COGNITIVE PSYCHOLOGY 3, 552–631 (1972)

Conceptual Dependency: A Theory of Natural Language Understanding[1]

ROGER C. SCHANK
Computer Science Department and Committee on Linguistics, Stanford University, Stanford, California 94305

1. INTRODUCTION

The goal of the research described here is to create a theory of human natural language understanding. While this goal may seem to be virtually unattainable, it is possible to divide the process of creating such a theory into subgoals which seem somewhat more attainable. In creating such subgoals it is reasonable to inquire how one would know when these subgoals had been achieved. In other words, it may be fine enough to create a theory of natural language understanding in a vacuum, but how does one select any given theory over any other? It seems to me that there are two possible general criteria by which such a theory can stand or fall. One is the ability to stand up under the tests that psychologists can devise. This is dependent on the claims that are made by such a theory being made explicit enough to be proved wrong. The second testing possibility comes from the field of computer science. It is highly desirable for computers to understand natural language. An explicit theory of human language understanding should, in principle, be able to be put on a machine to enable computers to communicate with people in natural language.

The question of natural language understanding by computers is so enormous that those who have made attempts to solve the problem have had to severely limit the domain of the particular problem that they were trying to solve, and sacrifice theoretical considerations for programming considerations. Previous attempts at natural language understanding have neglected the theory of an integrated understanding system for the practicality of having a system that operates. Winograd

[1] This research is supported by Grant PHS MH 06645-10 from the National Institute of Mental Health, and by (in part) the Advanved Research Projects Agency of the Office of the Secretary of Defense (SD-183). The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Project Agency or the U. S. Government.

(1970) and Woods (1967), for example, have created programs that could actually do something, i.e., affect manipulations of blocks with a robot or answer questions about a highly restricted data base, and thus can legitimately claim to have achieved some measure of understanding. But a general theory of language understanding is not attempted nor is there any reason to believe that less restricted data bases could not drastically alter their approaches.

Whereas it would seem reasonable to create understanding programs that can interact with humans, psychiatric interviewing programs that have been written, Colby and Enea (1967), and Weizenbaum (1968), have not attempted to do much more than demonstrate that it is possible for men to have conversations with machines.

Quillian's (1966) semantic memory, while attempting to model a human memory, has presented no theory of the processing of linguistic information within his model and has basically restricted himself to modeling a small portion of the understanding process, namely, the relating of tokens in a memory for the purpose of disambiguation of word senses.

What is needed, and what has been lacking, is a cohesive theory of how humans understand natural language without regard to particular subparts of that problem, but with regard to that problem as a whole. The theory that is described here is also intended to be a basis for computer programs that understand natural language. But what is described here is a theory not a program. A program does, in fact, exist that does many of the things that are described here. But the task as I see it is primarily to understand human understanding and secondarily to create computer programs to actually understand. Since programs are always far behind the theory, except when the program is the theory; and since programming practicalities often cause the alteration of theories, extant and future programs will only be briefly referred to here. What will be discussed is the theory of such a program or explicit procedure. Such theorizing is neither traditionally part of computer science or psychology but is rather in between somewhere. (If that is the case then so be it.) As computers become more and more powerful it will be necessary to create theories of this type in order to handle the enormous problems that we should like to solve.

2. THE THEORETICAL FRAMEWORK

2.1 *Conceptual-Base Theory*

The theory presented here has as its initial premise that the basis of natural language is conceptual. That is, I claim that there exists a conceptual base that is interlingual, onto which linguistic structures in a given language map during the understanding process and out of which such structures are created during generation.

Thus, the first subgoal that the theory presented here attempts to achieve is the representation of the conceptual base that underlies all natural languages. The simple fact that it is possible for humans to understand any given natural language if they are immersed in it for a sufficient amount of time and to be able to translate from that language to whatever other natural language with which they are well acquainted, would indicate that such a conceptual base has psychological reality. People fluent in many languages can pass freely from one to another, sometimes without even being overtly aware of what language they are speaking at a given instant. What they are doing is invoking a package of mapping rules for a given language from the conceptual base. The conceptual base has in it the content of the thought that is being expressed. This conceptual content is then mapped into linguistic units via realization rules. We will not discuss realization rules in any detail in this paper. The primary purpose here will be to explain what such a conceptual base looks like and how it functions during the understanding process.

There is evidence that such an interlingual conceptual base exists in people's heads. Both Lenneberg (1967) and Furth (1966) found that thinking is not all impaired by a lack of language. Inhelder and Piaget (1958) noted that logical thinking does not find its base in the verbal symbol. Anderson (1971) noted that subjects tend to remember the conceptual content of an utterance rather than a visual image or a more linguistic representation. Bower (1970) noted the need for hypothesizing such a conceptual base in order to handle similarities in visual and verbal processing.

What I am suggesting then is that such a conceptual base exists; that its elements are concepts and not words; that the natural language system is stratified with the actual language output being merely an indicator of what conceptual content lies beneath it; and that the conceptual apparatus that we tend to call thinking functions in terms of this conceptual base, with concepts and the relations between these concepts as the operands.

I shall refer in this paper to the conceptual content underlying an utterance, that is, what would be represented in the conceptual base, as the meaning of an utterance. The theory that is proposed here is doing its job if two linguistic structures, whether in the same or different languages, have the same conceptual representation if they are translations or paraphrases of each other. Furthermore, another subgoal for this research and test of the theory, is the question of the existence of explicit procedures for formally realizing two such linguistic structures as the one conceptual structure.

Most linguistic theories have not had these goals and hence need not be discussed at any length here. Since the transformational-generative grammar proposed by Chomsky (1957, 1965) is syntax-based it cannot seriously be proposed as a theory of human understanding nor is it intended as such. Linguists who have tried to modify traditional generative grammars have either remained within the problem of trying to account for syntax [e.g., Fillmore (1968)] or else have tried to reorient generative grammar to be semantics-based [e.g., Lakoff (1969) and Chafe (1970)]. These approaches tend to suffer because they are primarily interested in generation of random sentences; are word-based; and in the case of Chafe, fail to recognize the distinction between the identity of conceptual content and the intention of that content within a given situation. There is then, a need for a theory of natural language understanding that is conceptually based. Furthermore, there is a need for an understanding model that recognizes that syntax is not a relevant object of study in its own right, but should be studied only as a tool for understanding of meaning. Early attempts at computer programs that used natural language were primarily concerned with syntactic analysis [e.g., Kuno & Oettinger (1962)]. Whereas no one would claim today that syntactic analysis of a sentence is sufficient for programs which use natural language, it may not even be necessary. This is not to say that syntax is not useful: it most certainly is. But its function is as a pointer to semantic information rather than as a first step to semantic analysis as had been traditionally assumed. This will be discussed at length below.

It is also important to realize in attempting to understand human understanding, that humans certainly do not regularly engage in the process of understanding isolated sentences. They understand sentences with respect to the linguistic and situational contexts in which they were uttered and anv theory of natural language understanding must account for this too.

Lastly, it is necessary to recognize that an important part of the understanding process is in the realm of prediction. Kuno and Oettinger (1962) realized this in the predictive analysis program for syntactic analysis. However, humans engaged in the understanding process make predictions about a great deal more than the syntactic structure of a sentence, and any adequate theory must predict much of what is received as input in order to know how to handle it.

The point of this paper then, is to explicate a theory of natural language understanding that:

(1) is conceptually based;
(2) has a conceptual base that consists of a formal structure;
(3) can make predictions on the basis of this conceptual structure;
(4) is not limited to the understanding of isolated sentences;
(5) has formal rules for analyzing natural language utterances into the conceptual base.

In addition to the explication of this theory, this paper will also briefly touch upon the problems of:

(1) analysis of the intention of an utterance;
(2) prediction of the elements of communication that lie outside the conceptual content of an utterance;
(3) the connection of conceptual structures and the understanding process with an underlying memory structure.

2.2 *Conceptual Dependency*

The conceptual base is responsible for formally representing the concepts underlying an utterance without respect to the language in which that utterance was encoded. A given word in a language may or may not have one or more concepts underlying it. We seek to extract the concepts that the words denote and relate them in some manner to those concepts denoted by other words in a given utterance.

We are dealing here with two distinct levels of analysis that are part of a stratified system [cf. Lamb (1966)]. On the sentential level, the utterances of a given language are encoded within a syntactic structure of that language. The basic construction of the sentential level is the sentence. The words of the sentence are related to each other in certain specified ways that we shall briefly discuss in section 3.

The next highest level in the system that we are presenting is the conceptual level. We call the basic construction of this level the conceptualization. A conceptualization consists of concepts and certain formal relations that exist between these concepts. We can consider that both of these levels exist at the same point in time and that for any unit on one level, some corresponding realizate exists on the other level. This realizate may be null or extremely complex, (see Lamb (1964) for discussion of this general idea). The important point is that underlying every sentence in a language there exists at least one conceptualization. Conceptualizations may relate to other conceptualizations by nesting or other specified relationships, so it is possible for a sentence in a language to be the realization of many conceptualizations at one time. This is like saying that one sentence can express many complete ideas and the relation of those ideas.

The basic unit of the conceptualization is the concept. There are three elemental kinds of concepts. A concept can either be a nominal, an action, or a modifier. Nominals are considered to be those things that can be thought of by themselves without the need for relating them to some other concept. That is, a word that is a realization of a nominal concept tends to produce a picture of that real world item in the mind of the hearer. We thus refer to nominal concepts as PP's (for picture producer). A PP then, is the concept of a general thing for example, a man, a duck, a book, or a pen; or of a specific thing, for example, John, New York, or the Grand Canyon.

An action is that which a nominal can be said to be doing. There are certain basic actions (henceforth referred to as ACT's) that are the core of most verbs in a language, but this will be explained in section 4.

A modifier is a concept that makes no sense without the nominal or action to which it relates. It is a descriptor of the nominal or action to which it relates and serves to specify an attribute of that nominal or action. We refer to modifiers of nominals as PA's (picture aiders) and modifiers of actions as AA's (action aiders).

It should be emphasized here that what we have said so far about concepts refers to their conceptual properties and not their sentential ones. While it is possible to have a sentence without a verb, or without a subject, for example, or to have an adjective without a noun, conceptually, the corresponding things cannot exist.

Each of these conceptual categories (PP, ACT, PA, and AA) can relate in specified ways to each other. These relations are called dependencies. They are the conceptual analog of syntactic dependencies used by Hays (1964), Klein (1965), and others. A dependency relation between two conceptual items indicates that the dependent item predicts the existence of the governing item. A governor need not have a dependent, but a dependent must have a governor. The rule of thumb in establishing dependency relations between two concepts is whether one item can be understood without the other. A governor can be understood by itself. However, in order for a conceptualization to exist, even a governor must be dependent on some other concept in that conceptualization.

PP's and ACT's are inherently governing categories, while PA's and AA's are inherently dependents. However, any governor can also be dependent, and in order for a conceptualization to exist this must be the case for at least two governors. Conceptualizations can themselves be dependent on certain concepts and/or other conceptualizations in certain ways. This will be explained more fully in section 4.

We represent the conceptual base by a linked network of concepts and dependencies between concepts that is called a conceptual dependency network (which we abbreviate 'C-diagram'). Let us look at what such a network is like. Consider sentence (1):

(1) John hit his little dog.

'John' is the name of an object, so it represents a concept which can be understood by itself, and it is thus a PP. 'Hit' represents a concept of action. Each of these concepts is necessary to the conceptualization in the sense that if either were not present, there would be no conceptualization. Thus, we say that a two-way dependency exists between them. That is, they each act as governors which can be understood by themselves but which must both be present in order to form a conceptualization. We denote the two-way dependency by $\leftrightarrow$. The words 'his' and 'little' both represent dependent concepts in that in order to understand them it is necessary to hold them in waiting until what they modify appears. That is, they cannot be understood alone. 'Dog' is the name of a concept which is a PP and is, therefore, a governor. The PP 'dog' is conceptually related to the ACT 'hit' as object. That is, it is dependent on 'hit' in that it cannot be understood with respect to the conceptualization except in terms of 'hit.' We denote objective dependency $\overset{o}{\leftarrow}$. We thus have the following network so far:

$$\text{John} \leftrightarrow \text{hit} \overset{o}{\leftarrow} \text{dog}$$

We can now add the dependents that were waiting for 'dog' as governor. 'Little' represents a PA that is dependent on 'dog.' We call this attributive dependency and denote it by $\uparrow$. The concept given by 'his' would appear to be dependent on 'dog' as well, and it is, but it is not a simple concept. 'His' is really another syntactic representation of the PP 'John,' that is being used in the syntactic form that indicates possession. What we have is one PP acting as dependent modifier to another PP. We denote prepositional dependency by $\rceil$ between the two PP's involved, and a label indicating the type of prepositional dependency. (Here POSS-BY indicates that the dependent possesses the governor.) The final network is then:

$$\begin{array}{l} \text{John} \leftrightarrow \text{hit} \overset{o}{\leftarrow} \text{dog} \\ \qquad\qquad\qquad\quad \uparrow\rceil \;\; \text{POSS-BY} \\ \qquad\qquad\quad\;\; \text{little}\;\; \text{John} \end{array}$$

A conceptual dependency network may be treated as a whole unit by reference to the two-way dependency link. Thus, the time of the events of this conceptualization may have been 'yesterday.' This would be indicated by use of an attributive dependency between the time-PP (PP_T) 'yesterday,' and the $\leftrightarrow$ as follows:

$$\begin{array}{ccc} \text{John} \leftrightarrow \text{hit} & \overset{o}{\leftarrow} & \text{dog} \\ \uparrow & & \uparrow\!\!\mid\ \text{POSS-BY} \\ \text{yesterday} & \text{little} & \text{John} \end{array}$$

Similarly conceptualizations can relate to other conceptualizations and to ACT's through the two-way dependency link. This will be described in section 4.

It might be pointed out here, that while it appears as if each conceptual category is a variant of one other syntactic category, this is not at all the case. It is quite usual for nouns to be realized as ACT's for instance. This will be seen shortly.

2.3 *Components of the System*

Basically we can view the analysis of a sentence as proceeding through the following processors:

(A) *Syntactic Processor*

The function of the syntactic processor is to bracket the sentence into syntactically dependent units. This is done in conjunction with the following components:

(1) a dictionary of words and their syntactic categories; (2) a dictionary of verbs that chooses verb senses based on the surrounding syntactic and semantic environments; (3) a syntactic expectation maker that predicts the syntactic category most likely to follow the syntactic category of the present word; (4) a list of the kinds of syntactic dependencies that may exist; (5) a routine that finds the main noun and verb in a given sentence.

Syntactic processing is by no means done in isolation from the rest of the processes. It would be nonsense to consider that syntactic processing is completed before conceptual processing begins. The two processors 'talk together' while they work.

(B) *Conceptual Processor*

(1) a dictionary of the possible conceptual realizates of a word; (2) a dictionary of ACT's that is used to select the correct ACT realizate of a given verb given the semantic environment on the conceptual level; (3) a conceptual expectation maker that predicts conceptual information most likely to follow given the present incomplete conceptual structure; (4) a list of the different conceptual dependency rules that may exist;

(5) heuristics for searching through syntactic structures to find the main PP and ACT candidates for a conceptualization.

