XIII. MECHANICAL TRANSLATION*

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A. TRANSLATING ORDINARY LANGUAGE INTO FUNCTIONAL LOGIC

Work continues on the COMIT program, which was described in Quarterly Progress Report No. 68 (pages 174-175), for translating ordinary language into symbolic logic. The last report described a program for translating sentences and arguments formulated in ordinary English into the notation of propositional logic. Since that time, the author has been working on the extension of that program to perform translations into a "higher" type of logic, i.e., first-order functional calculus. The work that he has done thus far on this subject may be described under three headings: (I) the formulation of a logical grammar, which states the essential logical characteristics of some types of statements in ordinary language which are most readily analyzable into formulae in functional calculus; (II) the writing of a COMIT program that employs this grammar for random generation of sentences; and (III) the writing of a COMIT program for recognition of the grammatical structures of the sentences of the relevant type.

As for (I), the sentences that lie within the scope of our grammar are of two types. In the first type of sentence, an 'NP' (the commonly accepted abbreviation of 'noun phrase') is connected to another NP by a form of the verb 'to be'. In the second type, an NP is linked to another NP by what we may rather sententiously call a "binary relational construction," by which we mean a word or a phrase such as 'helps', 'belongs to', or 'is greater than'. These words and phrases do not fit snugly into any one grammatical category (for instance, they cannot all be described as transitive verbs), but all do the job of stating a comparison or relation between two essentially different NPs. These two sentential types are succinctly stated in two COMIT rules:

(1) S = NP + BE + NP; (2) S = NP + P/.2 + NP

in which 'S' stands for 'sentence', 'BE' for the verb 'to be', 'P/.2' for any binary relational construction, and 'NP', as stated above, for 'noun phrase'. Moreover, 'NP' may be expanded in either of two ways, formulable in the COMIT rules:

(3) NP = CONST; (4) NP = Q/X + PHI/X.

According to (3), 'NP' may be replaced by a proper name, such as 'George Washington'

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or 'Chicago'. According to (4), 'NP' may be replaced by a function 'PHI' of X preceded by a determiner or quantifier 'Q' for X. The 'Qs' of X are phrases like 'the X', 'some X', 'exactly five X', and 'at least two X'. The 'PHIs' of X are expressible in the following COMIT rules (a)-(g), in which the only symbol not previously explained is 'P/.1', which stands for nontransitive (or "unary") predicate constructions such as 'is a horse', 'is a Professor of Greek', 'lives', or almost any verb or verbal construction that is not followed by a direct object. (Many verbs, of course, are not definitely classifiable either as transitive or intransitive, e.g., 'believes' and 'sees'. In such cases the recognition program has to look at what immediately follows the verb before opting definitely either for P/.1 or P/.2).

(a) PHI/X = X + P/.1

(b) PHI/X = X + P/.2 + NP

(c) PHI/X = NP + P/.2 + X

(d) PHI/X = X + P/.2 + Y

(e) PHI/X = Y + P/.2 + X

(f) PHI/X = PHI/X + AND + PHI/X

(g) PHI/X = PHI/X + OR + PHI/X

In the formulae above, X and Y may be replaced by any letters from A to Z, subject to certain conditions. Whenever 'NP' is expanded into 'Q/X + PHI/X', in accordance with formula (4), the 'X' chosen is the next letter in alphabetical order; i.e., the first substitution for 'X' is 'A'; the second, 'B'; and so on. (An exception to this rule is made in sentences of type I, in which one may begin expanding both 'NPs' with the same letter 'A'.) The 'Y', in (d) and (e) above, is any letter that <u>has</u> been previously used. The following examples (i)-(vii) are all examples of 'NPs', according to our grammar. They illustrate, respectively, rules (a)-(g) above for the expansion of 'PHI/X'. In each case, the phrase 'such that', although logically redundant, is inserted between 'Q/X' and 'PHI/X' to improve legibility. The generation program, also, employs this device.

(i) The A such that A is a horse.

(ii) At least one D such that D admires George Washington.

(iii) Some B such that Chicago likes B.

(iv) Exactly three C such that C notices A.

(v) All B such that A is greater than B.

(vi) No A such that A is a horse and A is Chicago.

(vii) At most five C such that C is a Professor of Greek or C is a Professor of Latin.

An example of a complete sentence which may be translated into the terminology above is the following, taken from I. M. Copi's <u>Symbolic Logic</u>.[1]

(viii) The architect who designed Tappan Hall designs only office buildings.

