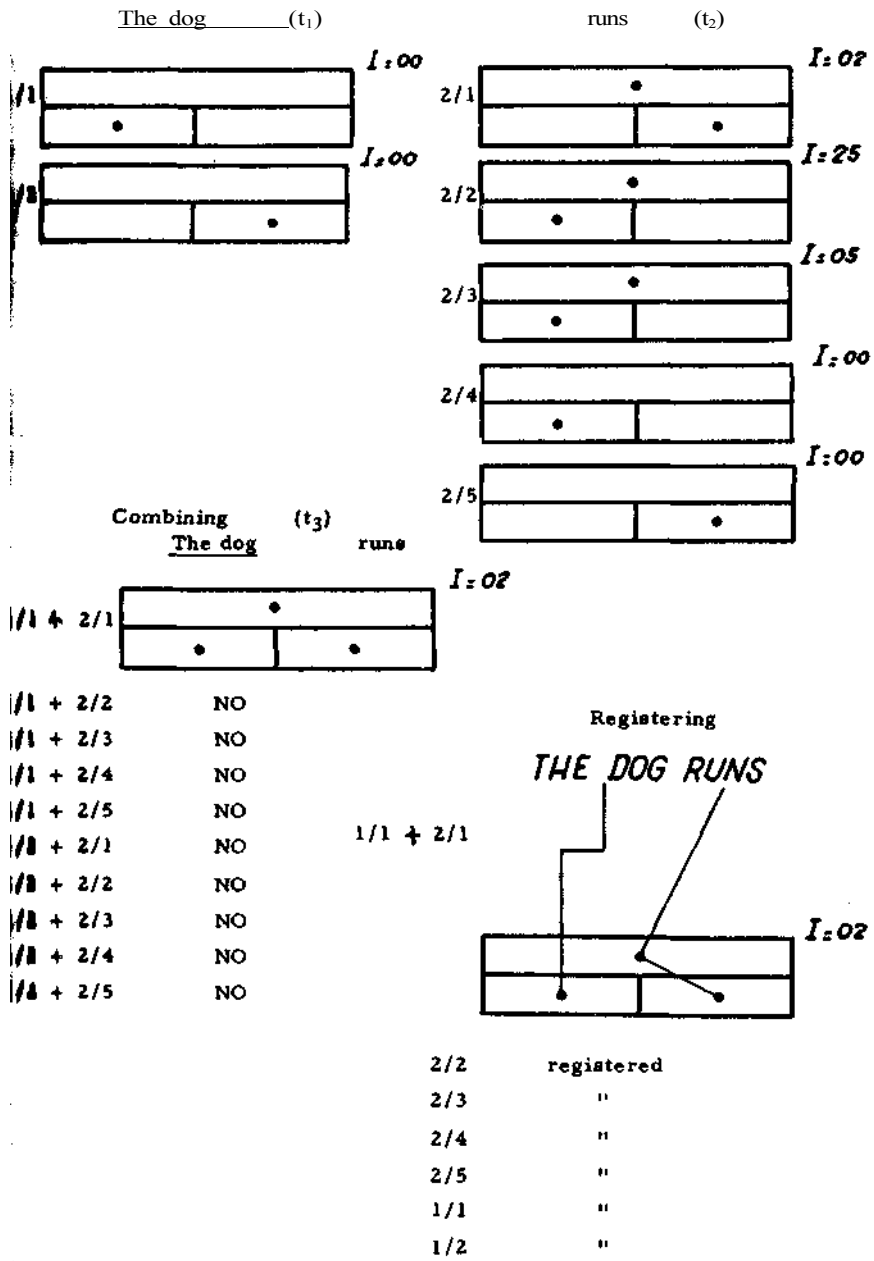
Rule C. The rule B does not apply to some particular correlational forms (for example, the C. F.'s corresponding to certain propositions), which are also registered as F. C. F.'s, obtained by freeing the place of the first correlatum.

Rule D. The rule A does not apply to the correlational constructs not utilized, which correspond to words in brackets, between parenthetic dashes, parenthetic commas, or preceding a semicolon or a colon.

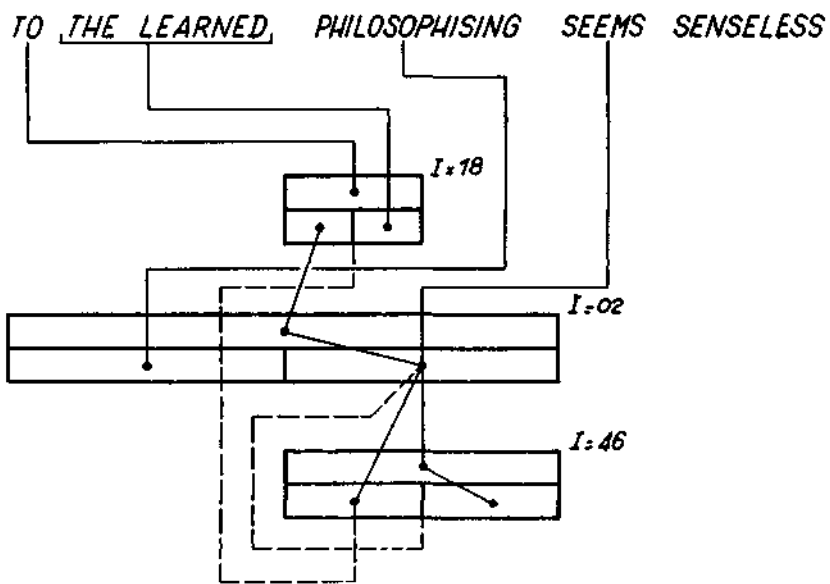
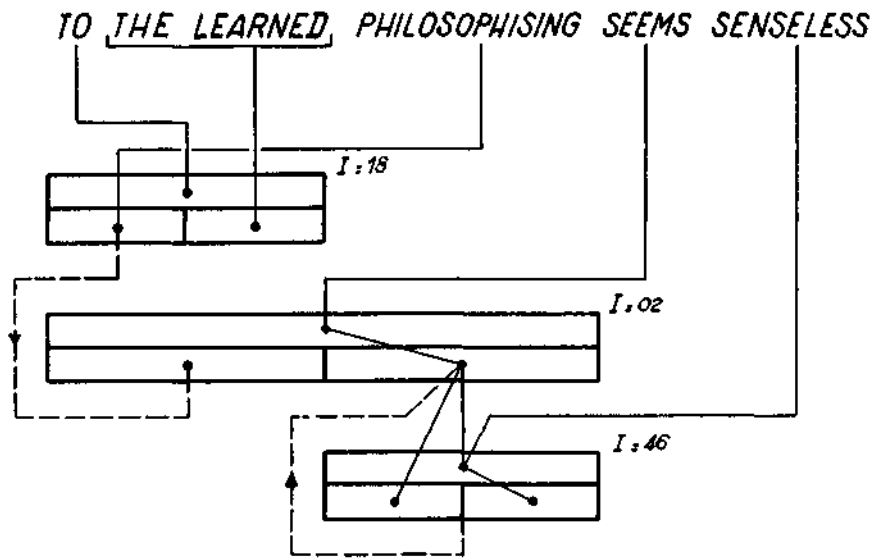
Rule E. The rule A does not apply to the correlational constructs which appear as duplicates of other already registered constructs.

