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FOREWORD

The work documented in this Final Report was conducted in support of Project 2801, Task 280115 by the Massachusetts Institute of Technology, Cambridge, Massachusetts under Contract AF 19(628)-2487. The work was also supported in part by the Joint Services Electronics Program, Contract DA36-039-AMC-02300(E), the National Science Foundation (Grant GK-835), the National Institutes of Health (Grant MH-04737-06), and the National Aeronautics and Space Administration (Grant NsG-496).

The program was monitored for the U.S. Air Force by John B. Goodenough, ESLFE, and was performed during the period 1 February 1963 through 29 February 1968. The draft final report was submitted on 15 March 1968.

This Technical Report has been reviewed and is approved.

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ABSTRACT

The most significant results of this research are embodied in the document entitled "Temporal Specification, Process, and the Converse Relation," by Jerrold J. Katz, which is part of this report.

This paper is concerned with the definitions of semantic properties and relations, and with the manner in which the meanings of expressions and of whole sentences are to be represented. It deals with these problems by studying a special case of expressions that are converses of each other such as "John bought a book from Bill — Bill sold a book to John" which have recently been widely discussed.

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STUDIES IN THE GRAMMAR AND SEMANTICS OF ENGLISH

I. INTRODUCTION

The research pursued constitutes a further development of a semantic theory along the lines laid down by Jerrold J. Katz and Jerry A. Fodor, in the "Structure of a Semantic Theory," Language, Vol. 39, No. 2, pp. 170-210, April-June 1963, and Jerrold J. Katz and Paul M. Postal in An Integrated Theory of Linguistic Descriptions, The M. I. T. Press, Cambridge, Mass., 1964 (also AF TR-64-157). The concept of a universal alphabet of semantic features and its definition have been elaborated and refined.

This research is directly relevant to a semantic component of a grammar of English and to the techniques by which a linguist can determine the semantic features of particular lexical items and the form of dictionary entries.

The most significant results of this research are embodied in the attached document (Sec. II), entitled "Temporal Specification, Process, and the Converse Relation," by Jerrold J. Katz.

The following publications pertain to research supported by this contract.

Jerrold J. Katz, "The Relevance of Linguistics to Philosophy," The Journal of Philosophy, Vol. 62, pp. 590-602, 1962.

Sylvain Bromberger, "Why - Questions," in Mind and Cosmos: Essays in Contemporary Science and Philosophy, Vol. III in University of Pittsburgh Series in the Philosophy of Science, 1966, pp. 86-111.

G. H. Matthews, "A Conjecture Concerning Non Context-free Languages," ICC Bulletin, Vol. 5, pp. 169-178, 1966.

Sylvain Bromberger, "Questions," The Journal of Philosophy, Vol. LXIII, No. 20, pp. 597-606, October 27, 1966.

Jerrold J. Katz, "Some Remarks on Quine on Analyticity," The Journal of Philosophy, Vol. 64, pp. 36-52, 1967.

Noam Chomsky, "The General Properties of Language," in Brain Mechanisms Underlying Speech and Language, New York: Grune and Stratton, Inc., 1967, pp. 73-88.

Paul Kiparsky, "Syntactic Relationship among Complement Types in English," a paper presented at the Linguistic Society of America Summer Meeting, Ann Arbor, Michigan, July 27-29, 1967.

Jerrold J. Katz and Edwin Martin, Jr., "The Synonymy of Actives and Passives," The Philosophical Review, Vol. LXXVI, No. 4, pp. 476-491, October 1967.

Jerrold J. Katz, "Recent Issues in Semantic Theory," Foundations of Language, Vol. 3, pp. 124-194, 1967.

Of special relevance is the following:

Noam Chomsky, "Remarks on Nominalization," to appear in Readings in Transformational Grammar (edited by P. Rosenbaum and R. Jacobs), New York: Blaisdell, 1968.

Morris Halle

II. TEMPORAL SPECIFICATION, PROCESS, AND THE CONVERSE RELATION

2.1 INTRODUCTION

Speaking in the most general terms, the present paper, like other works of mine on semantic theory, is concerned with the definitions of semantic properties and relations and the manner in which the meaning of expressions and whole sentences are to be represented in the semantic component of a grammar in order that their semantic properties and relations be marked correctly by such definitions. More specifically, however, this paper concerns a special case of the synonymy relation, its definition and the manner in which synonymous expressions or sentences that are instances of this case obtain their meaning, and hence their synonymy relations, as a compositional function of the meaning of their syntactic parts.

Two or more expressions or sentences are synonymous just in case they have the same meaning in all or some of their senses. To be more precise, we will say that expressions or sentences are fully synonymous in case they have every sense in common and that expressions or sentences are synonymous in case they have a common sense.¹ By the definition of synonymy in semantic theory, two expressions or sentences are marked as synonymous if the semantic component of the grammar assigns them each the same reading. But, by the nature of the compositional function that assigns readings to constituents on the basis of the readings of their syntactic parts and their underlying phrase marker, it happens that some synonymous expressions or sentences receive the same reading in a way different from that in which other synonymous expressions or sentences receive the same reading. This gives rise to special cases of the synonymy relation.

The special case with which we will be concerned here is the converse relation. In logic, the converse relation is a relation that holds of two relations R_1 and R_2 just in case

$$(1) \quad (x)(y)(xR_1y \equiv yR_2x)$$

For example, $<$ and $>$ are converses, since for any x and y , $x < y$ and $y > x$ are equivalent statements. This concept has found its way into linguistics as a convenient way of describing a certain grammatical relation between expressions and sentences in natural languages.² In this application of terminology from logic, a relation is given by a verb or verbal construction, adjective, or adverbial, and its terms are given by the noun phrases that appear as subject, direct object, indirect object, etc. Thus in

- (2) (i) John saw Bill
(ii) Bill was seen by John
- (3) (i) John is taller than Bill
(ii) Bill is shorter than John

- (4) (i) John runs faster than Bill
(ii) Bill runs slower than John

the underlined constituent of each (i) and (ii) pair are considered converses, while the noun phrases, "John" and "Bill", in each pair are taken as the terms of the relation in that example.

The fact to be explained here is that the members of the pairs (2) (i) and (ii), (3) (i) and (ii), and (4) (i) and (ii) are synonymous. Their synonymy explains their necessary equivalence, i.e., why if one member is true, so, necessarily, is the other, and if one member is false, so, necessarily, is the other. But their synonymy itself is unexplained. Simply calling such pairs of verbal constructions "converses", thought it is thereby indicated that the synonymy of (2) (i) and (1) (ii), (3) (i) and (3) (ii), and (4) (i) and (4) (ii) has to do primarily with a grammatical relation between the verbal constructions in them, does not explain what it is about such verbal constructions that makes these sentences paraphrases. Reference to the definition of the converse relation found in logic, *viz.*, (1), is only a way of saying that the members of such pairs are equivalent – of saying not why they are synonymous and hence have the same truth-conditions, but merely that they do have the same truth-conditions.

There are two ways to approach a genuine explanation of synonymy in such cases. One is to follow the direct lead of logic. This approach would say that constituents are converses because they express conceptual relations that bear the converse relation to one another. Here the crux of the matter is that the converse relation holds between conceptual relations expressed by linguistic constructions, and linguistic constructions, such as those in (2) - (4), are referred to as converses only by virtue of expressing converse conceptual relations. In contrast, the other approach assumes, as we have implicitly assumed in taking the converse relation to be a special case of synonymy, that the converse relation holds among linguistic constructions only. The crux of the matter here is that, instead of trying to explain the synonymy of linguistic constructions like the members of the pairs in (2) - (4) on the grounds that their meaning involves distinct conceptual relations that bear the converse relation to one another, we try to explain it on the grounds their having the same meaning. Both of these approaches offer the prospect of an explanation: in the first case, by an account of a relation between conceptual relations, and in the second, by eliminating such an independent conceptual relation in favor of a suitable account of synonymy for the range of cases in question.

We here adopt the latter of these approaches, that of trying to explain the special case in terms of the general one. The desirability of this form of explanation is suggested by example (2) and other cases of active-passive pairs. For in these cases, the explanation of sameness of truth-conditions is, quite plausibly, sameness of meaning, not a special relation between distinct senses of the active and its passive paraphrase.³ The question, then, becomes whether cases like (3) and (4), as well as other types of converses, can be accommodated under this form explanation, as was accomplished in the case of active and

their corresponding passives?

The difficulty that immediately arises is that active-passive cases can legitimately be thought of as different from such other converse cases in an essential respect: in active-passive cases the same verb occurs in both sentences, whereas in the other types different verbs occur in each sentence. The explanation in the case of active-passive pairs is based on the principle that transformations do not add to or subtract from or in any way change the meaning of a sentence as specified in terms of its underlying phrase marker and on the principle that purely grammatical morphemes like "Passive" have no semantic content.⁴ From these principles, it follows that the semantic interpretation for an active sentence and the semantic interpretation for its corresponding passive must represent them as having the same sense(s). But the difference cited above prevents us from carrying over this pattern of explanation to non-active-passive converse pairs. For the formal relation between the source underlying phrase markers that obtains in active-passive cases is simply not present in the others: whereas active-passive pairs differ at the level of deep structure only by a grammatical morpheme, other cases differ at this level by non-grammatical morphemes, which, characteristically, contribute semantic content to the meaning of the sentences in which they occur.

Therefore, to explain the synonymy of converse linguistic constructions in which different, non-grammatical morphemes occur in their deep structure, it will be necessary to consider them directly rather than to try to subsume them under the active-passive paradigm, and to develop their semantic representations in such a way that it comes out automatically that synonymy is the basis on which converse cases with inverse expressions are equivalent.

2.2 THE GENERAL PROBLEM

The constituents with which we will be predominately concerned are pairs of verbs such as the inverses "buy" and "sell", "give" and "receive", "borrow" and "lend", and so on. The reason for choosing these as the central cases has not only to do with their inherent suitability as central cases but also with the place they have occupied in certain recent discussions of the nature of semantic theory.⁵ We shall return to adverbials and adjectives like those in examples (3) and (4) at the end of the paper.

Consider the sentences:

(5) John sold the book to Mary

(6) Mary bought the book from John

They, like (4) (i) and (4) (ii) or (5) (i) and (5) (ii), are paraphrases. Both assert the occurrence of the same event, *viz.*, the sale of a certain book wherein John relinquishes possession of it and Mary gains possession of it in exchange for some unspecified sum of money. Accordingly, the grammar of English has to mark (5) and (6) as having a sense in common; which is to say, the semantically interpreted underlying phrase marker assigned to (5) and the one assigned to (6) have to contain the same reading associated with their full terminal string, i. e. each has to have the same reading in the set of readings assigned to their top sentence-node.

One way to obtain this result would be to try to formulate rules in the syntactic component that provide the same underlying phrase marker for (5) and (6). The other is to try to formulate lexical readings for "sell" and "buy" that yield the same derived reading for the top sentence-nodes in the underlying phrase markers of (5) and (6) by the operation of projection rules. In the former case, we have a syntactic solution to the problem of converse relations, and in the latter, a semantic solution. In this section, we shall show the impossibility of a syntactic solution, and in the following sections, we shall develop a semantic solution.

A syntactic solution could try to obtain a common reading for (5) and (6) in the same manner that stylistic variants like

(7) John looked up the address

(8) John looked the address up

receive the same reading. Both sentences would be assigned the same underlying phrase marker by the base of the syntactic component. The semantic component, since it operates exclusively on underlying phrase markers, would operate on the same syntactic object in each case, thereby assigning the same semantic interpretation. Since the transformational rules that map superficial phrase markers onto underlying phrase markers do not alter the semantic interpretation given to an underlying phrase marker, these sentences are assigned at least one common reading, thereby being represented as paraphrases.

However, this treatment requires that one of the two sentences in question be taken as more basic than the other, i. e., as closer in

its surface form than the other to the string of terminal symbols in their common underlying phrase marker. In this sense, (7) is more basic than (8): its T-marker is identical to an initial proper-part of the latter's. The rationale is that the surface structure of (7) retains more of the constituent structure common to both cases than does the surface structure of (8), for in (7) the full verb constituent "look up" occurs as a continuous substring in its surface form, whereas this is not so in (8), and they are otherwise no different in surface structure. Accordingly, since the underlying phrase marker for (7) and (8) must mark each of the constituents in them by a labelled bracketing of a continuous substring of its string of terminal elements, it follows, within transformational theory, that the T-marker of (8) represents a transformational development of (7) which begins with the transformational development of (7) and goes on by a transformational permutation that positions the noun phrase object "the address" between the verb "look" and its particle "up". Therefore, if one tries to obtain a common reading for (5) and (6) in the way a common reading is assigned to (7) and (8), he will be required to justify taking one of the sentences (5) and (6) as more basic. His solution to the problem of marking the paraphrase relation between (5) and (6) would be purely syntactic, taking the form of a set of base rules that give for both an underlying phrase marker modelled on the more basic of the two and a set of transformational rules that would derive the less basic one by a permutation akin to the exchange of subject and object in the derivation of passive sentences like (2).

But a syntactic solution of this type assumes, falsely, that either (5) or (6) differs from the other in a manner similar to the manner in which (7) differs from (8). Such a solution must choose between the alternatives: (i) (5) is more basic and (6) comes from a permutation of subject and indirect object with compensating switches of "sell" to "buy" and "to" to "from", or (ii) (6) is more basic and (5) comes from a permutation of subject and indirect object with compensating switches of "buy" to "sell" and "from" to "to". But there can be no rationale for choosing between (i) and (ii) because they, and the sentences in question, are perfectly symmetrical. Any argument that might be proposed to establish that one of these alternatives is preferable would encounter another argument of equal cogency to establish that the other is preferable. Since we will always have as good an argument for taking the other of these sentences as basic as we have for taking either one as basic, we can conclude that neither is can be taken as more basic than the other.

Another option exists for someone who seeks a purely syntactic solution, for accepting the conclusion just reaches does not preclude the possibility of deriving (5) and (6) from the same underlying phrase marker. Thus, he might propose to derive them, transformationally, from an underlying phrase marker representing a rather abstract, common deep structure that is not itself realized phonetically. That is, he might argue that (5) and (6) have a common underlying phrase marker, of such an abstract sort that with respect to it they are of a roughly equal degree of non-basiness and both can be derived from it by means of transformational derivations of roughly equal complexity.

This underlying phrase marker would have to represent the verbs "buy" and "sell" in terms of some abstract morpheme neutral between them and belonging to the category Verb. It would represent "to" and "from" in a similar way, so that one set of transformations gives the surface structure of (5) by realizing these abstract morphemes in the form "sell" and "to" and another gives the surface structure of (6) by realizing these morphemes in the form "buy" and "from".

But, besides its ad hoc character, there are a number of grave difficulties with this proposal, some of which are decisive against it. First, as Chomsky has pointed out,⁶ the simplicity metric for the selection of an optimal grammar must assign a very low value to the use of any abstract constituent that is language specific, as an abstract verb spanning just "buy" and "sell" or one spanning just "to" and "from" must, of course, be. Second, this solution can only avoid the symmetry-of-cases objection in connection with morphemic differences between (5) and (6). It utterly fails to avoid this type of objection in connection with differences in grammatical relations. Let us consider this in some detail.

For the sake of argument, let us suppose the following definitions of the relations subject of and indirect object of:

- (9) (i) x is the subject of the sentence s just in case x is the substring of the terminal string in s's underlying phrase marker that satisfies the function [NP, S].
- (ii) x is the indirect object of the sentence s just in case x is the substring of the terminal string in s's underlying phrase marker that satisfies the function [NP, PP, VP, S].⁷

With respect to (9) (i) and (9) (ii), or indeed any other definitions of the same kind, it is clear that there can be no rationale for choosing between, on the one hand, the alternative of an abstract underlying phrase marker in which "John" is the subject and "Mary" the indirect object of both (5) and (6) and, on the other hand, the alternative of an abstract underlying phrase marker in which "Mary" is the subject and "John" the indirect object of both (5) and (6). Any rationale for arranging the domination relations within that phrase marker so that "John" satisfies [NP, S] and "Mary" satisfies [NP, PP, VP, S], because of the complete symmetry of (5) and (6), would be faced by an argument of exactly equal cogency for arranging them so that "Mary" satisfies [NP, S] and "John" satisfies [NP, PP, VP, S], and vice versa. Here there is no way out. In the case of verbs, prepositions, or other sentential constituents, it is possible to hypothesize abstract morphemes spanning some very small subset of morphemes in the category. But in the case of grammatical relations, no such hypothesis is possible. Such notions, being relational, cannot be given in the form of substantive elements introduced into the terminal or non-terminal part of the vocabulary of the syntactic component (or even syntactic theory). Their characterization must be given by a formal relation among such substantive elements labelling nodes in underlying phrase markers and the

domination relations specified by those nodes and their branches.

The arbitrariness of this choice is seen to reach absurd proportions when it is realized that whichever of these two alternatives is adopted for (5) and (6), the other will have to be adopted for

(10) Mary sold the book to John

(11) John bought the book from Mary

since (10) and (11) are synonymous, for one thing, and for another, they are exactly parallel to but not synonymous with (5) and (6), i. e., (5) is not synonymous with either (10) or (11), nor is (6) synonymous with either (10) or (11). The absurdly arbitrary choice is now that of deciding which of the two alternatives presented immediately above is to be adopted for the pair (5) and (6) and which is to be adopted for the pair (10) and (11). Thus, again, we have a choice where any argument for one decision is faced with an equivalent argument for the opposite one. But if one alternative cannot be shown preferable, (5) and (6) cannot be assigned the same underlying phrase marker, and consequently, their synonymy cannot be explained on syntactic grounds.

Another point worth mentioning in this connection is that the proposal we have been considering conflicts with clear-cut linguistic intuitions that "John" is the subject of (5) and (11), that "Mary" is the subject of (6) and (10), that "John" is the indirect object of (6) and (10), and that "Mary" is the indirect object of (5) and (11). To put the matter another way, there appears to be no basis whatever for distinguishing (5) from

(12) John played the flute to Mary

or (6) from

(13) Mary stole the idea from John

in regard to subject of and indirect object of relations.