Stated in our terminology, it becomes

(ix) The A such that A is an architect and A designs Tappan Hall designs only B such that B is an office building.

It may be noted that two different variables, 'A' and 'B', are employed, and that the imperfect 'designed' is replaced by the present 'designs'. This replacement simplifies the sentence by reducing what are, on the face of it, two transitive verbs to one; and it does not affect the logic of the sentence. An example of a sentence that the machine randomly generated using our grammar is

(x) SIWASH + LIKES + EXACTLY + ONE + X/A + SUCH + THAT + X/A + IS + A + WOMAN + AND + SOME + X/B + SUCH + THAT + X/B + CAN + SWIM + FASTER + THAN + ANY + X/C + SUCH + THAT + X/C + IS + JACK + OF + X/A + CAN + COMMAND + X/A + AND + X/A + GETS + RUSSIA + .

The last example, as opposed to the immediately preceding one, is stated in COMIT notation. We have found it expedient to use as variables 'X/A', 'X/B', 'X/C', etc., rather than 'A', 'B', 'C', etc. In addition to strictly programmatic advantages, this device avoids any confusion between the article 'A' and the letter 'A'.

Next, the recognition program takes sentences such as (ix) and (x) and "parses" them, i.e., it tags each grammatical construction with its appropriate label. It thereby reveals how the sentences must have been, or could have been, generated. Using the recognition program, the computer correctly printed out the analyses of (ix) and (x); these are included below as (xi) and (xii), respectively.

(xi) S + NP + Q/A + THE + X/A + PHI/A + PHI/A + X/A + P/.1 + IS + AN + ARCHITECT + AND/A + PHI/A + X/A + P/.2 + DESIGNS + NP + TAPPAN/CONST + HALL/CONST + P/.2 + DESIGNS + NP + Q/B + ONLY + X/B + PHI/B + X/B + P/.1 + IS + AN + OFFICE + BUILDING + .

(xii) S + NP + SIWASH/CONST + P/.2 + LIKES + NP + Q/A + EXACTLY + ONE + X/A + PHI/A + PHI/A + PHI/A + X/A + P/.1 + IS + A + WOMAN + AND/A + PHI/A + NP + Q/B + SOME + X/B + PHI/B + X/B + P/.2 + CAN + SWIM + FASTER + THAN + NP + Q/C + ANY + X/C + PHI/C + X/C + P/.2 + IS + JACK + OF + X/A + P/.2 + CAN + COMMAND + X/A + AND/A + PHI/A + X/A + P/.2 + GETS + NP + RUSSIA/CONST + .

It may be noted that the recognition program erases the redundant phrase 'such that' whenever it encounters it in the input sentences. Also, it adds some additional subscripts. Proper names are subscripted with 'CONST' (for 'constant'), and conjunctions ('AND' and 'OR') are subscripted with the letter possessed by the two 'PHIs' which they connect. To discover the scope of any 'S', 'NP', or 'PHI', one may employ the following counting method: Starting immediately to the left of the symbol whose scope is to be discovered, initialize the count at 1 (in COMIT, one would use a marker with the numerical subscript of 1, e.g., 'M/.1'), and proceeding from left to right raise or lower the count in accordance with the rules:

PHI , S = +2; NP = +1; P/.2 , X , AND , OR , BE = -1;
P/.1 , any consecutive string of items labelled 'CONST' = -2;
all other items = 0.

The scope of the term in question is determined as soon as the count 0 is reached. More precisely, when the count 0 is reached, one continues counting items as long as the count remains 0. When an item is encountered which causes the count to deviate from 0, the counting stops, and the scope is taken to be everything except the last item. In other words, if 'P/.1' causes the count to go to 0, the counting continues until it includes everything labelled 'P/.1', such as 'IS + A + HORSE'.

The counting method just described for determining the scope of a term has not yet been programmed, but it will be an essential part of the next program that we intend to write, which will translate the parsed sentences, such as (xi) and (xii), into purely logical notation. The next task following the completion of this will be to write a program that will translate sentences stated in the ordinary English of (viii) into the quasi-logical language of (ix) and (x). These two uncompleted programs, in conjunction with those already written, will constitute a complete program for translating our particular types of sentences from ordinary English into first-order functional calculus.