Conceptual processing is also not done in isolation but is reliant on the memory structure operating above it in order to make some of its decisions.

(C) *Conceptualization-Memory Interface*

(1) a dictionary that relates two concepts or conceptual structures based on the individual experience of the hearer; (2) a dictionary that finds the function of a given PP in the real world; (3) a dictionary that recognizes the implications or connotations of a given word or concept and relates them to the intermediate memory; (4) a conceptualization expectation maker that predicts the next likely conceptualization; (5) a list of possible relations among conceptualization types; (6) a routine for searching through conceptualizations for information to be stored in long-term memory.

The Interface operates on the conceptualizations in order to know how to deal with them in intermediate memory so as to generate a response.

(D) *Intermediate Memory*

(1) core beliefs; (2) recent input conceptualization; (3) information about topic under discussion from long-term memory; (4) emotional variables dependent on input conceptualizations; (5) routine to modify long-term memory information; (6) response-initiator.

The Intermediate Memory is the operating memory whose function it is to begin responses to input conceptualizations and to affect the long-term memory. The long-term memory is the depository for information about everything.

(E) *Long-Term Memory*

(1) information about particular subject and experiences.

Considerable work has been done on parts A and B and a fair amount has been done on C. This will be the main subject of this paper. We are beginning to work on D and E but are not prepared to do more than barely touch on them here.

3. THE SENTENTIAL LEVEL

3.1 *The Syntactic Processor*

While it is unnecessary to do a complete syntactic analysis of a sentence in order to process it conceptually, it is necessary to be aware of the syntactic relationships that exist between words. The analysis method described here is conceptually based. Since that is the case, the syntactic bracketing that we do here is often not necessary. That is, syntactic routines could fail for one reason or another, and the correct analysis could still be obtained by the conceptual processor. It is sometimes possible to understand sentences (in a foreign language, for instance) where the words are known but the syntax is not. This is because the organization of the conceptual base is interlingual and thus the conceptual processing is identical to that done when the input is in the speaker's native language. But certainly it is the case that not all sentences can be understood without regard to syntax and so it is worthwhile to have a syntactic processor.

The primary function of the syntactic processor is to find the main noun and main verb in a sentence. Of secondary importance is the establishment of syntactic dependencies between the main noun and verb and the other parts of the sentence.

> In order to find the main noun and main verb in a sentence a set of heuristics are employed that make hypotheses about where these items are to be found and proceed to check these hypotheses. When a decision is made as to the most likely candidates for main noun and main verb, the verb dictionary is called. The verb dictionary is entered with a triple that consists of the following: (Subject, Verb + Verb type, Object). The object can be
>
> (a) Noun
> or (b) Noun, Noun
> or (c) nil
>
> The correct verb sense is chosen by finding the most explicit semantic category of the nouns in subject and object slots that applies for the correct verb type.

At this point, the main responsibility for processing is shifted over to the verb–ACT dictionary. This dictionary is the interface of the syntactic and conceptual systems, and initiates the creation of the conceptual networks. The verb–ACT dictionary will be described at length.

3.2 *The Verb–ACT Dictionary*

The verb-ACT dictionary is intended to sort out the different senses of a verb, so the appropriate one can be selected, and then to establish candidates for conceptual dependency. These candidates are accepted, rejected, or rearranged in a new conceptual order by the ACT part of the dictionary which will be discussed in section 4.

In this discussion, a verb-sense is defined as a different conceptual realizate for a given verb. So, if we say that a verb has four senses, what we mean is that the main noun (Subject), main verb, and object noun are arranged conceptually in four different conceptual configurations. These different configurations may in fact include entirely different ACT's. That is, we are saying that the given verb has four possible meanings. We select the thing that was meant in this instance by reference to the other information in the entering triple, namely, the verb-type, and the semantic information that is part of the given nouns.

Consider sentence (2):

(2) The big man took the book.

The syntactic processor will analyze this into a triple that is (man, take-vt, book). Furthermore, the syntactic dependency 'man' has been established.

$$\begin{array}{c}\text{man}\\ \uparrow\\ \text{big}\end{array}$$

The verb-type vt means that a transitive verb has been encountered, that is, a verb that has one noun as object.

The verb–ACT dictionary entry for 'take' is as follows: (For purposes of clarity, the conceptual networks that are actually given in the verb–ACT dictionary as the realizates of the triple will be written in English format in this section. The actual conceptual networks will be presented in section 4.)

take

verb-		semantic category		
type	conceptual meaning	of X	of Y	of Z
vt	X take Y to the possession of X	human	physobj	
vx	X take Z to the possession of Y	human	human	physobj
vt	X ingest Y to the innards of X	human	medication	

Since we were given the verb-type of vt by the syntactic processor, we consider only those entries that begin with vt. (Here X indicates the subject noun of the triple and Y indicates the object noun. Z indicates the second object noun if that exists.) The problem of conceptually analyzing this triple is then one of selecting between the alternative vt meanings. This is done by reference to the semantic categories of X and Y. These semantic categories are found as part of the entry of the dictionary for each noun. Often there are different senses of a noun and different categories to go with those senses. In that case all the senses are considered as possible candidates to be chosen by the verb dictionary. These semantic categories are similar in function to the selectional restrictions discussed by Katz and Fodor (1963) and Chomsky (1965). That is, these semantic categories exist at the sentential level. They can be considered the sentential semantics, or rules for combination of syntactic entities. What we are doing here is trying to accept the most likely interpretation of a given sentence by reference to the meaning of the elements of that sentence. Thus, the purpose here is different than that of the generative linguist whose idea it is to reject nonsensical utterances. We are interested here in rejecting only relatively nonsensical utterances. That is, we are looking for that combination which makes the most sense with respect to the alternatives so that we can select it.

The semantic category of man is 'human' and of 'book' is 'physobj.' The semantics accepts a 'human' as the potential actor (X) for both senses of the vt, but the object (Y) must be a 'medication' in the second vt. In the first, a physobj is required, which is what we have. Thus, we are now finished with the syntactic processing of this sentence, unless the conceptual processor rejects what has been output as conceptually unacceptable.

The other syntactic verb types that are used are as follows:

vx–*double-object verb.* A vx verb is present when two nouns follow that verb without the mediation of a preposition or the appearance of a new verb. (For example 'I gave the girl candy.')

vi–*intransitive verb.* A vi verb is present when no noun follows the verb and the only preposition-noun complexes that follow utilize prepositions such as, in, on, and other locations.

vio–*indirect object verbs.* A vio verb takes 'to' or 'from' or some other preposition that indicates direction before the noun that follows it.

vs–*state verb.* A vs verb is one that requires a verb or an entire sentence as object, such as 'like' in 'I like going' or 'wish' in 'I wish that he was here.'

4. THE CONCEPTUAL LEVEL

4.1 *Conceptual Rules*

The Conceptual Level is intended to represent the concepts and relations between concepts that underlie natural language utterances. The Conceptual Processor relies on the predictions that it can make from what it knows about the input it has already received in order to know how to deal with new input. The key to making these predictions is in the conceptual rules. The conceptual rules are the list of permissable conceptual dependencies. That is, there exist formally defined dependency relations between given categories of concepts. These conceptual dependencies, and only these, make up the formal organization of the conceptual networks of the conceptual level. These conceptual rules are, in essence, the rules for relating different categories of items in the universe based on the original assumptions in conceptual dependency theory. Thus, conceptual categories can relate in the following ways:

1. PP $\leftrightarrow$ ACT:
Ex: John $\leftrightarrow$ sleep
Sent: John is sleeping

The heart of any conceptualization is the two-way dependency between PP's and ACT's. This rule states that PP's can ACT and when they do there is a mutual dependence. This rule does not say that all PP's can ACT or that any PP can do any ACT. We define the particular possible relations between two categories as the semantics of that conceptual relation. That is, Rule 1 is a rule about the syntax of the conceptual level. It describes the possible combination of conceptual categories. The semantics of the conceptual level states which PP's can do which ACT.

Thus, the sentential level has syntax and semantics for the categories and particular words of that level. The conceptual level has its own syntax and semantics for the categories and concepts of that level.

2. PP $\rightleftarrows$ PA
Ex: John $\rightleftarrows$ tall
Sent: John is tall

A conceptualization that utilizes a $\rightleftarrows$ is called an attributive conceptualization. Such a conceptualization exists when an attribute is being predicated about a given PP. It is the predication of that attribute that makes the dependency two-way. That is, in order for these items to exist as a conceptualization, each is equally necessary.

3. PP $\rightleftarrows$ PP
Ex: John $\rightleftarrows$ doctor
Sent: John is a doctor

This rule is similar to Rule 2 and is a set inclusion-type predication conceptualization.

4. $\begin{array}{c} \text{PP} \\ \uparrow \\ \text{PA} \end{array}$
Ex: $\begin{array}{c} \text{man} \\ \uparrow \\ \text{tall} \end{array}$
Sent: The tall man

This is a dependency between a concept and an attribute of that concept that has already been predicated. In discourse, conceptual attributes are predicated, either explicitly or implicitly, before they are used to differentiate concepts of the same linguistic name. In other words, 'the tall man' would only be used to differentiate two men whose relative height is either visually apparent or has been previously remarked upon in a predication.

5. PP
$\uparrow$
PP

Ex: man $\uparrow$ LOC New York   dog $\uparrow$ POSS John

Sent: The man in New York . . .
John's dog . . .

Two conceptual objects in the world can be related to each other in various fashions. The three principal ones are containment, location, and possession and these are marked on the $\uparrow$ arrows. The direction of dependency indicates the concept which is being attributively differentiated, as in Rule 4. That is, 'in New York' is information about 'man' but 'man in' is not information of a useful kind about 'New York.'

6. ACT $\overset{o}{\leftarrow}$ PP

Ex: hit $\overset{o}{\leftarrow}$ boy

Sent: (He) hit the boy

This is objective dependency. The PP is related as object to the ACT which governs it. Government here is quite literal in that the semantics of the conceptual level works from ACT to the objective PP. That is, a given ACT may require a PP of a given type as its objective dependent. Certain ACT's do not require an objective PP, but those that do must have an object conceptually even if none was actually mentioned in the input discourse. That is, if an ACT like 'hit' is present, an object for 'hit' exists conceptually even if it is not explicitly in the sentence. This will be further elaborated upon in the discussion of 'case' dependencies (Section 4.3).

The six rules given thus far are enough to express the conceptual representation of the conceptualization underlying sentence (1). We will present other conceptual rules as they are needed for the examples.

4.2 *Underlying ACT's*

Until this point, it may have seemed that what we are passing off as conceptual ACT's are really no more than verbs in a different guise. This is only partially true. Actually, ACT's are whatever is verbal in nature on the sentential level, rewritten into a primitive form. 'Love,' for example, is an ACT, even if it is possible to nominalize it in English. In other words, it is the responsibility of the conceptual level to explicate underlying relationships that speakers know to exist. Although 'love' might be a noun in a given sentence, all speakers know that somewhere a subject and an object (for the right sense of 'love') must exist. It is the purpose of the conceptual rules to mark an ACT such as 'love' as requiring conceptual rules (1) and (6). Thus, when 'love' is encountered in a sentence, it is discovered to be the realizate of the ACT 'love' and immediately the question of the PP's that are its actor and object is raised. The conceptual processor can then search through the sentence to find the candidates for these positions. It knows where to look for them by the sentential rules given earlier and what it is looking for by the syntax and semantics on the conceptual level. Thus, it is the predictive ability of the formulation of the conceptual rules that makes them powerful tools.

It is interesting at this point to look at ACT's that do not have direct English realizates in order to more clearly pinpoint the problem of conceptual representation. Consider sentence (3):

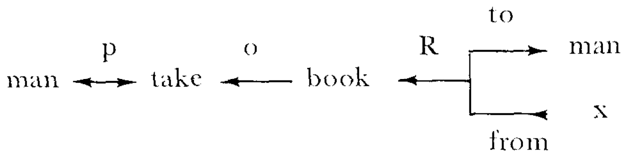
(3) The man took a book.

Since 'man' is the actor here and 'book' is the object of the action 'took,' it might seem to be appropriate here to conceptually analyze this sentence as:

$$\text{man} \overset{p}{\leftrightarrow} \text{take} \overset{o}{\leftarrow} \text{book}$$

(We write a 'p' over the $\leftrightarrow$ to denote that the event being referred to occurred in the 'past.')

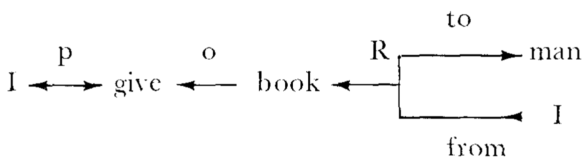
However, in attempting to uncover the actual conceptualization underlying a sentence, we must recognize that a sentence is often more than its component parts. In fact, a dialogue is usually based on the information that is left out of a sentence but is predicted by the conceptual rules. For example, in this sentence, we know that there was a time and location of this conceptualization and furthermore that the book was taken from 'someone' or 'someplace' and is, as far as we know, now in the possession of the actor. We thus posit a two-pronged recipient case, dependent on the ACT through the object. The recipient case is used to denote the transition in possession of the object from the originator to the recipient. Thus, we have the following network:



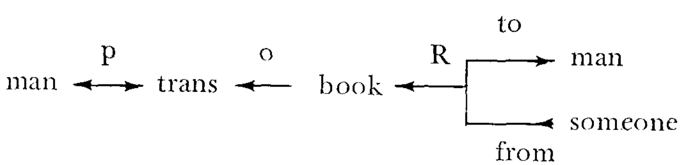
Now, suppose we were given sentence (4):

(4) I gave the man a book.

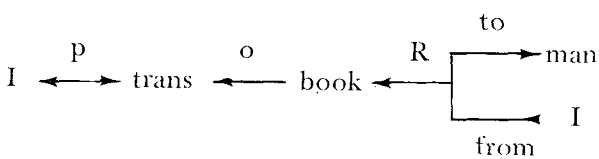
It is interesting to compare the underlying representations of these two sentences. 'Give' is like 'take' in that it also requires a recipient and an original possessor of the object. Then we have:



Note that these two conceptualizations look very much alike. They differ in the identity of actor and recipient in (3) and actor and originator in (4), and in the verb. But, is there any actual reason that the verbs should be different? Are they actually different? It would appear that conceptually the same underlying action has occurred. What is actually different between (3) and (4) (assuming that in (3) the originator was also 'I') is that the initiator of the action, the actor, is different in each instance. The action that was performed, namely, transition of possession of an object, is the same for both. We thus, conceptually realize both 'give' and 'take' by the ACT 'trans.' Thus, the conceptualizations underlying (3) and (4) are:



(3)



(4)

'Give' is then defined as 'trans' where actor and originator are identical, while 'take' is 'trans' where actor and recipient are identical.