Finally, one further argument. This one derives from the fact that sentences such as (5) and (6) express the occurrence of a transaction in which an object transfers possession from seller to buyer in exchange for a certain sum of money which transfers possession from buyer to seller. Since both these aspects of the meaning of such sentences will have to be accounted for syntactically on any syntactic solution for the synonymy of cases like (5) and (6), the putative common underlying phrase marker for such sentences will have to be considerably more complex than thus far supposed. It will have to take the form of a labelled bracketing of the compound string

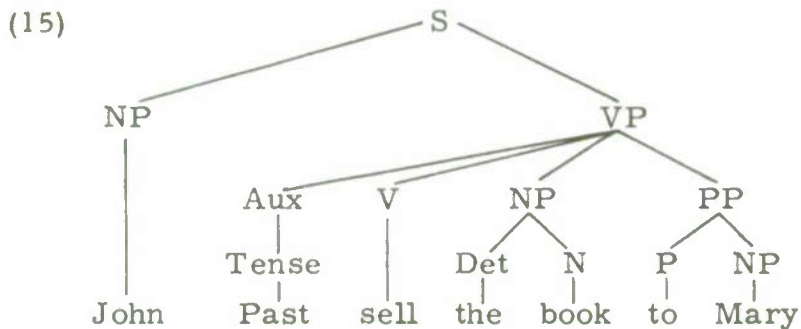
(14) John sold the book to Mary $\left\{ \begin{array}{l} \text{for which} \\ \text{and} \end{array} \right\}$ Mary paid a sum
of money to John

or of something very much like this. But such an underlying phrase marker for (5) and (6) would be totally out of the question insofar as it would be necessary to suppose that the underlined portion had been ellipsed in their derivation and such a transformational

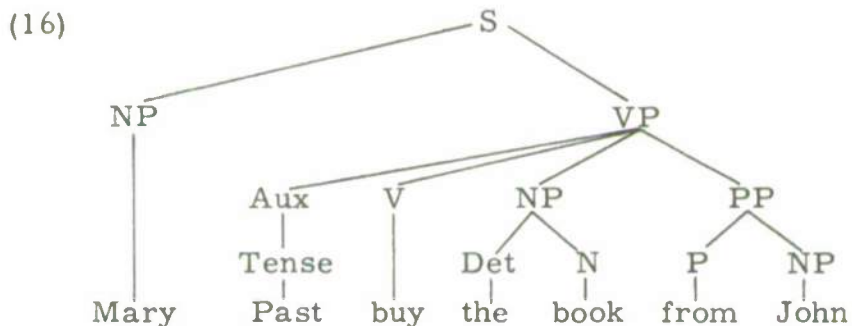
operation would be a flagrant violation of the principle of recoverable deletion.⁸

Therefore, the conclusion that the paraphrase relation in cases like (5) and (6) cannot be explained on syntactic grounds is inescapable. It must thus be explained on semantic grounds, and this is just what the next sections seek to do. But before we formulate a semantic explanation, we may briefly consider the advantages for syntax of turning this problem over to semantics.

In the first place, this means that cases like (5) and (6) can be given different underlying phrase markers by the rules of the base in the syntactic, and these can then be intuitively quite plausible ones, as, for example, for (5) and (6),



and



respectively. Moreover, assigning cases like (5) and (6) – and there will be a very great number of them – different underlying phrase markers means that language specific abstract constituents are not required for them, which raises the value of the grammar in a simplicity evaluation. The syntactic component will avoid absurdly arbitrary choices, and there will be no necessity to contradict clear-cut intuitions about subject and indirect object relations or worse yet, give up simple generalizations about the nature of them that are obviously true of indefinitely many straightforward cases and that provide a uniform account of these relations by extending their characterization in straightforward cases to cases like (5) and (6). Finally, the principle of the recoverability of deletion is preserved, thus preserving the ability of grammars to explain phenomena like ellipsis, pronominalization, reflexivization, etc.

2.3 THE CONCEPTS OF 'STATE' AND 'PROCESS'

In this section, we begin on a semantic solution to the problem of explaining the paraphrase relation in cases like (5) and (6). This section will set up the general conceptual apparatus for our solution. In subsequent sections, this apparatus will be developed in suitable detail and further apparatus will be added. Along the way, toward a solution, very many auxiliary problems about the semantic structure of natural languages will arise, some of which will be dealt with as they come up. In general, their treatment will be proportional to their bearing on the problem of converse relations and their own intrinsic interest considered from the viewpoint of the development of semantic theory.

Two major semantic categories into which words and expressions of a natural language divide (though not exhaustively, of course) are those of state and process. Examples of verbs, adjectives, and nouns in the former category are, respectively,

- (17) (i) sleep, wait, live, suffer, ...
- (ii) sick, healthy, bankrupt, ...
- (iii) sickness, boredom, death, ...

and examples of verbs, adjectives, and nouns in the latter category are, respectively,

- (18) (i) freeze, grow, dry, melt, ...
- (ii) dying, growing, drying, ...
- (iii) recovery, disappearance, birth, ...

Sentences using such words bring out clearly the intuitive difference between the concept of a state and that of a process, e. g. , compare the meaning of the sentence(s)

- (19) John is asleep (sick, bankrupt, ...)

with the meaning of the sentence(s)

- (20) John is freezing (dying, growing, ...)

We can express the nature of the difference by saying that a state is a condition of something (be it person, place, thing, or what-have-you) at a given time or during a given time interval, while a process is a change or transition from one state to another over a given time interval. Accordingly, a fundamental part of the job of developing conceptual apparatus to bring to bear on the problem of converse relations is that of explicating this difference, thus these concepts of state and process.

This explication must take the form of devising appropriate semantic markers. This treatment follows automatically from the manner in which other cases of the same sort are treated within semantic theory. On the one hand, to say that a word in a language falls under a category is to say that the complex of concepts that forms its sense includes that category as one of its component concepts. Therefore, the category of state, under which the examples in (17) are subsumed, must be one of

the concepts in their sense; and likewise, the category of process, under which the examples in (18) are subsumed, must be one of the concepts in their sense. Since each concept in a sense is represented by a semantic marker in the reading that represents that sense, it thereby follows that the category-concepts of state and process must each be explicated by a semantic marker that will form part of the reading of some sense of every word that falls under it. On the other hand, as we have noted, the words in (17) are semantically similar to one another and the words in (18) are too. Moreover, as we have also noted, the words in (17) are semantically dissimilar to those in (18), in essentially the way that (19) contrasts with (20). Finally, the semantic similarity of the cases in (17) lies in their each expressing a condition of something, the semantic similarity of the cases in (18) lies in their each expresses some change of condition, and the semantic dissimilarity between the two sets of cases lies, therefore, in the difference between the expression of a condition and the expression of a change from one condition to another. This type of situation is a familiar one from other cases of semantic similarity and contrast. Consider the cases:

(21) bachelor, uncle, brother, bull, colt, boy, ...

which are semantically similar to one another, and the cases

(22) spinster, aunt, sister, cow, filly, girl, ...

which are also semantically similar to one another. Here the two sets of cases are dissimilar in that the former cases express the concept of maleness and the latter express the concept of femaleness. Since these facts about semantic similarity and contrast are represented in the dictionary by including the semantic marker (Male) in the appropriate reading of the entry for each word in (21) and by including the semantic marker (Female) in the appropriate reading of the entry for each word in (22), consistency of treatment implies the corresponding facts about semantic similarity and contrast in connection with (17) and (18) be represented in the dictionary by including the semantic marker (State) in the appropriate reading of the entry for each word in (17) and by including the semantic marker (Process) in the appropriate reading of the entry for each word in (18). Again, it follows that the concepts of state and process be explicated by a pair of semantic markers.

In previous discussions of semantic theory,⁹ the distinction between state and process words was marked by entering cases like those in (17) in the dictionary with a lexical reading containing the semantic marker (State) and entering cases like those in (18) with a lexical reading containing the semantic marker (Process). In those discussions, no effort was made to characterize the nature of this distinction by suitably defining the semantic markers (State) and (Process). For, there, we were concerned exclusively with questions whose treatment only required reference to the distinction between state and process words, and for that purpose the use of the undefined semantic markers sufficed. Here, however, we are not concerned primarily with the existence of this distinction, but with its precise nature. Hence, our problem is to explicate, not simply to indicate, the distinction.

Explicating a concept, in the context of semantic theory requires a formalization of its internal structure in terms of a set of semantic markers representing the concepts that jointly define it. The empirical constraints on an explication are that it enable the semantic components of grammars to account for the manner in which words whose meaning the concept contribute to the meaning of complex constituents and sentences in which those words appear and thus to account for the semantic properties and relations they have by virtue of their compositional meaning.

We may start, then, by regarding the semantic markers (State) and (Process) as, ultimately, defined terms of semantic theory. We seek now to eliminate each of them, through definition, in favor of some construction out of other, more primitive, semantic markers. They should be defined away on the basis of definitions whose formal structure represents the internal structure of the concepts of state and process, so that it is possible to capitalize on the features of such definitions to explain interrelations between the meanings of state and process words, e. g., the relation between the state words "sickness" and "health" and the process word "recovery", and their semantic relations to other words in sentences, e. g., the relation between the temporal adverbials and tense-constituents and process words such as is found in a sentence like

(23) The ice froze yesterday during the cold spell

where the former determine the period in which the process occurs. Our aim, therefore, is to define these concepts in such a manner that such interrelations and relations that depend on aspects of the internal structure of the concepts of state and process, and which thus cannot be accounted for by the as yet undefined semantic markers (State) and (Process), can be accounted for in terms of the formal representation of the structure of these concepts provided in the definitions of (State) and (Process).

Given that the concept of a state is that of the condition of something at a given time or during a given time interval, we define the semantic marker (State) to be:

(24) ((Condition), (), ..., ()) of $\begin{bmatrix} X \\ < > \end{bmatrix}$ at $\begin{bmatrix} X \\ < > \end{bmatrix}$

'(Condition), (), ..., ()' indicates a set of semantic markers representing a condition of some sort. In any instance of (24), that is, in any particular state semantic marker occurring in the lexical reading of a specific morpheme, the part '(), ..., ()' would represent the unique condition that the state concept expressed by that morpheme contains. Thus, for the adjective "drunk" this part of the state semantic marker in its lexical reading would represent the condition of being intoxicated with liquor or other strong drink. This part of the lexical reading of "drunk" would, accordingly, be different from the comparable parts of "sick", "asleep", "dead", etc. Hence, in '(), ..., ()' we find represented what it is about each of these states that differentiates them from the other states for which there are words in the language.

The symbol 'X' with braces above and angles below is to be considered a single (complex) symbol which is a variable for readings of constituents in an underlying phrase marker. In previous discussions of semantic theory,¹⁰ we employed capital letters, 'X', 'Y', 'Z', etc., as such variables. These were categorized variables in the sense that their range of values, i.e., the readings that could be substituted in the case of one of them, were restricted by the category of the variable, which was fixed by the orthographic shape of the letter. Thus, the variable 'X' was a variable for one category, 'Y' for another, and so on. These categories themselves were determined by the grammatical relations defined within syntactic theory. A category determines that the values of its variable are only readings of constituents that stand in the prescribed grammatical relation to constituents in whose reading a semantic marker containing the categorized variable appears. 'X' was chosen as the variable categorized in terms of the grammatical relation subject of the verb, so that values of occurrences of the variable 'X' within readings of a verb are restricted to readings of the subject of the verb; 'Y' was chosen as the variable categorized in terms of the grammatical relation object of the verb, so that values of occurrences of the variable 'Y' within readings of a verb are restricted to readings of the object of the verb; and so forth. Thus, in the process whereby readings are combined to form a semantically interpreted underlying phrase marker, whenever the projection rules encounter a constituent whose reading contains a categorized variable, they may substitute for it a reading of the constituent bearing the proper grammatical relation to the constituent in whose reading that variable occurs.¹¹ The proper grammatical relation, the one that picks out the constituent whose reading may provide an appropriate value, is the one specified by the categorization of the variable in question.

The change introduced in (24) is actually only a notational one. Instead of using different capital letters, we propose to use just the letter 'X' with square brackets above it containing a grammatical function.¹² Each of the letters 'X', 'Y', etc. is to be now thought of as replaced by one such symbol in which the specification of the grammatical function appearing inside the square brackets explicitly expresses the categorization that the letter it replaces is defined to have. Accordingly, the categorized variables to be used in state semantic markers, as their use is indicated in (24), will be the following:

$$(25) \quad \begin{array}{ccccc} [\text{NP}, \text{S}] & [\text{NP}, \text{VP}, \text{S}] & [\text{NP}, \text{PP}, \text{VP}, \text{S}] & & \\ \text{X} & \text{X} & \text{X} & & \\ < > & < > & < > & , \dots \end{array}$$

where '[NP, S]' is the grammatical function specifying the subject of a sentential structure, '[NP, VP, S]' is the grammatical function specifying the object of a sentential structure, '[NP, PP, VP, S]' is the grammatical function specifying the indirect object of a sentential structure,¹³ and so on. As Chomsky points out, the grammatical relations are definable derivatively in terms of these functions, as, for example, in a definition of the subject-verb relation as the function of functions '[[NP, S], [[V, VP], [VP, S]]]'.¹⁴ But we need only use the grammatical

functions themselves, insofar as they will occur in the reading of a unique constituent 'C' in a sentence structure and it may be taken as understood, by convention, that a function '[F₁]' appearing inside square brackets over an occurrence of 'X' is to be short for "[[F₁],[F₂]]", where '[F₂]' specifies the relation that the constituent 'C' bears to the sentence structure. Thus, the first categorized variable in (25) will have readings of the subject of the constituent in whose reading it occurs as its values, the second will have readings of the direct object of the verb in whose reading it occurs as its values, the third will have readings of the indirect object as its values, and so on.

The angles under a categorized variable specify the selection restriction that determines whether a reading in the range of values of the variable can be substituted for that variable to form a derived reading. We will impose the following convention as part of the definition of a categorized variable within semantic theory:

- (26) If there is no available value to be substituted for an $\begin{matrix} [\\ X \end{matrix}$ for an occurrence of a categorized variable $\begin{matrix} [\\ X \end{matrix}$ because $\langle \rangle$ there exists no constituent in the underlying phrase marker satisfying $[]$, as opposed to there being such a constituent without a reading or one whose reading does not satisfy the condition expressed by the selection restriction $\langle \rangle$, then the value of $\begin{matrix} [\\ X \end{matrix}$ is the full set of semantic markers in $\langle \rangle$.

This convention says simply that the value to be substituted for a categorized variable that cannot obtain one from the reading of the constituent standing in the specified grammatical relation to the constituent in whose reading it appears is the set of semantic markers inclosed in the angles in it. The significance of this convention will be developed in section 5.

In terms of the above discussion, the first categorized variable in (24) will be one whose values are readings of subjects or heads of modifier constructions or objects, as the case may be.¹⁵ The second categorized variable in (24) will be one whose values are readings of the tense constituent in the auxiliary, together with, when applicable, readings of temporal adverbials. This will be explained in detail in the course of sections 4 and 5.

The concept of a process is, as indicated above, that of a transition from one state to another, as, for example, the process of recovery is a transition from the state of sickness to that of health. Thus, we can define the semantic marker (Process) in terms of the definition given in (24) for the semantic marker (State):

- (27) ((Process)₁ & (Process)₂ & ... & (Process)_n)

where $n \geq 1$ and each term '(Process)' has the form:

$$(28) (((\text{Condition}), (), \dots, () \text{ of } \begin{matrix} [] \\ < > \end{matrix} X \text{ at } \begin{matrix} [] \\ < > \end{matrix} X), \dots, \\ ((\text{Condition}), (), \dots, () \text{ of } \begin{matrix} [] \\ < > \end{matrix} X \text{ at } \begin{matrix} [] \\ < > \end{matrix} X))$$

(28) represents a process as a transition of states by representing a process semantic marker as a sequence of state semantic markers. (27) allows that a process may be single, double, triple, etc. Here we will be able to distinguish between a single process like that expressed by "give" and a double process like that expressed by "sell", which, as was observed before, involves one change from the state in which the seller possesses the object to be sold to another in which the buyer possesses it and another change from the state in which the buyer possesses the sum of money to be paid to another in which the seller possesses it. Since the second categorized variable in each state semantic marker will have as its value a reading that expresses a time designation, it will be possible to specify the initial state of a process as the one whose time designation is lowest and to specify the terminal state as the one whose time designation is the highest. Any semantic marker whose time designation is greater than that in the one representing the initial state but less than that in the one representing the terminal state will represent an intermediate state. The dots between the initial and terminal state semantic markers in (28) indicate the possibility of intermediate states in the process. If this possibility has to be precluded by virtue of the meaning of a certain process word, we write the process semantic marker in its lexical entry in the form

$$(29) ((\text{State})_1 (\text{State})_2)$$

When the meaning of a process word inherently involves a particular intermediate state, as in the case of "relapse" in the sense of slipping back into a former state after a change from it to another, e.g., becoming ill again or reverting to evil ways, we write the connection between the initial and terminal states in the form:

$$(30) ((\text{State})_1, \dots, (\text{State})_i, \dots, (\text{State})_n)$$

where the time-designation in '(State)_i' will necessarily be greater than that in '(State)₁' and less than that in '(State)_n' by virtue of an aspect of the second categorized variable in each of these semantic markers, which will be explained in section 5.

2.4 LINGUISTICALLY EXPRESSED TIME RELATIONS

This section will develop the theoretical apparatus for expressing time designations that is necessary to complete the definitions of state and process semantic markers. It will also deal with certain semantic problems in connection with the expression of time relations within sentences of a natural language. In this way, we will both illustrate the application of this apparatus and provide independent motivation for its employment in section 2.5.