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References

1. I. M. Copi, Symbolic Logic (Macmillan Company, New York, 1958), p. 158.

B. FUNDAMENTAL SENTENCE-MEANING

In previous Quarterly Progress Reports[1-3] I have pointed out that a general explanation of the phenomenon of linguistic paraphrase cannot be achieved within the framework of a theory of semantics that makes the tacit assumption that word-synonymy (or morpheme-synonymy) alone can account for it. Such a view not only leads inexorably to the absurd conclusion that a structural-constant, such as 'all', 'only', 'any', 'some', 'not', 'ever', must at times be considered as synonymous with one structural-constant and at other times synonymous with a different structural-constant, but fails to provide the technical means powerful enough to discover fundamental semantical relations that exist among these structural morphemes, relations that can be formulated into linguistic laws that are general in that they encompass vast areas of linguistic phenomena, and are explanatory in that they provide reasons why one cannot always substitute the same structural-constant for another in all sentences containing an occurrence of that morpheme and obtain sentences that are synonymous, why and when there occurs a change of meaning if one makes morpheme substitution of this kind, and so on. The reason why a method of discovery based upon such a view of semantics cannot be powerful enough to discover more fundamental laws is that it has been, by definition, restricted to the use of only substitution rules for the greater part. That is to say, on the basis of this assumption concerning semantics, the structure of the grammatical strings – the very structure that is to be investigated – has been predetermined to be essentially of the phrase-structure type, wholly accessible to constituent analysis, with some rules of ordering of constituents thrown in when necessary. The type of grammar has already been assumed to be a context-free grammar.

In the theory of semantics proposed by the author, it is held that the word-meaning of these critical structural morphemes always remains constant – hence the name structural-constant – and that the sentence-meaning can vary according to the particular configuration of structural-constants which occurs in the sentence. Some configurations give rise to sentences whose sentence-meanings are synonymous although there is no one-to-one morpheme correspondence, and others give rise to sentences whose sentence-meanings are different. In order to illuminate how the meaning of a semantical structural-constant can remain constant and at the same time the sentence-meaning can vary depending upon the structural context, let us construct the following analogy.

Let us liken the structural configuration of a sentence-type to a machine constructed out of cogwheels, levers, rods, bolts, screws, and other such parts. The particular set of parts and the manner in which they are connected to one another give rise to a machine that has a certain output. The same parts, when combined in a different way, give rise to a different machine. It may happen that particular choices of parts and different combinations of them give rise to several machines that operate to produce the same output, although they are not structurally isomorphic; these could be called synonymous machines. In this case it could be said that the machines have the same fundamental construction. In the case in which several machines are not structurally isomorphic and do not operate to produce the same output, the machines are said to have different fundamental constructions. A construction engineer knows which choice of parts and which combinations of them give rise to the various kinds of machines. In the case in which the engineer has built two or more machines that appear to be structurally isomorphic but operate to produce different output, some of the machine parts have become built-in units; the structures that differ are hidden under the cover of a closed unit. Such machines could be said to be ambiguous.

It is obvious from the analogy that the author believes that only a context-sensitive grammar is adequate to handle the structure of language. The analogy is so obvious that one need not dwell on it. But I would like to discuss briefly the semantical structural-constants, 'all' and 'only'. It is only when one regards 'all' as a constant, analogous to a functioning meaningful machinery part, that one can explain why 'all' can range in meaning over 'everything', 'the totality', 'the whole', 'the end', etc. As an operator whose function is to determine the extent of the upper boundaries enclosing all members from the inside to the outer limits, it can range over many different types of things; sometimes it operates on countable argument individuals, sometimes on predicate functions such as verbs, adjectives, and nouns, sometimes on functions of functions such as adverbs. Sometimes it operates upon the infinitely divisible parts belonging to a whole or single individual. But it always has one job to do, a job that never varies. The morpheme 'only' also functions to determine a boundary, but, unlike 'all', it does not specify that the total membership is involved; rather it restricts, or clamps the lid down on the upper boundary from outside the set. 'All' and 'only' are closely related operators in that they operate in the reverse of each other. Examples (1) and (3) have been selected to illustrate the comparison. Since, however, there does not exist a logical operator corresponding notationally to the grammatical form of 'only', 'only' is expressed symbolically in the predicate calculus through a paraphrase of the sentence containing an occurrence of 'only', a paraphrase in which 'all' appears. The English language often makes use of this paraphrase to express 'only'. Illustrations of this usage are given in examples (7) and (9) and again in examples (20a) and (20b). In order that people untrained in the logical symbolism of the predicate calculus can follow the text more easily, I shall not use symbolic notation in this report. However, it must be kept in mind that for each sentence in the examples there is a general schematization, a symbolic formula in which the denotative terms of the sentence are expressed as variables, only the range of the variable having structural significance; this formula represents the sentence-type of the sentence in question.