Important here, is that a great many other verbs besides 'give' and 'take' are realized as 'trans' plus other requirements. For example, 'steal,' 'sell,' 'own,' 'bring,' 'catch,' and 'want,' all have senses whose complex realizates include as their ACT, the ACT 'trans.' It is this conceptual rewriting of sentences into conceptualizations with common elements that allows for recognition of similarity or paraphrase between utterances.

The recognition of paraphrase is central to the problem of conceptual representation. If two sentences are agreed to have the same meaning, one conceptual dependency diagram must suffice to represent them. We shall see in section 5 how the three sentences

(5) I want a book.
(6) I want to get a book.
(7) I want to have a book.

can be analyzed into one C-diagram representative of the meaning that is shared by one interpretation of each of them.

4.3 *Conceptual Cases*

We have seen in the last section a new conceptual rule which we label (7):

7. $$\text{ACT} \xleftarrow{\;R\;} \begin{cases} \rightarrow \text{PP} \\ \leftarrow \text{PP} \end{cases}$$

This conceptual rule states that certain ACT's require a two-part recipient in a dependency similar to that of objective dependency. The similarity lies in the fact that this type of dependency is demanded by certain members of the category ACT. If it is present at all, it is because it was required. There is no option and no ACT's can have a recipient dependency without having required it. Thus, this dependency can in a sense be considered to be a part of the ACT itself.

We call those dependents that are required by the ACT, conceptual cases. There are four conceptual cases in conceptual dependency, namely, OBJECTIVE, RECIPIENT, DIRECTIVE, and INSTRUMENTAL. We use conceptual case as the basic predictive mechanism available to the conceptual processor. That is, if I say 'I am going,' a very reasonable inquiry would be 'Where?' Dialogues are often partly concerned with the filling in of the case slots in a conceptualization. People do not usually state all the parts of a given thought that they are trying to communicate. Usually this is because the speaker was trying to be brief and leave out assumed or unessential information or simply information that he did not want to communicate. A conceptual case often may not be realized in a given sentence. The sentence will nevertheless appear well-formed syntactically. But, a C-diagram that contains only the sententially realized information will not be well-formed conceptually. That is, a conceptualization is not complete until all the conceptual cases required by the ACT have been explicated. The conceptual processor makes use of the unfilled case slots to search for a given type of information in a sentence or larger unit of discourse that will fit the needed slot. In an interactive situation, some measure of the desire to fill such slots is necessary in order to direct the response initiator to form an inquiry as to the nature of the missing case concepts when such information has not been previously stated.

Linguists who are interested in syntactic well-formedness have begun to look into the possibility of using cases in their representations recently (e.g., Fillmore (1968)). However, the cases used by these linguists are syntactic cases and should not be confused with conceptual cases. Syntactic cases have to do with the well-formedness of a sentence given a particular verb. Conceptual cases have to do with the well-formedness of a conceptualization given a particular ACT. The two are not always the same. Consider for example, the problem of instrument in sentence (8):

(8) John grew the plants with fertilizer.

Here, 'fertilizer' is the instrument of the verb 'grow.' This is a syntactic case relation and is treated as such by certain linguists including Fillmore. But, conceptually the job is not so simple. Why? Simply because 'grow' is not something that 'John' can do to something else. The conceptualization

$$\text{John} \overset{\text{p}}{\leftrightarrow} \text{grow}$$

is perfectly, all right, but it means that 'John grew.' If we mean 'the plants grew' then the representation of that is:

$$\text{plants} \overset{\text{p}}{\leftrightarrow} \text{grow}$$

But where is 'John'? In the conceptualization underlying this sentence, 'John' was doing something that caused these plants to grow. What was he 'doing'? We don't know exactly, but we do know that he did it with the fertilizer. We might be tempted to posit a conceptual instrument here and have a conceptualization with no particular ACT in it (represented by a dummy ACT—'do'). Thus, we could have (allowing a new conceptual rule (ACT $\overset{I}{\leftarrow}$ PP)):

$$\text{John} \leftrightarrow \text{do} \overset{I}{\leftarrow} \text{fertilizer}$$

We then could relate this conceptualization to the previous conceptualization. They relate to each other casually since John's action caused the plants to grow. We denote causality by $\uparrow\uparrow$ between the two-way dependency links. This indicates that it was not the actor or the action by itself that caused the new conceptualization, but rather it was the combination of the two that caused a new actor–action combination. The causal arrow is a dependency, and consequently the direction of the arrow is from dependent to governor or in this instance from caused to causer. That is, the caused conceptualization could not have occurred without the causer occurring so it is dependent on it. Thus, we have (placing an 'i' over the $\uparrow\uparrow$ to denote intentional causation):

$$\begin{array}{lcl} \text{John} & \overset{p}{\leftrightarrow} & \text{do} \overset{I}{\leftarrow} \text{fertilizer} \\ & \uparrow\uparrow i & \\ \text{plants} & \leftrightarrow & \text{grow} \end{array}$$

Now, while this is roughly a characterization of what is going on here, it is not correct. In fact, 'fertilizer' was not the instrument of the action that took place. It was the object. Consider what probably happened. John took his fertilizer bag over to the plants and added the fertilizer to the ground where the plants were. This enabled the plants to grow. This is conceptually another instance of 'trans.' What we have is this:

$$\begin{array}{lcl} \text{John} & \overset{p}{\longleftrightarrow} & \text{trans} \overset{o}{\longleftarrow} \text{fertilizer} \overset{R}{\longleftarrow} \left[\begin{array}{l} \rightarrow \text{plants ground} \\ \leftarrow \text{bag} \end{array} \right. \\ & \Uparrow i & \\ \text{plants} & \longleftrightarrow & \text{grow} \end{array}$$

Thus, what appeared to be an instrument syntactically and then conceptually turned out to be an object of an action after all. This, as it turns out, is what always happens to a conceptual instrument. That is not to say that there is no conceptual instrumental case, but simply that a single PP cannot be a conceptual instrument.

Consider sentence (9):

(9) Fred hit the boy with a stick.

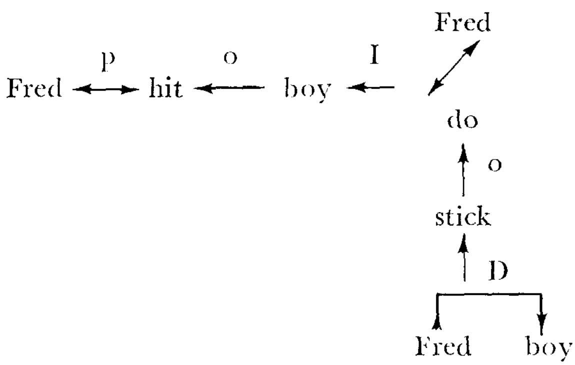
This sentence means that the boy was hit by a stick. We assume that the stick didn't do the action of its own accord, so it is reasonable to have the actor be 'Fred.' But we have just stated PP's cannot be conceptual instruments. Thus,

$$\text{Fred} \overset{p}{\leftrightarrow} \text{hit} \overset{o}{\leftarrow} \text{boy} \overset{I}{\leftarrow} \text{stick}$$

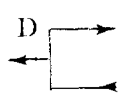
is no good. What actually happened here is that Fred threw the stick or swung the stick or performed some other action with the stick as object. In other words, what we call 'Fred hitting the boy' is really another action entirely which we interpret as Fred hitting the boy. We thus allow a new conceptual rule (8).

8. $\text{ACT} \overset{I}{\leftarrow} \nearrow\!\!\!\swarrow$ This rule states that an entire conceptualization can be the instrument of a given ACT. Since this is a case dependency, the new conceptualization can be considered to be part of the original ACT and thus the original conceptualization in some sense subsumes the instrumental conceptualization.

Thus, the underlying conceptualization for sentence (9) is:



The 'do' here indicates that we really don't know what the action was exactly. However, the requirements on what could possibly fit the 'do' slot are rather stringent. That is, it must be an action that takes OBJECTIVE and DIRECTIVE cases (DIRECTIVE case is denoted by



and will be discussed below) and furthermore the particular semantic categories of 'boy' and 'stick' must be allowed. It turns out that 'throw' and 'swing' are about the only ACT's that will fit those requirements.

The instrumental conceptualization is written vertically simply because we have no Z—coordinate to write in. The instrumental conceptualization should be considered to be like the other cases, a mainline dependent of the ACT.

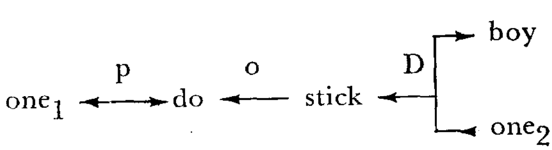
Syntactic instruments are nearly always realized conceptually as the object in the instrumental conceptualization. Usually, these syntactic instruments are so stated because of brevity and because of the possible endless nesting of instruments. All conceptualizations that take RECIPIENT or DIRECTIVE case and most that take OBJECTIVE case, take INSTRUMENTAL case as well. Thus, every time a conceptualization is used instrumentally, it is likely that there is an instrument of that instrumental conceptualization. For example, in the instrumental conceptualization for (14) the instrument there could be something like 'Fred grabbed the stick.' In turn, the conceptualization's instrument could be something like 'Fred moved his hand to the stick.' In other words, there is a great deal of information underlying the information actually stated in a given sentence. Which of this information must be retrieved is of concern to the individual in the dialogue situation. Our concern here is to make explicit the relationships that exist between concepts that have been referenced and to be able to discover those we deem it necessary to know.

One more thing must be made clear about sentence (9) however. It would not be incorrect to say that 'The stick hit the boy.' Since conceptual dependency is supposed to handle paraphrase it is necessary that this information be derivable from the above representation. It turns out that it is.

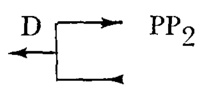
One of the important principles in conceptual dependency representation is that actors can only be animate or some natural phenomenon. If we had the sentence (10):

(10) The stick hit the boy.

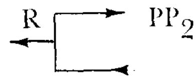
the conceptual representation would be:



Here, 'one$_1$' and 'one$_2$' are dummy PP's which could be 'Fred' and 'Fred' or could be 'gravity' and 'tree.' No matter which it was, the actual hitting is represented by the contact of $\xleftarrow{o}$ PP, and



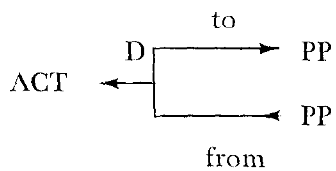
That is, when an object and a directive object exist in the same conceptualization they can be said to have made physical contact. By the same token, when $\overset{o}{\leftarrow} PP_1$, and



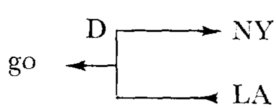
exist in the same conceptualization they can be said to have made social and possibly physical contact. That is, object and recipient, for example, 'book' and 'Fred' in (4) represent the possessive relationship when they exist in the same conceptualization. All this is of interest for operation on these conceptual structures and will not be further touched upon in this section. In other words, there are implications that can be drawn from these conceptualizations. We shall see an extension of this in section 8.

It may not have been obvious why, in conceptual rule (7) for example, the recipient case is written as dependent on the ACT and not on the object as it is written in the C-diagram. These cases are equally dependent on the ACT. They are written in no particular order except that it is necessary to write the object near the recipient or directive because of the implications that can be made from the existence of these two cases simultaneously. Thus, we should consider that the conceptual cases are retrievable through the ACT itself rather than through each other. But it should not be surprising if it turns out that the recipient calls to mind the object or vice versa.

9.



Ex:



Sent: (He) went to N.Y. from L.A.

This rule indicates that two PP's can be dependent on the ACT as DIRECTIVE case. The directive case is extremely similar to the recipient in form and is almost in complementary distribution with it. That is, the two never appear together and would seem to be different forms of the same phenomenon. The most common ACT that takes directive case is 'go.' Like 'trans,' 'go' is a primitive that is actually the underlying ACT for most verbs of motion.

Rules 6, 7, 8, and 9 constitute the conceptual cases of conceptual dependency theory. Thus, there are only four cases, of which there can be as few as none or as many as three for a given ACT. Each ACT category (explained in section 4.5) requires a certain set number of cases. Thus, any given ACT requires a given number of cases and, no matter what the English realization, will have exactly that number in the C-diagram.

The notion of syntactic case is not used at all in conceptual dependency. Traditional linguists' ideas about case are only about so-called case languages. English is not traditionally a case language so the syntactic processor for English has no need of case. Although Fillmore's (1968) remarks on the underlying syntactic cases in English are well taken, his ideas are within the framework of generative grammar and, therefore, do not pertain here. That is, we are not interested in what is, and what is not, an acceptable utterance in English. Syntactic rules that explain what syntactic cases can be omitted in a syntactic construction shed no light on how the understanding of natural language can best be effected.

We are concerned, however, with recognizing when a syntactic construction is reflective of an underlying conceptual case. The four cases are usually realized in English by the following constructions following the verb (where N is the PP for that case, or in the instance of instrument, the N is the ACT of the instrumental conceptualization if it can be so realized or else it is the objective PP).

OBJECTIVE—(nil) N
RECIPIENT—(to, from) N
INSTRUMENTAL—with N, by N(-ing), using N
DIRECTIVE—(to, from, toward) N

In addition, there are quite a few other constructions which realize conceptual cases. For example, 'by the N' as object of a motion verb (such as 'go') is a realizate of directive case, as is 'at the N.' But it is important to understand that since case requirements are established by the ACT, prepositional phrases are mapped into those cases that are needed by the ACT if the semantic category of the PP is all right.

As examples of the conceptual cases we have the following sentences and their conceptual realizates:

OBJECTIVE

(11) I ate an apple.

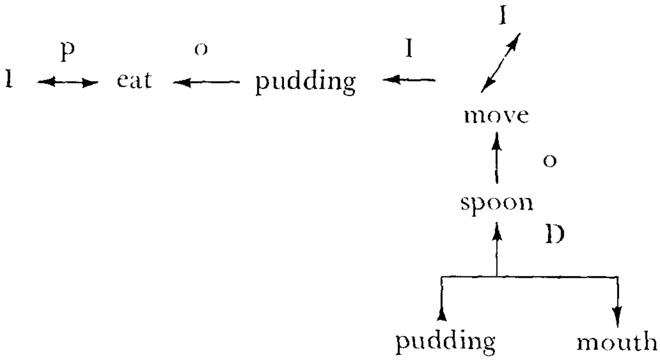
$$\text{I} \overset{p}{\leftrightarrow} \text{eat} \overset{o}{\leftarrow} \text{apple}$$

(12) The man was eaten by a tiger.

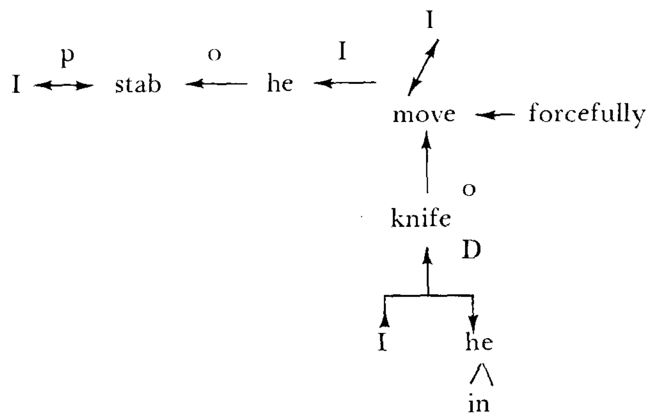
$$\text{tiger} \overset{p}{\leftrightarrow} \text{eat} \overset{o}{\leftarrow} \text{man}$$

INSTRUMENTAL

(13) I ate the pudding with a spoon.