The fundamental way in which a sentence of a natural language relates the things about which it speaks – the states, processes, occurrences, actions, activities, achievements, etc. – is in terms of their relations to one another in time. Not all sentences express time relations among events, as in the case of

(31) The number two is the only even prime

(32) The owl is a nocturnal bird

But except for sentences about abstract objects or generic sentences, the expression of temporal relations is a ubiquitous semantic feature of the grammar of sentences.¹⁶

A sentence does not temporally relate the things it is about to one another directly. Rather, it first relates them each to a fixed reference point and then relates them to each other indirectly by virtue of their relations to the reference point. This reference point is the origin of a time dimension, which extends infinitely in both directions. Each event or thing that a sentence is about is related to the reference point, the origin of the time dimension, by being accorded a position on this dimension, i.e., assigned to a point on it. Thus, each event or thing is automatically related to others by their respective relations to the reference point, such relations being specified by the distance between points and their direction with respect to the origin. Accordingly, the time relation holding between two things is given by a sentence in terms of the distance between their positions on the time dimension and the direction of each from its origin.

In order to establish an origin for the time dimension, we think of the sense of the tense constituent as indexical in the way that ordinary pronouns are. For example, the occurrence of the first person pronoun "I" in a sentence like

(33) I am in John J. Smith's house

will refer to different persons when (33) is uttered by different speakers, as contrasted with proper nouns like "John J. Smith", which come about as close as natural language permits to having unique reference no matter who the speaker is or what context he is speaking in. The tense constituent is indexical in just the way that "I" is in (33), since the present tense constituent in (33) will refer to different times when (33) is uttered on different occasions. But this variation in reference of the present tense constituent in utterance tokens of (33) is restricted within limits set by the meaning of this constituent in the sentence type. This restriction is parallel to the restriction of ordinary first, second, and

third person pronouns to referents belonging to a class fixed in advance by their meaning. Thus, just as "I" can refer only to the speaker, "you" to the person(s) addressed, "he" to male humans, etc., so the present tense constituent can only refer to the time at which the utterance of the sentence occurs, the past tense constituent to some time earlier than the utterance point, and the future tense constituent to some time later than the utterance point. Accordingly, the sentence

(34) The man is entering the house

is about the single event of the man's entering the house and it locates it at the utterance point itself. The sentence

(35) The man entered the house

locates the man's entering the house at some unspecified time in the past relative to the utterance point, and the sentence

(36) The man will enter the house

locates this event somewhere in the future relative to the utterance point. Natural languages thus divide time, basically, into two parts, past and future, the point of division being the moment at which the speaker utters the sentence.

This leads naturally to our taking the origin of the time dimension to be the utterance point, the points to the left of the origin to be past times, and those to the right to be future times. More complex tense constituents will pick out points and intervals on this dimension in terms of the interpretation of its origin as the utterance point and of past and future as its left and right segments, respectively. The readings of tense constituents will take the form of designations of positions on this dimension.

When two or more events are spoken of in a sentence that relates them temporally, their relation is expressed by means of some temporal adverbial such as "before", "after", "simultaneous with", etc. which introduces a clause containing the description of one or more of the events. Typically, then, events are temporally interrelated as illustrated in

(37) I entered the room before John arrived
and

(38) I will enter the room before John arrives

In (37) my entering the room and John's arrival are related to the utterance point by both being located in the past relative to it but they are related to each other by virtue of the former event's being located at a point some distance farther from the utterance point than the point at which the latter is located. In (38) my entering the room is still specified as occurring earlier than John's arrival but both events are now specified as future relative to the utterance point.

Facts such as these constitute the basic semantic features of sentences that the theoretical apparatus to be developed here must be adequate to represent formally within the semantic interpretations. But

in addition to representing such features, it is equally important that this apparatus provide readings of sentences that enable us to mark those of their semantic properties and relations that depend on the time relations expressed in them. And it should turn out that the apparatus that most naturally describes time relations like those in (34) - (38) enable us to mark semantic properties and relations on the basis of definitions of them already set up in semantic theory for other semantic structures.

Examples of some of the semantic properties and relations that must be dealt with are illustrated by the sentences:

(39) The truth of the statement lasted only three days
as contrasted with

(40) Her memory of the statement lasted only three days
and

(41) An hour is longer than a minute
and

(42) He worked for an hour during the last minute
and

(43) If John slept for an hour and Bill slept for only a
minute, then John slept longer than Bill
or

(44) If John arrived before Bill and Bill arrived before
Sam, then John arrived before Sam
and

(45) He rested for a minute
(46) He rested for sixty seconds
or

(47) He rested a longer time than she
(48) She rested a shorter time than he

(39) is semantically anomalous, as contrasted with (40) which is not. (41) is analytic, whereas (42) is contradictory. (43) and (44) are examples of entailments. (45) and (46) are paraphrases, as are (47) and (48). Accordingly, (39) but not (40) must be represented as having a null set of readings; (41) must be represented as having a reading of its predicate that contains only semantic markers found in the reading of its subject; (42) must be represented as having a reading of its subject and a reading of its predicate such that each contains a semantic marker drawn from the same antonymous n-tuple; and so forth.¹⁷ Therefore, both facts about the time relations expressed in the meaning of a sentence and facts about the semantic properties and relations that a sentence has by virtue of its meaning set the empirical constraints on

the apparatus one may introduce to represent linguistically expressed time relations.

Since the semantic component of a grammar requires a specification of the constituents of a sentence and their grammatical relations in order to provide its semantic interpretation, the first step for us to take in developing a scheme for representing time relations is to determine what types of constituents in an underlying phrase marker have to do with time relations and what grammatical relations obtain between them. To determine this, we can use the following rough test. We ask whether the replacement of a constituent of one type by one of another of the same type changes the time relations expressed in a sentence. If such replacement, by itself, does change time relations, then that type of constituent is involved in the expression of time relations. If not, then that type does not contribute to the expression of time relations. For example, the change from

(49) The man will arrive after the girl sees the foolish boy

to

(50) A woman will arrive after the children see the lazy dog

preserves the time relations: (49) and (50) both say someone's arrival follows upon some one or more persons' seeing something. If we were to apply this test to each type of constituent, it would turn out, generally speaking, that replacing nouns in simple noun phrases (say within subjects, objects, indirect objects, etc.), replacing articles or other components of the determiner system, descriptive adjectives, adverbials of manner, locatives, etc. do not alter time relations. The sentence that results from such replacements expresses the same time relations but now for a new n-tuple of events and/or objects and/or states of affair, etc. Since such replacements change only the events, objects, states of affair, etc., the constituents that turn out, not unexpectedly, to be relevant to the expression of time relations are the verbs in a sentence, the tense of the auxiliary, and the temporal adverbials, including those of phrase and clause type. Changes in any of these, characteristically, do alter time relations, as a comparison of (49) with

(51) The man arrived when the girl saw the foolish boy

shows. Thus, the syntactic structure underlying the expression of time relations forms a fairly tight-knit, self-contained system.¹⁸

This being so, it should be possible, without considering any aspects of syntax other than verbs, tenses, and temporal adverbials, to specify the grammatical relations required by projection rules in terms of syntactic properties of constituents in this system. We may suppose that the base of the syntactic component contains the rules in (52) or else ones sufficiently similar:¹⁹

- (52) (i) $S \longrightarrow NP \widehat{\text{Predicate-Phrase}}$
(ii) $\text{Predicate-Phrase} \longrightarrow \text{Aux} \widehat{VP} (\text{Locative Adv})(\text{Time adv})$
(iii) $VP \longrightarrow \left\{ \begin{array}{l} \text{Copula} \widehat{\text{Predicate}} \\ V \left\{ \begin{array}{l} (\text{NP})(\text{Prep-Phr})(\text{Prep-Phr})(\text{Manner adv}) \\ S' \\ \text{Predicate} \end{array} \right\} \end{array} \right\}$
(iv) $\text{Copula} \longrightarrow \text{Aux} \widehat{\text{be}}$
(v) $\text{Aux} \longrightarrow \text{Tense (M)}(\text{Aspect})$

Phrase structure rules of this type suggest that we require one kind of grammatical relation to hold between a verb and the tense of its auxiliary and another to hold between a verb and its time adverbials. Let us call the former the 'inflectional relation' and the latter the 'temporalization relation', and define them, respectively, by the functions:

- (53) $[[\text{Tense, Aux, Predicate-Phrase}], [V, VP, \text{Predicate-Phrase}]]$

and

- (54) $[[\text{Time Adv, Predicate-Phrase}], [V, VP, \text{Predicate-Phrase}]]$

We can now further specify (24) as follows:

- (55) $((\text{Condition}), (), \dots, ()) \text{ of } \begin{array}{c} [] \\ X \\ < > \end{array} \text{ at } \begin{array}{c} [\text{Tense, Aux, Pred-Phrase}] \\ X \\ < > \end{array})$

The projection rule that will provide derived readings for constituents on the basis of readings of verbs, nouns, or adjectives that express state or process concepts and of readings of the tense constituent will operate on an instance of (55), either as a state semantic marker or as a component of a process semantic marker, by substituting the tense constituent's reading for an occurrence of the categorized variable $[\text{Tense, Aux, Predicate-Phrase}]$

$\begin{array}{c} X \\ < > \end{array}$ just in case the reading of the verb, noun,

or adjective contains the semantic markers to satisfy the selection restriction $< >$. The projection rule that will provide derived readings for constituents on the basis of readings resulting from such substitutions and of readings for time adverbials will operate by converting the substituted reading of the tense constituent into another complex of symbols (representing the semantic contribution of the time adverbial) just in case the selection restriction in the reading of the time adverbial is satisfied by the reading of the head it modifies. Both these projection rule operations presuppose the prior operation of a projection rule which combines the readings of the various morphemes that make up the tense constituent to form a derived reading for the full tense constituent. It is to this that we now turn.

We wish to construct a notation system for time designation in the form of a set of semantic markers to serve as the components of lexical

readings of the various components of the tense constituent. We will use the small letter 't' with subscripts to serve as the values of the variable categorized for the inflexional relation. The symbol 't' stands for some unspecified position on the time dimension and the subscripts attached to an occurrence of 't' specify particular positions on this dimension. These subscripts can either be constants or variables. 't_o', that is, 't' with the subscript constant 'o', represents the origin of the time dimension, the utterance point regarded as the time span from the onset to the termination of the utterance. The subscript variables indicate positions in the past or future by having either a plus or a minus prefixed to them. Thus, if the subscript variables 'n', 'm', 'u', etc. stand for some arbitrary position some number of units away from the origin, the prefixed '+' or '-' indicates the direction from the origin. Letting '+' stand for right of the origin and '-' for left of it, a symbol like 't_{+n}' determines some point n units to the right of the origin, and a symbol like 't_{-n}' determines some point n units to the left of it. Under our general interpretation, then, the former symbol is understood as specifying a point somewhere in the future with respect to the utterance point and the latter symbol is understood as specifying a point somewhere in the past with respect to the utterance point.

With this fragment of the notation for time designation, we can set up lexical readings for the morphemes 'PRESENT', 'PAST', and 'FUTURE', which we may presuppose to be options within the tense-constituent, introduced by some such base rule as

$$(52) \quad (iv) \quad \text{Tense} \longrightarrow \left\{ \begin{array}{l} \text{PRESENT} \\ \text{PAST} \\ \text{FUTURE} \end{array} \right\}$$

These lexical readings are, respectively, the semantic markers (t_o), (t_{-n}), and (t_{+n}). The projection rule that provides a derived reading from inflectionally related constituents, e. g., from a verb and the tense constituent in its auxiliary, simply substitutes the lexical reading of the tense constituent, which if the tense constituent is 'PRESENT', 'PAST', or 'FUTURE' is '(t_o)', '(t_{-n})', or '(t_{+n})', for the appropriate occurrence

[Tense, Aux, Predicate-Phrase]
of the variable $\begin{array}{c} X \\ < > \end{array}$. Thus, the time relations represented in the readings of such simple, one-event sentences as

(56) John is hungry

(57) John was hungry

(58) John will be hungry

are as follows: the reading of (56) specifies John's being hungry as contemporaneous with the utterance of (56); the reading of (57) specifies John's state of hunger as existing and terminating before the occurrence

of the utterance of (57); and the reading of (58) specifies John's state of hunger as an event in the future, as something to happen after the utterance of (58).

We may now consider cases where two or more events are temporally related within a single sentence. For example,

(59) John kissed Mary before Bill arrived

Both events in (59) are past, relative to the utterance point, but John's kissing Mary antedates Bill's arrival. In

(60) John kissed Mary after Bill arrived,

where "before" in (59) is replaced by "after", the events are simply switched around, so that Bill's arrival antedates John's kissing Mary. But, again, both events are past relative to the utterance point, as indicated by the fact that the tense of each verb's auxiliary in both sentences is 'PAST'. This suggests that the lexical readings for "before" and "after", whose meaning effects the temporal ordering of the two events with respect to one another, be given as

(61) (i) before; $V[T^S] \longrightarrow (V[T^m] + (+r)), <SR>$

(ii) after; $V[T^S] \longrightarrow (V[T^m] + (-r)), <SR>$

[]
The symbol ' $V[\begin{smallmatrix} X \\ < > \end{smallmatrix}]$ ' is to be understood as the value that the variable ' X ' receives in the sentence. The symbols ' T^S ' and ' T^m ' are to be

$< >$
abbreviations, respectively, for the variable categorized for the inflexional relation within the subordinate (or dependent) clause and for the variable categorized for the inflexional relation within the main clause.

Thus, ' $V[T^S]$ ' stands for the reading of the tense constituent in the verb-phrase of the subordinate clause of a compound sentence, while ' $V[T^m]$ ' stands for the reading of the tense constituent in the verb-phrase of its main clause. 'r' is some arbitrary number of units on the time dimension less than the absolute value of the subscript on ' $V[T^m]$ '. The selection restriction in both (61) (i) and (61) (ii) is that the readings of the main and subordinate clauses contain, respectively, the semantic markers $V[T^m]$ and $V[T^S]$. This requirement, in effect, says that neither clause can be generic or express a timeless sense. Thus, it serves to mark semantically anomalous sentences such as

(62) John kissed Mary before (after) the owl is nocturnal

(63) The owl is nocturnal before (after) John kissed Mary

(64) John kissed Mary before (after) two plus two equal four

(65) Two plus two equal four before (after) John kissed Mary

Finally, as suggested by (61), we give as the reading for expressions like "contemporaneous with", "simultaneous with", "at the same time as", etc. the rule:

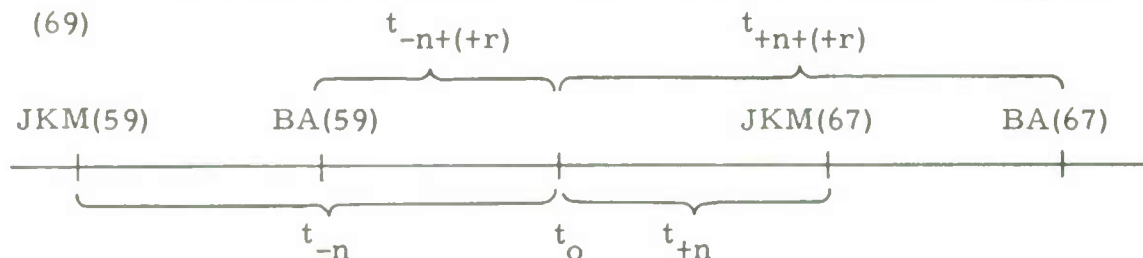
$$(66) V[T^S] \longrightarrow (V[T^m]), <SR>$$

Let us now explain these rules somewhat further by illustrating how they specify the temporal relations in (59) and (60) and similar cases. Let us contrast (59) with (60) and

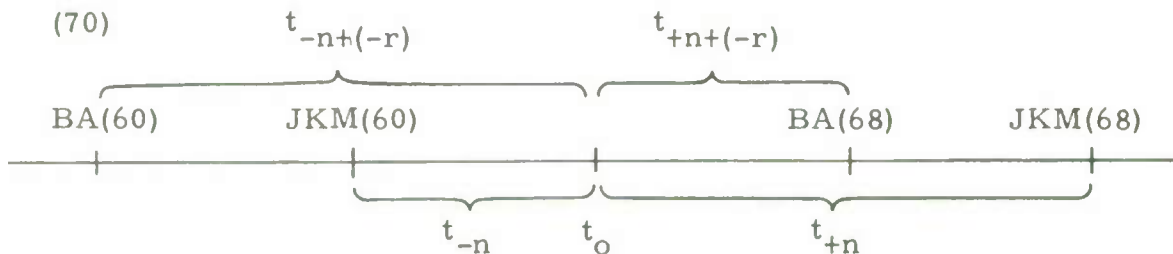
(67) John will kiss Mary before Bill will arrive
with

(68) John will kiss Mary after Bill will arrive

In (59) and (60), $V[T^m] = (t_{-n})$; in (67) and (68), $V[T^m] = (t_{+n})$; in (59) and (60), $V[T^S] = (t_{-m})$; in (67) and (68), $V[T^S] = (t_{+m})$. Let us introduce the symbol ' $\S$ ' as a variable over the signs '+' and '-' prefixed to subscripts. Then, (61) (i) says that $(t_{\S m})$ is rewritten as $(t_{\S n+(+r)})$ and (61) (ii) says that $(t_{\S m})$ is rewritten as $(t_{\S n+(-r)})$. Since the addition of signed elements proceeds in accord with the conventions for adding (and subtracting) signed numbers in algebra,²⁰ the temporal relations between the events in the sentences (59) and (67), i.e., the sentences in which the adverbial clause is introduced by "before", are represented as given in



and the temporal relations between the events in the sentences (60) and (68), i.e., the sentences in which the adverbial clause is introduced by "after", are represented as given in



Now, comparing (59), (60), (67), and (68) with

(71) Bill arrived after John kissed Mary

(72) Bill arrived before John kissed Mary

(73) Bill will arrive after John kisses Mary

(74) Bill will arrive before John kisses Mary

we see that they are, respectively, pairwise paraphrases, i.e., (59) is synonymous with (71), and so on. Applying (61) in the semantic interpretation of (71) - (74) as we did in connection with (59), (60), (67), and

(68), will assign the events in (71) to the same positions as those in (59) are assigned in (69), the events in (72) to the same positions as those in (60) are assigned in (69), the events in (73) to the same positions as those in (67) are assigned in (70), and the events in (74) to the same positions as those in (68) are assigned in (70). Hence, these pairs will be marked as paraphrases. Furthermore, it is easy to see that entailments like (44), which are based on the transitivity of "before" and "after", will be marked by a semantic component containing the lexical entries given for 'PAST', 'PRESENT', and 'FUTURE', and (61).

