A SYSTEM OF SEMANTIC PRIMITIVES

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In a linguistic theory, the semantic representation of a sentence is meant to be a formal characterization of the information conveyed by the sentence. This information can be thought of as a set of claims about various individuals, properties, events, and/or states of affairs, and about the relationships among them. A satisfactory semantic theory must not only account for the information conveyed by a sentence; it must also account for how the sentence conveys that information, expressing both the syntactic and semantic generalizations of the language. A semantic theory is explanatory when linguistically significant generalizations are inherent in the choice of formalism, when the theory claims the language would be more complex any other way. Such a theory claims that the language learner does not have to learn these generalizations; rather they are determined by his innate capability to learn a human language and to conceptualize the world.

This paper sketches a semantic theory for verbs, based on the analysis of Gruber (1965) and Jackendoff (1972), which expresses certain semantic generalizations in such a way that they correspond very closely to syntactic generalizations. The generality of the semantic analysis will be demonstrated by stating inference rules whose side applicability depends crucially on the form of the semantics. Thus it will be shown that the choice of semantic primitives made here is explanatory in the sense set out above. The theory is expounded in much greater detail in Jackendoff (1975), of which this is an extreme condensation.

1. GO, BE, and STAY verbs.

In sentences such as (1),

(1)a. The train traveled from Detroit to Cincinnati.
b. The hawk flew from its nest to the ground.
c. An apple fell from the tree onto Ike's head.

there is a common element of motion expressed. We will refer to the object in motion as the Theme of the sentence, to the Theme's initial position as the Source, and to its final position as the Goal. The semantic similarity between the sentences in (1) is expressed by assigning a common element in their semantic representation, a function GO(x,y,z). This function makes the claim that there has taken place an event consisting of the motion of x from y to z. In other words, the first variable of GO corresponds to the Theme, the second to the Source, and the third to the Goal.

The semantic differences between the sentences are expressed in two distinct ways. First, the different Themes, Sources, and Goals are derived by inserting the interpretations of the various noun phrases in the sentences for the variables x, y, and z, according to the lexical correlation of the verb's strict subcategorization feature with its semantic representation. The other semantic differences are described by adding a restrictive modifier expressing manner of motion, in these cases lexically determined, but in many cases due to an adverb in the verb phrase. So, for example, (1b) is represented as

GO(THE HAWK, ITS NEST, THE GROUND).
Manner: THROUGH THE AIR

(I use capitals to represent semantic markers for the corresponding English expression -- unsystematically, unless it is relevant to the present discussion.) Of course, a full explication of fly would involve further analysis of the manner marker; but what is relevant here is that the common element of meaning has been extracted from all verbs of physical motion.

Next consider (2).

(2)a. Max is in Africa.
b. The cat lay on the couch.
c. The statue stands on Cambridge Common.

These do not describe a motion, but rather the location of an object relative to some object. The formal semantic representation of (2) will thus include a function BE(x,y), where x is the Theme (the object being located) and y its Location. As in (1), the differences of meaning among the sentences in (2) are expressed by substituting different markers for x and y and by attaching different manner markers as restrictive modifiers of the function BE.

In addition to the verbs of location illustrated in (2), there is a second, smaller class of locational verbs with rather different semantic properties:

(3)a. The bacteria stayed in his body.
b. Stanley remained in Africa.
c. Bill kept the book on the shelf.

These differ from (2) in that (i) they cannot refer to a point in time, as can (2); (ii) they can serve as a complement to what happened was that, whereas (2) cannot.

(4)a. The bacteria ⎡were in his body at 6:00.
⎣*stayed
b. The cat ⎡lay on the couch at 6:00.
⎣*remained

(5) What happened was that
⎡Stanley remained in Africa.
⎢Bill kept the book on the shelf.
⎢*Max was in Siberia.
⎢*The statue stood on Cambridge
⎣Common.

The verbs in (3) will be represented in part as STAY(x,y), where x is the Theme and y its Location.