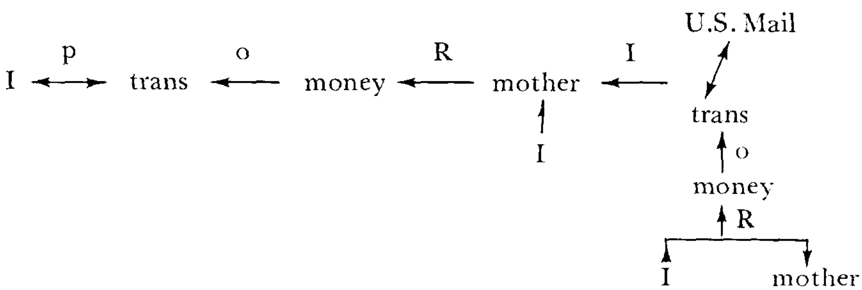


(14) I used a knife to stab him.

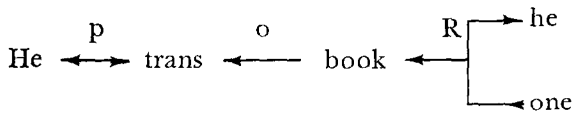


RECIPIENT

(15) I sent mother money.

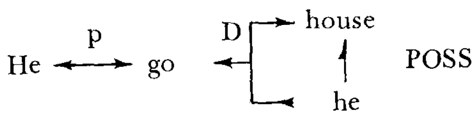


(16) It was the book that he took.

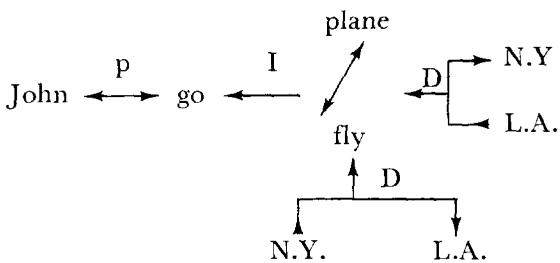


DIRECTIVE

(17) He went home.



(18) John took a plane from New York to Los Angeles.



The C-diagrams given here often make assumptions that may seem to be unwarranted. Rather than put no conceptual realizate in certain slots (e.g., 'U.S. Mail' in (15)) I put in what I thought might have been right. Sentences are not usually spoken in isolation so it is often easier to know what fits in these slots. But sometimes guesses like this are warranted, although I do not mean to imply that the given C-diagrams are the only possible ones for a given sentence. Rather, the cases and semantic requirements on those cases are the only ones possible for a given sentence, but the actual concept in those slots, with the exception of the ACT, if not explicitly stated is just assumed by me. Similarly in (18), it may be that the intended meaning is that 'John stole the plane.' Certainly the C-diagram presented does not represent that interpretation. If a sentence is ambiguous, the C-diagram of the sentence that is given here is only what I consider to be the most likely. A computer program must have a mechanism for making such educated guesses also, and we will discuss a limited version of such a thing in section 7.

In (14), we have used a new conceptual rule for modifying ACT's.

10. ACT
$\uparrow$
AA

Ex: move ; run
$\uparrow$ $\uparrow$
forcefully quickly

Sent: thrust; run quickly

This rule provides for the modification of particular ACT's according to the degree or the dimensions of the ACT. That is, ACT's can be modified as to speed, force, and others. English adverbs are not always AA's. 'Happily' describes a PP for example not an ACT. The upward direction of the arrow in this rule indicates that the AA is a minor aspect of the conceptualization. That is, the main line of the conceptualization consists of the PP's and ACT's on the horizontal plane. Vertical dependencies are less significant and are called below-the-line dependents.

4.4 *ACT Categories*

Central to the problem of analyzing natural language conceptually is the problem of predicting what conceptual information must be found in order to complete a given conceptualization. These predictions are based principally upon the conceptual rules and the ACT categories.

The category of an ACT is an indication of what cases an ACT must take. Thus, when a word is realized as an ACT, the ACT's category can be looked up, and the case requirements of that ACT made known. The semantic requirements of each case are then discovered for the individual ACT. This allows for powerful predictions to be made and changes the basic analysis process from bottom-up to top-down and bottom up.

There are the following ACT-types:

PACT—Physical ACT–PACT's require an objective case and an instrumental case. They are representative of the traditional actor-action–object-type constructions. Example: hit, eat, touch.

EACT—Emotional ACT–EACT's require an objective case only, and are abstract in nature. Example: love.

TACT—Transfer ACT–TACT's require objective, recipient, and instrumental cases and express alienable possession. Example: trans.

CACT—Communication ACT–CACT's also require objective, recipient, and instrumental cases. The object, however, is never concrete and, in fact, is never a PP but always a conceptualization. Example: communicate, say, read. In order to do this, we need a new conceptual rule:

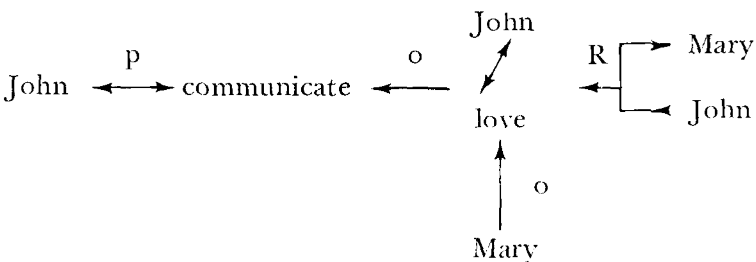
11. CACT $\overset{o}{\leftarrow\!\swarrow}$

This rule states that a particular type of ACT, a CACT takes a conceptualization in the objective slot rather than a PP. Whereas most other conceptual rules about

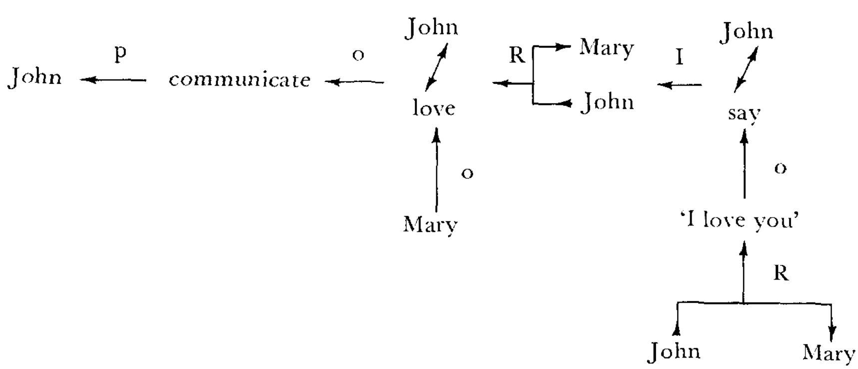
ACT's hold for all ACT's, this one does not, but rather supercedes the corresponding general rule when the ACT is a CACT.

An example of this type of ACT can be seen in the conceptual construction underlying sentence (19):

(19) John told Mary that he loves her.



This conceptual construction says that 'John communicated to Mary that he loves her.' Actually, John could have done that in any of a number of ways not involving speech. We say that 'tell' means conceptually 'communicate by saying,' i.e., you can communicate ideas by saying words. Thus, there is an instrument missing here whose object must be the actual words. Since the object consists of words and not concepts as is usual, we write the ideas in quotes to indicate that they actually are not part of the C-diagram:



Here again, this might not be exactly what was said in (19) since the instrument could have been left out of the sentence. The sentence could have ended with 'by kissing her' and then that would belong in the instrument conceptualization. We use the C-diagram shown above until given reason to do otherwise. That is, we make assumptions about the information that was not explicitly stated. This is something that humans do, and therefore something that a theory of understanding and an interactive computer program must do. We now return to the ACT categories.

DACT—Direction ACT–DACT's take directive case, objective case, and instrumental case and express motion of objects that are inanimate. Example: move.

RACT—Reflexive ACT–RACT's take directive and instrumental case. The object of the action is the same as the actor in these instances. We somewhat arbitrarily do not state them twice although inferences that can be made from object and directive case's concurrence can also be made from the actor and directive case for RACT's. For example, 'the actor is located in the directive PP at the end of the ACT.' Example: go.

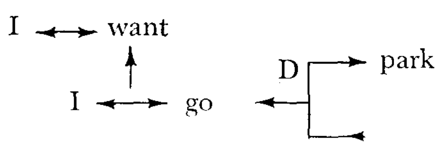
IACT—Intransitive ACT–IACT's are actions that are performed by an actor in isolation. That is, IACT's have to do with the state of existence of the actor and nothing else. Thus, IACT's take no case at all. Example: sleep, be.

SACT—State ACT–SACT's are a special kind of ACT in that they serve to introduce another conceptualization that they are not a part of. That is, whereas instrumental conceptualizations are actually part of the complete process of which the main ACT is the name, SACT's describe the actor's relationship to the nested conceptualization that the SACT requires. We can consider the nested conceptualization of the SACT to function as objective case. However, since the object conceptualization here is the primary assertion we write it horizontally and thus need another conceptual rule. Example: want, believe.

12. $\begin{array}{c}\text{SACT}\\ \uparrow \\ \leftrightarrow\end{array}$ This rule indicates that certain conceptualizations can be dependent on an ACT in a manner other than that of a case dependent.

As an example of an SACT consider sentence (20):

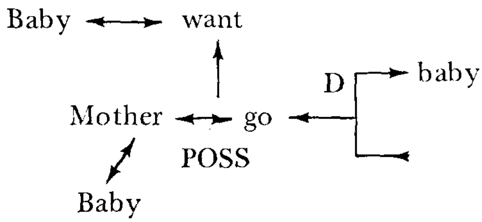
(20) I want to go to the park.



The usefulness of the prediction of a conceptualization made by an SACT is seen in analyzing a sentence such as (21):

(21) The baby wants his mother.

The syntax of English leads one to believe that this *is* a simple actor–action–object construct. But 'want' is the realization of the SACT 'want.' Thus, there must be an object conceptualization. So, we have:



The 'go' conceptualization is gotten from the verb–ACT, dictionary for 'want' as will be seen in section 5.

Just as two sentences which look the same can be conceptually quite different, so those that look different can be conceptually quite similar. Consider sentences (22) and (23):

(22) Sam believes that John is a fool.
(23) Sam believes Fred.

(22) is:

$$\begin{array}{rl} \text{Sam} \leftrightarrow & \text{believe} \\ & \quad\uparrow \\ \text{John} & \rightleftarrows \text{fool} \end{array}$$

(23) is again an instance of an SACT that is realized sententially as a transitive verb. However, what we mean by (23) is that 'Sam believes that what Fred said is true.' Thus, we have:

$$\begin{array}{r} \text{Sam} \leftrightarrow \text{believe} \\ \uparrow \quad \\ \text{Fred} \overset{p}{\leftrightarrow} \text{communicate} \overset{o}{\leftarrow} \swarrow\!\!\nearrow \rightleftarrows \text{true} \end{array}$$

This brings up three conceptual rules that need to be introduced:

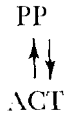
13. $\swarrow\!\!\nearrow \rightleftarrows$

Ex: $\begin{array}{l} \text{John} \\ \swarrow\!\!\nearrow \rightleftarrows \text{nice} \\ \text{hit} \\ \uparrow o \\ \text{Fred} \end{array}$

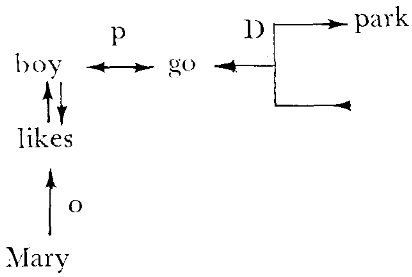
Sent: It is nice that John hit Fred.

This rule says that a conceptualization can be the subject of a prediction about that conceptualization. It is this rule that is used to handle 'John's love of Mary was beautiful' as will be seen in section 5.

14.



Ex:

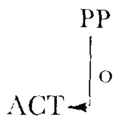


Sent: The boy who likes Mary (went to the park).

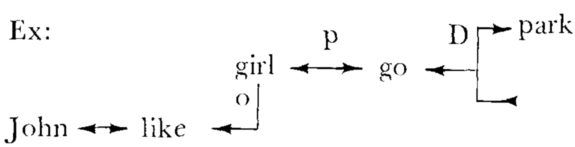
Rule 14 indicates that a conceptualization can be used to modify a PP rather than to predicate something about it. This takes care of 'who' constructions in English for example. It is a two-way dependency in that the PP is needed as actor for this conceptualization. Yet it is an attributive dependency in that it further specifies which PP is being talked about.

Julian

15.



Ex:



Sent: The girl John likes (went to the park).

It is possible for PP's to have dependent attributive conceptualizations in which they are the object rather than the actor. That is, the fact that they were the object of some conceptualization serves to identify them. Actually this is not a new rule, but is rather a new way of writing an old rule to indicate that a conceptualization relates attributively to a part of the conceptualization being predicated. When a ↔ appears in a case slot it can also be treated in this way. This is what was done for (23). A paraphrase for (23) would thus be (24):

(24) The statement that Fred made is believed to be true by Sam.

4.5 *Conceptual Relations*

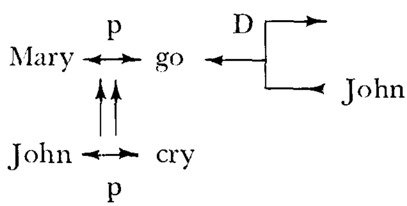
So far we have been discussing the conceptualization. The conceptualization is the basic construction of the conceptual level. However, it is the fact that conceptualizations can relate to other conceptualizations that makes natural language useful and makes thought interesting. The dependencies that denote the way conceptualizations relate to other conceptualizations are called conceptual relations.

The most important conceptual relation is that of causality.

16. $\overset{\displaystyle\leftrightarrow}{\underset{\displaystyle\leftrightarrow}{\uparrow\uparrow}}$ Causality is denoted by ↑↑, and indicates that the governor caused the dependent to exist. This is not an implication arrow and should not be read as that logical symbol. It is a dependency arrow and signifies that the governor's existence preceded that of the dependent, and, in this instance, caused the dependent.

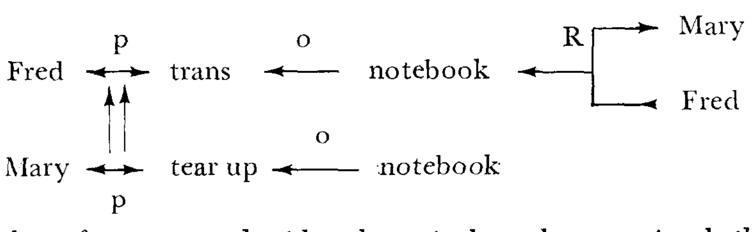
The causal arrow is realized in English in a great number of ways. The simplest form uses some variant of the word 'cause' as in sentence (25):

(25) John cried because Mary left him.