Note—The C. F.'s with index number $I = 00$ are always carried forward. In fact they are never utilized as such, because they either assume the particular index number \underline{n} , when a C. F. with $I = 00$ meets a C. F. with particular index ($I = n$), or give rise to C. F.'s which are always particular when two C. F.'s with $I = 00$ meet.

Example of combining and registering



Example to the Rule C. (see p. 728)



The proposition "To the learned philosophising seems senseless" can be interpreted in two ways. But, if the place of the first, correlatum in the C. F. with $I = 18$ were not freed, the second interpretation would be excluded.

Coupling with Correlational Constructs

Before introducing a new word, the correlational constructs registered are coupled together. The coupling operation is made according to the rules of composing.

Rule A. The duplicate of the correlational constructs are deleted.

Rule B. The correlational constructs duplicating the correlational constructs already deleted are deleted.

Rule C. The results of the coupling operations are registered together with those already obtained from the preceding correlational operations.

THE MODIFICATION OF THE CORRELATIONAL NET

The correlational net (which acts as bridge between one language and another in translating) does not always coincide perfectly in the input and the output languages. Thus the input correlational net must be modified.

The rules for modification must take into account differences of thought contents, which sometimes concern the particular things correlated, and sometimes one or more whole C. F.'s.

Hence these rules are of two types:

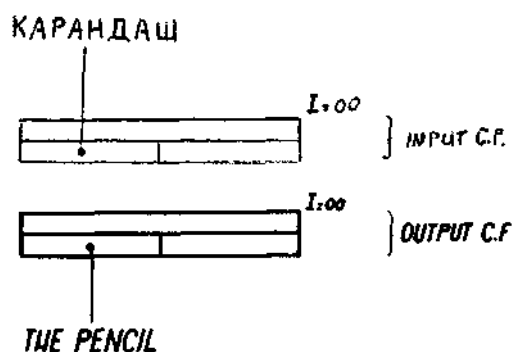
- A. Modification of a single thing,
- B. Modification of the correlational net.

The modification of A occurs by

- (1) enriching the content,
- (2) impoverishing the content,
- (3) substituting the content.

The modification of B occurs by

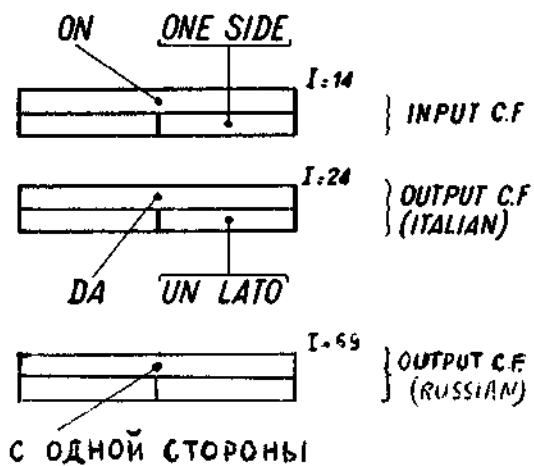
- (1) adding a C. F.,
- (2) eliminating a C. F.,
- (3) substituting a C. F.

Examples**Type A.1)**

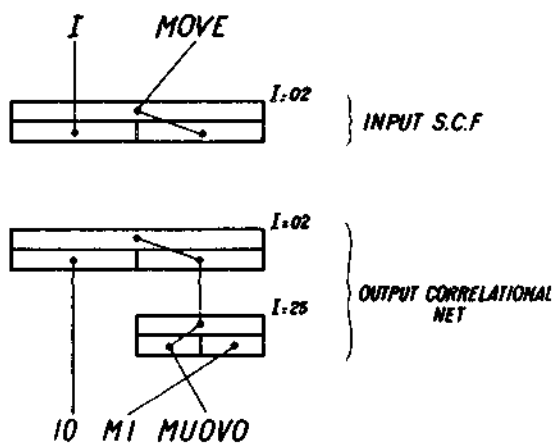
A PENCIL

Type A.2) - As an example of the rule following the pattern of A₂ take the passage in the opposite direction.