The evidence from <u>what</u> <u>happened</u> <u>was</u> indicates that STAY verbs, like GO verbs, represent <u>events</u>, while BE verbs represent <u>states</u> <u>of</u> <u>affairs</u>.

2. Position, Possession, and Identification

The most important aspect of Gruber's analysis is his extension of the interpretations of GO, BE, and STAY to a wide variety of examples where the "position" (Source, Goal, or Location) of the Theme is not specified in physical terms, as it is in (1)-(3). Consider these examples:

(6)a. Harry gave the book to the library.
   b. Charlie bought the lamp from Max.
   c. Will inherited a million dollars.

(7)a. The book belonged to the library.
   b. Max owned an iguana.
   c. Bill had no money.

(8)a. The library kept the book.
   b. The iguana stayed in Max's possession.
   c. The leopard retained its spots.

In (6), the object described by the direct object of the sentence undergoes a change in whom it belongs to. By analogy with (1), we can call the object undergoing change the Theme, and the initial and final states Source and Goal respectively. (7) expresses states of possession; by parallel with (6) and (2), we will call the possessed object Theme and the possessor Location. (8) also expresses a single unchanging possessor; but <u>at</u> <u>6:00</u> may be added only to (7), not to (8), and <u>what</u> <u>happened</u> <u>was</u> may be prefixed only to (8), not to (7).

Thus there is an important parallel between (6)-(8) and (1)-(3). Gruber chooses to represent this parallel by claiming that (6) are GO verbs, (7) are BE verbs, and (8) are STAY verbs. The difference between (6)-(8) and (1)-(3) is expressed by a modifier on the functions. For physical motion and location, the modifier is <u>Positional</u>; for possession, it is <u>Possessional</u>. (1a), for example, is now represented as GO$_{posit}$ (THE TRAIN, DETROIT, CINCINATTI); (6a) is GO$_{poss}$ (THE BOOK, HARRY, THE LIBRARY).

Another important "mode of location" besides Positional and Possessional is illustrated in the following examples.

(9)a. The coach changed from a handsome young man into a pumpkin.
   b. The metal turned red.
   c. The ice became mushy.

(10)a. The coach was a pumpkin.
   b. The metal was red.
   c. The pumpkin seemed tasty.

(11)a. The poor coach stayed a pumpkin.
   b. The metal remained red.
   c. The redness persisted.

The same three-way contrast obtains. (9) describes changes of state; (10) describes a state; (11) describes the persistence of a state. Of the two nonmotional cases, <u>at</u> <u>6:00</u> may be added only to (10), and <u>what</u> <u>happened</u> <u>was</u> may be prefixed only to (11). Gruber proposes a modifier <u>Identificational</u>, which indicates that the Location or Source and Goal of the function to which it is affixed make claims about <u>what</u> the Theme is, rather than <u>where</u> or <u>whose</u> it is. Thus for example, (9a) is represented as GO$_{ident}$(THE COACH, A HANDSOME YOUNG MAN, A PUMPKIN). (For sentences such as (9a) in which one of the arguments is absent from the sentence, the semantic representation will contain a free variable.)

By adopting the markers Positional, Possessional, and Identificational as restrictive modifiers on the functions GO, BE, and STAY, we capture important semantic distinctions and generalizations. The combination of the three markers with each of the three functions yields a particular class of verbs, accounting for the similarities and differences among the classes in a natural way. As evidence that this is the correct breakdown, we observe that many verbs occur in more than one locational mode, while preserving their classificaton as GO, BE, or STAY verbs:

(12)a. The coach turned into a driveway.
         (Positional)
      The coach turned into a pumpkin.
         (Identificatonal)
    b. The train went to Texas.
         (Positional)
      The inheritance went to Philip.
         (Possessional)
    c. Max is in Africa.
         (Positional)
      Max is a doctor.
         (Identificational)
    d. Bill kept the book on the shelf.
         (Positional)
      Bill kept the book.
         (Possessional)
    e. The coach remained in the driveway.
         (Positional)
      The coach remained a pumpkin.
         (Identificational)

In each pair, the same verb is used in two different locational modes. Since these uses are not a priori related, it is a significant generalization that a sizable number of verbs exhibit such behavior. In the present formalism the relationship between the uses is clear and nonaccidental: the verb stays fundamentally the same, changing only the value of the restrictive modifier denoting locational mode.