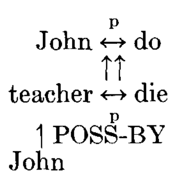
Another common causal takes sentential form using 'when.'

(26) When Fred gave Mary his notebook she tore it up.



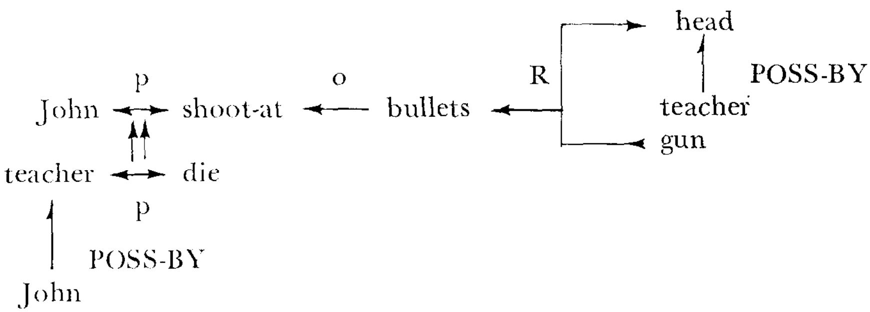
Causal is often expressed with only a single verb expressing both the causal and the end result.

(27) John killed his teacher.



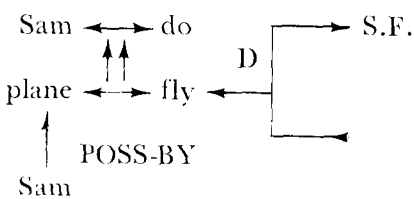
The 'do' used here is a dummy standing for an ACT which was left unstated. If the ACT were stated it would be realized sententially by use of a 'by' construction as in (28):

(28) John killed his teacher by shooting him in the head.



'Kill' is a member of a class of transitive verbs that we call pseudo-state verbs. They all have the property that the object of the verb is the actor of the dependent conceptualization. Often, the verb is the ACT of that dependent conceptualization as in (29):

(29) Sam flew his plane to San Francisco.



Here, the 'do' is a substitute for either the actions which are required to pilot a plane, or an action such as 'pushing the remote control button.' In interactive situations, if the context does not clarify the nature of the 'do,' it might be correct to question the speaker as to its nature.

Another type of disguised causal is represented by the class of transitive verbs that we call ZPA's indicating that they will become mental state PA's. ZPA's are quite similar to pseudo-state verbs in that they realize causal conceptualizations where the object of the sentence is the actor of the dependent conceptualization.

(30) John comforted Mary.

$$\begin{array}{c} \text{John} \overset{p}{\leftrightarrow} \text{do} \\ \uparrow\uparrow \\ \text{Mary} \underset{p}{\rightleftarrows} \text{comfortable} \end{array}$$

'Comfortable' is a PA. John's specific actions are unknown but their result was a mental state for Mary.

The nature of the causal relation represents a step away from the notion that semantic representation must operate with the same elements as syntactic representations do.

There is no particular reason why what is realized in English as a verb must by necessity be represented semantically by something that is verb-like (e.g., the PRO-verbs of Lakoff (1970)). Often, a linguistic entity can best be realized by a relation rather than a concept. A representation must consist of concepts and relations. There is no intrinsic reason why these relations should not be realized in a language by a word. The justification for doing so has to do with the basic syntax of such a representation schema. That is, there are rules for making a certain relationship between concepts in a representation. If these rules are cohesive, then certain predictions can be made on the basis of the absence of some item from the representation. If relations predict different things than do concepts, a decision on what can be an adequate representation of a word or group of words is made on the basis of the predictive power of the choice of the different representation. Clearly, if the predictions of a relation are more useful in a given situation than those given by a concept, a relation is chosen.

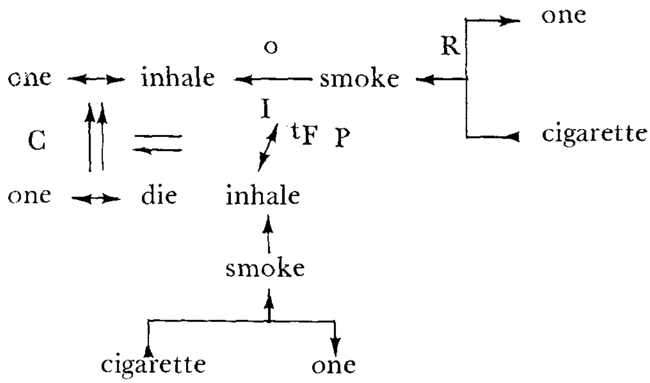
This brings up the question of what makes a relation different from a case. The answer is that a case is part of an underlying ACT and is predicted by that ACT. A relation is a rule for connecting different conceptualizations. Thus, relations serve as connectors within a memory whereas other types of dependency connect things within a conceptualization. That, by the way, is the reason that SACT's are not considered to take objective case. SACT's are on the border between cases and relations. While they require a conceptualization as part of the ACT, they are at the same time relating two conceptualizations.

Conceptual relations predict other conceptualizations, so, to the extent that a conceptual relation is expressed by a word of a language, predictions can be made about future conceptualizations on the basis of that word.

An important reason for treating relations differently than ACT's (as in 'cause' for example) has to do with the inherent properties of a relation as opposed to an ACT. A relation is used to relate dependencies not concepts. Thus, it is the relational quality of 'cause' that allows sentences like (31):

(31) Since smoking can kill you, I stopped.

This sentence contains two conceptualizations related by a causal and a causal relating that causal to a third conceptualization. Such a thing is nearly impossible to handle in more traditional linguistic representations.



In this example, I am just assuming cigarettes to be the donor whereas the computer system would put in 'smokeable object' of which cigarette is a member. Two new symbols have been introduced in this C-diagram and they bear an interesting relationship. Any conceptualization can be modified by certain conceptual tenses of which 'p' for past is one. The others are:

F—future
C—conditional
t—transition
t_S—beginning transition
t_F—finished transition
k—continuing
?—interrogative
/—negative
nil—present
△—timeless

These tenses modify a conceptualization as a whole. The English word 'stop' for example is actually an instance of the conceptual tense 't_F' and thus predicts an ACT. That ACT was unstated in (31) but was actually 'inhale.'

The interesting point here is that causal links behave as conceptualizations rather than as ACT's in that they also can be modified by conceptual tense. Thus 'can' in (31) is realized as a 'c' over the causal link generated by 'kill.' What is being expressed there is that the causal connection is potential rather than actual. Thus, the entire conceptual construction states that the actor did something because of a potential causality.

The other conceptual relations are time and location. The time of a given conceptualization can be another conceptualization. We have two conceptual rules expressing time.

17. T
↓
↔
Ex: yesterday
↓
↔
Sent: (It happened) yesterday.

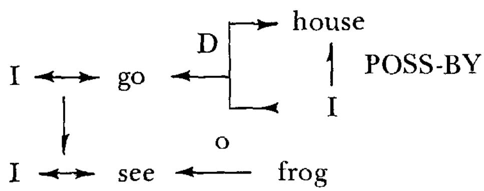
This rule relates another conceptual category ('T' for concepts like 'yesterday' or '12 o'clock') and a conceptualization. Most conceptualizations require a time. The time of something modifies the entire conceptualization and not any particular item in it. Thus, it is the time of the joining together of the actor and the ACT.

18. ↔
↓
↔

This rule states that one conceptualization can be the time of another. The dependency is usually realized in English by 'while.'

Thus, we have sentence (32):

(32) While going home I saw a frog.



The other conceptual relation is location. Location is not considered to be a case simply because it refers, as do all relations, to the conceptualization as a whole rather than the ACT in particular. The location of a conceptualization is the location of each dependent together with the actor and ACT. All conceptualizations that have time have location.

19. PP
↓
↔
Ex: park
↓
↔
Sent: In the park (I saw an elephant).

The symbol for the location relation is ⇃ between the location and the conceptualization. The location modifies the entire conceptualization, although there does exist a rule (Rule 5) which will allow individual PP's to have their own attributive locations.

A sentence that utilizes different types of location is (33):

(33) Yesterday, the boy in that chair hit the boy on the piano in the mouth in the park.

```
           yesterday
               ↓
                        o
     boy1  ↔  hit  ←  mouth
              ⇑      POSS-BY ⇑
 LOC ⇑  park           boy2
   chair                 ⇑ LOC
     ↑                  piano
   specific               ↑
                        specific
```

5. THE CONCEPTUAL PROCESSOR

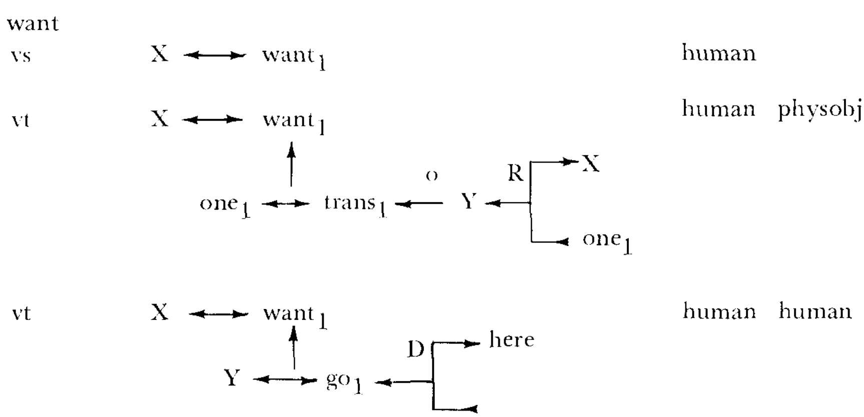
5.1 *Processing*

The conceptual processor receives as input the triple consisting of the main noun, main verb, and the verb category, and the direct object(s) of the verb. From this information it must decide upon a conceptual configuration that will be valid by using the verb–ACT dictionary, the conceptual rules, and the conceptual semantics. Furthermore, it must make predictions as to what information is required by the conceptual construction and proceed to search the unprocessed part of the sentence for this conceptual information. The trick to this seemingly top-down part of the analysis process is that when some piece of the sentence is encountered that was not predicted, it must shift gears and process that piece as if it were at the beginning of the bottom-up process. It can then finish the process by again searching for what it needs after having disposed of what it finds.

Let us consider sentence (34):

(34) I want to go to the park with the girl.

Upon entering the verb–ACT dictionary, we find for 'want':



The verb–ACT dictionary is actually a list of potential conceptual realizates for given verbs in given sentential environments. Thus, entire conceptual structures can be formed when a triple containing a verb and its sentential environment is discovered to have a unique conceptual realizate. One more part of the process remains after the correct conceptual realizate is discovered and that is the looking up of the newly given ACT (in the verb–ACT dictionary, concepts are subscripted and words are not) in a dictionary of ACT's. This dictionary sets up the case requirements on the ACT and the semantic requirements on the cases. In addition, the actor is connected to the ACT given that conceptual semantic requirements on conceptual actor are the same as those on X (the main noun) sententially.

The entry in the ACT dictionary for 'want_1' is simply:

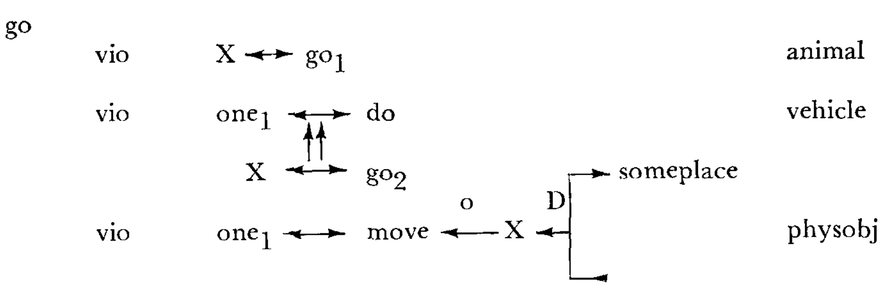
	ACT-category	actor
want_1	SACT	animal

Since we had a vs, the first realizate for 'want' is the only possible one. Thus, 'want_1' is looked up in the ACT dictionary and the conceptual construction indicated there is set up:

$$\begin{array}{c} \text{I} \leftrightarrow \text{want} \\ \uparrow \\ \leftrightarrow \end{array}$$

Since SACT's demand a conceptualization, we prepare for it by placing the $\leftrightarrow$ in the right position. The main conceptualization is established as soon as the ACT dictionary entry is found to be compatible with the information with which it was presented.

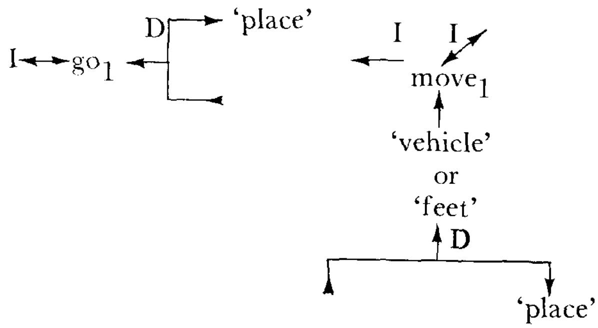
The triple for the next verb in the sentence (I, go–vio, nil) is encountered and the verb–ACT dictionary is entered, but this time with the information that a conceptualization is expected and when found that it will be placed in the awaiting dependent spot. The entry for 'go' is:



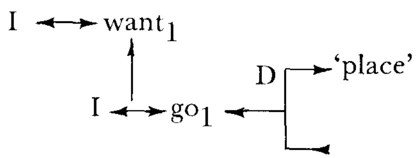
Since X here is 'I,' the first entry is correct, and the ACT dictionary for 'go_1' is entered:

ACT-cat.	actor	directive	instrumental
go_1 RACT	animal	place	(animal ↔ $move_1$ $\xleftarrow{o}$ {vehicle / feet} $\xleftarrow{D}$ place)

A conceptualization is set up including the conceptual semantic requirements of the cases whose specific concepts are unknown (written in quotes):

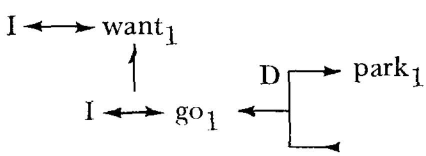


This construction is then placed in the spot that required it, so we have:



(For simplicity, we will leave the instrument out of the C-diagram until we need it.)

Now the processor goes back to the sentence to pick up what is left. It is looking for a directive case realizate primarily and an instrumental case realizate secondarily (this is because instruments are the least often realized of the cases). It finds '$\xleftarrow{\text{to}}$ park' and discovers 'to' to be a directive case indicator. A check is made to see if 'park' is a 'place.' Since it is, 'park' is put into the C-diagram, and we have:



Returning to the sentence, there is still the possibility of another directive case realizate or an instrumental realizate. The syntactic dependency '$\xleftarrow{\text{with}}$ girl' is found. 'With' is known to be an object of instrumental case realizate. So, the attempt is made to place 'girl' as object of the instrumental case. Since 'girl' is neither 'vehicle' or 'feet,' this fails. Now the expectations are exhausted and the question is where else will a 'with' construction fit? It is easy to see from examination of the following sentences that 'with' is a many ways ambiguous word:

(35) I went with a book to the park.
(36) I went to the park with the playground.
(37) I went with the girl to the park.
(38) I hit the boy with the bat.
(39) I hit the boy with the girl.
(40) I hit the boy with vengence.