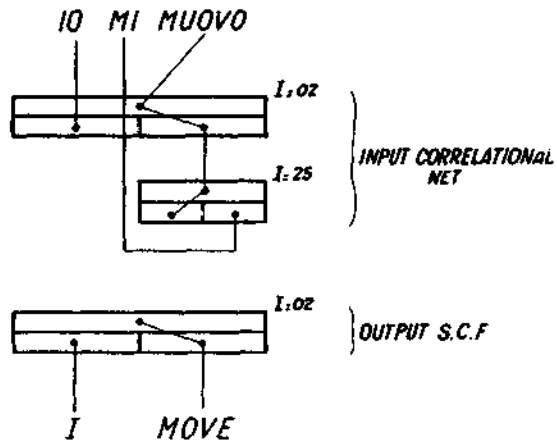
Type A₃)



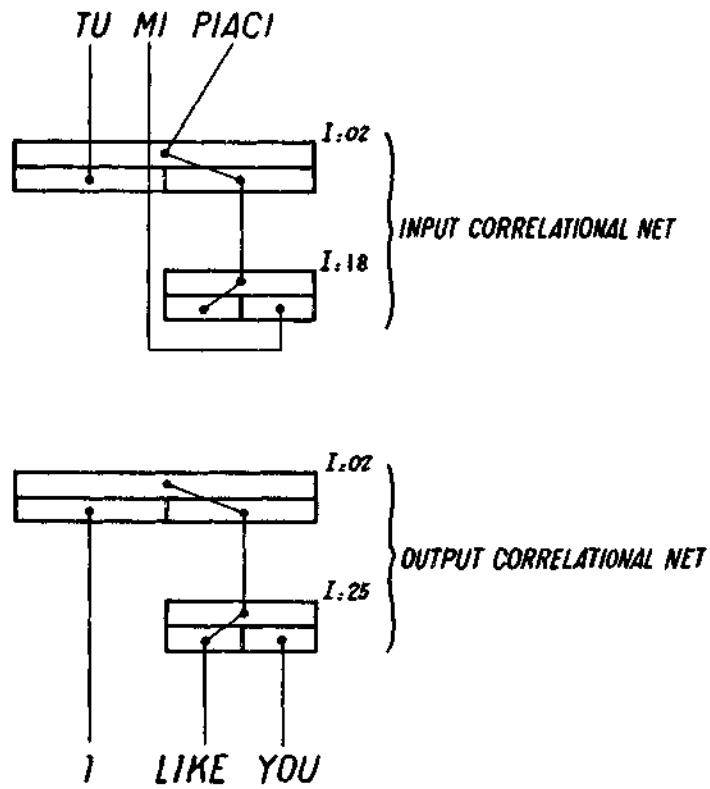
Type B.1)



B2



B3)



Rule for example A. 1): If the thing has already been named, either directly or indirectly by other things connected to it in the notional sphere (criterion N. 22), then place the sound "the" before "pencil;" if the thing has not been already named, place the sound "a" before "pencil."

Rule for example B. 1) (from English into Italian): If the word "move" is found in a C. F. with $I = 02$, then substitute for C. F. 1 a C. F. 2 constituted as follows:

- the first correlatum of C. F. 1 becomes the first correlatum of C. F. 2;
- the second correlatum of C. F. 1 is substituted by a C. F. 3, made up as follows:
 - as first correlatum, the word corresponding to "move" in the output language,
 - as second correlatum the personal pronoun in case n. 4, corresponding to the first correlatum of C. F. 1.

FROM THE CORRELATIONAL NET TO THE OUTPUT TEXT

As it has been said, the translation is carried out proposition for proposition, that is by thought units.

The only exception to this is in the case of the single word which occurs in isolation, in a title for example, and is translated directly as it stands.

Since a single S. C. F. or S. C. N. corresponds to the propositions, when we start from a C. N. the first operation is the search for the widest C. F.

The output begins with the search for the widest C. F., the one, namely, which is not contained in any other. A C. F. is contained in another when it constitutes its correlator or one of its correlata.

Example:

See p. 725, "Mary jumps and Louis runs," where "Mary jumps" and "Louis runs" are contained in the C. F. ($I = 12$).

Having individuated the widest C. F., its translation is carried out, beginning from the correlator. To it will correspond a word in the output language, which designated it in isolation or together with another.

The scratch is collocated in a particular place in an output register.

The choice of the output graphic material concerning the correlator is directly dependent on the index number of the C. F. and can correspond to a word or to an alternative or words. The choice among these words is made in function of the other input words, as they enter.

If the correlator cannot be designated in isolation, the possibilities are:

- (a) that the word designating it indicates also another part of the correlation, or

(b) that it is designated by the order of the words designating the correlata.

In the case (a): search for the stem of the output word corresponding to the input word, by means of the supplementary indications supplied by the individuation column (of the matrix).

In the case (b): search for the stems of the output words, corresponding to the input words concerning the correlata, and, starting from the left, arrange them in the order which designates the correlator.

Should the correlator be designated in isolation, after arranging it in the output register, the two correlata are arranged in the positions required by the rules of the particular language and according to the particular correlation in question.