In order to see the effect that 'only' can make on the fundamental sentence-meaning, let us first examine an example of a rather simple sentence-type whose subject noun phrase contains a universal quantifier,

(1) All women are frail

whose fundamental sentence-meaning is

(2) To be a woman is a sufficient condition of being frail.

If we replace 'all' by 'only' in sentence (1), we obtain

(3) Only women are frail

whose fundamental sentence-meaning is the reverse of sentence (2), namely,

(4) To be a woman is a necessary condition of being frail.

The morpheme 'only' functions here to reverse the order of the asymmetrical operation of implication. In other words, if 'all' is the major quantifier of a sentence S that can be represented by the general formula in the predicate calculus '$(x)[f(x) \supset g(x)]$' (read: for every x, if x is f then x is g), then if 'only' is the major quantifier of a sentence S' containing all the same morphemes as S with the exception of 'all', then the general formula is written '$(x)[g(x) \supset f(x)]$' (read: for every x, if x is g then x is f). Inspection of the symbolic forms of these two formulas reveals the reversal in the order of the left-hand term before the symbol for implication and the right-hand term after the symbol.

Given an example of a sentence-type like

(5) John needs to move to feel pain

which already expresses necessary condition, since its fundamental sentence-meaning is

(6) Moving is a necessary condition that John must satisfy in order to feel pain

we see that the addition of 'only' after 'needs' in sentence (5) serves again to reverse the fundamental sentence-meaning. The resulting sentence

(7) John needs only to move to feel pain

expresses the fundamental sentence-meaning

(8) Moving is the only condition that John must satisfy in order to have pain.

The reversal that the addition of 'only' accomplishes is seen in the fact that sentence (8) implies that not only is moving a necessary condition of feeling pain but a sufficient condition; that is, since moving is the only condition needed, it is <u>the</u> necessary and sufficient condition of producing pain. Sentence (7) is synonymous with

(9) All John needs to do is to move to feel pain

since both express the same fundamental sentence-meaning. The fundamental sentence-meaning could be expressed in a grammatical form notationally closer to sentence (9) by

(10) All conditions that John must satisfy in order to feel pain are the same as to move.

Incidentally, note that both sentence (7) and sentence (9) are synonymous with

(11) John need only move to feel pain

and

(12) All John need do to feel pain is to move

in both of which 'need' is clearly a modal. Compare sentences (11) and (12) with the sentence-type of sentence (5) in which there is not the option of using the modal form or the verbal form of 'need'; the verbal form is obligatory.

By understanding the role that the semantic and purely syntactic structural-constants play in giving rise to sentence-meaning, there does not seem to be anything more mysterious in the concept of sentence-synonymy than there is in two maps, very different in outward shape, representing the same country through different projections. As long as there exists a one-to-one mapping between the projections, the two maps are regarded as fundamentally isomorphic. In the investigation of fundamental semantical relations of a natural language system, we search for translation rules that transform one sentence into another sentence that is synonymous with it. These translation rules are the mapping rules of the linguist interested in a semantically grounded grammar.

Every translation rule is justified as a correct rule if and only if there corresponds to it a metalanguage statement, empirically established as true, which states the fundamental sentence-meaning that the synonymous sentences have in common. Basic translation rules are, of course, not easy to discover, particularly if the problem is attacked by a hit-or-miss, trial-and-error method. Since the domain of linguistic data is so immense, a procedure without a logically directed program of attack can be quite fruitless. Fortunately, one can utilize the knowledge gained from the advances made in the understanding of the logical structure of artificial language systems such as the predicate-calculus to construct such a program, even though one knows from experience that a natural language system is not as limited in scope or purpose as an artificial one. If we regard the artificial logical calculi as analogs of natural language systems, we are justified in assuming that there must exist a metalogic for any language system, that is, a body of implicit basic rules governing the use of the conventional symbols in the language: implicit derivation rules, formation rules, and axioms. If there did not exist such a logical set of rules governing the grammatical forms of sentences, it would be difficult to understand how a language could be mastered, since it would then not be a system but a very large set of unconnected strings. When one masters a language one has learned how to use these rules; but there is a difference between being able to use a rule and being able to state the rule explicitly. Observation and intuitive knowledge of the language in question can lead to the establishing of a set of explicit translation rules, accepted as correct because many sentences have been tested empirically to confirm the fact that the structural-constants do, in fact, behave in the way stipulated. Thus when one has stated some of the metalogical rules, one can use them to demonstrate, according to the metalogic of that language, that certain sentences are synonymous. That is, one can validate the intuitive recognition of synonymy of several sentences by logical proof, a logical proof that utilizes only a partial knowledge of the meanings of some important structural-constants in that language, the meanings of the denotative constants, and the fundamental meanings of a few well-chosen sets of synonymous sentences regarded as axioms, and the logical rules of deductive inference. If the synonymy of sentences can be validated, one is confirmed in believing that the rules already formulated are actually basic to that language system. Furthermore, new structural-constants and new rules can be discovered in terms of the old. The following examples have been selected to illustrate how English sentences, found intuitively to be synonymous, can be proved to be synonymous by a tentatively accepted metalogic of English.