Another linguistic phenomenon that is handled by this apparatus is the often remarked on temporal sense of certain conjunctions.²¹ For example, it is quite clear that the sentences

(75) Mary became pregnant and Mary got married
and

(76) Mary got married and Mary became pregnant,
in the senses in which the two occurrences of "Mary" are coreferential and in which the conjunction is not interpreted as simply jointly asserting the occurrence of the two events in question – as if either (75) or (76) were equally good, equivalent answers to the question "Name two things that happened last year?" – are not synonymous, since the temporal order of the events are opposite on those senses. (75) means that Mary became pregnant and then got married, while (76) means that she got married and then became pregnant. This is why (75)'s use would encourage a suspicion that (76) would not. But given these facts, on the senses in question, (75) is synonymous with

(77) Mary became pregnant before Mary got married
while (76) is synonymous with

(78) Mary got married before Mary became pregnant

This suggests a very natural way to mark this temporal sense of "and", namely, to include as part of the lexical entry for "and" the same lexical reading as given in (61) (i) for "before". This will have the effect of predicting that any sentence in which a pair of constituents are conjoined by "and" has a sense expressing temporal order just in case those constituents have readings that satisfy the selection restriction in (61) (i). For instance, it will be predicted that the sentence

(79) Drinking and driving don't mix
has a sense in which drinking before driving is proscribed, since "drinking" and "driving" are nominalizations of verbs and so contain the categorized variable for the inflexional relation in their reading. But it will also predict that the sentence

(80) Oil and water don't mix
does not have a sense involving temporal order, since "oil" and "water" do not come from verbs and hence lack the requisite semantic markers.

Up to now, we have been dealing with the representation of temporal

relations among events located at a particular point in time. Of course, not all time relations are of this sort. Consider those expressed by sentences, such as

(81) John is eating soup

(82) John was (has been) eating soup

(83) John will be eating soup,

where the progressive form of the tense constituent appears. In (81) - (83), John's act of eating soup is not located at a point but is spread over a segment on the time dimension. That is, in such sentences the event concerned is said to occur over an interval of time, to be on-going through that interval. In past progressive sentences like (82), the event is described as in progress from some undesigned point in the past to some later undesigned point in the future, and in future progressive sentences like (83) the event is described as in progress from some undesigned point in the future to some later undesigned point in the future. This is clear. But in the present progressive case the situation is not so clear. Is the event referred to in a sentence with a present progressive tense, say in a sentence like (81), described as on-going throughout an interval which is included in the interval bounded by the onset and termination of the utterance of that sentence, or is the event described as on-going throughout an interval which properly includes the interval bounded by the onset and termination of the utterance of that sentence? To give an affirmative answer to the latter question is to say that in any utterance of (81) that makes a true statement the eating referred to must have either begun before the onset of the utterance or gone on after its termination. But, although this is usually the case with activities such as eating, it is not at all necessarily the case. For example, it is perfectly clear that there can be utterances of the sentences

(84) I am uttering an English sentence

(85) You are listening to me speaking this sentence

which make true statements and which, by the nature of the case, must describe activities, my uttering the sentence I'm uttering and your listening to me speaking the sentence I'm speaking, if true describe an event that is included in (though not properly, of course) in the interval bounded by the onset and termination of the utterance. Moreover, it seems plausible to answer affirmatively to the first question even in cases like eating soup, for one can imagine that John is a notoriously fast soup eater and the speaker is an extraordinarily slow speaker. Thus, as John sits down to his soup the speaker begins to utter (81) but before finishing the sentence John has finished eating the soup. Accordingly, we introduce

(86) $t_{su} \longrightarrow ((t_{su+(-r_1)}), \dots, (t_{su}), \dots, (t_{su+(+r_2)}))$

as the lexical reading for the morpheme 'PROGRESSIVE' in the auxiliary. ' t_{su} ' is the value of the variable categorized for the inflexional

relation, either the reading of 'PRESENT', 'PAST', or 'FUTURE', and 'r' is, again, some arbitrary number of units on the time dimension less than the absolute value of the subscript 'u' (where differently subscripted cases can be different numbers).

Let us see how (86) marks the time-relations in (81) - (83). In (81) the tense constituent contains 'PRESENT', and so $(t_{\S u}) = (t_o)$. (86) thus converts it into $((t_{o+(-r_1)}), \dots, (t_o), \dots, (t_{o+(+r_2)}))$, which, by the algebra of signed numbers, reduces to $((t_{-r_1}), \dots, (t_o), \dots, (t_{+r_2}))$. In (82) the tense constituent contains 'PAST', and so $(t_{\S u}) = (t_{-n})$. (86) converts it into $((t_{-n+(-r_1)}), \dots, (t_{-n}), \dots, (t_{-n+(+r_2)}))$. In (83) the tense constituent contains 'FUTURE', and so $(t_{\S u}) = (t_{+n})$. (86) converts it into $((t_{+n+(-r_1)}), \dots, (t_{+n}), \dots, (t_{+n+(+r_2)}))$.

Next, we consider sentences that temporally relate two events which span an interval of time, e. g.,

(87) John was eating soup while Bill was eating bread

(88) John will be eating soup while Bill is eating bread

Compare (87) and (88), respectively, with

(89) John was eating soup and Bill was eating bread

(90) John will be eating soup and Bill will be eating bread

In the cases of (87) and (88), but not in the cases of (89) and (90), we can infer that the progress of the events spoken of in the main and subordinate clauses of the sentence begin at the same point and end at the same point. That is, the adverb "while" identifies the time interval over which the first event occurs with the time interval over which the second occurs. This can be accounted for by a general convention that we always choose a different subscript variable for each lexical reading of 'PAST' or 'FUTURE' occurring in an underlying phrase marker. That is:

(91) For each pair of semantic markers $(t_{\S u_i})$ and $(t_{\S u_j})$ assigned to morphemes in an underlying phrase marker, $i \neq j$, i. e., different natural numbers must be used to provide the subscript indices for the variable subscripting 't'.

Given this convention that each variable subscripting 't' must receive a different subscript index and given, further, that "while" has the lexical reading of "contemporaneous with", "at the same time as", etc., viz., (66), it follows that in (89) and (90) the events in the main clause and subordinate clause are represented in such a manner that it is left unspecified whether these events occur at the same time or different times and that in (87) and (88) the events are represented as occurring over the same time interval. For the lexical reading for "while" takes

the form of a rule for replacing the different subscript indices (assigned by the convention (91)) by a common subscript index, viz., the one on the variable subscripting the occurrence of 't' in the main clause.

Now consider the sentences:

(92) John is eating soup while Bill is eating bread

(93) John is eating soup and Bill is eating bread

Here there is no contrast such as in the comparison of (87) with (89) or (88) with (90). Not only do the events in (92) progress through a common time interval, but so do the events in (93). This can be accounted for on the basis of the fact that no subscript variables are involved. In both clauses of both sentences, the present tense occurs, and in the lexical reading of the present tense morpheme the subscript on 't' is the constant 'o'. (91) applies only to subscripts of 't' that are variables, so (91) does not apply in form the semantically interpreted underlying phrase markers for (92) and (93). Hence, in the case of (92), the reading for "while" replaces $V[T^S]$ by $V[T^m]$, which is just replacing ' $(t_{o+(-r_1)}), \dots, (t_o), \dots, (t_{o+(+r_2)})$ ' by itself. Accordingly, the semantic repre-

sentation of (92) describes John's eating soup and Bill's eating bread as occurring over the same interval. Hence, in the case of (93), there being nothing to index differently owing to the fact that the subscripts on each occurrence of 't' is the constant 'o', the semantic representation of this sentence describes John's eating soup and Bill's eating bread as occurring over the intervals designated by ' $(t_{o+(-r_3)}), \dots, (t_o), \dots,$

$(t_{o+(+r_4)})$ ' and ' $(t_{o+(-r_5)}), \dots, (t_o), \dots, (t_{o+(+r_6)})$ '. This says that

these events are asserted by (93) to be on-going at the utterance point, but it is allowed that the starting and stopping points of the intervals they span can be different.

Consider the sentences:

(94) John was eating soup before Bill was eating bread

(95) John was eating soup after Bill was eating bread

(96) John will be eating soup before Bill will be eating bread

(97) John will be eating soup after Bill will be eating bread

These cases can be handled parallel to (59), (60), (67), and (68). What is required is that ' $V[T^S]$ ' in (61) (i) and (ii) be understood to be the semantic marker ' $(t_{su+(-r_i)})$ ' in the reading for a progressive form.

Thus, for example, John's eating soup in (94) is described as occurring over the interval specified by ' $(t_{-n+((-r_1)+(-r_3))}, \dots, (t_{-n}), \dots,$

$(t_{-n+(+r_2)})$ ', whereas Bill's eating bread in this sentence is described

as occurring over the interval specified by ' $((t_{-n+(-r_1)}), \dots, (t_0), \dots, (t_{-n+(+r_4)}))'$.

The final types of relations that must be considered here are, first, the type involving the location of an event at a particular point within an interval and, second, the type involving the location of an event spanning an interval within an interval. Consider:

(98) John kicked George during the time Bill was sleeping

(99) John was eating soup during the time Bill was sleeping

In the former case, John kicked Bill at some point in time within the interval through which Bill's sleeping occurred. In the latter, the interval through which John was eating soup is included within (but not necessarily properly included in) the interval through which Bill was sleeping. These types of time relations can be handled on the basis of a lexical reading for the adverbs that, like "during", effect the insertion of an event within an interval. Thus, as paradigmatic, we introduce

$$(100) \text{ during; } V[T^S] = ((t_{\S u+(-r_i)}), \dots, (t_{\S u}), \dots, (t_{\S u+(+r_j)})) \\ \longrightarrow ((t_{\S u+(-r_i)}), \dots, V[T^m], \dots, (t_{\S u+(+r_j)}), <SR>$$

where the selection restriction is the same as in previous cases.

According to this rule, (98) is represented as saying that John's kicking George is located at the point specified by ' $(t_{-n})'$ and that Bill's sleeping is spread over the interval ' $((t_{-m+(-r_1)}), \dots, (t_{-n}), \dots, (t_{-m+(+r_2)}))'$,

and so the occurrence of the former event is specified as occurring with the interval through which the latter occurs. According to (100) also, (99) is represented as saying that John's eating soup spans the interval ' $((t_{-n+(-r_1)}), \dots, (t_{-n}), \dots, (t_{-n+(+r_2)}))'$ and that Bill's sleeping spans the interval ' $((t_{-m+(-r_3)}), \dots, (t_{-n+(-r_1)}), \dots, (t_{-n}), \dots, (t_{-n+(+r_2)}), \dots, (t_{-m+(+r_4)}))'$. This, then, says that the interval through which the

former event occurs is within the interval through which the latter occurs. Notice, finally, that the iteration of interval inclusion, as illustrated by

(101) John's eating soup occurred during Bill's nap which
occurred during Sam's trial which occurred during
Mary's holiday trip which occurred during . . . ,

is quite naturally accounted for by (100) given that syntactic can define the notion of a clause being subordinate to another clause even though that second clause is not itself the main clause of the entire sentence.

We can now turn our attention to the semantic representation of temporal relations that locate events with respect to intervals whose size is

fixed linguistically. Consider the sentences:

- (102) John has been eating jam in the last hour
- (103) John has been eating jam for the last hour
- (104) John ate (eats, will eat) cake yesterday (today, tomorrow)
- (105) John ate cake a (three) minute(s) ago
- (106) John will see George an hour ago

The primary question here is how to represent fixed time intervals, i.e., how to represent the meaning of words like "hour", "second", "minute", "day", etc. which express intervals of fixed size.

Another way to regard the problem is to take it as requiring that some apparatus for compositionally determining the meaning of temporal adverbials such as those in (102) - (106) from the meanings of their subconstituents and for compositionally determining the meaning of predicate-phrases from the meanings of the constituents grammatically related by the temporalization relation be introduced into the system for describing time relations developed thus far.

The meaning of time adverbials like those that occur in (102) - (106) involves a number concept, a unit concept, and a direction concept. Sometimes these are differentiated by the words that make up the adverbial, as in (105) and (106), and sometimes not, as in (104). Semantically, then, the only difference between cases like "two days ago", "one hour hence", "the last six days", "a second from now", "in a day's time", etc. and cases like "yesterday", "today", etc. is that in the former ones the complex concept is compositionally formed from the concepts of number, unit, and direction that are assigned lexically to morphemes while in the latter the complex concept is itself lexically assigned. We shall not say anything about the number concept, since it is not special to the representation of time relations and involves enormous complications. Thus, we focus our attention on the concepts of unit and direction.

To define the unit concept on the basis of a reading we must institute some division of the time dimension into basic units. For this purpose, we choose the smallest temporal unit for which there is a name in common speech, *viz.*, the second. It is true that natural languages contain names of smaller units, e.g., "microsecond", but we are not saying the second is a primitive unit and even terms for smaller units than the second indicate in their compositional structure that the second is basic, e.g., "microsecond" means the one millionth part of a second. Given that the units larger than a second are definable in a straightforward way in terms of the second unit — a minute is sixty seconds, an hour is sixty minutes, a day is twenty four hours (though, of course, not any twenty four hour period), a week is seven days, and so on — it will be possible to provide lexical readings for each of the morphemes that express these larger units in terms of multiples of the basic unit second. Accordingly, (45) and (46) will automatically come out to be synonymous. The number concept can be taken as just a coefficient of the unit concept, i.e., can be treated as its multiplier, since

the expressions "sixty seconds" and "an hour", "one hundred and twenty seconds" and "two hours", etc. are synonymous. The direction concept indicates the direction from the origin, left in the case of past and right in the case of future. Thus, except for "now", which can be represented as the origin itself, we can take the direction concept to attach either a plus or minus sign to the result of multiplying the number concept by the unit concept: a plus in the reading of an expression like "one day hence" and a minus in the reading of an expression like "one day ago". Accordingly, the derived reading for "two minutes ago" would be ' $-(2 \times 120)$ ' or ' (-240) '.

Hence, the derived readings for these temporal adverbials are constants representing a fixed number of basic units and a direction from the origin. This is as it should be, since, generally, the semantic effect of these temporal adverbials is not to change any time relations already determined by the tense constituent but only to make such relations more determinate, e. g., to specify precisely the span of the interval in which some event is said to occur as in (102), over which some event is said to occur as in (103), and so forth. Examples (106) and (42) show that the semantic effect of such adverbials can be to produce incompatible temporal designations, thereby resulting in contradictory sentences, but even here no change in the time relations specified in the tense constituent is brought about. This suggests that the natural way of forming derived readings from the readings of temporal adverbials and the readings of the verb after the reading of the tense constituent is substituted. It is to substitute a reading of the temporal adverbial for the appropriate occurrences of the variables appearing as subscripts on 't' within the reading of the verb. Given this projection rule operation, the time relations in the sentence

(107) John kicked Bill two minutes ago

are obtained, first, by forming the time representation determined in the auxiliary, ' (t_{-n}) ', second, by substituting it for the appropriate categorized variable in the reading of the verb, and, then, substituting ' (-240) ' for ' $-n$ '. Thus, John's kicking Bill in (107) would be represented as located 240 basic units to the left of the origin, which is 240 seconds in the past with respect to the utterance point.

There are two slight complications to be considered. First, we must distinguish between temporal adverbials and adverbials of duration and frequency. Consider the contrast between

(108) John was eating cake for one minute

(109) John was eating cake one minute ago

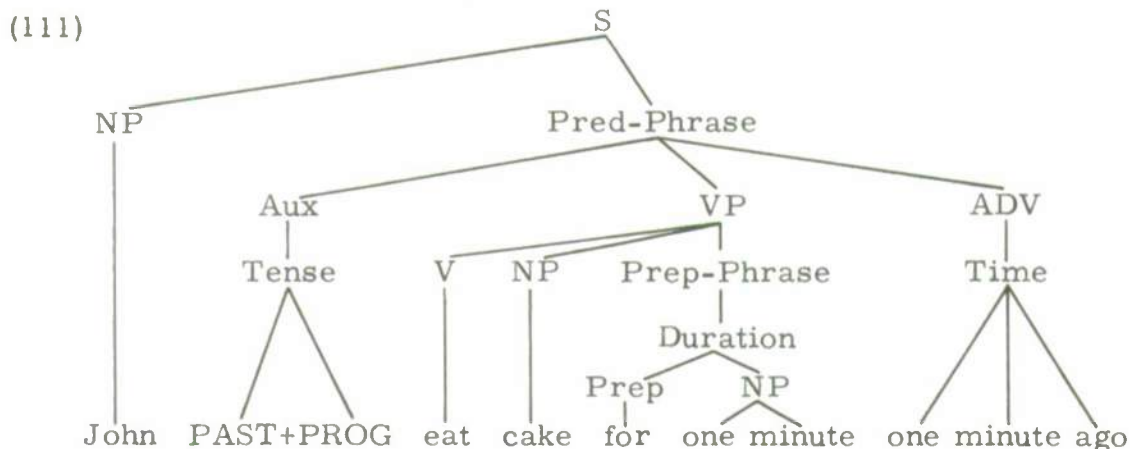
or

(110) John was eating cake for one minute one minute ago

Fortunately, there is a syntactic basis for this distinction. The syntactic component provides this basis in a rule of the form

(52) (iii) Prep-Phrase $\rightarrow$ Duration, Frequency, Place, Direction, ...²²

The effect of (52) (iii) together with (52) (i) - (iv) is to provide the sort of phrase marker illustrated by



in which there is a basis for distinguishing the temporalization relation from the grammatical relation that holds between the verb and an adverbial of duration or frequency. In terms of this distinction, we can introduce two projection rule operations, one of which applies to cases where the verb is modified by a temporal adverbial and the other where it is modified by an adverbial of duration or frequency. In the former case, the derived reading is formed, as suggested above, by substituting the constant in the reading of the time adverbial for the subscript variable on occurrences of 't' in the reading of the verb. The latter case divides into two subcases: the case of duration adverbials and the case of frequency adverbials. In the first, the derived reading for the verb is formed by substituting the constant in the reading of the duration adverbial for a certain variable in a reading formed from the reading of the verb. Notice that (108) and

(112) John ate cake for one minute

are synonymous. This means that part of the rule for combining the reading of the verb with the reading of an adverbial of duration is a rule for turning the reading for past into the reading for past progressive. This we give as the reading for "for", i.e., for the preposition that introduces such adverbials:

(113) $\underline{\text{for}}; (\underline{Z}, \dots, (t_{\S u}), \dots, \underline{W}) \longrightarrow ((t_{\S u+(-r_1)}), \dots, (t_{\S u}), \dots, (t_{\S u+(\S r_1+\Phi)}), \text{ where } \underline{Z} \text{ and } \underline{W} \text{ may both be null or where } \underline{Z} = '(t_{\S u+(-r_1)})' \text{ and } \underline{W} = '(t_{\S u+(+r_2)})'.$

Given the operation of (113), the combination of the reading of the duration adverbial with the reading of the verb – where the time designation in it is now of the form given by the right hand side of (113) – consists simply in substituting the constant in the reading of the duration adverbial for the variable ' Φ '.²³ Finally, the derived reading for the verb is formed from its reading together with a reading of an adverbial of

frequency by the rule

$$(114) (t_{\S u_i}) \longrightarrow (t_{\S u_1}), (t_{\S u_2}), \dots, (t_{\S u_i}), \dots, (t_{\S u_k})$$

The sentences

(115) John hit Bill repeatedly

(116) John hit Bill again and again (and again, etc.)