In the case of three words, there are three possibilities:

(a) the two correlata on the left of the correlator

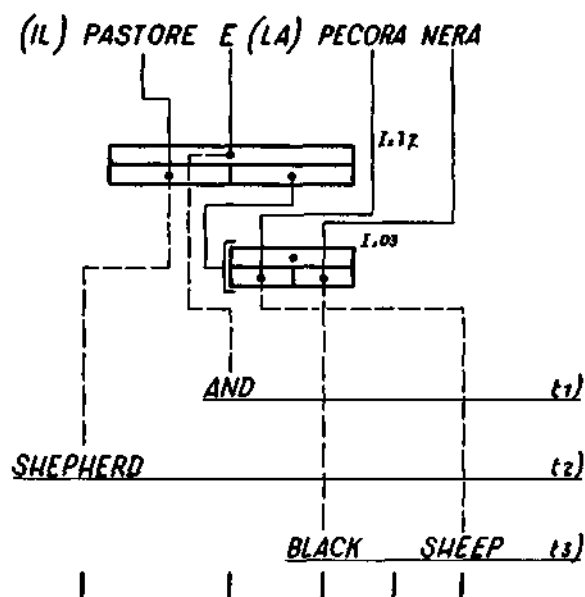
(b) the two correlata on the right of the correlator

(c) one correlatum on the left, the other on the right of the correlator.

The situation now described, apart from the search for the C. F., that would no more be carried out, is yet characteristic of a correlational form whose correlata are constituted of single things, and not of other C. F.'s. However, in the S. C. N. there is always at least one other S. C. F.

Should the correlatum be constituted by a C. F., the procedure adopted for the wider C. F. is followed; that is the correlator is produced first, and then the correlata, which in their turn may be other C. F.'s.

Example:



In this example the widest C. F. is the I = 02, which contains as its first correlatum the thing named by the sound "pastore," and as its second correlatum the C. F. with I = 03. The rules of English grammar lay down that in the C. F. with I = 12 the first correlatum be placed on the left of the correlator, which is designated in isolation with the sound "and," and the second correlatum on its right. Developing the second correlatum of I = 12, which is the C. F. with I = 03, the rules of English for I = 03 lay down that the first correlatum be set on the right of the second correlatum.

In the diagram, the horizontal lines indicate the times of output, the vertical lines indicate the correspondence between the words and the elements of the correlation.

The Elaboration of the Stems

A progressive choice of the words to elaborate is carried out, according to a priority depending on the necessity, in many languages, of making certain words agree with certain others. For example, in English, the verb, that is the second correlatum of a C. F. with I = 02, agrees, in number and person, with the subject, that is the first correlatum of the same C. F.

The elaboration of the stems is carried out taking into account:

- (a) the output stem
- (b) the classifications contained in the matrices under the head "individuation" and the possible modifications of the C. N.
- (c) the functions they absolve in the C. F. they belong to
- (d) should the words be independent, the agreement rules too.

The elaboration is carried out from a pre-established table containing the various forms that the stems may take on. For example, "to see" has "sees," "saw," "seen," "have seen," "shall see," "will see;" "dog" has only "dogs."

FUNCTIONING CYCLES

The cycles of functioning of a translating machine are as follows:

Cycle I—Choice and arrangement of the matrices corresponding to the words of the input language.

Cycle II—Construction of the correlational net corresponding to the input language.

Cycle III—Modification of the input correlational net.

Cycle IV—Alignment of the output stems.

Cycle V—Elaboration of the output stems.

Cycle I.—Cycle I, starting from the input graphic material, prepares the matrices corresponding to it for the subsequent operations. The graphic material is fed-in element by element by the feeder. The feeder's advance orders are established by the effectuation of each operational subcycle.

The first examination which the graphic material undergoes serves to establish whether or not it is an element that stops the cycle.

Full stops, question marks, and exclamation marks not followed by commas are considered stop elements.

Every input word determines, as a preliminary operation, the choice from the dictionary of the matrix corresponding to it. As has been described above, the matrix contains the classifications corresponding to the content and form of the words.

From this point on, the machine no longer operates on words, but only on indications contained in the matrices.

In the first cycle, the first two columns of the matrices, corresponding to the splitting and blending, are utilized, and the following possibilities are examined:

- 1—use of the isolated words,
- 2—use of the split words,
- 3—use of the words blended with others,
- 4—use of the isolated and split words,
- 5—use of the isolated and blended words.

The matrices are prepared in a register, in which they are also progressively numbered. Of course, when the word can be used isolated and split (case 4), or isolated and blended (case 5), all the possibilities concerning such a situation are ready in the register. They will be eliminated in the subsequent operational cycle.

Cycle II.—The matrices stored in the first register are taken one after another and each of them is used as an operator with regard to the result previously obtained.

The operations carried out in the cycle are as follows:

- (a) the construction of C. F.'s and of the C. N., according to the indications supplied by the matrices,
- (b) tests of the possibility and allowability of the correlational constructs obtained,
- (c) progressive registration of the constructs obtained.

In carrying out these operations we utilize the classifications contained in the columns of the matrices:

- (a) correlation (column Example 3),
- (b) acceptance (column Example 4),
- (c) agreement (column Example 5).

Should the tests of possibility and allowability permit us to build up more than one correlational construct, then the constructs obtained are examined, applying the classifications contained in the columns:

- (a) polysemanticity (column Example 6),
- (b) notional sphere (column Example 7).

Cycle III.—This cycle is constituted by the operations for modifying the correlational constructs corresponding to the input text, to obtain the correlational construct corresponding to the output languages, where these constructs do not coincide.

For this, we apply the classifications contained in the columns:

- (a) notional sphere (column Example 7), and
- (b) individuation (column Example 8),

on which we base the modification rules, proper to each particular language.

Cycle IV.—This cycle starts from the output correlational constructs and goes to the alignment of the stems of the words of the output language.

The operations carried out are as follows;

(a) search of the widest C. F., that is the one which is not contained in any other,

(b) laying down in a place of the stem, or stems, corresponding to the correlator of the C. F. individuated, or the indication of a place,

(c) collocation of the correlata in the places required by the correlator,

(d) repetition of the cycle until all the C. F.'s, making up the correlational net are exhausted.

The output stem is indicated in the "OUTPUT" column of the input matrices.