The concepts of upper and lower bounds play an important role in the English language. Since the quantifier 'all' is essential in symbolic formulas expressing ideas concerning limits, let us compare some sentences containing different grammatical occurrences of 'all' with their respective intuitively synonymous sentences.

(13a) I helped him all I could
(13b) I helped him as much as I could

(14a) St. Paul is the farthest I will go
(14b) I will go only as far as St. Paul
(14c) St. Paul is all the farther I will go

(15a) What big eyes you have! All the better to see you, my dear
(15b) What big eyes you have! So much the better to see you, my dear

(16a) He was all but smiling
(16b) He was almost (nearly) smiling

(17a) He was anything but smiling
(17b) He was far from smiling

(18a) All I could do was to smile
(18b) I could only smile

(19a) It was all I could do to smile
(19b) I could hardly smile

(20a) I was all afire
(20b) I was completely afire

(21a) All of the class was excited
(21b) The whole class was excited

According to grammarians such as Poutsma, 'all' in sentence (13a) is to be equated with 'as much as' in sentence (13b), since these words can be interchanged with the meaning of the original sentence preserved. According to the principle of sentence-synonymy, the two sentences as wholes have the same fundamental sentence-meaning but no synonymy holds between 'all' and 'as much as'. In sentence (13a), the universal quantifier ranges over the set of possible degrees of help that x_1 was able to give; thus x_1 helped x_2 with every degree of help that it was possible for x_1 to give x_2. If x_1 helped with all possible degrees, x_1 helped with the highest degree as well. That is to say, x_1 helped up to the limit of his ability. Another sentence that is synonymous with sentences (13a) and (13b), which corresponds to this last statement that was derived by logical inference, is 'I helped him the most I could'. Sentence (13b), on the other hand, states that the amount of help given to x_2 was 'equal to' or 'as much as' the amount x_1 was able to give. Since the amount that it was possible for x_1 to give is, in fact, the greatest amount, more being impossible, the amount of help given equals the largest or the upper limit. Ergo, the fundamental sentence-meaning for all three statements has been proved to be identical. Their sentence-types, however, are different. It is to be noted that the verb 'help', conceived as having different intensities ordered as to degree, is a necessary assumption to the explanation of the sentence-synonymy. The English language makes much use of the notion of ordering, as we shall see in examples (14)-(19).

The sentence-meaning of sentence (14a) is a very direct expression of the fundamental sentence-meaning of all three examples in set (14), which is

(22) St. Paul is the upper limit of the distance from an initial point that x_1 is willing to go

because the sentence itself identifies by means of the word 'is' the place, St. Paul, with '<u>the</u> point that is <u>farthest</u>', the use of the superlative guaranteeing the uniqueness of the point that is farther than all other points x_1 is willing to go to from a given starting point. The sentence-meaning of (14b) states that x_1 is willing to go (from some given point) as far as St. Paul but no farther; thus sentence (14b) states that x_1 is willing to go from an initial point to a point that is 'equal to' or 'as far as' the upper bound, St. Paul, and does not exceed that point. Whether St. Paul is said to be the limit itself, or the distance that x_1 is willing to go is declared to be as far as but not farther than the limit, the distance in both cases is the same; hence the two sentences are synonymous. The grammatical differences and similarities between the two sentences are easily seen when both are put into their schematic formulations.