The fundamental concept represented by sentences in the present theory, then, is giving the location(s) of an object at a particular time or during a particular interval; the richness of expression available to natural language comes in part from extending the concept of location to other than physical position.

3. Causative and Permissive Agency

In addition to the three functions discussed so far, there are two which describe different kinds of causation. Compare (13a,b,c).

(13)a. The rock fell from the roof to the ground.
   Dick received the money.
   The bird went out of the cage.
   Noga stayed sick.
  b. Linda lowered the rock from the roof to the ground.
   Dick acquired the money.
   Laura took the bird from the cage.
   David kept Noga sick.
  c. Linda dropped the rock from the roof to the ground.
   Dick accepted the money.
   Laura released the bird from the cage.
   David left Noga sick.

The events of the a. sentences are also described in the b. and c. sentences, but the latter two claim that the events are due to the agency of the subject, who is thus termed an Agent. In turn, (13b,c) differ in the kind of action performed by the Agent: (13b) is bringing the event about, or causing: (13c) is ceasing to prevent the event, or letting. We will symbolize these two kinds of agency as CAUSE (x,e) and LET (x,e) respectively. The first examples of each group in (13) receive the representations (14a,b,c) respectively.

(14)a. GO$_{posit}$ (THE ROCK, THE ROOF, THE GROUND)
  b. CAUSE (LINDA, GO$_{posit}$ (THE ROCK, THE ROOF, THE GROUND))
  c. LET (LINDA, GO$_{posit}$ (THE ROCK, THE ROOF, THE GROUND))

The last sentences in each group are (15a,b,c,).

(15)a. STAY$_{Ident}$ (NOGA, SICK)
  b. CAUSE (DAVID, STAY$_{Ident}$ (NOGA, SICK))
  c. LET (DAVID, STAY$_{Ident}$ (NOGA, SICK))

CAUSE is quite familiar from the literature, LET less so. There are two interesting distinctions between them besides the inferences to be discussed below. First, CAUSE allows an expression of instrument, but LET appears not to: in (16) the _with_-phrase can be interpreted only as accompaniment.

(16)a. Linda dropped the rock with a cable.
  b. Dick accepted the book with a $5 bill.
  c. David left the bird in the cage with a lock on the door.

Second, the final argument of LET may be either an event or a state of affairs, as seen from the following contrast.

(17)a. David let Laura out of the room.
  b. David allowed Laura out of the room.

(17a) must be interpreted as David permitting Laura to _go_ out of the room; (17b) does not say anything about her movements, but only where she may _be_. On the other hand, CAUSE requires its final argument to be an event. All the causative locational verbs such as _hold_, _keep_ and _retain_ are of the form CAUSE (x, STAY(...)) rather than CAUSE (X, BE(...)). The verb _cause_, which does allow things like _Dollie caused Martin to be happy_, has a more complicated analysis than just CAUSE, as will be seen below in (36). (One should be immediately suspicious, since this example means "Dollie caused Martin to _become_ happy" -- see (40b) below).

4. Inference Rules

We will now develop inference rules to derive logical entailments of sentences on the basis of their semantic representatins. An obvious rule of inference is that if an event is caused, it happens. This is formalized as (18).
   (18) CAUSE(X,E) -> E

A typical inference derivable by this rule is (19).