Cycle V.—In this cycle the stems, aligned in the cycle IV, are elaborated. This elaboration is carried out giving precedence to the leader stems, and making the others follow according to the established order.

The elaborated words are found in a storage which contain the tables corresponding to the output stems. This happens according to the indications supplied by the particular correlational function absolved by the thing it names and also by the classifications, supplied by the stem corresponding to it, in the individuation column of the input matrices.

The elaboration of the dependent words is carried out with the previous procedure and observing any agreement rules there may be.

III. CONSTRUCTION OF THE CORRELATIONAL NET BY MEANS OF DIGITAL COMPUTERS*

by E. Albani

INTRODUCTION

The following is a summary of some results obtained from linguistics analyses, which constitute the basis of this report.

A. Definition of "correlating," "correlation," and "correlational net"

(1) "Correlating" is an activity which gives a certain temporal order to three things. The three things are called: first correlatum, correlator, and second correlatum.

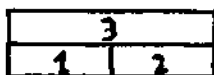
*The program has been built up with a view to applying it on the IBM 650 calculator; it is not, however, in its general outlines, bound up with the characteristics of this calculating machine. The chief point of contact with this computer is the use of machine words or "heads" of 10 decimal figures plus sign.

(2) A thing can be designated by a sound or a relation between sounds, or by both of these together.

(3) The results of correlating, called "constructs," or "correlations," are differentiated:

- 1—by the characteristics of the things correlated,
- 2—by the characteristics of the "correlational relationship," or the "correlation between the things."

(4) Let us introduce the following geometrical diagram:



in which the place 1 is to contain the first correlatum, the place 2 the second correlatum, and the place 3 the correlator.

This diagram is called a "structure," or "correlational form."

The indication concerning the particular correlational relation between the things is added, if necessary, by marking the structure with an index number.

The introduction of the structure is dictated by the necessity of following a correlation as it is being made. That is to say, we can think of the structure as empty or while the three things are located in their places and "are set in a particular correlational relationship."

If one of the three things is missing, the structure is said to be "open," or "free"; otherwise it is "closed," or "saturated."

(5) When the things to be correlated have a closed structure, the presence of an element in common acts as a link for the correlation. This method of correlating is called "correlating by superimposing," or "by substitution."

When the things to be correlated have an open structure with regard to a given "correlational relation," the method of correlating is called "correlating by insertion."

(6) The "correlational net" results from correlating three things, of which at least one is a construct having closed structure.

B. "Indications" which a word carries

- 1—word = correlatum
- 2—word = correlator
- 3—word = correlator + correlatum
- 4—word = correlator + correlata

Since, generally, the correlator decidedly suggests the correlational relation, that is to say it binds the choice of the relation to a limited number of possible relations, we shall call it "relation-correlator."

Nevertheless, only the presence of the missing things usually decides the choice, although the final decision sometimes requires a wider context.

C. Results of the analysis of indications given by single words

(1) If a word carries the indication B. 1 all the relations are possible.

(2) If a word carries one of the indications B. 2 and B. 3, only certain relations are possible. The number of possible relations is generally more than 1

(3) All the words carry the indication B. 1.

(4) If a word carries one of the indications B. 2 and B. 3, the relation must be given, so that the places of the correlata can be established.

(5) If a word carries the indication B. 1, when the correlator has been found and the relation defined, the places of the correlata are also established.

(6) The indication B. 1, taking into account the result C. 1, is represented by introducing a correlation known as "general" compared to the others, known as "specific," or "particular." Hence the indication B. 1, "correlatum of the general correlation," is equivalent to the statement: the relation-correlator of the word carrying the indication B. 1 is any relation-correlator. According to C. 3, all the words carry this indication, that is to say they can be first and second correlatum of the general correlation.

(7) The indications B. 2 and B. 3 are represented by adding the indication of the particular relations which the word carries.

In consequence of C. 4, with respect to each of these relations the places of the correlata are definitely established.

(8) When the indication B. 1 is associated with the correlational relation known as "general correlation" and the indications B. 2 and B. 3 with "specific correlations," we obtain the so-called "correlational possibilities" of the word carrying the indications.

PRELIMINARY HYPOTHESES

A. The program does not cover any research on input vocabulary

Every word, punctuation marks included, enters provided with all the indications concerning:

- (1) its order number with respect to the input and output words
- (2) its correlational possibilities
- (3) its characteristics concerning acceptance, agreement, a. s. o.

B. It is assumed that all the blending and splitting up of words has been carried out.

C. It is assumed that the number of specific correlations be at most 98. They are numbered with the numbers 01-98.

The numbers 00 and 99 are reserved for special purposes.

D. It is assumed that no word or construct has more than 10 correlational possibilities. Two of those are always the general ones:

that the element can be the first and the second correlatum of any correlation.

The remainder, 8 at most, are specific correlational possibilities.

DESCRIPTION OF THE INDICATIONS CONCERNING
A WORD OR A CONSTRUCT

A. The pieces on which we have to work are of two kinds:

first: data, which we shall call generically "words,"

second: constructs, having as their component parts two elements, which can be words or constructs.

A piece is represented by 7 heads, utilized as follows:

Head 1 { for the words—reference to the input and output words
for the constructs—characterization of the composition of the construct with respect to the component parts.

Heads 2, 3, 4,—contain the correlational possibilities, at most 10, with which a word or a construct is provided.

Heads 5, 6, 7,—contain the remaining indications concerning acceptance, agreement, a. s. o., with which a word or a construct is provided.

B. Description of heads 2, 3, 4

(1) They are to contain the codes of the correlational possibilities. Each code number is constituted by three decimal figures, of which the first two are the code number of the correlation into which the piece can enter as an element, and the third indicates the function it has in the structure of the correlation.