The proof of the synonymy of sentence (14c) to (14a) and (14b) is more complicated. The phrase 'all the farther' refers to the total increase in distance. The complete meaning of 'x is farther than y' has to be expressed 'x is farther from an initial point y_0 than y is by a specific but unknown amount a', i.e., x increases in distance away from y_0 more than y increases in distance by a definite increase. It should be noted that in any ordering relation applied to things, whether the ordering be in terms of intensity, degree, or size, there is always an amount involved. Sentence (14c) identifies two classes by means of the word 'is', which stands between the left-hand phrase that defines the set of points, '(from y_0 to) St. Paul', and the right-hand phrase that defines the well-ordered set of points, 'all the increases in distance x_1 is willing to go'. The right-hand phrase can be represented as the union of the collection of sets containing as members all of the a's, which are obtained by taking in their ordered turn all those points that are distant from y_o to which x_1 is willing to go. Thus each new point that x_1 is willing to go to starting from y_o farther than the previous point becomes an upper bound in its turn so that the smallest that each increase can be is simply from one point to the next farther point. The sum of all of these increases (or all farther points) is, of course, equal to the distance from y_o to St. Paul because the sentence has equated these two sets. The sets are identical because each set has exactly the same members. The sentence-type of (14c) is quite different from those of (14a) and (14b). Both (14a) and (14b) correspond notationally to the standard symbolic definition of an upper bound; sentence (14c), by declaring the two sets to be identical, lays down a condition under which there must exist an upper bound to the set of points to which x_1 is willing to go.

In (15a) we have the familiar lines in the nursery tale of Red Riding Hood and the wolf. There is again ordering according to size; but in this example two properties are being ordered and the ordering is correlated, since the value of the increase or decrease in one variable depends upon the determination of the increase or decrease in the other. The wolf's assumption is

(23) The bigger the eye, the better the sight of the eye.

The fundamental sentence-meaning of (23) is that the goodness of the sight of the eye increases as a function of the greatness of size of the eye. In sentence (23), the independent variable is given in the first phrase, the dependent in the second, so that the ordering of the two phrases is an indispensable feature of the sentence-meaning. If the order is reversed, grammatical changes occur; the synonymous sentence would then be

(24) The sight of the eye is better, the bigger the eye.

When Red Riding Hood asserts that Grandma's eyes are large, she means that as eyes they have the property of largeness, since size is never an absolute property but is relative to the kind of object talked about. Hence the word 'large' must be defined 'large with respect to some standard'. Grandma's eyes being a specific amount, although an unknown amount, larger than average, the ability of her sight is directly correlated to that amount and can, in theory, be calculated. The phrase 'all the better to see you' in sentence (15a) is similar to the phrase 'all the farther' in the previous example, since it too denotes the set of 'all the increases in goodness of seeing'. The sum of all these increases equals the amount that her eyes are larger than average. Hence sentence (15b) that asserts 'that much (or so much) better to see you' is synonymous with sentence (15a) because the union of the set of all the increases equals that definite amount, the difference in size of eye; hence 'so much the better' can replace 'all the better'.

Examples (16)-(19) illustrate that the English language possesses techniques for handling the concept of proximity to total absence or total presence of a property. Does a person either smile or not smile? Our language is able to construct statements expressing how close to the boundary of yes or no a fact may be. In sentence (16a) x_1 is not smiling but very near to the upper bound of the separation between not smiling and smiling. The definition of the complex quantifier 'almost' involves the occurrence of the universal quantifier 'all' in combination with the structural-constant 'except' or 'but' to exclude a limited finite number or amount from the total set – an amount that approaches but never reaches zero as the limit. Hence, the words 'all but' correspond directly to the definition of 'almost'.

Sentence (17a) states that x_1 was not smiling but states that every property that could be included as part of smiling was absent; hence x_1 is far from the upper bound of the separation between smiling and not smiling.

The synonymy of sentences (18a) and (18b) was treated in detail in Quarterly Progress Report No. 66 (pages 289-293). I included them in this report to complete the list of different grammatical occurrences of 'all' and to bring into sharp focus the critical effect resulting from additional words such as 'It was' placed in front of sentence (18a), as in example (19a). Sentence (19a) expresses the sentence-meaning that although x_1 smiled, it was necessary for him to use the limit of his ability to do so. Thus x_1 was close to the lower limit of smiling, that is, close to not smiling.

The synonymy of sentences (20a) and (20b) is demonstrated by showing that the universal-quantifier 'all' ranges over all of the parts of an individual. Since 'all' is a unity, it includes all of its parts and is therefore complete.

The explanation of the synonymy of sentences (21a) and (21b) is similar to the explanation of set (20). It should be pointed out that sentences (20a) and (20b) are synonymous with 'I was wholly afire'. In set (21), the universal-quantifier 'all' again operates upon the parts of an individual. In the case of sentence (21a) the use of the definite article before 'class', a collective noun, shows that 'class' is regarded as singular. 'All of the class' and 'the whole class' refer to the class as a complete unity, that is, the individual composed of all of its parts.