(117) John hit Bill over and over (and over, etc.) again

are examples of ones that this rule is to be used for.

We have constructed part of a representation system for time designations and some rules that assigns represents from this system compositionally: as the result of the application of projection rules (to lexical readings in the system) dealing with such grammatical relations as the inflexional relation and the temporalization relation, derived readings as assigned to sentences as an abstract representation of the time relations between the events spoken of in them. (39)–(48), (106), etc. show that the time relations described in this system also underlie semantic properties and relations, e.g., semantic anomaly, analyticity, contradictoriness, and so forth, of sentences. Let us now turn to a brief consideration of this.

(106) and the sentence

(118) John kicked Bill one minute from now

are contradictory because they express incompatible temporal locations for the event they are about. In order for us to be able to mark such cases of contradiction by the general definition for a contradictory sentence, we require a convention governing the substitution of constants, i.e., readings of the time adverbials in a sentence, for subscript variables on occurrences of 't' when the sign of the subscript variable differs from the sign on the constant. Thus, the former convention of substituting the constant for the variable is to be regarded as applying only when the signs are the same. The full convention may be stated as follows:

(119) The result of substituting ' $\S N$ ' for ' $\S u_i$ ' in ' $(t_{\S u_i})$ '
is ' $(t_{\S N})$ ' in case the $\S$'s are identical and the
result is ' $(t_{\S u_i}, \S N)$ ' in case the $\S$'s are different.

(119) can be regarded as a clause of the projection rule concerned. According to (119), the time relations in (118) will be represented as ' $(t_{-n}, +60)$ ' and the time relations in (106) will be represented as ' $(t_{+n}, -3600)$ '. '-' and '+' will be taken as antonymous semantic markers, and accordingly, by the definition of 'contradictory sentence',²⁴ sentences whose predicate readings contain a semantic marker of the form ' $(t_{-n}, +W)$ ' and one of the form ' $(t_{+n}, -W)$ ', where

'W' is either a constant or a variable, as in the case of

(120) John will kick Bill some time ago,

will be marked as contradictory (on a reading). Thus, (106), (118), and (120) will each be marked contradictory, thereby representing the fact the events they refer to are incompatibly located at different points in time. Hence, just as the semantic machinery for marking contradiction in the case of ordinary predication reflects the principle that one single object cannot have both of two incompatible properties, so the machinery developed in this section reflects the principle that one single event cannot occur at each of two incompatible temporal locations.²⁴

Notice, however, that not only are (106) and (118) contradictory but their negations, respectively,

(121) John will not see George an hour ago

and

(122) John did not kick Bill one minute from now

are also contradictory. To bring out more the sense of an event in such cases, consider the pairs:

(123) John will avoid seeing George an hour ago

(124) John will not avoid seeing George an hour ago

and

(125) John did refrain from kicking Bill one minute from now

(126) John didn't refrain from kicking Bill one minute from now

Again, both the original sentence and its negation are contradictory. Such cases constitute an interesting aspect of the distinction between sentences and their senses, the propositions they express. For, as these examples show, the relation of being a negation of is distinct from the relation of being a denial of. The second term of the former relation is a sentence, while the second term of the latter is a proposition. The relation of being a negation of holds of a pair of sentences by virtue of their syntactic form – roughly, one differs from the other by virtue only of an occurrence of "not" in its main verb-phrase. Denial, on the other hand, is not a purely syntactic, but rather a logical one primarily. The denial of a sentence expresses a proposition incompatible with the proposition expressed by the sentence of which it is the denial: if the denial is true, then the sentence of which it is the denial is false, and vice versa. But in the case of two sentences one of which is the negation of the other, it does not follow that if one is true, the other is false. Consider, for example, Churchill's famous comment in the House of Commons that

(127) Half of the ministers are asses

and his remark when criticized for this comment

(128) Half of the ministers are not asses

Every declarative sentence is the denial of some sentence, but, of course, not every declarative sentence is the negation of some sentence. The sentences

(129) John is alive

and

(130) John is dead

are denials of each other, though neither is of negative form.

Accordingly, the examples (106) and (121), (118) and (122), (123) and (124), and (125) and (126) are counter-examples to the principle that the negation of a contradictory sentence is analytic, for they show that there are cases where the negation of a contradictory sentence is itself contradictory. But this is of no interest by virtue of the fact that the negation of a sentence, as understood above, is not a logical object, subject to the laws of logic. But they also are counter-examples to the principle in semantic theory, say as set forth in "Analyticity and Contradiction in Natural Language",²⁵ that the denial of a contradictory proposition is analytic. Since this conflict is significant, let us explore the matter to see if there is some plausible way of reformulating the principle.

Let us focus attention on cases like (121) and (122) which, we admit, are not merely negations of the sentences that are identical to them except for the occurrence "not" (like (106) and (118)), but are genuine denials except for the contradiction in both the negation and the sentence of which it is the negation. It is impossible to avoid the conflict between such cases and the principle by somehow changing the rules that comprise the lexical reading for "NEG", whose occurrence in the auxiliary constituent of the underlying phrase marker of (121) and (122) is the source of their negativity. These rules, it will be recalled, apply to the semantic markers of a reading in the scope of "NEG" and have the function of replacing certain of these semantic markers by a certain set of other semantic markers, each replaced semantic marker (M_i) being supplanted by the union of all and only the semantic markers in the antonymous n-tuple to which (M_i) belongs except for (M_i) itself.

But the readings or parts of readings that represent time relations are not in the scope of "NEG", as must be the case because of examples like:

(131) John did not hit Bill at 2 o'clock

(132) John hit Bill at some time other than 2 o'clock

where there can be no entailment of (132) by (131), since (131) can be true and (132) false on the condition that John never hits Bill. Since the contradiction in cases like (121) and (122) are independent semantically of the operation of these rules, our resolution of the conflict must be sought elsewhere.

The resolution we suggest is to reformulate the principle as:

- (133) The denial of a contradictory determinable proposition is an analytic proposition.

and to redefine the notions "determinable" and "indeterminable" so that the category of indeterminable propositions includes not only sentences with contradictory subjects but also ones with contradictory temporal relations, i. e., ones where the semantic markers in the reading for the predicate-phrase that represent time relations express incompatible temporal locations for an event.²⁶

We have been considering one form of contradiction that can arise in connection with the expression of time relations in sentences, viz., where different signs occur in the subscript of the same variable 't'. But this is not the only kind of contradiction that can arise, and we shall briefly consider some other kinds now.

Sentences can also be contradictory in their expression of time relations by virtue of an occurrence of 't' whose subscript contains different constants with the same sign or different variables with the same sign. This, however, is a special case:

- (134) John first kissed Mary an hour ago and a minute ago

- (135) John first kissed Mary at one time and then at another

For clearly the sentences,

- (136) John kissed Mary an hour ago and a minute ago

- (137) John kissed Mary at one time and then at another

are not contradictory. These latter cases should be handled on the model of adverbials of frequency as discussed above, as the sentence

- (138) John kissed Mary a minute ago, two minutes ago, an hour ago, and a day ago

entails the sentence

- (139) John kissed Mary a number of times

Thus, the representation of (137)'s time relations will be ' $(t_{-n_1}), (t_{-n_2})$ '

and the representation of (136)'s will be ' $(t_{-360}), (t_{-60})$ '. But part of the meaning of "first" (which it shares with "last", for example) is the concept of uniqueness. This can be explicated by the rule, which will be part of the lexical reading of "first",

- $$(140) \quad (t_{\$n_1}), (t_{\$n_2}), \dots, (t_{\$n_k}) \longrightarrow (t_{\$n_1}, \$n_2, \dots, \$n_k) \\ (t_{\$N_1}), (t_{\$N_2}), \dots, (t_{\$N_k}) \longrightarrow (t_{\$N_1}, \$N_2, \dots, \$N_k)$$

With (140), we can mark (134), (135), and sentences like them as contradictory on the condition that a single occurrence of 't' has more than one subscript designation (as indicated by being set off by commas, as opposed to symbols being connected by '+' or '-', which count as one designation).

Another kind of contradiction is found in (42), which contrasts with the synthetic sentence

(141) He worked for a minute during the last hour,

and which is contradictory because it includes a one time span in another that is smaller than it. Other kinds are exemplified by:

(142) He will work for a day a day ago

(143) He will work for a minute during the last hour

and, of course, mixed cases like:

(144) He will work for an hour during the last minute

These can be defined on the basis of the representation scheme given for time relations, but involve complications that we need not go into here.²⁷

It is worth noting that, although we get analytic sentence like (41), we do not get analytic sentences corresponding to the contradictory sentences (106) and (118). That is, the sentences

(145) John will see George at some time in the future

(146) John kicked Bill at some time in the past

involve redundancy not analyticity. They are more like

(147) John is a male bachelor

than they are like

(148) A bachelor is male

since they, like (147), are synthetic, i. e., possibly false for contingent reasons. These facts are accounted for easily by the definitions of analyticity and redundancy. It will be recalled that sentence is analytic – to simplify – if the reading of its predicate phrase contains only semantic markers that already appear in the reading for its subject and that a constituent (below the full sentence constituent) is redundant – simplifying again – if a subconstituent of this constituent is a modifier of another subconstituent and the reading of the former contains only semantic markers that already appear in the reading for the latter. Accordingly, in cases like (145) and (146) the time adverbial and the tense constituent are both subconstituents of the predicate-phrase, the former is a modifier of the latter, and the former's reading contributes no semantic markers to the latter's, the predicate phrases of these cases will be redundant. Since, however, these predicate phrases do have readings that contain semantic markers not appearing in the readings of their subjects, (145) and (146) will be marked as non-analytic, like (147) but unlike (148).

Analytic sentences like (41) and entailments like (43) and (44) depend on the meaning of comparative forms "longer" in addition to the constituents involved in the expression of time relations. The semantic account of the analyticity of (41) and the synonymy of (45) and (46) can be given on the basis of a lexical reading for "longer" having the form

of a semantic marker whose first symbol is a categorized variable whose values are readings of subjects, then a symbol that expresses the proper inclusion of the segment on the time dimension picked out by value of the time designation in the reading of the verb-phrase, and so, finally, a variable categorized for such values. Since both "hour" and "minute" will be expressed as some number of basic units on the time dimension, (41) will involve vacuous predication of the concept of sixty seconds. The treatment of the synonymy of (47) and (48), as well as the analyticity of (41) and the entailment in (43), can be given by regarding "longer" and "shorter" in their temporal application as corresponding, respectively, to "before" and "after" in the sense that they are interval versions of the latter. The difference between them is, then, just that in comparative sentences "longer" ascribes a larger interval to the event it modifies than the one over which the other event occurs, while "shorter" ascribes a less extensive one. This difference can be represented by having the lexical reading of "longer" take the form of a rule that says that its interval is equal to the other plus some time constant, and the opposite for "shorter."

This concludes our discussion of time relations, even though there is, certainly, far more to be said.²⁸ However, our concern was not to elaborate the details of their representation, but, rather, to develop the general framework for temporal representation.

2.5 THE SOLUTION TO THE PROBLEM OF CONVERSES

The concepts of state and process presented in section 3 together with the framework for representing temporal relations in section 4 provide the apparatus for a semantic solution to the problem of explaining the nature of the paraphrase relation in connection with converse expressions like those in (5) and (6). This semantic solution will consist in showing that, on the basis of this conceptual machinery, we can so represent the meaning of verbs like "buy" and "sell" that the operation of projection rules automatically assigns sentences like (5) and (6) the same derived reading.

We begin by applying our previous discussion in order to fill out the abstract form of the process semantic marker as described in (28). By this, we will obtain the semantic markers required to represent the meaning of "buy" and "sell" in the desired way.

Our discussion of categorized variables provides us with the conceptual apparatus for fully specifying the brackets of the categorized variables in the special case of (28) that will be the lexical reading for "buy" and in the special case of (28) that will be the lexical reading for "sell". Here, of course, we refer to the functions that define the subject of, object of, indirect object of relation, etc., as well as the temporalization, inflexional, and other relations involved in the expression of time relations. As to the selection restrictions on these categorized variables, nothing general needs to be said about the content of the angles of the variables categorized for any of the former grammatical relations, since the semantic marker content varies with the particular sort of state or process involved. Thus, the condition involved will fully determine the selection restriction, since the question of what the restriction is answered when it is known what kinds of things it make sense to say are in that condition. For example, since it makes no sense to say of a corpse or rock or abstract idea that it recovered from its illness, so the selection restriction for categorized variable in the reading for "recover" that takes readings of the subject as its values must exclude readings of nouns that are semantically non-living. We will consider the particulars about the selection restriction for "buy" and "sell" after we consider the nature of the condition in these cases.

However, something general can be said about the selection restriction involved in the variable categorized for one of the temporal grammatical relations. In connection with (62) - (65), we found that time adverbials like "before" and "after" require a reading with a selection restriction that imposes the condition that readings of main subordinate clauses connected by such adverbials contain either a variable categorized for the inflexional relation or some value substituted for it, either further developed by readings of time adverbials or not. The same restriction is required for a verb like "lasts", as the contrast between the semantic anomalousness of (39) and the non-anomalousness of (40) shows. For unlike "truth", which must be represented as something timeless, "memory" must be represented as something involving the passage of time. This has nothing to do with the fact that "truth" is a

nominalized adjective, while "memory" is a nominalized verb. Some verbs have to be accorded a timeless sense, e.g., "proves" in

- (149) The Gödel theorem proves that no formal system containing the ordinary operations on positive integers, truth functions, quantification, and identity is complete, if it is, in fact, ω -consistent.

and some adjectives have to be accorded a non-timeless sense, e. g., "sick". Rather, this has to do with the fact that the meaning of "memory" is, roughly, the storage of information in the mind for a period of time (or the faculty for doing so). Therefore, since processes are, by definition, things that take place through time, it is clear that this selection restriction which occurs in the readings of adverbials like "before" and "after" and verbs like "lasts" should be an inherent feature of the process semantic marker.

But, then, it is also an inherent feature of processes, and one on which the former one depends, that their states succeed each other in time. Accordingly, the time designations in a process semantic marker must determine an interval on the time dimension, such that the initiating point of this interval is specified by the time designation in the semantic marker representing the initial state of the process and the terminating point of this interval is specified by the time designation in the semantic marker representing its terminal state.