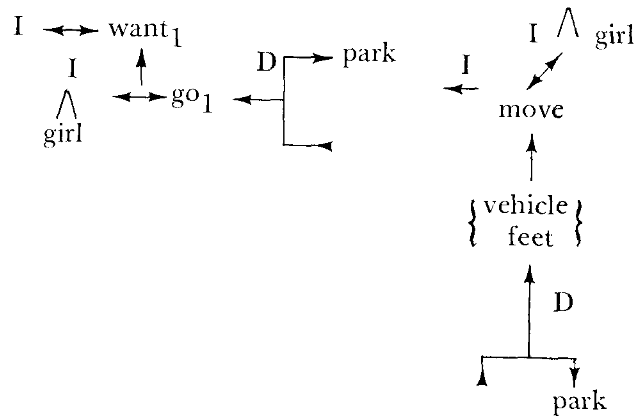
Basically there exist four conceptual realizations for 'with PP.'

(1) PP is object of instrumental case.
(2) PP is an additional actor of the conceptualization.
(3) PP is an attribute of PP immediately preceding.
(4) PP is an attribute of the actor of the conceptualization.

These potential realizates are checked for conceptual validity in roughly the order given. The 'roughly' refers to the interface with memory that the conceptual processor must deal with. That is, the conceptual processor only processes in isolation for certain things. It is often the case that the memory must be consulted in order to go on (this will be further discussed in section 8).

The first possibility has been eliminated by the conceptual semantics. But the question of whether 'park with a girl' is a recognizable unit has been begged. That is, is there, in the intermediate memory, some park that has been previously described as containing a girl? If such a unit exists it must be recognized before processing on it takes place. That is, even before 'with' is checked for possible indication of instrument. This is precisely the same process as that which must be followed for idioms. If the unit as a whole is recognized by memory as having recently occurred before, then the previously assigned conceptual realizate takes precedence over any processed ones. (We have not yet investigated the possibility of the learning of idiomatic expressions in sufficient detail to eliminate processing of anything but wholly new phrases, but it presents an interesting possibility.) Thus, a previous reference to 'the park with a girl' can interrupt the processing.

Assuming no such reference is found, then the next possibility is the main line place for 'girl' as additional actor. Except for the above-mentioned circumstance, main line concepts are searched for before the attributes of those concepts are. Thus, since 'with' indicates a possible additional actor, the conceptual semantics are checked to see if 'girl' can 'go,' i.e., if 'girl' is an 'animal.' Since it is, we are done, and we have (using the logical 'and' to indicate two actors):



If 'girl' had not fit as actor it would have been checked as a possible attribute of 'park' as would be done for (36).

The order of checking things presented here is not ad hoc. It is necessary in conceptual processing to go from generality to specificity. If 'girl' had first been checked as an attribute of 'park,' it would have been virtually impossible to eliminate it. We cannot really hope to put in a memory all the things that a 'park' can contain, simply because that list is infinite. Thus, we check conceptual dependencies according to the predictions made by the conceptual rules (as for the cases) first, by the likelihood of such a syntactic construction existing second, and lastly by the compatibility with the world model for a given concept.

5.2 *Conceptual Semantics*

So far we have made use of the idea of conceptual semantics without actually explaining it. The conceptual semantics are the delimitations on possible conceptual dependencies. That is, whereas the conceptual categories of two concepts may allow their combination in some specified way, the actual concepts may not make sense when combined. It is the job of the conceptual semantics to keep out the nonsense.

Every PP has at least one semantic category of which it is a member. These semantic categories are the same for the sentential semantics and the conceptual semantics. Their job is to reduce the amount of information necessary to produce a simplistic world model. It is important to recognize that the conceptual semantics can be wrong, that is, what is ruled out may be just what was meant. Sometimes this can be corrected by lack of choice and sometimes by the interactive situation. Consider sentence (41):

(41) The boy ate a book.

The verb–ACT dictionary entry for 'eat' is:
eat

vt	$X \leftrightarrow \text{eat}_1 \leftarrow Y$	animal	food
vi	$X \leftrightarrow \text{eat}_1 \leftarrow$	animal	

'Book' is listed as having the semantic category 'readable object,' and thus the only vt sense that exists is not satisfied. The only alternative here is go back to the syntactic processor and see if there were any ambiguous paths. Clearly there were not, so the same triple is again presented to the verb–ACT dictionary. It must be passed on to the ACT dictionary when a triple is presented for the second time and this is done. The ACT entry for 'eat,' is:

	ACT-cat	actor	object	instrument
eat_1	PACT	animal	food	$(\text{animal} \leftrightarrow \text{trans}_1 \leftarrow \text{food} \overset{R}{\leftarrow} \begin{cases} \rightarrow \text{mouth} \\ \leftarrow \end{cases})$

Here again the semantics fail to accept the input. Ordinarily the syntactic processor and verb–ACT dictionary would be asked for another interpretation. But it is already known that none is available. So, the input is accepted and this C-diagram is produced:

$$\text{boy} \overset{p}{\leftrightarrow} \text{eat}_1 \overset{o}{\leftarrow} \text{book*}$$

The asterisk is an indicator to memory to do one of two things. Either the conceptual semantics must be altered to include 'book' as 'food' or the system must understand that something very odd has occurred and react accordingly. The decision as to which to do is part of another problem and will not be discussed in this paper.

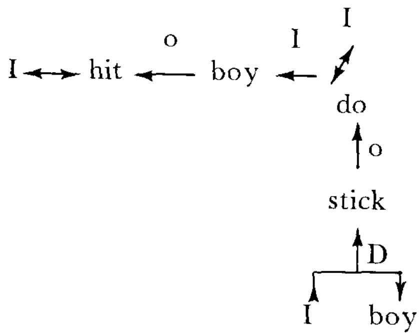
The other situation occurs in sentences of the type of (42) and (43):

(42) I hit the boy with a stick.
(43) I hit the boy with long hair.

The problem here occurs in the semantics of the ACT 'hit':

	ACT-cat	actor	object	instrumental
hit_1	PACT	human	physobj	$(\text{human} \leftrightarrow \text{do} \overset{o}{\leftarrow} \text{weapon} \overset{D}{\leftarrow} \begin{cases} \rightarrow \text{physobj} \\ \leftarrow \end{cases}$

The semantics for instrument require a 'weapon' as object, and since 'stick' is a weapon, there is no problem in the analysis of (42). However, in (43) 'hair' is not a weapon so the possibility of dependence on 'boy' is tried. It is found that 'boy' is 'animal' and 'hair' is a 'body part.' The information that animals possess body parts is part of the conceptual semantics for animals and thus this construction is all right. The two analyses are:



(43)

$$\begin{array}{c} I \leftrightarrow hit \overset{o}{\leftarrow} boy \\ \uparrow POSS \\ hair \\ \uparrow \\ long \end{array}$$

The 'do' in (42) can then be found to be either 'throw,' or 'swing,' by searching for ACT's that require directive case and weapons as object. That problem will not be discussed here. What is of interest is that either of these analyses could be wrong. That is, the boy could have been carrying a stick in (42) and in (43) he could have actually been hit with long hair.

There is no way of always being correct in natural language understanding simply because natural language is full of ambiguity. What we strive for is the right guesses for the right reasons. If we then fail, we can correct ourselves. Were either of the alternate interpretations the intended ones in (42) or (43) we would not have wanted to change our analysis procedure. The only change that we would want to make, upon finding a mistake to have been made would be to add to the meaning of 'hair' that it is a potential weapon. Such category learning would be however a thing that required reinforcement. That is, if such a use of hair did not turn up for a long while, the new category would be forgotten.

It can be seen then that the conceptual semantics are weighted with respect to the listing of the most usual occurrences first. In addition, the conceptual semantics are hierarchic. That is, food, readable object and weapon are all physical objects as are animals. The hierachy is not the usual type however. For example, 'human institution' is not in the hierachy, yet it is a semantic category. We are in the process of replacing the hierarchic system with a feature system, so we shall not dwell on the semantic categories being used here. A feature system offers the latitude of referring to the actual features that are necessary for a category (i.e., a weapon is above all 'rigid' and 'holdable') so that one can gauge the effectiveness of things performing in certain slots (i.e., 'hair' is not 'rigid' and thus will not serve well as an instrument of 'hit' even if it is so used). This system has been worked out by Sylvia Weber Russell but is not documented yet (except see Weber (1971)).

The remaining question is how do the conceptual semantics differ from the sentential semantics? Although they seem quite similar that is only because often the subject and object of a sentence perform the same function in a conceptualization. But, the job of the sentential semantics is basically to enable the conceptual processor to determine which syntactic construction was found. The sentential semantics serve to more clearly spell out the sentential environment and the selection is made by choosing the most specific environment (or lowest semantic category in the hierarchy) in the verb–ACT dictionary and selecting the conceptual realizate for that environment.

The conceptual semantics have the job of arranging the given concepts so that they make sense with respect to the world model. Thus, the conceptual semantics are interlingual, i.e., the same no matter what language you started with. They represent the rules for organizing the world conceptually. The sentential semantics have to do with the particular language only. Thus, sententially it is all right for 'man' to be the actor of 'fly' because you can say this in English. Conceptually, 'men' have yet to 'fly' as such, so the conceptual semantics would find this invalid. But actually, the finding of an invalidity rarely occurs. The verb–ACT dictionary would have found 'go,' for the verb 'fly' and the conceptual semantics for 'go,' would be those checked.

Thus, the conceptual analysis process is concerned with finding what is valid as a conceptual realizate for a sentential part. The conceptual level is interlingual, the sentential level and the list of realizations of sentential pieces are part of a given language.

5.3 *Syntactic Ambiguity*

One of the biggest problems that has plagued computational linguists who build parsing systems is that of syntactic ambiguity. The traditional approach has been to find all the possible syntactic analyses for a given sentence. Kuno and Oettinger's (1963) 'Time flies like an arrow' is famous in this regard.

Such an approach disregards the problem of simulating human understanding. Certainly humans do not find all the syntactic interpretations of a sentence before they consider the meaning of the sentence. Human frequently fail to see alternative interpretations of a sentence even if prompted that a second interpretation exists. On the other hand, it can be shown that humans try wrong paths in understanding and are forced to back up and try another analysis.

Whereas it is possible to have a conceptual analyzer use rules of syntactic structure to produce conceptual dependency diagrams, it is not really advisable. Initial versions of the computer implementation of conceptual dependency theory, (Schank & Tesler (1969)) simply reversed the realization rules that mapped conceptual structures into linguistic ones. The result of parsing by such syntactic rules was that syntactic ambiguity was resolved in an ad hoc manner. That is, if a sentence is two ways ambiguous there exist two different mapping rules that map the two conceptual structures into the one sentential structure. In analysis, the problem of choosing which realization rule to try first could only be decided randomly. Decisions of which rule to apply in a given situation can be shown to be not random. Since our computer system is intended to mimic a human engaged in the same task, it is important for us to find an analysis procedure that at least does what we know a human does even if we cannot verify all of the things it does in this way.

Consider sentence (44):

(44) I saw the Grand Canyon flying to New York.

This sentence is interesting because of what would be considered its poor syntactic structure. Because the instantaneous image of the 'Grand Canyon flying' is called into the mind of the hearer, often this sentence evokes a chuckle when told to an audience. The fact is that most people attempt to attach 'fly' to 'Grand Canyon' fail, and then find the correct analysis of this sentence. We require that our processing system will do the same.

The syntactic processor passes the triple (I, see-vt, Grand Canyon) to the conceptual processor when it encounters this sentence. The verb-ACT dictionary entry for 'see' is:

see

$$
\begin{array}{llll}
\text{vi} & X \leftrightarrow \text{understand}_1 & \text{human} & \\
 & \quad\uparrow & & \\
 & \quad\leftrightarrow & & \\
\text{vs} & X \leftrightarrow \text{see}_1 \overset{o}{\leftarrow} \swarrow\!\!\nearrow & \text{animal} & \\
\text{vt} & X \leftrightarrow \text{see}_1 \overset{o}{\leftarrow} Y & \text{animal} & \text{physobj}
\end{array}
$$

The vt sense outputs the given structure for the ACT see_1. The ACT 'see_1' is given as follows:

$$
\begin{array}{lllll}
 & \text{ACT-cat} & \text{actor} & \text{object} & \text{recipient} \\
\text{see}_1 & \text{CACT} & \text{animal} & \left\{\begin{array}{l}\text{physobj} \\ \text{conceptualization}\end{array}\right\} & \text{animal}
\end{array}
$$

$$
\text{instrument}
$$

$$
\left(\text{animal} \leftrightarrow \text{look-at}_1 \overset{o}{\leftarrow} \left\{\begin{array}{l}\text{physobj} \\ \text{conceptualization}\end{array}\right\}\right)
$$

Thus, the following conceptual structure is found:

$$
\begin{array}{l}
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad I \\
I \leftrightarrow \text{see}_1 \overset{o}{\leftarrow} \text{Grand Canyon} \overset{I}{\leftarrow} \swarrow\!\!\nearrow \\
\qquad\qquad\qquad\qquad\qquad\qquad\quad \text{look-at}_1 \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad \uparrow o \\
\qquad\qquad\qquad\qquad\qquad\qquad \text{Grand Canyon}
\end{array}
$$

The next word in the sentence is 'flying.' Since 'flying' is realized by an ACT only, it is the candidate for the verb part of a new triple to be sent up to the conceptual processor. Since a prepositional phrase beginning with 'to' follows, it is a vio verb. However the problem exists of what the subject of the triple for 'flying' is. This problem is not divorced from the problem of where to attach the new conceptualization that will be formed from this triple. Previously, when we entered the conceptual processor with a triple, there was a place waiting for it in the old conceptualization or else there was no old conceptualization, in which case there was no problem. But here we are within a sentence and we already have all the main line elements of a conceptualization filled in.