It has perhaps been remarked that the phrase 'fundamental sentence-meaning' has been used frequently. What is the exact meaning of this phrase and just what is the relation between fundamental sentence-meaning and ordinary sentence-meaning? In this report I would like to discuss and clarify this elusive concept and try to explain its role in relating sentences as synonymous.

In Quarterly Progress Report No. 68 (pages 176-180) I stated that the fundamental sentence-meaning was logical in form, not grammatical; it was the forms of the sentences found to be synonymous by empirical observation which were grammatical. On the basis of my present point of view, I would not now deny grammatical form to the sentence stating the fundamental sentence-meaning of a set of sentences that are alike in expressing that sentence-meaning. Rather, I would describe the relationship of this sentence to the others as follows. While it is true that fundamental sentence-meaning is a concept belonging properly to the field of logic, this fact means that the sentence stating the fundamental meaning of a set of synonymous sentences belongs properly to the metalanguage of our language system; the synonymous sentences referred to by the metalinguistic statement belong to the object language of English. The metalinguistic statement states explicitly, by means of denotative terms, the specific kind of relation that exists between the events or things designated by specific types of object-language sentences. That is, the metalinguistic sentence, by stating which basic relation the object-language sentences express, is using the name of this particular relation denotatively; thus, for example, the phrase 'necessary condition' is itself not a structural-constant but a denotative term, defined lexically in the same manner as other nouns, and behaving grammatically as one. Like all other sentences, the metalanguage sentence has a grammatical structure that can be described, and a sentence-meaning of its own. In fact, it is possible for the metalanguage statement itself to be synonymous with other metalanguage statements if the denotative constants are the same, as we saw in examples (8) and (10). On the other hand, the object-language sentences that the metalanguage sentences refer to as being synonymous do not use the denotative term to refer reflexively to themselves; they express the particular relationship that they have in common by using the proper structural-constants in specific configurations. They are sentences in the object language because they use structural-constants that can be defined only in the metalanguage. Let us inspect two synonymous sentences in the object language that are grammatically similar in that all of their denotative terms are the same, such as

(25a) If John is to be president, he must get his organization ready now
(25b) Only if John gets his organization ready now can he be president

and compare their grammatical forms with the grammatical form of the metalanguage sentence (26) stating their common fundamental sentence-meaning

(26) The fundamental sentence-meaning of 'If John is to be president, he must get his organization ready now' and 'Only if John gets his organization ready now can he be president' is that John's getting his organization ready now is a necessary condition for John's being president.

Sentences (25a) and (25b) do not explicitly state that one event is a necessary condition of the other; rather each expresses this fact through its grammatical form. On the other hand, sentence (26), although it too expresses through its grammatical form a fundamental sentence-meaning that could be made explicit by a meta-metalanguage statement, states explicitly which fundamental sentence-meaning examples (25a) and (25b) have in common, and the fundamental sentence-meaning of metalanguage sentence (26) is not the fundamental sentence-meaning referred to by its subject noun phrase. However, if we look at only the clause 'John's getting his organization ready now is a necessary condition for John to be president', we see that this part of sentence (26) has the grammatical structure of a complete sentence and it is synonymous with sentences (25a) and (25b) even though its denotative terms are not everywhere the same as those of (25a) and (25b). Indeed, if this sentence were not synonymous, it could not have been identified with the fundamental sentence-meaning of these object-language sentences. It appears, then, that one sentence out of a set of synonymous sentences – a wider set that includes synonymous sentences whose denotative terms are not everywhere the same – has been selected as the sentence whose ordinary sentence-meaning is regarded as expressing the fundamental sentence-meaning of the set. That the selection of this one sentence is not arbitrary is seen by the fact that it alone (or synonymous sentences whose sentence-type may differ but whose denotative terms are everywhere the same), because of the type of grammatical structure that it has, can appear intact in a metalanguage statement of the sentence-type represented by sentence (26) in which the subject, which refers denotatively to the concept 'the fundamental sentence-meaning' specifically identifies this sentence with it. It is obvious that neither of the object-language sentences (25a) or (25b) could serve grammatically in this capacity. It is by this grammatical criterion that the sentence-type of a sentence expressing the fundamental sentence-meaning can be objectively established as of a higher structural level than the ordinary object-language sentences.

It should be remarked that the infinite regress that one is forced into by admission of a hierarchy of levels of language is not so ominous as it appears, since the grammatical structure of all levels has been assumed, on the basis of experience with levels already constructed, to be similar.