Therefore, (28) should be further specified as:

- (150)
- $$(((\text{Condition}), (), \dots, ()) \text{ of } \begin{matrix} [] \\ X \end{matrix} \text{ at } \begin{matrix} [\text{Tense, Aux,} \\ X_{+(-r_1)} \end{matrix} \\ < > \quad < (\dots t \dots) >$$
- Pred-Phrase]
- $$), \dots, ((\text{Condition}), (), \dots, ()) \text{ of } \begin{matrix} [] \\ X \end{matrix} \text{ at } \begin{matrix} [\text{Tense, Aux, Pred-Phrase}] \\ X_{+(+r_2)} \end{matrix} \quad \text{)).}$$
- $$< > \quad < (\dots t \dots) >$$

where the reading of the tense constituent is substituted for each occurrence of the variable categorized for the inflexional relation, ' $t_{\S u}$ ' becoming ' $t_{\S u+(-r_1)}$ ' in the substitution for the first occurrence of this variable and becoming ' $t_{\S u+(+r_2)}$ ' in the second. Consider the sentences:

- (151) The ice just melted
(152) The ice melted
(153) The ice will melt

The process of the ice's going from a solid state to a liquid state is temporally located by (151), (152), and (153), respectively, over the intervals ' $t_{0+(-r_1)}$ ', $\dots$, ' $t_{0+(+r_2)}$ ', ' $t_{-n+(-r_1)}$ ', $\dots$, ' $t_{-n+(+r_2)}$ ', and

'($t_{+m+(-r_1)}$), ..., ($t_{+m+(+r_2)}$)'. Now consider:

(154) The ice is melting

(155) The ice was melting

(156) The ice will be melting

Comparing the sentence whose tense is continuous with (151), (152), and (153), it is clear that, although in the process of melting is said to terminate (respectively, at the present, in the past, or at some time in the future) in (151), (152), and (153), it is not said to terminate but just to have begun in (154), (155), and (156). This is made clearer by the contrast of

(157) The ice melted a minute ago

and

(158) The ice was melting a minute ago

where (157) says that the terminal state of the process took place sixty seconds before the utterance point and (158) says that the initial and some intermediate states of the process took place prior to (the last of these intermediate state at) sixty seconds before the utterance point. Thus, to account for (154) - (156), we should further specify (28) as:

(159) (((Condition), (), ..., () of $\begin{bmatrix} \end{bmatrix}$ at $\begin{matrix} \text{[Tense, Auxiliary,} \\ X^1 \end{matrix}$ $\begin{matrix} < > & & <(\dots t \dots)> \end{matrix}$ $\begin{matrix} \text{Pred-Phrase]} \\ \end{matrix}$), ..., ((Condition), (), ..., () of $\begin{bmatrix} \end{bmatrix}$ $\begin{matrix} < > \end{matrix}$ at $\begin{matrix} \text{[Tense, Auxiliary, Pred-Phrase]} \\ X^n \end{matrix}$ $\begin{matrix} <(\dots t \dots)> \end{matrix}$), ..., ((Condition), (), ..., () of $\begin{bmatrix} \end{bmatrix}$ at $\begin{matrix} \text{[Tense, Auxiliary, Pred-Phrase]} \\ X^0 \end{matrix}$ $\begin{matrix} < > & & <(\dots t \dots)> \end{matrix}$)).

where the superscript on an occurrence of 'X', either '1', '2', ..., 'n', determines the semantic marker from the reading of the continuous tense constituent is substituted for it, and where '0' on an occurrence of 'X' excludes any reading from being its value. That is, the reading of a continuous tense constituent, by (86), has the form ($t_{\S u+(-r_1)}$), ...,

($t_{\S u}$), ..., ($t_{\S u+(+r_2)}$), which means it has a first and an nth semantic

marker, and so the first, i. e., ' $t_{\S u+(-r_1)}$ ', is the value of ' X^1 ' and

the nth, i. e., ' $t_{\S u+(+r_2)}$ ', is the value of ' X^n '. We can combine (150)

and (159):

(160)

$$\begin{array}{c}
 \left[\begin{array}{c} \text{[Tense, Auxiliary,} \\ \text{X}_{+(+r_1)} \end{array} \right] \\
 (((\text{Condition}), (), \dots, () \text{ of } X \text{ at} \\
 < > \left[\begin{array}{c} \text{X}_{+(+r_1)} \\ \text{X}_{+(-r_1)}, (t_{\S u}), (t_{\S u+(+r_2)}) \end{array} \right] > \\
 \text{Pred-Phrase]} \\
 \text{X}^1 \left[\begin{array}{c} \text{X}_{+(-r_1)}, (t_{\S u}), (t_{\S u+(+r_2)}) \end{array} \right] > , \dots, (((\text{Condition}), (), \dots, () \\
 < (t_{\S u+(-r_1)}), (t_{\S u}), (t_{\S u+(+r_2)}) > \\
 \left[\begin{array}{c} \text{[Tense, Auxiliary, Pred-Phrase]} \\ \text{X}^n \end{array} \right] > , \dots, (((\text{Condition}), \\
 \text{of } X \text{ at} \left[\begin{array}{c} \text{X}^n \\ \text{X}_{+(-r_1)}, (t_{\S u}), (t_{\S u+(+r_2)}) \end{array} \right] > \\
 < > < (t_{\S u+(-r_1)}), (t_{\S u}), (t_{\S u+(+r_2)}) > \\
 \left[\begin{array}{c} \text{[Tense, Auxiliary, Pred-Phrase]} \\ \text{X}^0 \end{array} \right] > \\
 (), \dots, () \text{ of } X \text{ at} \left[\begin{array}{c} \text{X}^0 \\ \text{X}_{+(-r_1)}, (t_{\S u}), (t_{\S u+(+r_2)}) \end{array} \right] >
 \end{array}$$

where the bar over a semantic marker appearing in a selection restriction requires the absence of the semantic marker under the bar from any reading that is to satisfy the selection restriction.²⁹

Because of the complexity of (160), we shall consider only simple, i.e., non-continuous, tense sentences in connection with the problem of converse relations. Thus, we shall use (150) instead of (160) as the general specification of a process semantic marker.

Given such a general specification, different particular processes are obtained by introducing different conditions in the component state semantic markers or by different orderings of the same set of conditions. For example, the process semantic marker for "melt" will have the condition semantic marker '(Liquid)' in the state semantic marker representing its terminal state, whereas the process semantic marker for "vaporize" will have the condition semantic marker '(Gaseous)' in the state semantic marker representing its terminal state. Therefore, to obtain the lexical readings for the process words "buy" and "sell", we must determine the conditions involved in the states of these processes.

Earlier we suggested that buying and selling are processes in which possession of something is transferred from one person to another in exchange for a sum of money. That the condition for these processes is possession will be granted, I assume, if a case can be made against the condition being the stronger one of ownership, and such a case is made by the observation that it is possible to buy or sell stolen goods, i.e., goods that the seller does not own, but merely possesses. That is to say, the sentence

(161) John sold the book to Mary who only after the sale found out that John did not own it.

is not semantically anomalous, which it would have to be were it only possible to sell or buy things owned by the seller.

Hence, we may say that in the initial state of the process of selling the full condition is that the seller possesses the thing he sells and that in the terminal state of this process the full condition is that the buyer possesses the thing bought. But, since the specifications of the initial and terminal states must include a determination of the article possessed by the seller in the former and by the buyer in the latter, and since, moreover, what this article is is determined by the direct object in sentences like (5) and (6), the semantic markers representing these states will have to contain an occurrence of the variable categorized for the grammatical relation of direct object of the verb.

Towards the end of section 2, we pointed out that sentences like (5) and (6) express a transaction in which possession of the article in question is exchanged for possession of a sum of money. This means that the verbs "buy" and "sell" express double processes and must be entered in the dictionary with a lexical reading having the form of (27) where $n = 2$. The second process must be one in which the initial state is that the buyer is in possession of a sum of money and the terminal state is that the seller is in possession of that sum of money. Accordingly, the specifications of these initial and terminal states must include a determination of the monetary sum possessed by the buyer at the beginning of the transaction and by the seller at the end. However, as also observed in section 2, ordinary sentences like (5) and (6) do not always contain a constituent that specifies the monetary sum. Some, like

(162) John sold the book to Mary for $\left(\begin{array}{l} \text{only a penny} \\ \text{twenty cents} \\ \text{one dollar} \end{array} \right)$,

do. We will call the grammatical relation that the noun-phrase in such prepositional phrases bears to the main verb in their verb-phrase the relation of being the "secondary indirect object of". A reason for taking such noun-phrases to be objects is that they answer what or whom questions of the sort that indirect objects and direct objects answer. For example, with respect to (162), we have:

(163) What did John sell to Mary? the book

(164) Whom did John sell the book to? Mary

(165) What did John sell the book for? twenty cents

Thus, on the assumption that such noun-phrases are (secondary indirect) objects, which is not absolutely necessary for our treatment of their semantic contribution to sentences, the particular monetary sum involved in the specification of the initial and terminal states of this second process is determined in sentences like (162) by the meaning of the secondary indirect object. Accordingly, the semantic markers representing these states will have to contain an occurrence of the variable categorized for this grammatical relation. The principle (26)

enables us to employ these semantic markers in connection with sentences like (5) and (6) if the selection restriction on this categorized variable in the readings for "sell" and "buy" is the condition that a substitution contain the semantic marker '(Monetary Sum)'. We shall further discuss this choice of a selection restriction at a later point.³⁰

The other selection restrictions required are one for the variables categorized for the subject and indirect objects, i.e., the constituents that refer to the buyer and seller, and one for the direct object, i.e., the constituent that refers to the article bought or sold. In the former case the natural hypothesis is that the angles under the variable contain '(Human) & (Infant)', while in the latter it is that the angles under the variable contain '(Physical Object)'. I do not wish to present an extended argument for these choices, but clear-cut semantic anomalies like

- (166) The rock (newborn infant, snake, number five, etc.) sold
the book to the cloud (bear, noun, chair, etc.)

provide some motivation for former choice and ones like

- (167) The man sold the shadow (reflection, number, etc.) to
the woman.

I recognize that often we speak of selling an idea, but it seems best to take this to mean selling the rights to any of its practical uses. Selling uses, services, etc. involve physical objects, and it seems best in such cases to impose the condition that meaningfulness depends on such physical objects being involved, since when they are not, as in

- (168) John sold James use of his shadow

- (169) James hired someone's reflection,

the sentences alleged to express the transaction are semantically anomalous. But nothing much here hangs on being exactly right about these selections restrictions, which involve many quite subtle and complicated semantic relationships.

We now present the lexical readings for "sell" and "buy":³¹

- (170) sell; (((Condition)(Possesses $\begin{matrix} \text{[NP, VP, S]} \\ X \end{matrix}$) of
<(Physical Object)>
 $\begin{matrix} \text{[NP, S]} \\ X \end{matrix}$ at $\begin{matrix} \text{[Tense, Auxiliary, Pred-Phrase]} \\ X_{+(-r_1)} \end{matrix}$),
<(Human) & (Infant)> <(... t ...)>
..., ((Condition)(Possesses $\begin{matrix} \text{[NP, VP, S]} \\ X \end{matrix}$) of
<(Physical Object)>

[NP, PP / Prep / (^{to}_{from}), VP, S] [Tense, Aux, Pred-Phrase]
_X at _X_{+(+r₂)})
 <(Human) & (Infant) >
 <(...t...) >

& (((Condition)(Possesses [NP, PP / Prep / for, VP, S]
_X) of
 <(Monetary Sum) >

[NP, PP / Prep / (^{to}_{from}), VP, S] [Tense, Aux, Pred-Phrase]
_X at _X_{+(+r₁)}),
 <(Human) & (Infant) >
 <(...t...) >

..., ((Condition)(Possesses [NP, PP / Prep / for, VP, S]
_X <(Monetary Sum) >

of [NP, S] [Tense, Aux, Pred-Phrase]
_X at _X_{+(+r₂)})).
 <(Human) & (Infant) >
 <(...t...) >

(171) buy; (((Condition)(Possesses [NP, VP, S]
_X) of
 <(Physical Object) >

[NP, PP / Prep / (^{to}_{from}), VP, S] [Tense, Aux, Pred-Phrase]
_X at _X_{+(+r₁)}),
 <(Human) & (Infant) >
 <(...t...) >

..., ((Condition)(Possesses [NP, VP, S]
_X) of
 <(Physical Object) >

[NP, S] [Tense, Aux, Pred-Phrase]
_X _X_{+(+r₂)}) &
 <(Human) & (Infant) >
 <(...t...) >

((Condition)(Possesses [NP, PP / Prep / for, VP, S]
_X) of
 <(Monetary Sum) >

[NP, S] [Tense, Aux, Pred-Phrase]
_X at _X_{+(+r₁)}), ...,
 <(Human) & (Infant) >
 <(...t...) >

$$\begin{array}{c}
\text{[NP, PP / Prep / for, VP, S]} \\
\text{((Condition)(Possesses } \overset{X}{\text{ }} \text{) of}} \\
\text{(Monetary Sum)} \\
\\
\text{[NP, PP / Prep / (}^{\text{to}}_{\text{from}}\text{), VP, S]} \quad \text{[Tense, Aux, Pred-Phrase]} \\
\text{ } \overset{X}{\text{ }} \text{ at } \overset{X}{\text{ }}_{+(+r_2)} \text{)}). \\
<(\text{Human}) \& (\text{Infant}) > \quad <(\dots t \dots) >
\end{array}$$

These lexical readings have the general form:

(172) sell; (((Condition)(Possesses Y)) of X at T_i), ...,
 (((Condition)(Possesses Y)) of Z at T_j) &
 (((Condition)(Possesses W)) of Z at T_i), ...,
 (((Condition)(Possesses W)) of X at T_j)).

(173) buy; (((Condition)(Possesses Y)) of Z at T_i), ...,
 (((Condition)(Possesses Y)) of X at T_j) &
 (((Condition)(Possesses W)) of X at T_i), ...,
 (((Condition)(Possesses W)) of Z at T_j)).

where the letters 'X', 'Y', 'Z', 'W', and 'T' stand for the variables categorized for the subject of, object of, indirect object of, secondary indirect object of, and inflexional relations, respectively. As the general form of these lexical readings for "sell" and "buy" shows, these readings are exactly the same except that where the variable categorized for the subject of relation appears in one variable categorized for the indirect object of relation appears in the other, and vice versa. This suggests the following definition of the converse relation:

(174) A constituent C is a converse of a constituent C', and vice versa, if, and only if, their readings are the same except for the categorized variables $v_1, v_2, \dots, v_n$ occurring in the reading of C and the categorized variables $v'_1, v'_2, \dots, v'_n$ occurring in corresponding positions in the reading of C' (i.e., $v_1 \neq v'_1, v_2 \neq v'_2, \dots, v_n \neq v'_n$), where $n \geq 1$, and if $v_i = v_j$, then $v'_i = v'_j$ and if $v'_i = v'_j$, then $v_i = v_j$, and, finally, for each v_i and v_j , if $v_j = \text{image of } v_i$, then the image of $v_j = v_i$, and for each v'_i and v'_j , if $v'_j = \text{image of } v'_i$, then the image of $v'_j = v'_i$.

We wish now to show that if there are two sentences constructed in the way (5) and (6) are and if their converse constituents have readings satisfying the conditions in (174), then these sentences are synonymous. Notice, first, that the words "sell" and "buy" are represented by (170) and (171) as ones whose meaning expresses the same process: the process of someone relinquishing possession of something to gain possession of a sum of money which someone else relinquishes possession of to gain possession of that thing. Notice, second, that the inverse positioning of the categorized variables in (170) and (171) says that the person relinquishing possession of the item and gaining possession of the sum of money, the seller, is described by the subject of "sell" and the indirect object of "buy", whereas the person relinquishing possession of the sum of money and gaining possession of the item, the buyer, is described by the indirect object of "sell" and the subject of "buy". Notice, third, that this inverse positioning corresponds directly to the inverse relations that "John" and "Mary" bear to the verb in (5) and in (6), as these relations would be picked out on the basis of (15) and (16): "John" is the subject in (15) and the indirect object in (16) while "Mary" is the indirect object in (15) and the subject in (16). Thus, in (5) and (6) "John" denotes the seller and "Mary" the buyer. Then, both (5) and (6) expresses the same proposition, viz., that John relinquishes possession of the book to gain possession of a sum of money which Mary relinquishes to gain possession of the book.

The reading representing this proposition expressed by both (5) and (6) will be assigned to them by the operation of projection rules on the lexical readings assigned to the lexical items in (15) and (16). Consider first the semantic interpretation of (15). Take first the process semantic marker that appears as the first component of the double process semantic marker that is the lexical reading of "sell". Because the variable categorized for the subject of relation appears in the semantic marker representing the initial state and the variable categorized for the indirect object of relation appears in the semantic marker representing the terminal state, the derived reading of the sentence (5), which will have the form displayed in (172), will contain the reading of (5)'s subject in the first state semantic marker of the first process semantic marker and the reading of (5)'s indirect object in the last state semantic marker of the first process semantic marker. That is, the reading of "John" will occur where "X" occurs in the first conjunct of (172) and the reading of "Mary" will occur where "Z" occurs in this conjunct. Next, take the process semantic marker that appears as the second component of the double process semantic marker that is the lexical reading of "sell". Because the variable categorized for the indirect object of relation appears in the semantic marker representing the initial state and the variable categorized for the subject of relation appears in the semantic marker representing the terminal state, the derived reading of (5) will contain the reading of (5)'s indirect object in the first state semantic marker of the second process semantic marker and the reading of (5)'s subject in the last state semantic marker of the second process semantic marker. That is, the reading of "Mary" will occur where "Z" occurs in the second conjunct of (172), and the

reading of "John" will occur where "X" occurs in this conjunct. Thus, the derived reading of (5) will take the form:

(175) (((Condition)(Possesses R-"the book")) of R-"John" at $t_{-n+(-r_1)}$), . . . , (((Condition)(Possesses R-"the book")) of R-"Mary" at $t_{-n+(+r_2)}$) & (((Condition)(Possesses (Monetary Sum))) of R-"Mary" at $t_{-n+(-r_1)}$), . . . , (((Condition)(Possesses (Monetary Sum)) of R-"John" at $t_{-n+(+r_2)}$))),

where 'R-". . ."' indicates the reading of the constituent ". . ." from the underlying phrase marker (15).

Now, consider the semantic interpretation of (16). Take first the process semantic marker that appears as the first component of the double process semantic marker that is the lexical reading for "buy". Because the variable categorized for the indirect object of relation appears in the semantic marker representing the initial state and the variable categorized for the subject of relation appears in the semantic marker representing the terminal state, the derived reading of the sentence (6), which will have the form displayed in (173), will contain the reading of (6)'s indirect object in the first state semantic marker of the first process semantic marker and the reading of (6)'s subject in the last state semantic marker of the first process semantic marker. That is, the reading of "John" will occur where "Z" occurs in the first conjunct of (173) and the reading of "Mary" will occur where "X" occurs in this conjunct. Accordingly, the first conjunct in the derived reading for (6) will be identical to the first conjunct in (175), which is the derived reading of (5). Next, take the process semantic marker that appears as the second component of the double process semantic marker that is the lexical reading of "buy". Because the variable categorized for the subject of relation appears in the semantic marker representing the initial state and the variable categorized for the indirect object of relation appears in the semantic marker representing the terminal state, the derived reading of (6) will contain the reading of (6)'s subject in the first state semantic marker of the second process semantic marker and the reading of (6)'s indirect object in the last state semantic marker of the second process semantic marker. That is, the reading of "Mary" will occur where "X" occurs in the second conjunct of (173) and the reading of "John" will occur where "Z" occurs in this conjunct. Accordingly, the second conjunct in the derived reading of (6) will be identical to the second conjunct in (175), and consequently, the reading of (6) will be identical to the reading of (5), thereby marking (5) and (6) as synonymous sentences.

Here, then, is our solution to the problem of converse relations, and our explanation of why sentences, or constituents, involving converse relations are synonymous. Though the treatment of the problem

was given only in terms of one case, it is, of course, easy to see how it would be generalized for others. In section 2.7, we shall consider its application to some other cases.