(2) There are 6 possible functions; they are given together with their corresponding "structure", or "correlational form."

Simple functions:

- 0 correlator
- 1 first correlatum
- 2 second correlatum



Complex functions:

- 3 correlator and first correlatum
- 4 correlator and second correlatum
- 5 correlator, first and second correlatum



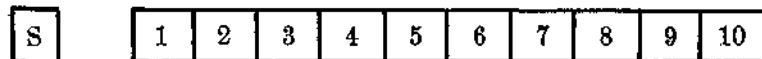
(3) The three figures 001 and 002 indicate the general correlational possibilities, that the element can be the first and the second correlatum of any correlation.

The three figures 999 serve to cancel out a correlational possibility.

The three figures 000 serve as a stop sign to indicate a series of correlational possibilities less than 10 in number.

The sign of head 2 serves for a differentiation that will be introduced later.

C. Description of head 1 for the constructs



(1) Places 1 and 2 are to contain the code number of the correlation that has produced the construct.

(2) Place 3 is to contain the code number of the structure of the construct.

There are 10 possible structures. They are:

Correlations by insertion		Resulting structures
Function first element	Function second element	
0	1	0
0	2	1
0	3	2
0	4	3
1	2	4
1	4	5
2	3	6
3	4	7

The missing combinations of the correlations by insertion correspond to combinations of incompatible functions. The coupled functions in the table are said to be compatible. Function 5 corresponds to a closed structure which cannot be correlated by insertion, and consequently it has been left aside.

Correlations by superimposition		Resulting structures												
first element	second element													
(1) <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>A</td><td>B</td></tr></table>			A	B	(2) <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>A</td><td>C</td></tr></table>			A	C	8 <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>(1)</td><td>C</td></tr></table>			(1)	C
A	B													
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(1) <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>A</td><td>B</td></tr></table>			A	B	(2) <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>C</td><td>A</td></tr></table>			C	A	9 <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td> </td><td> </td></tr><tr><td>C</td><td>(1)</td></tr></table>			C	(1)
A	B													
C	A													
C	(1)													

In the correlation by superimposing, code number 8 means that the first element goes to substitute the first correlatum of the second element, code number 9 that first element goes to substitute the second correlatum of the second element.

The missing case, that the element substituted be a correlator, does not appear.

Structures 0, 1, 2, 3 are said to be open, or free; structures 4, 5, 6, 7, 8, 9 closed, or saturated.

By inverting the position of the first with that of the second element, we get no change in the resulting structures.

To differentiate the way in which the resulting structure has been obtained, we shall call the combinations indicated above direct combinations, the others inverse.

(3) Place 4 is to contain one of the figures 8 and 9; 8 for the open constructs, 9 for the closed ones.

(4) Places 6-6-7 and 8-9-10 are to contain the index number of the component elements.

Places 5-6-7 will contain the index number of the element of smaller order number if the mode of construction is direct, greater if it is inverse.

These index numbers, each of three decimal figures, are composed as follows: the first two figures on the left indicate a class to which the elements belong, the third figure individuates the element in the class.

Hence we can state:

Additional hypotheses 1—The classes have at most 10 elements.

The use of an index number covering three places implies another additional hypotheses which will be stated later.

(5) Place S of the sign will be "-" for the words, "+" for the constructs.

D. The description of heads 5, 6, 7 is of no importance for this report.

E. To conclude: An element is represented by 7 heads. The indications contained in it are divided up into three parts:

First part (head 1)—concerns the composition, or history, of an element.

Second part (heads 2, 3, 4)—concerns the possibilities of an element of operating with another.

Third part (heads 5, 6, 7)—concerns the check on the operating when this is possible.

GENERAL RULES OF CORRELATING

A. Restrictive rules

1—An element, word or construct, cannot be correlated with itself.

2—Two constructs containing the same two elements cannot be correlated.

3—No correlational possibility of an element can be used twice to produce an allowable correlation. The allowability of a correlation is established by operations of comparison on the indications contained in heads 5, 6, 7. These operations depend on the particular features of the correlation.

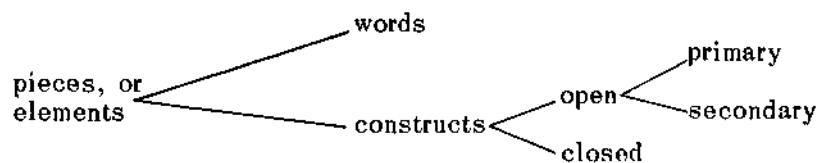
B. Definition of primary and secondary element.

(1) A construct is said to be primary if it is open and has words as its component parts.

Otherwise it is said to be secondary.

(2) The primary open constructs will be distinguished from the secondary ones by the sign of the head 2, which will be "-" for the primary, "+" for the secondary.

C. To recapitulate: The pieces, or elements, we are working on are:



D. Conditions A1, A2, A3 and A4 for correlating

- A1—The elements to be correlated have compatible functions in the structure of the same specific correlation.
- A2—The elements to be correlated have compatible functions in the structures of two different correlations of which one is the general one.
- A3—The elements to be correlated have compatible functions in the structure of the general correlation.
- A4—The elements to be correlated have a component part in common.

E. Ways of correlating

There are two possible ways:

- 1—Correlating by superimposing, or by substituting, when both the elements are of closed structure.
They can be correlated if condition A4 is fulfilled.
- 2—Correlating by insertion, when at least one element is of open structure. Let us distinguish two cases:
- 2/1—both the elements are primary
They can be correlated if one of the conditions A1, A2, A3 is fulfilled.
- 2/2—at least one element is secondary
They can be correlated if one of the conditions A1, A2 is fulfilled.