These two problems have the same basis for solution. There is no place in the right side of the conceptualization to place a new conceptualization. But, there is also no immediate candidate for the position of subject of the new conceptualization. The rule in situations such as this is always the same. If there is no PP available as subject, the last PP which was placed in the conceptualization from the sentence is the prime candidate. This takes care of the problem of the entering triple for the conceptual processor, but still does not explicate where the new conceptualization is to be placed. The actual problem is where to place the 'fly' construction since Grand Canyon has already been placed in the old conceptualization. The conceptual rules are checked to find a place for connecting 'fly' to something already in the conceptualization. Again, 'Grand Canyon' is the prime candidate for attaching 'fly' since it was the last concept placed in the conceptualization. The conceptual rule PP is found and now it is clear where such a connection would go.

$$\begin{array}{c} \text{PP} \\ \uparrow\downarrow \\ \text{ACT} \end{array}$$

So the verb–ACT dictionary is entered with the triple (Grand Canyon, fly–vio, nil). The entry for fly is:

fly

vio	$X \leftrightarrow fly_1$	bird plane insect	
vt	$\begin{array}{c} X \leftrightarrow do \\ \uparrow\uparrow \\ Y \leftrightarrow fly_1 \end{array}$	human	plane
vio	$X \leftrightarrow go_1 \; \begin{array}{c} \text{plane} \\ \text{I} \\ \leftarrow\!\swarrow\!\!\!\nearrow \\ fly_1 \end{array}$	human	

The vio entry for 'fly' is checked, but the sentential semantics does not allow places to function as subject of the vio- 'fly.' Thus, the triple is rejected and sent back to the syntactic processor. In other words, the attempt has been made to connect 'fly' to 'Grand Canyon' in a construction that could be roughly paraphrasable as (45):

(45) I saw the Grand Canyon which was flying to N. Y.

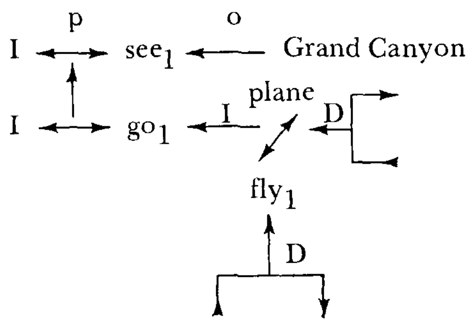
Something else must be tried. Again we are faced with the problem of finding a suitable PP for subject and a place to put the new conceptualization. It is important to bear in mind that, although conceptual information is being used, it is the syntactic processor that is operating here in an interface with the conceptual processor. I mention this because decisions that are made at this point are rules of English that are conceptually based. They are not interlingual rules.

The only other subject that is available for the triple with 'fly' is 'I' because it is the next to most recent PP that was processed (it is also the only other PP that was processed). Now we could apply the same reasoning that was used for Grand Canyon with respect to where to attach the conceptualization that will be found for this triple. However, there is a rule of English for operating on conceptual structures that states that it is not permissable to cross the two-way dependency link from right to left after the two-way link that has been placed in the

C-diagram. If a PP is needed from the left side of the conceptualization it must be the subject of a time conceptualization that modifies the original conceptualization. This is a rule of English and has no universal validity.

Thus, we can enter the verb–ACT dictionary with the new triple (I, fly–vio, nil) and we have a place to put it in the C-diagram, namely, as the time of the first conceptualization.

This time the verb–ACT dictionary accepts the triple, and consulting the ACT dictionary sets up the directive case, so we now have:



Again 'to' is found to indicate directive case and 'New York' is placed in the 'to' part of both directive cases in the C-diagram.

A more traditional example of syntactic ambiguity is given by the classic sentence (46):

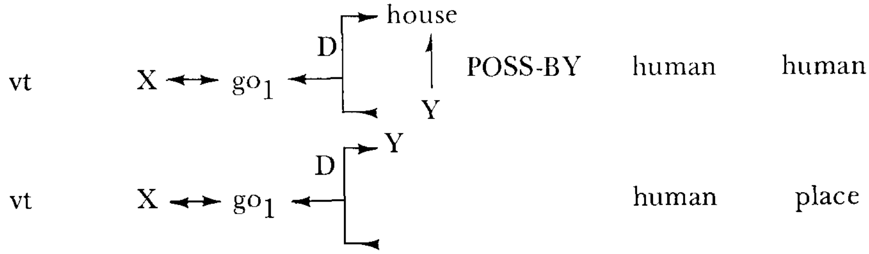
(46) Visiting relatives can be a nuisance.

This sentence has three possible interpretations roughly paraphrased by (47), (48) and (49):

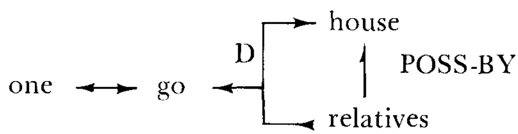
(47) Relatives who visit can be a nuisance.
(48) To visit relatives is a nuisance.
(49) When relatives visit, it can be a nuisance.

I have stated previously that whereas we want to be able to represent the three different meanings of sentences like this conceptually, it does not necessarily follow that a conceptual analyzer should find all three meanings at once. Rather, we want to find the most likely first and so on. Since all speakers of English don't find the same meanings first, we are dealing with an individual model. That is, we want to naturally find one meaning and then another, without claiming that this is the way all speakers operate, but stating that it might be the way many of them operate.

Let us see how this sentence is processed. The syntactic processor is immediately faced with the ambiguity decision because the triple created by 'visit' can have the noun following it as either subject or object when there is no other normal modifier. Often syntactic agreement cleans this up, but for 'can' this doesn't work. If we choose the object slot for the noun, 'relatives' we will get (48). Thus, we have the triple (nil, visit–vt, relatives). We find for 'visit':



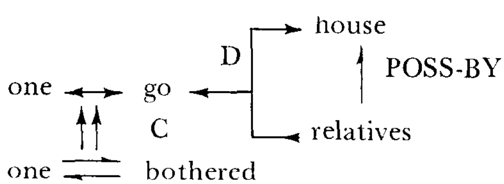
Since the subject is nil, we assume that it was unstated and that the semantic requirements on that slot conceptually are correct. 'Relatives' are human so we select the first sense. After consulting the ACT dictionary we have:



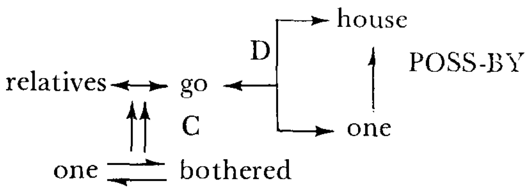
The next phrase is handled by the syntactic processor as a conditional predication about this conceptualization. 'Nuisance' is looked up in the dictionary and turns out not to be a PA, but rather it represents a larger conceptual structure, namely:

$$\begin{array}{c} \text{one} \leftrightarrow \text{do} \\ \uparrow\uparrow \\ \text{one} \rightleftarrows \text{bothered} \end{array}$$

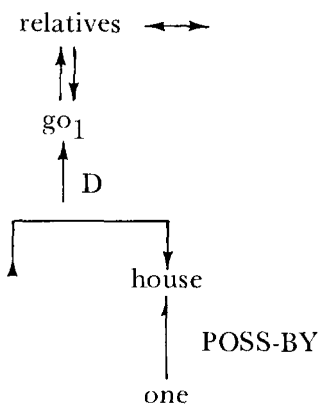
'Bothered' is a mental state PA. Thus, we have a command to the conceptual processor to combine these two structures. Since the previous conceptualization is an example of 'one ↔ do' and this is all one sentence, adding the conditional we have:



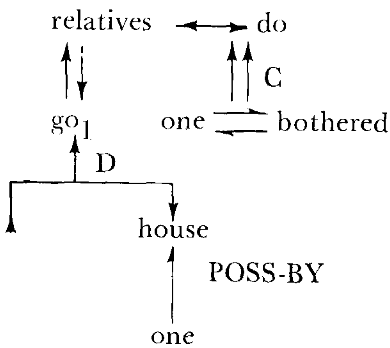
It is easy to see that (49) would be analyzed nearly the same way but the initial triple would have reversed subject and object. Thus, the result would be:



The third interpretation (47) comes from the nature of the relationship between PP's and ACT's. Basically there are three conceptual rules that deal directly with PP and ACT: PP $\leftrightarrow$ ACT, ACT $\xleftarrow{o}$ PP, and $\begin{array}{c}\text{PP.}\\ \uparrow\downarrow\\ \text{ACT}\end{array}$ The first two interpretations utilized the first two conceptual rules. The third conceptual rule can also be realized in English as 'V-ing N.' When this syntactic interpretation is tried, the same triple as occurred for (49), (relatives, visit–vt, nil) is obtained. The same processing occurs, only this time the two-way link *is not* $\leftrightarrow$ but $\uparrow\downarrow$, *indicating* that another predication will be made about the main PP. Thus, we have:



When 'can be a nuisance' is encountered it is treated the same as before, that is, causally dependent on the $\leftrightarrow$. We still need an ACT for relatives, but there is no more sentence, so we insert the dummy 'do':



This conceptualization represents that the relatives who are visiting can bother you by doing something other than visiting. For example, they might be a nuisance because they eat a lot. This interpretation of this sentence is rarely found in linguist's discussion of this sentence, but, it would seem to me to be the most valid interpretation. That is, one is tempted to inquire after hearing this sentence as to what the relatives do that is so bothersome. That is expressed by the last C-diagram. We would thus, orient a computer analyzer to look for this interpretation first.

5.4 *Semantic Ambiguity*

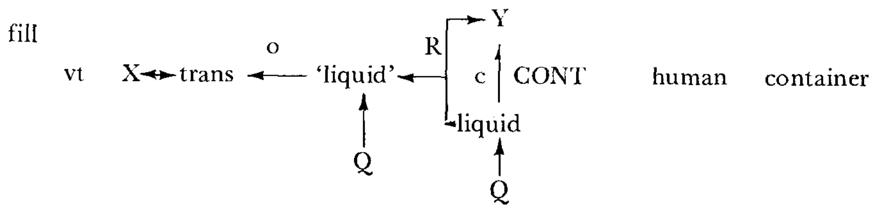
A classic example of semantic ambiguity is expressed in sentence (50):

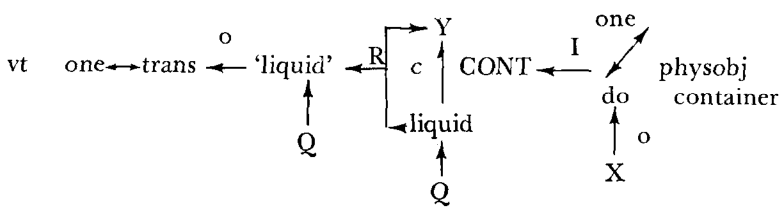
(50) The old man's glasses were filled with sherry.

From the point of view of analysis, this sentence is different than others presented since it is a passive. No rules were given for passive constructions in the section on the syntactic processor, but a simple rule is that when a passive particle (e.g., 'were') followed by a verb in past tense, is found then the main noun that was found is placed in the object slot of the triple. If a 'by N' is found following the verb then it is the subject, otherwise there is no subject.

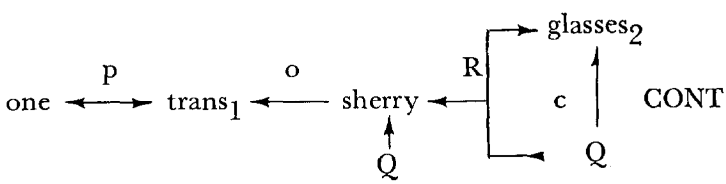
In this sentence, the syntactic dependencies between 'old,' 'man's,' and 'glasses' are established with 'glasses' at the head. The passive is encountered, turned around, and the entering triple is (nil, fill–vt, glasses). When 'glasses' was looked up in the dictionary it was found to be a noun. However, conceptually, 'glasses' is semantically ambiguous. That is, the word 'glasses' represents two different concepts, 'drinking glasses,' and 'spectacles.' The ambiguity is carried along syntactically until it can be resolved conceptually.

The entering triple calls 'fill' from the verb-ACT dictionary:





The C-diagram for the first sense of 'fill' indicates that this means that a person will put an amount of liquid, Q, into a container that can contain at most amount Q of liquid. Since the semantic requirements on the sentential object need a 'container,' here is where the choice between the different senses of 'glasses' is made. 'Glasses_2' whose semantic category is container is chosen. Here, the 'with sherry' construction looks like a candidate for instrument. But once the conceptual realization for 'fill' has been selected, the conceptual processor switches to a top-down mode allowing for it to look for what it needs. It most clearly needs a 'liquid' as object and this is what is searched for. Since 'sherry' is the next PP to be treated, and is a liquid, it is immediately placed in the C-diagram. Here again, we see that all conceptual cases are not equal in their demand to be filled. Object is always first if it is required and instrument is always last. Since the subject is nil, the final C-diagram is:



The most interesting aspect of this sentence, however, has not yet been discussed. Namely, it is nearly always the case that when English speakers hear this sentence they select 'glasses_1' first meaning spectacles, and then revise their choice after hearing 'fill.' This is certainly not what we did here, and this is a problem for a system that is supposed to be a simulation of human understanding.

It is interesting to consider what the reasons might be for the common choice of the spectacle sense of glasses in this sentence. We are assuming here that the underlying conceptual system is image-like in nature. That is, that each concept is processed with respect to the whole picture that is created. In other words, when part of a picture is ascertained, there are some valid predictions that can be made about the nature of what will follow. These predictions are made from the organization of the parts of the conceptual whole (conceptual rules); from the requirements on the whole of a given concept (conceptual semantics); and from likely relationships that exist between items in the world that are simply a function of experience (this can include all linguistic rules, for example, syntactic expectation). It is this latter type that is being used in this example. Speakers of English know that humans tend to possess certain types of things in the sense that is commonly referred to. That is, whereas, a man could have either type of glasses as his legal possession, we tend to speak about his possessions which are pseudoinalienable, i.e., his car, his house, and his clothing. So, when a possessive occurs in English, we can predict that the possessive refers to things that we would tend to associate with that human. If, for example, the phrase had been 'the bartender's glasses' we would likely have chosen the container, or in any event the choice would be somewhat more difficult. But no matter what, we would have chosen something. That is to say, understanders do not carry along alternative parses of a sentence or alternative senses of a word. Rather, they select one, and if they are wrong, they go back. Their selection is based on context and the context in this case is the prediction made by possession. We are not, in this system, at a point where we can be making all the predictions that a human makes in a given situation. A human is making a great number of predictions at every point in an analysis. Some of those predictions are crucial and we will speak more about those that we have heretofore ignored in section 7. But many of those predictions are wrong or irrelevant. So, in our system, we cannot really bother making the prediction about glasses. But we can select one sense of glasses, based upon the frequency with which it is used. If that selection is shown to be wrong by the sentential semantics, we go back and try the other. In this example then, we would have selected 'glasses,' based on a frequency count of our own experience, and then have gone back and selected the container sense of glasses. It is important to point out that this theoretical procedure is correct in that alternative senses of a word are not carried along. However, even though the correct result is obtained, the actual procedure employed is not based on human processes. We thus consider this procedure to be only partly theoretically valid. At such time that contextual prediction can be effected we shall implement that. Right now, most predictions of this kind would be useless, which seems to point out that such a procedure should be avoided until a tight theory regarding this problem can be worked out.

5.5 *Syntactic Similarity*

Consider sentences (51) and (52):

(51) John's love of Mary was beautiful.
(52) John's can of beans was edible.

While these two sentences conform to identical syntactic patterns, they are quite different conceptually. We would expect then, that they should be processed in syntactically identical fashion while being processed quite differently on the conceptual level.