2.6 A RECONSTRUCTION OF 'SEMANTIC FIELDS'

In this section, I wish to sketch out the manner in which the ideas about semantic representation developed in the previous section can be used to provide a formal reconstruction of the notion of a semantic field as put forth by neo-Humboldtians like Trier.³² Their notion, stripped down to its linguistic essentials, is that the vocabulary of a language divides into classes of items, each marking off an integrated conceptual domain within which the conceptual space is differentiated into elementary regions whose boundaries delimit and are delimited by the boundaries of others. These elementary regions, either individually or taken together in groups, are labelled by words in a vocabulary, the elementary region or compound region labelled by a word being regarded as its meaning. Different languages label different sets of regions in a conceptual space, and so can be compared with one another as we might compare different maps of the same geographic terrain drawn according to diverse cartographical interests. Hjelmslev cites the example of the region of the kinship field corresponding to the concept of the sibling relation which is broken down into elementary regions 'elder male sibling', 'younger male sibling', 'elder female sibling', and 'younger female sibling', where Hungarian labels each of these elementary regions by a distinct word, English labels the first two together with one word and the second two together with one, and Malay labels the whole four regions together by one word.³³ Other fields that have been studied within this framework are color-names, intellectual qualities, moral properties, and animal terminologies.

The main deficiency of this work on semantic fields, even after it is stripped of all its speculative trappings,³⁴ is that it is, without exception, carried out independently of the principles of semantic interpretation that operate in grammar and in a manner that is even more intuitive and informal than classical works on syntax such as Jespersen. The former deficiency has led to an isolation of work in field theory from traditional semantic problems such as those of semantic ambiguity, synonymy, meaninglessness, etc., while the latter has led to vagueness and obscurity in determining what has been revealed in such work and by what methods it proceeds. But no one, I think, can reasonably doubt that field theorists have provided us with an interesting range of semantic problems and with some helpful, though somewhat crude and metaphorical, ideas to use in orienting our thinking about these problems.³⁵ Consequently, it is incumbent on those developing the theory of generative, transformational grammars to try to incorporate the work of field theorists. For by integrating the ideas of field theorists with the principles of semantic interpretation in transformational grammar, the problems raised by field theorists can be formulated within a framework far more suitable to their solution and the ideas proposed by them can be related to more traditional semantic problems (like ambiguity, synonymy, etc.) and formulated without appealing to metaphors or our intuitive understanding of language, i.e., expressed formally. On

the other hand, by such integration transformation grammar increases the area of linguistic phenomena with which it deals.

In our attempt take the first steps toward such a reconstruction of the notion of a semantic field, we shall reverse perspective. Instead of selecting a conceptual domain studied by field theorists and seeking to formalize it within the framework of the theory of transformational grammar, we shall try to show that a formalization of a conceptual domain naturally falls out of the treatment of certain linguistic phenomena within the theory of transformational grammar. This case may then serve as a model for others.

The case to be taken up is the treatment of the converses "sell" and "buy" developed in the previous sections. What we shall now try to show is that this treatment can be extended within semantic theory to provide an account of the conceptual domain that is covered in English by the class of words including, besides "sell" and "buy", the words "trade", "exchange", "swap", "give", "receive", "lend", "borrow", "inherit", "lease", "hire", "rent", and so forth. To obtain this extension to a formalization of the domain in the conceptual space having to do with processes involving transfer of possession, we start with the account of "sell" and "buy" given in the lexical readings (170) and (171), regarding them as defining a region within this domain, in particular, that region onto which the two English words "sell" and "buy" are mapped by the grammar of English as its label. We assume that there is a basic formal structure to the readings of "buy" and "sell" which is the same for the readings of "trade", "exchange", "swap", "give", "receive", etc. and which defines the conceptual domain in question. We assume, then, that each of these words that label regions in this domain can be defined by lexical readings that vary in formal structure in ways that leave the basic structure of the domain invariant. Thus, we try to obtain the extension we seek by providing lexical readings of words in this class that can be gotten from (170) and (171) by alterations that do not affect their basic form.

One obvious alteration in (170) and (171) is to eliminate the second conjunct, the second process semantic marker, in both. This gives us a lexical reading representing a process in which the possession of something is transferred from one person to another without anything being given over in return. This is the sense of "give" and "receive", since they are converses, "give" corresponding to "sell" and "receive" corresponding to "buy", we can provide them with the lexical readings that result from eliminating the second conjunct in (170) and (171), respectively. These readings will explain why

(176) John gave the book to Mary

(177) Mary received the book from John

are paraphrases, parallel to (5) and (6).

Another type of alteration that is possible is to change the semantic markers that specify the condition in the state semantic markers representing the initial and terminal states of the process. For example, we might replace the semantic marker of the form '(Possesses Y)' in both

its occurrence in the first and its occurrence in the last of the state semantic markers of the first process semantic marker in both (170) and (171) by one of the form '(Possesses Y at T_j , ..., T_{j+k})', where ' T_j ' indicates the time designation in the final state semantic marker of the process semantic marker, as shown in (172) and (173). The readings that result represent a process in which someone temporarily relinquishes possession of something to someone else who gains possession of it temporarily, over the time period during which the first person relinquishes possession, in exchange for a sum of money. Thus, these readings are appropriate lexical readings, respectively, for the words "hire" and "let" ("lease" used in its ordinary sense where it does not imply that the person taking temporary possession has signed a lease). The word "rent" covers either of these cases.

Clearly, both this type of alteration and the former one can be carried out jointly. If, then, we were to make the replacement described in the previous paragraph within the lexical readings of "give" and "receive", we would obtain the lexical readings, respectively, for the words "lend" and "borrow".

Another type of alteration is to replace the semantic markers occurring in a selection restriction by other semantic markers. If, for example, we replace the semantic marker '(Physical Object)' in the angles under the variable categorized for the direct object relation in the reading for "hire" by the semantic marker '(Transportation vehicle)', then we obtain the lexical reading for "charter".

Another example of this is the following. The selection restriction '<(Monetary Sum)>' occurring in the first and last state semantic markers of the second process semantic marker in both (170) and (171) is what distinguishes the sense of "sell" and "buy" from the sense of "trade", as, for instance, in

(178) Jack traded his mother's cow to a man for some beans

Thus, the lexical reading for "trade" should be identical to the reading for "sell" given in (170) except that where the latter contains the selection restriction '<(Monetary Sum)>', the former contains the selection restriction '<(Physical Object)>'. This shows up in an interesting way in sentences like

(179) Jack traded the cow for a dollar

(180) Jack traded (an indian head) penny for a (Confederate)
one hundred dollar bill

(179) does not have the sense that someone paid Jack a dollar for the cow but, rather, has the sense that a certain dollar bill was exchanged for Jack's cow in a swap. (180) is an even clearer example, having very much the sense of a numismatic transaction. The word "swap" can be given the same lexical reading as "trade", being only somewhat more colloquial, and so can "barter", which is slightly archaic. The word "exchange", aside from its specialized sense in reference to bringing back to a store an item bought there and receiving in return another, more suitable, item, seems to have two features that distinguish it

from "trade", "swap", and "barter". One is that when exchanging things, as, for example in

(181) John exchanged toys with Mary

(182) John exchanged his water pistol for Mary's,

possession is only temporarily acquired. That, is, "exchange" is to "trade", "swap", and "barter", as "borrow" and "lent" are to "buy" and "sell". This is not absolutely clear, but if this is true of "exchange", it can be represented in its lexical reading by giving "exchange" the same lexical reading as "trade" except that in the semantic markers representing the terminal states in both conjuncts the semantic marker of the form '(Possesses Y)' is replaced by one of the form '(Possesses Y at T_j , ..., T_{j+k})'. The other feature of "exchange" is that exchanges must be for equivalent items. If this is the case, then, although (182) is meaningful, the sentence

(183) John exchanged his water pistol for Mary's coat

is to some extent semantically anomalous. This feature can be stated in a lexical reading for "exchange", but its status is too dubious for us to go into the matter now.³⁶

We have considered three types of alteration: changing the number of conjuncts, changing the condition specified by state semantic markers, and changing the selection restrictions on categorized variables. Two general questions arise in this connection, first, what are the limits on such changes, and second, what other changes can be made to give rise to other regions of this conceptual space. These are not questions that can be answered at this stage in the development of semantic theory. However, consideration of them, even in every attenuated form, leads to some interesting consequences.

In the first place, it is clear that, for the conceptual domain we have been considering, we can change the number of conjoined process semantic markers but there must be at least one such semantic marker. It cannot be changed into something that is not a process semantic marker. Further, we can change aspects of the conditions specified in its state semantic markers, as indicated above or more extensively as would be required by "inherit",³⁷ but we cannot remove the specification of these conditions as having to do with possession, nor can we eliminate the features of the process semantic marker that represent the change of possession. Finally, we can change certain selection restrictions, but, of course, not all. For example, it is necessary in order that a reading represent one of the concepts in this conceptual domain that its categorized variables whose values specify who has possession of the transferred item at the outset of the process and who has possession at the end have a selection restriction that excludes readings for things that are not alive, e.g.,

(184) The corpse sold the book to Mary

(185) The mud bought the book from John

must be semantically anomalous. However, there are certain changes that are certainly allowable, i.e., lead to other regions, other concepts, but which are not required in order to obtain a lexical reading needed by a dictionary. For example, consider the reading that is identical to the reading for "trade" except that the selection restriction under the categorized variable 'W' is '<(Artifact)>' instead of '<(Physical Object)>'. This reading represents the concept of giving something over to someone in exchange for some artifact only. This concept, although it is not, in fact, expressed by a word in English, and perhaps by no word in any other natural language either, nonetheless, is a possible concept: it could be so expressed, but just happens not to be. Thus, semantic theory will reveal – moreover, formally define – concepts for which some or perhaps all natural languages contain no word to express. The existence of such cases, as pointed out by field theorists, (provide an important way in which languages can be compared semantically. We can ask, relative to full specification of a conceptual domain within semantic theory, which languages do and which do not map some word onto this, that, or the other particular region in it. The results of charting the regions mapped lexically by different languages and comparing them can be quite significant also for anthropology which can then ask why, culturally, do the languages L_i and L_j differ in their vocabulary for such-and-such a conceptual domain or why do all languages leave certain regions of this domain unmarked.³⁸

Of equal interest will be the discovery of impossible concepts, ones that not only are not but could not be expressed, ones, that is, for which the conceptual domain provides no region. The principles that determine the limits on changes taking us from one to another region in a conceptual domain will certainly exclude the selection restriction under the categorized variable 'W' in the reading for "trade" from being '<(Perceptual Object)>', i.e., such a "reading" cannot represent a region of a conceptual domain. Accordingly, there cannot be, in any language, a word for the process whereby one person exchanges something like an after-image, shadow, reflection, etc. to another for some object, perceptual or not. These principles are so little understood at present that it is not easy to explicitly state the principle that explains why this is an impossible concept. Roughly, the explanation runs as follows. It is clear that objects such as after-images, shadows, reflections, etc. are in some sense possessed by people, for the expressions

(186) John's after-image (shadow, reflection, etc.)

are not semantically anomalous. Yet, possession in that sense is not transferable to another, as shown by the semantic anomaly of

(187) John sold (traded, etc.) his after-image (shadow, reflection, etc.) to Bill for his (book).

The reason such objects are not transferable is that transferability, as is shown by our analysis of the processes of selling, trading, etc., involves relinquishing possession of something on the part of one person and gaining possession of it on the part of another, whereas,

whatever the sense possession in (186), it is not one where the termination of possession by gaining possession by someone else. For if John no longer has his after-image (shadow, reflection, etc.), then the object has ceased to exist, thereby making it impossible for another person to obtain it. To make this explanation explicit, however, requires a representation of this sense of possession, one that brings out the respects in which it differs from the other.

The principles of semantic theory that say what changes can be made in the structure of a semantic marker to form another semantic marker that represents another region within a conceptual domain and what the limits of such changes are can be viewed as conditions that define, formally, the notions of 'semantic marker' and 'reading', i.e., as conditions that define well-formedness for the system of semantic representations that linguistic theory provides for particular grammars. Abstract semantic markers, like that representing a process in which possession of something is transferred from one person to another, provide the general form of a conceptual domain, distinguishing it from other domains within the full semantic field underlying natural languages. Given such an abstract semantic marker, the conditions of well-formedness allow it to be developed, combinatorially, by changes of the types illustrated above, thereby giving rise to semantic markers that represent the individual regions in the domain, like, for example, the lexical readings of "sell", "borrow", etc.

Now, suppose that, in this manner, semantic theory recursively specifies a particular conceptual domain in terms of a set of readings. Then, the dictionary in a grammar of a particular languages L maps the lexical items of L (its morphemes and idioms) onto some of the regions of the domain by associating each complex symbol in the lexicon of the syntactic component with one or more readings in the set. In this way, certain of the concepts in such a space of possible concepts are associated with certain phonological representations as their lexical meaning, and no phonological representation can be associated with an impossible concept.³⁹

But the dictionary is not the full grammatical mechanism for labelling regions in a conceptual domain. Syntactically complex, non-idiomatic, expressions are associated with such regions by the operation of projection rules. This is one respect in which a reconstruction of the notion 'semantic field' such as ours far outstrips the theoretic potentialities of the work of field theorists.

Consider the word "resell". In the first place, it is clear that its meaning is included in the conceptual domain that we have been working with above. Second, it is also clear that this word is not a lexical item, but, rather, a syntactically composite formed from a prefix and a stem-morpheme, from "re" and "sell". Each of these elements must be entered in the dictionary as separate lexical items, since, if "resell" itself were entered, there could be no explanation in grammar of how the meaning of this syntactically complex constituent is a compositional function of the meanings of its parts. Moreover, the existence of a very

large number of other forms with the same prefix, such as "re-enlist", "relight", "reopen", "relapse", etc., excludes the possibility of listing any of these forms as separate lexical items, since this would enormously complicate the dictionary beyond what it would be were it to list each stem-morpheme but list "re" only once.

We will now illustrate how projection rules of the semantic component associate expressions in English with regions in a conceptual domain by showing how to form a derived reading for "resell" from the reading of "sell" and a reading for "re". The lexical reading for "sell" is (170). The derived reading for "resell" should be:

$$\begin{aligned}
 (188) & \left(((\text{Condition})(\text{Possesses} \begin{array}{c} [\text{NP, VP, S}] \\ \text{X} \end{array} \text{ of } \begin{array}{c} [---] \\ \text{X} \end{array} \text{ at} \right. \\
 & \quad \left. <(\text{Phy. Obj.}) > \quad <(\text{Hum. \& Inf.}) > \right. \\
 & \quad \left. [\text{Ten., Aux., Pred-Ph.}] \right. \\
 & \quad \left. \text{X}_{+(-r_1)+(-r_3)+(-r_4)}, \dots, ((\text{Condition})(\text{Possesses} \right. \\
 & \quad \left. \begin{array}{c} [\text{NP, VP, S}] \\ \text{X} \end{array} \right) \text{ of } \begin{array}{c} [---] \\ \text{X} \end{array} \text{ at } \begin{array}{c} [\text{Ten., Aux., Pred-Ph.}] \\ \text{X}_{+(-r_1)+(-r_3)} \end{array} \left. \right) \& \\
 & \quad \left((\text{Condition})(\text{Possesses} \begin{array}{c} [---] \\ \text{X} \end{array} \right) \text{ of } \begin{array}{c} [---] \\ \text{X} \end{array} \text{ at} \\
 & \quad \left. <(\text{Mon. Sum}) > \quad <(\text{Hum. \& Inf.}) > \right. \\
 & \quad \left. [\text{Ten., Aux., Pred. -Ph.}] \right. \\
 & \quad \left. \text{X}_{+(-r_1)+(-r_3)+(-r_4)}, \dots, ((\text{Condition})(\text{Possesses} \right. \\
 & \quad \left. \begin{array}{c} [---] \\ \text{X} \end{array} \right) \text{ of } \begin{array}{c} [---] \\ \text{X} \end{array} \text{ at } \begin{array}{c} [\text{Ten., Aux., Pred. -Ph.}] \\ \text{X}_{+(-r_1)+(-r_3)} \end{array} \left. \right), \\
 & \quad <(\text{Mon. Sum}) > \quad <(\text{Hum. \& Inf.}) > \\
 & \quad \dots, (170).^{40}
 \end{aligned}$$

That is, "resell" express a process wherein something sold once before is again sold, but where the previous seller and buyer can be different from the present ones and where the sum of money paid for it previously can be different from the sum paid in the resale. Thus, the sentence

(189) John resold the book to Mary

expresses a second sale of the book in question (hence, the presence of the grammatical function 'NP, S' within the brackets over the variable within the semantic markers representing the condition of the initial and terminal states of the first process) wherein John is the seller and Mary the buyer, where the first sale was of the same book but the buyer and seller are left unspecified (hence, the absence of a grammatical function within the appropriate brackets as indicated by the dashes).⁴¹

The lexical reading for "re", therefore, should combine with (170) to produce (188). Let us suppose that we can define the grammatical relation that holds between a prefix and its stem-verb by the function '[stem, V, VP, S]', then the lexical reading for "re" can be given as:

$$(190) \text{ re; } \Psi\left(\begin{array}{c} [\text{Stem, V, VP, S}] \\ X \\ \langle \text{SR} \rangle \end{array}\right), \dots, \left(\begin{array}{c} [\text{Stem, V, VP, S}] \\ X \\ \langle \text{SR} \rangle \end{array}\right)$$

where the operator ' Ψ ' transforms the reading that is the value of the first occurrence of 'X' according to the principles:

- (191) (i) every grammatical function within brackets except for cases of 'NP, VP, S' are replaced by a small Greek letter, identical grammatical functions by the same Greek letter and different ones by different Greek letters. each subscript on an occurrence of 't' in a semantic marker representing an initial state has '+(-r₃)+(-r₄)' added, and each subscript on an occurrence of 't' in a semantic marker representing a terminal state has '+(-r₃)' added.⁴²

The selection restriction in (190) is that the semantic markers that represent the terminal and initial states of the process semantic markers that are the reading of the verb-stem be different at least in their categorized variables. This accounts for the semantic anomaly of sentences such as

$$(192) \text{ John } \left\{ \begin{array}{l} \text{rewaited} \\ \text{restayed} \\ \text{reslept} \end{array} \right\} \text{ in the house}$$

since it is characteristic of the meaning of verbs such as "wait", "stay", "sleep", etc. that it is the same agent in both initial and terminal state and no change in his state comes about with the passage of time.