OPERATIONS FOR THE CONSTRUCTION OF THE CORRELATIONAL NET

A. To this end two operations, $O(n)$ and $\bar{O}(n)$, are introduced

(1) The function of operation $O(n)$ is to try to correlate by insertion the word p_{n+1} with each of the preceding words and each of the constructs obtained.

The restrictive correlating rule 3 must be respected.

(2) The function of operation $\bar{O}(n)$ is to try to correlate, by insertion or by superimposition, each of the constructs obtained by the operation $O(n)$, with each of the words p_1, p_2, \dots, p_{n+1} , and with each of the constructs obtained.

The restrictive correlating rules 1, 2, and 3 must be respected.

B. Description of operations $O(n)$ and $\bar{O}(n)$

(1) Let us designate the r -th word with p_r , and with C_r and \bar{C}_r two classes of constructs of order r . Henceforth we shall call ${}_r c_k$ and ${}_r \bar{c}_k$ the k -th constructs of the classes C_r and \bar{C}_r respectively.

The operations leading to the construction of the correlational net are indicated by the following symbols:

$$\begin{array}{l}
 \left\{ \begin{array}{l}
 1) (p_1) \mathcal{L} p_2 \rightarrow C_2 = D_{a+1} \\
 \bar{1}) (p_1 p_2 C_2) (\mathcal{L}\theta) C_2 \rightarrow \bar{C}_2 = D_{a+2} \\
 2) (p_1 p_2 C_2 \bar{C}_2) \mathcal{L} p_3 \rightarrow C_3 = D_{a+3} \\
 \bar{2}) (p_1 p_2 C_2 \bar{C}_2 p_3 C_3) (\mathcal{L}\theta) C_3 \rightarrow \bar{C}_3 = D_{a+4} \\
 \dots \\
 n) (p_1 p_2 C_2 \dots \bar{C}_n) \mathcal{L} p_{n+1} \rightarrow C_{n+1} = D_{a+(2n-1)} \\
 \bar{n}) (p_1 p_2 C_2 \dots \bar{C}_n p_{n+1} C_{n+1}) (\mathcal{L}\theta) C_{n+1} \rightarrow \bar{C}_{n+1} = \\
 D_{a+2n}
 \end{array} \right.
 \end{array}$$

We shall call operations $\theta(n)$ and $\bar{\theta}(n)$ those indicated symbolically in paragraphs $n)$ and $\bar{n})$.

The meaning of the terms of the operations is

(operanda) operation operator \rightarrow result

(2) In operation $\theta(n)$:

operanda—the words p_1, p_2, \dots, p_n , and the constructs of classes $C_2, \bar{C}_2, C_3, \bar{C}_3, \dots, C_n, \bar{C}_n$.

operation—indicated by \mathcal{L} , tries to correlate by insertion.

operator—the word p_{n+1} .

result—the constructs of class C_{n+1} .

(3) In operation $\bar{\theta}(n)$:

operanda—The words $p_1, p_2, \dots, p_n, p_{n+1}$, and the constructs of classes $C_2, \bar{C}_2, C_3, \bar{C}_3, \dots, C_n, \bar{C}_n, C_{n+1}$.

operation—indicated by $(\mathcal{L}\theta)$, tries to correlate either by superimposition or by insertion.

operator—the constructs of class C_{n+1} .

result—the constructs of class \bar{C}_{n+1} .

C. Flow of the operations $\theta(n)$ and $\bar{\theta}(n)$

1) Let us introduce the following symbols:

θ —to indicate the operation to try to correlate by superimposition.

X_k —to indicate an operandum running in the set of operanda.

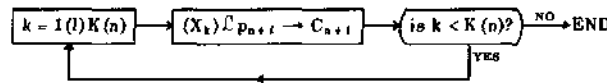
$K(n)$ —to indicate the number of the operanda in $\theta(n)$.

$\bar{K}(n)$ —to indicate the number of the operanda in $\bar{\theta}(n)$.

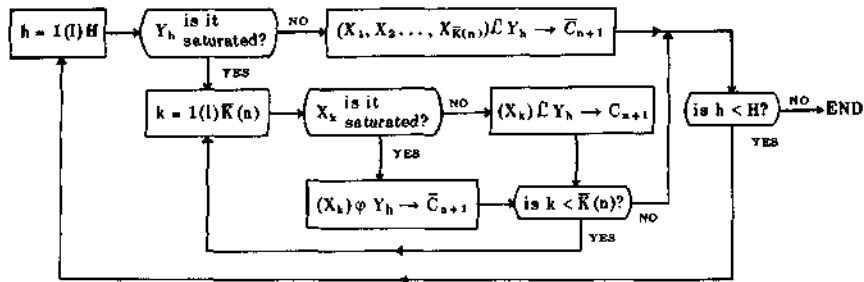
Y_h —to indicate an operator running in the set of operators, for $\bar{O}(n)$ only.

H —to indicate the number of operators, for $\bar{O}(n)$ only.

2) The flow of the operation $\theta(n) \equiv (X_1, X_2, \dots, X_{K(n)}) \mathcal{L} p_{n+1} \rightarrow C_{n+1}$ is:



3) The flow of the operation $\bar{O}(n)$ is:



D. Steps in operation \mathcal{L} : to try to correlate by insertion

- 1—to consider a correlational possibility of the operator.
- 2—to try to saturate it with each of the correlational possibilities of the operandum.
- 3—for each possible correlation, to carry out the corresponding generator sub-routine.
This decides whether the correlation is allowable, and if so, sets up the resulting construct with the indications concerning it in the class of constructs C_{n+1} .
- 4—to repeat steps 1, 2 and 3 for all the correlational possibilities of the operator.

E. Steps in operation θ : to try to correlate by superimposition

- 1—to test whether the operator and operandum have an element in common.
- 2—if they have an element in common, to perform a step analogous to step 3 of $\theta(n)$.