   (19) Max gave Joe the money.
      CAUSE(MAX,
         GO$_{poss}$ (THE MONEY, MAX, JOE))
      -> Joe received the money from Max.
         GO$_{poss}$ (THE MONEY, MAX, JOE)

The related inference with LET is that if someone doesn't let an event happen, it doesn't happen:

   (20) NOT LET(X,E) -> NOT E

A typical inference from this rule is (21).

   (21) Al didn't drop the pancake to the floor.
      NOT LET(AL,
         GO$_{posit}$ (THE PANCAKE,y,
                  THE FLOOR))
      -> The pancake didn't fall to the floor
      NOT GO$_{posit}$ (THE PANCAKE,y,THE FLOOR)

The inverses of these inference rules are not valid in general: something may happen even if no particular thing one can name is its cause; if something is permitted, that does not guarantee that it happens (although in certain situations such as _dropping_ the inference does go through).

The rest of the inference rules concern GO, STAY, and BE, and can be stated in terms of simple spatial intuitions. First, there is the principle that if someone _stays_ someplace for a period of time, he _is_ in that place at any instant during that time.

   (22) STAY (X,Y) FROM t_1 TO t_2
      -> BE (X,Y) AT t_3
      Condition: $t_1 \leq t_3 \leq t_2$

(22) permits inferences such as (23).

(23) Carl remained in the room from Tuesday
     to Friday.
    $STAY_{posit}$ (CARL, THE ROOM)
      FROM TUESDAY TO FRIDAY
-> Carl was in the room on Wednesday.
    BE_{posit}(CARL, THE ROOM) AT WEDNESDAY

(18) and (22) work together in this inference (assuming proper times):

(24) David kept Noga Sick
        -> Noga stayed sick
        -> Noga was sick.

     CAUSE(DAVID, $STAY_{ident}$ (NOGA,SICK))
     $STAY_{ident}$ (NOGA,SICK)
     BE_{ident} (NOGA,SICK)

The inverse inference is that if someone doesn't stay someplace during an interval, there is a time during the interval when he isn't there. This can be formalized similarly.

The parallel inference rule for GO is that if something goes from one place to another, it was at the first place first and the second place second:

(25) GO(X,Y,Z) AT t_1 ->
    for some times t_2 , t_3 such that
        $t_2 < t_1 < t_3$,
        BE (X,Y) AT t_2
        BE (X,Z) AT t_3

A typical entailment from this rule is (26).

(26) Phil gave the bill to Lyn.
    CAUSE(PHIL,GO_{poss}(THE BILL,PHIL,LYN))
$\overset{(19)}{\Longrightarrow}$ GO_{poss}(THE BILL,PHIL,LYN)

$\overset{(25)}{\Longrightarrow}$ Phil had the bill, and then Lyn had
    it.
    BE_{poss}(THE BILL,PHIL) AT t_1 AND
    BE_{poss}(THE BILL,LYN) AT t_2
    for some t_1 , t_2 such that $t_1 < t_2$

There is no inference from NOT GO, since if someone didn't go from one place to another we can make no inferences about where he was at any time, without further knowledge.

A very important inference rule is that if and only if someone is not someplace, he is somewhere else. We represent the sense "a place other than Z" as NOT Z, for reasons to become clear shortly.

(27) NOT BE (X,Z)<->BE (X, NOT Z)

Also, if and only if someone is someplace, he is not elsewhere.

(28) BE (X,Z)<->NOT BE (X, NOT Z)

These rules play a role in inferences such as if John was not inside the house, he was outside of it (Positional); if either John or Bill had the book and John didn't, then Bill did (Possessional); and if Sue was sick, she wasn't healthy (Identificational). The complete derivation of such inferences, however, involves other steps including

factual knowledge, and is too complex to include here.

Similar to (27)-(28) are inference rules (which we won't formalize here) that if you're going someplace you're not staying anywhere, and if you're staying someplace you're not going anywhere.