The fundamental sentence-meaning, I suspect, is what has often been called the 'proposition' that sentences signify or designate. There has been much philosophical discussion concerning the nature and ontological status of the so-called proposition. I would not like to regard the proposition as a logical entity that is incapable of having grammatical form. Such a view would make a mystery of what the proposition is; it seems dubious that it could be logical in character if it cannot be expressed in language.

Once it is recognized that sentences do have a sentence-meaning that is quite distinct from word-meaning, that there is synonymy of sentence, as well as synonymy of word, we no longer need the 'abstract proposition' to relate sentences having the same meaning to one another; the concept of fundamental sentence-meaning, which states what the synonymous sentences express, suffices. (Incidentally, if it is possible that a sentence expresses a sentence-meaning that is not synonymous with that of any other sentence of the same level, its fundamental sentence-meaning must still be stated in the metalanguage of that language, since the metalanguage statement would utilize denotative terms to refer explicitly to the meaning that the structural configuration of that sentence expresses.)

The concept of 'proposition' referred not only to the entity that synonymous sentences within the same language system designated; it stood also for the entity that related sentences having the same meaning but belonging to different language systems because it was felt that there must be some absolute underlying logical construction that these sentences designated which made possible translation from one language to another. Since the proposition could not be expressed in any of these concrete languages because then it would be a sentence of that language, it was deemed to be not expressible in any natural language; it stood between any two languages. It was supposed that the predicate calculus itself was the underlying logical structure of all natural language systems, that the predicate calculus played a role similar to the mathematical symbolism used universally by mathematicians, each of whom could use the symbolism within his own native language. The inadequacy of the predicate calculus to fill this role has been amply demonstrated.

According to this theory of the semantics of sentence-meaning, the concept of fundamental sentence-meaning is instrumental in character, not absolute, since it is fundamental with respect to some language system, determined implicitly by the formation rules, derivation rules, and axioms of its metalanguage. The applicability of any logical system depends upon how well it serves its recognized purpose, whether it be a calculus constructed by known men or a naturally developed language constructed gradually by many unknown men; therefore it is not surprising that the basic foundations of the highly developed language systems that these philosophers and mathematicians had command of contained concepts mutually recognized as important.

It should be noted that the basic concepts referred to by the fundamental sentence-meanings are man's constructs, not things of the world; they are man's way of looking at the world, organizing its material in ways useful to him. The fundamental sentence-meanings refer to such concepts as necessary and sufficient conditions, causality, generalization, unexpected occurrences, and possibilities. Since these are man's concepts, a pertinent question that one should raise about the possibility of writing contrastive grammars for languages in general and about the possibility of mechanical translation from any language to any language, in particular, is: Are the fundamental sentence-meanings belonging to each of the natural languages that are expressible by the manifold linguistic devices displayed by each of these widely differing grammars, sufficiently universal to serve as the mapping functions with which to coordinate the sentence-types of <u>any</u> language system with those of <u>any</u> other language system? Could there be such wide agreement about what concepts are fundamental even though the cultural environments of man are so diverse? I think one can make an educated guess based on empirical evidence that it is quite likely that there would be considerable overlap of the fundamental sentence-meanings belonging to different language systems. During the natural weeding-out process that must have taken place during the development of a language, it must have been found out from experience that knowledge of some concepts served man's purposes better than others; hence the general adoption of grammatical techniques to express these important ideas was not just arbitrary; they were selected in terms of their being the best instruments to reach a goal. The goals determining the selection processes are the primary needs and purposes of man. And his most fundamental need is to get along in his environment. Language then has to be an instrument that is capable of communicating knowledge that members of a language community need to express and wish to express to one another. To help one another to adjust to nature, to control it to some extent, to make plans, men need to predict it, to have some sense of order, to construct laws about it, and so forth. Concepts like necessary and sufficient conditions, concepts necessary for the possibility of making inferences, concepts like negation and affirmation that permit the possibility of distinguishing between truth and falsehood would all appear universally needed by a society that is intelligent enough to create and use such an abstract and complicated system of conventional signs as a language. Also, as our biological knowledge of the organization of the human brain increases, it may at some future time be shown that, in the evolutionary process of adaptation, the human brain became structured in such a way that it organizes the raw material of the senses in specific ways.

An interesting project would be a comparison in the sophistication of the concepts involved in fundamental sentence-meaning – all languages possess fundamental sentence-meanings, if not the same ones – between the language of a highly civilized society and the language of what is considered by anthropologists to be a very primitive society.

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References

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