Another respect in which our reconstruction outstrips the theoretic potentialities of informal work by field theorists, is that it formally represents the regions in a conceptual domain so that such formal representations fall in the range of the definitions of semantic properties and relations. Hence, the traditional concerns of semantics with these properties and relations are integrated with the description of the semantic structure of conceptual domains. To illustrate this consider the description of the conceptual domain developed above. On the basis of this representation scheme, we were able to mark the synonymy of (5) and (6), we can mark the synonymy of (189) and

(193) Mary rebought the book from John

we can mark the semantic anomaly of (187), (184), (185), and (192), the semantic redundancy of

(194) John sold the book for a sum of money
and so on.

2.7 SOME SUGGESTED EXTENSIONS

In this concluding section, I wish to suggest some directions in which the work presented here should be extended.

The first has to do with extending the central feature of the solution to the converse problem, *viz.*, the idea of positioning categorized variables one way in the reading of one of a pair of constituents and the reverse way in the reading of the other, so that, by the operation of projection rules from the semantic component, the reverse order of other constituents related to them is compensated for when the readings of the full sentences are obtained. It is worth considering how this idea can be applied to another type of case, one that does not involve converse constituents, i. e., two phonologically distinct lexical items that, by (174), bear the converse relation to one another. The case to which I want to apply it is that of two phonologically identical but syntactically distinct lexical items that are not full converses.

Consider the intransitive and transitive forms of "open", as in

(195) John opened the door

(196) The door opened

The semantic fact to be accounted for here is that (195) entails (196). We can account for this, in face of the further fact that the "the door" is the grammatical direct object of "open" in (195) and the subject of "open" in (196) by the following lexical readings:

(197) open, [$+_\text{NP}$, ...]; (($\begin{matrix} \text{[NP, S]} \\ \text{X} \end{matrix}$ causes
<(Phy. Object) v (Phy. Event)>

((Condition)(Positioned to prevent passage between inside

and outside of $\begin{matrix} \text{[NP, PP, NP, S]} \\ \text{X} \end{matrix}$) of $\begin{matrix} \text{[NP, VP, S]} \\ \text{X} \end{matrix}$ at
<(Inclosure)> <(Barrier)>

[Tense, Aux., Pred-Phrase]
 $\text{X}_{+(-r_1)}$), ..., ((Condition)(Positioned
<(...t...)>

to allow passage between inside and outside of $\begin{matrix} \text{[NP, PP, NP, S]} \\ \text{X} \end{matrix}$)
<(Inclosure)>

of $\begin{matrix} \text{[NP, VP, S]} \\ \text{X} \end{matrix}$ at $\begin{matrix} \text{[Tense, Aux., Pred-Phrase]} \\ \text{X}_{+(+r_2)} \end{matrix}$)
<(Barrier)> <(...t...)>

(198) open, [-__NP, ...]; (((Condition)(Positioned to prevent

[NP, PP, NP, S]
 passage between inside and outside of $\begin{matrix} X \\ \text{< (Inclosure) >} \end{matrix}$) of

$\begin{matrix} \text{[NP, S]} \\ X \end{matrix}$ at $\begin{matrix} \text{[Tense, Aux., Pred-Phrase]} \\ X_{+(-r_1)} \end{matrix}$), ..., ((Condition)
 < (Barrier) > < (...t...) >

(Positioned to allow passage between inside and outside

$\begin{matrix} \text{[NP, PP, NP, S]} \\ \text{of } X \end{matrix}$) of $\begin{matrix} \text{[NP, S]} \\ X \end{matrix}$ at $\begin{matrix} \text{[Tense, Aux., Pred-Phrase]} \\ X_{+(+r_2)} \end{matrix}$)
 < (Inclosure) > < (Barrier) > < (...t...) >

In connection with these lexical readings, note that the semantic marker '(Barrier)' will be a common member of the readings of "door", "gate", "lid", "cover", "hatch", "barricade", etc., and the semantic marker '(Inclosure)' will be common to the readings of "room", "fence", "jar", "hall", "wall", "office", etc. Note also that in the lexical reading for the intransitive form of "open" the process semantic marker is not a part of a semantic marker expressing a causal operation. The reason is that (196) does not imply the existence of a cause of the process's occurrence, unlike, say,

(199) The door was opened

which should be taken as a short passive of a sentence-structure whose underlying phrase marker has an indefinite subject and a transitive form of "open", and "the door" as its object.

Second among my suggestions is that certain semantic markers so far taken as unstructured can be structured with respect to some of the ideas in the representation scheme for time relations. The need for such structuring crops up in terms of examples like:

(200) Joan married a bachelor a year ago and divorced him today where the pronoun "him" is a pronominalization of the direct object of "married", and hence is co-referential with it. Since it is impossible for a bachelor to divorce someone, the reading of "bachelor" cannot contain a semantic marker representing the concept 'unmarried' that is time independent. That is, the sentence (200) is surely not semantically anomalous, as the sentence

(201) John divorced a bachelor

is, and moreover, (200) does not entail (201). This situation can be easily handled if the semantic marker '(Unmarried)' is structured

'(Unmarried at $\begin{matrix} \text{[Tense, Aux., Pred-Phrase]} \\ X_{+(-r)} \end{matrix}$)'. The other semantic markers in the reading of "bachelor" can, of course, be left as representations of time-independent properties.

Third, the work here makes it possible to define some new semantic relations. Consider the semantic relation, which I will refer to as a "conversion triple", that holds between the ordered triples:

- (202) (i) sick, well, recovers
 (ii) knows, doesn't know, forgets
 (iii) asleep, not asleep (awake), awakes
 (iv) alive, dead, dies

or in the ordered triples of expressions:

- (203) (i) well, sick, becomes ill
 (ii) doesn't know, knows, learns (comes to know)
 (iii) not asleep (awake), asleep, falls asleep
 (iv) dead, alive, become resurrected

Without entering into the details, it is clear that the first two members of such a triple are state expressions, i. e., will have state semantic markers in their lexical entries, such that they belong to the same antonymous n-tuple ($n=2$), and the third expression is a process expression, i. e., will have a process semantic marker in its reading, such that the initial state of the process is the same as that expressed by the first expression of the triple and the terminal state is the same as that expressed by the second. Furthermore, there is another semantic relation to be defined here, which I will refer to as "inverse conversion triple pairs", that holds between (202) (i) and (203) (i), (202) (ii) and (203) (ii), (202) (iii) and (203) (iii), and (202) (iv) and (203) (iv). Here the relation is to be defined as holding for a pair of conversion triples just in case reading of the first expression in one is the reading of the second expression in the other and the reading of the second expression of one is the reading of the first expression in the other. We may also say that the third expressions in each are, under this condition, "inverse process expressions".⁴³

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Footnotes and References

1. That is, the condition of their being fully synonymous is that their sentence constituent is assigned the same set of readings, and the condition of their being synonymous (in a sense) is that the same reading is assigned to the sentence constituent of both. Having drawn this distinction, I shall ignore it in the ensuing discussion for purposes of simplicity, reference to synonymy or paraphrase being intended in the latter sense unless otherwise indicated in the text.
2. Lyons, John. Structural Semantics: An Analysis of Part of the Vocabulary of Plato. Oxford University Press, 1963, p. 72.
3. Cf. Katz, J. J. and Postal, P. An Integrated Theory of Linguistic Descriptions. The M. I. T. Press, Cambridge, Mass., 1964; and Katz, J. J. and Martin, E. "The Synonymy of Actives and Passives", The Philosophical Review, Vol. LXXVI, No. 4, Oct. 1967, pp. 476-491.
4. That is, as described in the references cited in the previous footnote, the semantic component operates exclusively on the underlying phrase marker(s) of a sentence, which are generated by the base of the syntactic component, and syntactic symbols like the passive have no entry in the dictionary. Consequently, an active and its corresponding passive will be assigned the same set of readings because they have the same constituents, as far as those bearing lexical readings are concerned, and they bear the same grammatical relations to each other in the two cases.
5. Lyons, J. Op. cit. Also, Bar-Hillel, Y. "Dictionaries and Meaning Rules", Foundations of Language, Vol. 3, 1967, pp. 409-414; and Staal, J. F. "Some Semantic Relations between Sentoids", Foundations of Language, Vol. 3, pp. 66-88. I have no desire to reply explicitly to these latter two papers, for the present paper does this quite effectively. However, one or two comments about these papers deserves mention. Both claim that cases like the synonymy of (5) and (6) cannot be accounted for on my conception of semantic theory. Of course, if the present paper does what it sets out to do, so-much for these claims. But it may be worthwhile to indicate where Staal and Bar-Hillel have gone wrong. Staal's mistake is to view the relation underlying the synonymy of cases like (5) and (6) as syntactic, on the model of passivization. He never considers the question of whether this can be so, nor does he explore the alternative of a purely semantic relation, but simply rules it out a priori (cf. p. 68). Bar-Hillel's mistake is, first, to accept Staal's (p. 409); second, to add his own a priori claims about the limitations of dictionary entries in expressing semantic relations (p. 413); and third, to rely on pejoratives where argument is needed (cf. the section titled Postscriptum).

6. Chomsky, N. in conversation.
7. Here, and the rest of the text, I rely on Chomsky's discussion of the definition of grammatical relations, cf. Chomsky, N. Aspects of the Theory of Syntax, The M.I. T. Press, Cambridge, Mass., 1965, pp. 63-74. The definitions given here are, of course, to be taken as just as tentative as Chomsky's. However, there is some reason for adopting the definition (9) (ii) rather than one that assumes that the deep structure of sentences with indirect objects does not contain prepositional phrases in which the indirect object is found but instead contains the indirect object as its first noun phrase following the verb. One reason is that there are verbs that take the indirect object but do not have a form without the prepositional phrase, e. g., "declare", "state", "describe", "explain", "dedicate", etc.
8. Cf. Chomsky, N. Op. cit., pp. 144-147.
9. For example, cf. Katz, J. J. and Fodor, J. A. "The Structure of a Semantic Theory", in The Structure of Language: Readings in the Philosophy of Language, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964, p. 501.
10. Katz, J. J. "Recent Issues in Semantic Theory", Foundations of Language, Vol. 3, 1967, pp. 124-194.
11. As this statement suggests, there may need to be only one projection rule, which, taking a general form, says that a reading is to substitute for a variable if it is assigned to a constituent bearing the grammatical relation for which that variable is categorized to the constituent assigned the reading containing the categorized variable, and if the reading satisfies the selection restriction associated with that occurrence of the categorized variable in the reading that contains it.
12. Cf. Chomsky, N. Op. cit., pp. 63-74.
13. Cf. footnote 8 above.
14. This is an abbreviation for the relation of the subject-of a sentence to the main-verb-of the predicate-of the sentence.
15. The choice is made on the basis of the syntactic character of the constituent in whose reading the categorized variable appears.
16. This is what was meant when we said earlier that time-relations are the fundamental way in which sentences relate the events they are about. For it is not necessary that the events spoken of in a sentence be related spatially, causally, etc. Whether they are related in one of these ways or not is a matter of what the speaker wants to say. But if he is going to talk about something other than abstract objects, he has no choice but to relate his topics temporally, though, of course, he chooses the particular temporal relations as he sees fit.

17. That is, the same definitions used to mark semantic anomaly, analyticity, contradiction, entailment, synonymy, etc. in cases where time relations do not underlie a sentence's having one or another of these semantic properties or relations must also suffice to mark them in cases where such relations do.
18. I wish to make it clear that the assumptions I make about the auxiliary and tense systems, which are, roughly, those of Aspects of the Theory of Syntax, are in no way necessary, should it turn out that a deeper analysis of this area of syntax undermines them. A close examination will reveal that all that is necessary for my semantic treatment of time relations is some set of syntactic distinctions corresponding to the ordinary distinctions we make between tenses, together with an appropriate set of grammatical relations between the components of the tense system, this system and the verb, and the verb and temporal adverbials.
19. These rules are adapted from Chomsky, N. Op. cit., chapter 2, section 3. The same comment as made in footnote 19 applies here.
20. These conventions can be regarded as having the same status as the principles of logic that define the notion of derivation in syntax, i. e., as part of the general mathematical apparatus available to linguistics for the definition of its constructs.
21. Strawson, P. F. Introduction to Logical Theory. Methuen and Co., London, 1952, pp. 79-82.
22. Chomsky, N. Op. cit., p. 107.
23. For example, $\S r_1 + \Phi = r_2$ Schema

-130	60	-70	
70	60	130	
-20	60	40	
-40	60	20	

24. Which, in turn, corresponds to the principle that a single object cannot be at two places at once.
25. Katz, J. J. "Analyticity and Contradiction in Natural Language", in The Structure of Language: Readings in the Philosophy of Language, Op. cit., pp. 519-543.
26. Cf. Katz, J. J. The Philosophy of Language. Harper and Row, Publishers, New York, 1966, pp. 211-220.

27. Roughly, one of the complications is that the notion of an antonymous n-tuple has to be broadened, so that we can speak antonymous semantic markers over an infinite range such as is involved here in the use of the natural numbers. There is no special difficulty in this, for we can define two designations of temporal intervals as antonymous just in case either the designation of the initial point or the designation of the terminal point of the included interval determine a location on the time dimension outside the including interval.
28. Of particular importance will be the extension of this work on time relations to more complex tenses and the definition of other temporal adverbials in terms of lexical readings that are specified on the basis of these representations.
29. Cf. Katz, J. J. The Philosophy of Language, op. cit., p. 160.
30. The categorized variables are so defined that in case there is no reading to be substituted for one from the sets of readings associated with the nodes in a semantically interpreted underlying phrase marker, its value is the semantic markers in its own selection restriction (cf. (26)). Thus, in the semantic interpretation of (5) and (6), the value of the variable categorized for the secondary indirect object is the semantic marker '(Monetary Sum)', which is the sole semantic marker in its selection restriction. In the sentence "Harold sold the book for six dollars", there is no constituent that is the indirect object of the verb, but the fact that its sense involves a sale to someone can be explained on (26), since its reading will represent the concept of a buyer who is human and not an infant. This feature of categorized variables can be regarded as an extension of the 'selector' concept, cf. Katz, J. J. and Postal, P., op. cit.
31. Here I have used the device of slashes in the formulation of a syntactic function to indicate domination in the sense that '[..., A/B/C, ...]' means 'C' is dominated by 'B', which is, in turn, dominated by 'A'. This was done in order to be able to distinguish between indirect and secondary indirect objects for the practical purpose of having a rough such distinction to work with. I am fully aware that this overall scheme made use of in the text is unsatisfactory, if for no other reason than that it defines grammatical relations in a way that is not linguistically universal, since it refers to specific English morphemes, "to" and "from".
32. Cf. Ullmann, S. Semantics: An Introduction to the Science of Meaning, Oxford, Basil Blackwell, 1962, pp. 243-253 for a convenient general exposition, and cf. Ullmann's footnotes for an extensive bibliography.
33. Ullmann, S. Op. cit., p. 247.

34. I have in mind here speculations about national souls, tie-ins with phenomenology and the Whorf hypothesis about the relation of language to thought, and so on.
35. Contrast this assessment with Ullmann's, op. cit. p. 250.
36. Webster supports this feature, as does the intuitions of many speakers of English, but doubts crop up in connection with whether the sense of "exchange" in "The salesgirl at the department store told Joe he could exchange his pants for a baseball "glove" is the same or not.
37. Where procedure by which someone comes into possession must refer to the relinquishing of possession by the death of the person possessing it.
38. Thus, semantics can set certain problems for anthropology, as, of course, has been recognized in the area of anthropological linguistics known as "componential analysis".
39. Consider another case where the structure of a conceptual domain excludes the possibility of there being certain words in a language referring to concepts in the domain. "trade", unlike "buy" or "sell" has no converse. Moreover, in no natural language is there a word that stands to the translation of "trade" in that language as "sell" stands to "buy". The reason "trade" and its translations have no converse is that it is a double-process concept like the sense of "buy" or "sell", not a single-process concept like the sense of "give" or "receive". As such, the existence of a converse depends, as (174) shows, on the variables categorized for the direct object and secondary indirect object relations having different selection restrictions. If, as in the case of "trade", the selection restriction on the values of occurrences of these categorized variables is identical (i. e., in both cases it is '(Physical Object)', then the second conjunct can no longer represent half of the transaction but must represent another transaction which is the reverse of the one represented by the first, e. g., compare "John traded the book to Mary" with "Mary traded the book to John", where they express reverse processes, not the same one.
40. The occurrence '(170)' here merely abbreviates the whole of the reading given in (170).
41. Actually, dashes are not enough. As indicated below, we will use Greek letters within brackets to indicate that the person who possesses the book initially is the one who gets the money and vice versa. Cf. (191) (i) below.

42. It is interesting to note that the lexical reading for "re" as given in (190) and (191) is a transformational rule, as would be the lexical reading for "un", which would switch initial and terminal state semantic markers in process semantic markers like the reading for "freeze" which have initial and terminal state semantic markers that are antonymous. This latter feature would have to be part of the selection restriction in the lexical reading of "un", since construction like "unbuy" are meaningless. Further, it seems that such transformational rules in the semantic component do not have the profound significance that the existence of transformational rules in syntax had, simply because they do not point the way to a deeper level of linguistic organization, as did syntactic transformations.
43. Note also that in cases like "awakes" and "recovers", helping verbs like "falls" in "falls asleep", or "becomes" in "becomes ill", function to provide a way of forming an expression to mark a certain process concept in a conceptual domain when there exists no special word in the language to mark that region.

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13. ABSTRACT

A paper by Jerrold J. Katz, entitled "Temporal Specification, Process, and the Converse Relation," which illustrates the research carried out under this contract, is concerned with the definitions of semantic properties and relations, and with the manner in which the meanings of expressions and of whole sentences are to be represented. It deals with these problems by studying a special case of expressions that are converses of each other such as "John bought a book from Bill - Bill sold a book to John" which have recently been widely discussed.

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