What makes the sort of inference rules proposed here of interest is the way they provide evidence for the explanatory power of the present theory of semantic description. For in this system, a rule of inference is simpler if it generalizes over all modes of location. The theory claims that it is no accident that the inference rules generalize in the way they do -- rather it is an essential part of the structure of the semantic description. I consider it a striking property of the present system that very simple principles about spatial understanding can be stated formally in such a way that they provide a rich variety of inferences in domains which bear no a priori relation to physical space.

5. Circumstantial Location

Consider the interpretations of (29a,b).

(29) a. Laura kept David in the room.
     b. Laura kept David working. (In
       deep structure, Laura kept David
       [$_s$ David working])

The interpretation of (29a) is CAUSE(LAURA,$STAY_{posit}$(DAVID, THE ROOM)). If the verb <u>keep</u> is to be essentially the same in (29b), we must provide (29b) with a similar interpretation, though clearly none of the modes of location discussed so far can provide one. We introduce a mode called Circumstantial: if an individual is in a Circumstantial Location, where the location is an event or state of affairs, this is taken to mean that the individual is involved as a participant in that event or state of affairs. Then we can assign (29b) the reading (30).

(30) CAUSE(LAURA,$STAY_{circ}$(DAVID,DAVID WORK))

This claims that Laura caused David to continue to be involved in the situation of working, precisely the desired interpretation, and furthermore of precisely parallel form to its Positional analogue (29a). Other examples:

(31) a. Linda kept Laura (away) from the
     cookie jar.
     CAUSE(LINDA,$STAY_{posit}$(LAURA, NOT THE
     COOKIE JAR))
           $\begin{bmatrix} kept \\ prevented \end{bmatrix}$
     b. Linda $\begin{bmatrix} kept \\ prevented \end{bmatrix}$ Laura from
     screaming.
     CAUSE(LINDA,$STAY_{circ}$(LAURA, NOT(LAURA
     SCREAM)))

(32) Laura$\begin{bmatrix} kept \\ continued \end{bmatrix}$screaming.
    $STAY_{circ}$ (LAURA, LAURA SCREAM)

(33) a. David avoided the beach.
STAY$_{posit}$ (DAVID, NOT THE BEACH)
b. David avoided playing checkers.
STAY$_{circ}$ (DAVID,NOT(DAVID   PLAY
CHECKERS))

(34) a. Jim forced the ball into the hole.
CAUSE(JIM,GO$_{posit}$(THE   BALL,y,THE
HOLE))
b. Jim forced Phil into confesing.
to confess.
CAUSE(JIM,GO$_{circ}$(PHIL,y,
PHIL CONFESS)) ·

(35) Dick stopped the car from coughing.
CAUSE(DICK,GO$_{circ}$ (THE CAR,y,
NOT(THE   CAR
COUGH)))

(36) Dollie caused Martin to be happy.
CAUSE(DOLLIE,GO$_{circ}$(MARTIN,y,
BE$_{ident}$(MARTIN,HAPPY)))

(37) a. John allowed Fred in the room.
LET(JOHN,BE$_{posit}$ (FRED, THE ROOM))
b. John allowed Fred to wash the
dishes.
LET(JOHN,BE$_{circ}$ (FRED,
FRED WASH THE DISHES))

(38) Jack exempted Jim from fighting.
LET(JACK BE$_{circ}$(JIM,NOT(JIM FIGHT)))

There are four points to observe about these representations. First, where a verb that takes a sentential complement has a Positional variant, the two versions of the verb have identical representatons but for the locational mode. Thus in the present system it is no accident that the verb occurs in two seeming disparate syntactic and semantic frames.

Second, the NOT meaning "somewhere other than" in Positional contexts appears to generalize fully with the NOT of sentence negation in Circumstantial contexts.

Third, complement type is related to semantic representation. Gerundives typically correspond to Locations or Goals; from-ing complements are negated Locations and negated Goals; to-infinitive complements are Goals of various sorts (including Goals of intentions, not discussed here); that-complements are typically Themes. The correspondence is hardly exact partly because there are far more semantic positions for clauses than there are complement types: but it is far from random either.