ARRANGEMENTS OF THE INDICATIONS AND STEPS OF MAIN PROGRAM

A. Arrangement of the indications

- (1) "Register" of heads 1-7 of the words and constructs.
If the number of the words to be processed is N, this

register is composed of $a + 2(N - 1)$ "blocks," the same number as the classes necessary to contain N words and the constructs which can be obtained by processing N words.

The classes are placed in the order: $D_1, \dots, D_a, D_{a+1}, \dots, D_{a+2(N-1)}$.

Each block is made up of M "lines," one for each element.

Each line is of 7 heads: heads 1-7, which represent a specific element.

(2) "Block" of the correlational possibilities of the constructs.

If m is the number of the correlational possibilities, this block has m lines, each of which is made up of 3 heads.

They contain the correlational possibilities resulting from a specific correlation.

B. Calculation of the maximum number of words which can be processed simultaneously

(1) Let us indicate with $I(x)$ the maximum integer so that

$$M \cdot I(x) < x$$

and

$$R(x) = x - M \cdot I(x)$$

(2) We use the first classes D_1, \dots, D_a to classify the words, and the subsequent ones to classify the constructs.

Then the i -th word is the element $R(i)$ of the class D of order $I(i) + 1$.

If N is the number of words, $I(N) + 1$ is the number of D classes occupied by the words. That is, the index number "a" of D is equal to $I(N) + 1$.

The subsequent classes of order number $I(N) + 2, I(N) + 3, \dots$ are occupied by the constructs. Hence the correspondence between classes C and \bar{C} , and D is:

$$C_2 = D_{I(N)+2}; \quad \bar{C}_2 = D_{I(N)+3}$$

.....

$$C_N = D_{I(N)+2N-2}; \quad \bar{C}_N = D_{I(N)+2N-1}$$

Additional hypotheses 2—It must be that

$$I(N) + 2N - 1 \leq 100$$

Hence at most 48 words can be processed simultaneously.

C. Additional hypotheses 3

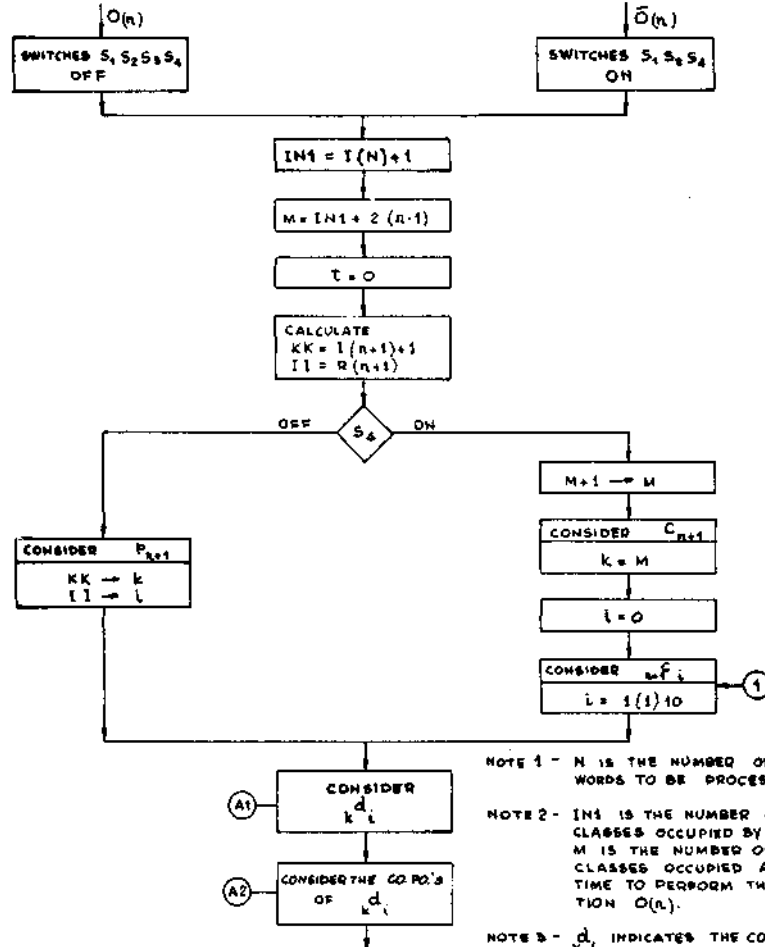
For the additional hypotheses 1, it is $M \leq 10$.

It will be assumed $M = 10$

D. Steps of main program

- 1—to read the words; let them be N
- 2—to take the decision dependent on the characteristics of the word p_{i+1}
- 3—to carry out $\bar{O}(i)$
- 4—to carry out $\bar{O}(i)$
- 5—to repeat steps 2, 3, 4 for $i = 1, 2, \dots, N - 1$
- 6—to write the "register" of heads 1-7

BLOCK DIAGRAM OF THE SUB-ROUTINE FOR THE OPERATIONS $O(n)$ AND $\bar{O}(n)$.



- NOTE 1 - N IS THE NUMBER OF THE WORDS TO BE PROCESSED.
- NOTE 2 - $IN1$ IS THE NUMBER OF THE CLASSES OCCUPIED BY THE WORDS. M IS THE NUMBER OF THE CLASSES OCCUPIED AT THE TIME TO PERFORM THE OPERATION $O(n)$.
- NOTE 3 - $d_{k,l}$ INDICATES THE CONSTRUCT k^l OF THE CLASS k USED AS OPERATOR. f IS THE INDEX NUMBER OF THE CO. PO.'S OF k^l .
- NOTE 4 - CO. PO. = CORRELATIONAL POSSIBILITY.