Fourth, and most striking, the inference rules of the previous section can be applied to Circumstantial verbs quite freely. Given the special inference rule (39), which follows immediately from the definition of Circumstantial location, we can derive such inferences as (40) (omitting time dependencies).

(39) BE$_{circ}$ (X,E)->E

(40) a. Laura kept David working.

CAUSE(LAURA,STAY$_{circ}$(DAVID, DAVID WORK))

$\overset{(18)}{\Longrightarrow}$ STAY$_{circ}$ (DAVID,DAVID WORK)

$\overset{(22)}{\Longrightarrow}$ BE$_{circ}$ (DAVID, DAVID WORK)

$\overset{(39)}{\Longrightarrow}$ David worked
DAVID WORK
b. Lyn caused Bob to be happy.

CAUSE(LYN,GO$_{circ}$(BOB,y,BE$_{ident}$
(BOB,HAPPY)))

$\overset{(18)}{\Longrightarrow}$ GO$_{circ}$ (BOB,y,BE$_{ident}$(BOB,HAPPY))

$\overset{(25)}{\Longrightarrow}$ BE$_{circ}$(BOB,y)   and later
BE$_{circ}$(BOB,BE$_{ident}$(BOB,HAPPY))

$\overset{(39)}{\Longrightarrow}$ y and later BE$_{ident}$(BOB,HAPPY)

[because Source and Goal must be distinct]

y $\not=$ BE$_{ident}$(BOB,HAPPY)

$\overset{(27)}{\Longrightarrow}$ Bob was unhappy and later he was happy.

BE$_{ident}$(BOB, NOT HAPPY)   and later
BE$_{ident}$(BOB, HAPPY)
c. Jack didn't exempt Jim from fighting.

NOT LET(JACK, BE$_{circ}$(JIM,NOT(JIM FIGHT)))

$\overset{(20)}{\Longrightarrow}$ NOT BE$_{circ}$(JIM, NOT(JIM FIGHT))

$\overset{(21)}{\Longrightarrow}$ BE$_{circ}$(JIM, JIM FIGHT)

$\overset{(39)}{\Longrightarrow}$ Jim fought.

JIM FIGHT

This kind of inference is characteristic of the "implicative" verbs described by Karttunen (1971). In the present system it follows immediately from the semantic analysis and the generalization of the inference rules for spatial location to the circumstantial mode.

Lest the generalization from Positional to Circumstantial should still seem marginal and unmotivated, notice that it is quite pervasive in the language. For a few very clear random examples, consider to come to be called Max, to lead someone to believe, to drive someone to confess, to bring oneself to acknowledge something, and, among nominals, the way to find out. For an even more interesting example, consider the meaning of force in (34a). In addition to the semantic description given there, there is a marker of manner roughly paraphrasable as "by applying pressure against the ball's resistance." Here the concepts of pressure, applying pressure, and resistance are purely physical. But in fact the same manner marker "by applying pressure against Phil's resistance" is miraculously perfect for (34b), where the concepts of pressure, applying pressure, and resistance are much more abstract in nature. Surely this is no coincidence; it argues that the extension

from Positional to Circumstantial is highly determined in human cognition, and that the generalization of a verb´s meaning follows innate lines of analogy. The present theory of semantic description is explanatory in that these generalizations fall out immediately from the choice of semantic primitives, which are in turn chosen on linguistic grounds.

This result is consistent with Piaget´s view (1947, 1970) that (nonverbal) knowledge of physical spatial relations is the ·most basic sort of knowledge we have, and that all other kinds of knoweldge develop out of it. Within such a framework, the inference rules proposed here are not merely linguistic but conceptual, and correspond closely to Piaget´s principles of conservation and identity. The growth in one´s ability to handle abstraction then consists (in part) in understanding new modes of location and being able to generalize the rules of inference to a new system of relations. If this is so, the theory proposed here is a deep result not only for linguistic theory but for the study of human conceptualization.

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