The main verb in each of these sentences is 'be.' Conceptually, however, there really is no predicated action here and consequently the verb–ACT dictionary is never called. There is a syntactic rule that states that if a 'be' particle is discovered, then if an adjective or noun immediately follows, the verb–ACT dictionary is not consulted. Instead a special attributive conceptualization is set up (denoted by $\rightleftarrows$ in conceptual dependency). This attributive conceptualization requires a PP on the left side of the link and either a PA or PP on the right side. Consequently, what is passed to the conceptual processor is a double consisting of the main noun found by the same procedure as before and the predicated noun or adjective.

For (51) and (52) then all that is required by the conceptual processor is the marking of the syntactic dependencies, and the double (main noun, $\left\{\begin{matrix}\text{adjective}\\\text{noun}\end{matrix}\right\}$). The syntactic rules given above mark 'love' as the main noun in (51) and 'can' as the main noun in (52). 'Can,' in English, is syntactically ambiguous. That is, 'can' can be a verb, a noun, or an auxiliary. It is not an auxiliary because there is no verb following. It is necessary for the syntactic processor to predict a verb when a potential auxiliary has been spotted. This prediction fails to materialize. However, another interesting problem crops up in (52). It is possible to eliminate the verb possibility for 'can' because of syntactic placement. That is, after encountering 'John's' the prediction (as made implicitly in the syntactic rules) is that a noun will follow. Both 'can' and 'canning,' in this syntactic slot must be considered to be nouns since that is the only thing predicted by the syntax. So, no matter what, the main noun configuration is:

$$\begin{array}{ccc} & \text{can} & \\ \text{possession} & \uparrow\uparrow & \text{of} \\ \text{John} & & \text{beans} \end{array}$$

But, conceptually 'can' is also ambiguous. Not surprisingly, the fact that 'can' can take these two syntactic forms is reflective of the fact that sentential 'can' is conceptually both the PP 'can' (the object) and the ACT complex which means 'can' (to place in a can). Because there is no '-ing' ending, the 'can' here is a PP.

This ambiguity does not exist conceptually in (6). That is, 'love' is an action no matter what syntactic form it comes in. But, here 'love' is processed as a noun in the same way as 'can' and for the same reasons. So we have:

$$\begin{array}{ccc} & \text{love} & \\ \text{possession} & \uparrow\uparrow & \text{of} \\ \text{John's} & & \text{Mary} \end{array}$$

But, it is important to note, that before the syntactic processing is complete, all syntactic–conceptual interface problems must have been met. Since in (51) 'love' is realized as an ACT, a triple is formed for entering the verb–ACT dictionary that has 'John' as Subject and 'Mary' as object. The triple (John, love, Mary) is then passed on to the verb–ACT dictionary.

It is interesting to notice here, that it is only the very superficial aspects of these two sentences that are similar. It is for that reason we expect the processing of the two sentences to bear only little similarity. From this point in the analysis process, all similarity is lost since their superficial similarity has no meaning to the conceptual system. The point made earlier about this should be emphasized. While syntax is useful for finding the parts of the sentence that are to be conceptually processed, of itself it has no value. A conceptual analyzer uses the results of certain syntactic observations based on the success or failure of syntactic predictions. The syntactic rules are simply heuristics for finding things. We make the claim that this is all that need be done in an analysis.

The verb–ACT dictionary processes the triple for (51) into:

$$\text{John} \overset{p}{\leftrightarrow} \text{love} \overset{o}{\leftarrow} \text{Mary}$$

since love is an EACT (takes object only). Now, the predication marked by 'was PA' causes an attributable dependency to be established with the entire conceptualization as subject. Since 'beautiful' is a PA, and thus fits the conceptual rule requirements for attributive two-way dependency, the final analysis is:

$$\begin{array}{c} \text{John} \quad {}^{p} \\ {}^{p} \; \rightleftarrows \quad \rightleftarrows \text{ beautiful} \\ \text{love} \\ \uparrow o \\ \text{Mary} \end{array}$$

Sentence (52) is a bit more interesting. We have the syntactic dependency group:

$$\begin{array}{c} \text{can} \\ \text{Poss} \uparrow\uparrow \text{of} \\ \text{John} \quad \text{beans} \end{array}$$

but, we have no entering triple. Thus, we have, a PP, 'can' and the predication 'was edible.' Looking up edible we find that it is not a PA or a PP. Therefore, the prediction that an attributive two-way dependency was present fails. 'Edible' is in the dictionary as follows:

$$\text{`animal'} \overset{c}{\leftrightarrow} \text{eat} \overset{o}{\leftarrow} \text{`food'}$$

This definition means that 'edible' represents a conceptual construction about the possibility of eating something which is assumed to be a food. 'Not edible' would indicate that the object of the action is not a 'food.' In other words, this is at the same time a definition of the semantic category 'food.' (The quotation marks indicate realizable semantic categories.)

Thus, we now have a conceptualization, given by the definition of 'edible.' We are faced now with the problem of filling in the unrealized slots in this conceptualization. We begin a search for the cases and look for a 'food.' The only place that there is to look at all is the syntactic dependency complex given above. The head of that construction is 'can' and 'can' is not a 'food.' So we must search the dependents and here we find 'beans' is a food. We thus have:

$$\text{`animal'} \overset{c}{\leftrightarrow} \text{eat} \overset{o}{\leftarrow} \text{beans}$$

We must now conceptually realize all the elements that are part of the syntactic complex that 'beans' is in. 'Beans' is related to 'can' by 'of' and we find that this is a containment relation (this is handled by a program that is not described here, see Weber (1971)). But, if 'can' is used here, 'John's' must be used also since it is related to can as a modifier of possession. The final C-diagram is then:

$$\begin{array}{l} \text{one} \overset{c}{\leftrightarrow} \text{eat} \overset{o}{\leftarrow} \text{beans} \\ \qquad\qquad\qquad\quad \uparrow \text{CONT-BY} \\ \qquad\qquad\qquad\quad \text{can} \\ \qquad\qquad\qquad\quad \uparrow \text{POSS-BY} \\ \qquad\qquad\qquad\quad \text{John} \end{array}$$

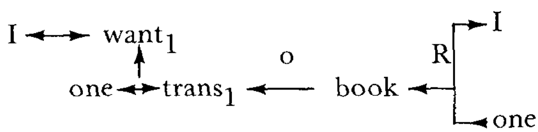
Now it is possible that this was not what was meant here. It could be that, the 'can' was being referred to as 'edible' as was predicted by the syntax and rejected by the semantics. Here again, we are making no effort to guess what could possibly have been meant but rather what was most probably meant. We can always correct any mistake in an interactive situation, and we can alter our probabilities.

It now remains to discuss sentences (10), (11), and (12) mentioned earlier:

(10) I want a book.
(11) I want to get a book.
(12) I want to have a book.

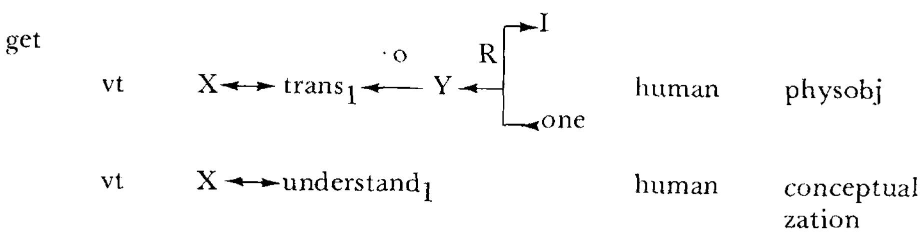
The assumption here is that these sentences all mean the same thing. While it can be argued that they do not because of varying contexts or connotations, we assume the context where the conceptual content of all three sentences is the same and disregard for the moment implications.

Using the verb–ACT definition of 'want' given in section 5.1, we see that for the vt sense that exists in (10), an entire structure is the realizate of the idea of 'want a physobj,' namely, for (10):

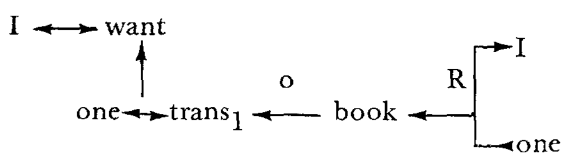


The idea here is that what is wanted is that somebody give this book to the subject in any unspecified manner.

The same structure can be realized for (11) given that this is the vs sense of want and that the verb–ACT entry for 'get' is:

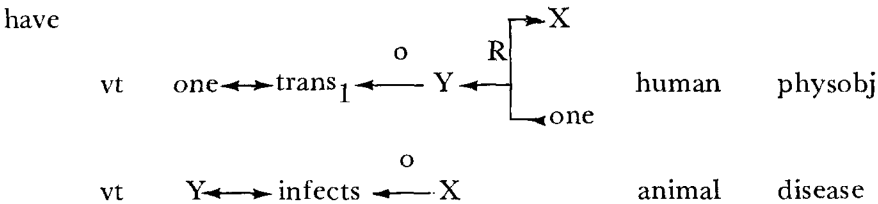


Thus, given that the SACT 'want' requires a conceptualization and that 'book' is a physobj, we have.

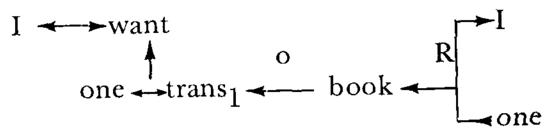


which is the same as the above conceptual construction.

We have not, until this point, discussed the verb 'to have.' Since 'have' in its alienable sense represents the result of a conceptualization that involves acquiring the object in the first place, we consider 'have' to be an instance of 'trans.' After the 'trans' has been completed, 'have' can be assumed to be an implication derived from the 'trans' about a relationship between two PP's. But it is important to understand that 'have' presupposes this 'trans' relationship for alienable possession. If such is the presupposition then it is part of the conceptual content and therefore must be represented in the conceptual diagram. The verb–ACT entry for 'have' is:



Thus, this is virtually the same as the previous example and the SACT, 'want,' requires the first conceptualization:



There exists, at the Stanford Artificial Intelligence Project, a computer program that will do all that has been described so far in this paper. Of course, all of the details of the conceptual processing that takes place in that program have not been described here, but the actual conceptual analyzer works roughly in the above manner.

6. CONCEPTUAL DEPENDENCY REVIEWED

It is perhaps reasonable to inquire at this point about the nature of conceptual dependency.

We can consider that a theory such as conceptual dependency is doing its job based upon the following things:

(a) *Predictive ability.* The theory must predict accurately what kinds of conceptual items have not been explicitly mentioned from the sentence or group of sentences being processed. This predictive ability as to type (e.g., conceptual or semantic category), allows for two things. First, it furthers the analysis process by directing the search through data for the information that is needed, or by formulating inquiries as to the needed information when such inquiries are called for. Second, such predictions form the basis of the system's interaction with memory. For example, certain kinds of information are left out of a sentence largely because the information is redundant within context. It is necessary to predict the existence of this redundant information in the first place and then to find its appropriate manifestation in context. (We will explore this in more detail in section 7.)

(b). *Responses.* The conceptual dependency networks must form the basis for the memory structure by treating certain constructions as commands to the memory. For example, 'trans' is a command to the memory to erase the object from the possession of the donor and place it in possession of the recipient. Here erasure is not to be considered the same as forgetting. If the donor were previously unknown, such a person must be created with the appropriate possession and then the possession must be erased, i.e., erased with a trace of the former presence still around. Similarly 'go' is a command in that it changes the location of the subject from one spot to another in memory. All IACT's change the state of the subject in memory as to form of existence, e.g., now dead, or now asleep. In a sense IACT's are like PA's in that they change an attribute of the subject in memory. Other conceptualizations are commands to add a belief to the belief structure of the hearer or to the hearer's conception of the belief structure of the speaker. Any predication, that is, new information or relationships that are being introduced go into a file that states 'this speaker believes that. . . .' Such information can be operated on to become a belief of the hearer in the right circumstances. (See Colby & Smith (1969) for a computer implementation of this.)

In turn, the internal responses generate external responses based upon the coherence of the new conceptualization with previous memory information. We have just begun to work on this and thus leave the response aspect of the problem for the time being.

(c) *Paraphrase.* If two sentences that express the same conceptual content are analyzed into the same conceptual structure we have done the job that we have been attempting. As long as the paraphrase relation always holds and no input utterance that is agreed to be meaningful cannot find a conceptual representation, the major aspect of the theory has been realized.

(d) *Computer programs.* If (c) holds true, and the procedure has been explicitly stated clearly enough, it should be in principle possible to create a computer program to do these analyses. This would, of course, be of immense usefulness. It may be necessary to modify traditional computer programming approaches in order to accomplish the task set out here. The bottom-up parsing technique must be switched to a top-down one and back again, in this system. This may well require a nondeterministic algorithm of the kind of which Floyd (1967) spoke. Such an attempt is currently being worked out at Stanford.

(e) *Psychological models.* Conceptual dependency makes some psychological claims that have yet to be tested. It states that the basis for language is an interlingual conceptual structure; that there exists a network of concepts and relations of which one relation is the central core ($\leftrightarrow$); that an action is made up of from zero to three principal dependents one of which is itself another action construction, and that it is, therefore, virtually impossible to succinctly describe an action in words; that these dependents are retrievable through the ACT and that it is probably not possible to think of an actor and a case dependent without somehow thinking of the action that links them. Furthermore, the claim is made, that while some dependents are retrievable through each other (object and recipient for example) this is because of an immediate implication that is generated by their simultaneous existence and is, thus, an item retrieved from memory that is derived from the conceptualization. It claims that, while the case dependents are retrievable through the ACT, many things are retrievable as relations connected to the core of the conceptualization ($\leftrightarrow$) or the simultaneous occurrence of an actor and action. Thus, time and location of a conceptualization should function more like causals than like cases. And it claims that conceptualizations relate to other conceptualizations as either subsuming them (as instruments) or causing them in a specified way.

These remarks are intended only to make clear some of what we are claiming to the psychologist. We anxiously await results of tests that could prove such claims to be in error.

7. ANALYSIS OF INTENTION

7.1 *Expectations*

We have been, so far in this paper, treating sentences as if they existed in isolation, a procedure not uncommon in most discussions by linguists. But, people do not understand sentences in isolation and it is necessary to recognize this in any theory of understanding. It is, however, possible to extend some of the techniques of prediction described so far in this paper to the problem of predicting more than just syntactic or conceptual types that are likely to occur.

There are also predictions that can be made that are based on criteria other than that directly derivable from the stratified linguistic system that comprises conceptual dependency theory. Consider the following situation and conversation:

John meets his friend Fred on the street. Fred is holding a knife. John is angry because his wife Mary has yelled at him.

Fred: Hi.
John: What are you doing with that knife?
Fred: Thought I'd teach the kids to play mumbletypeg.
John: I could use a knife right now. (agitated tone)
Fred: What's the matter?
John: Damn Mary, always on my back. She'll be sorry.
Fred: I don't think a knife will help you.
John: You're just on her side. I think I ought to . . . .

Now what can Fred expect that he will hear next? There are at least six distinct types of information with which we can answer this question. Sententially, Fred expects a verb. Conceptually, since 'ought' is an SACT, a conceptualization is expected. But we can also make predictions based on context. According to the context, there are only a certain set of concepts which will fit into the needed conceptualization such that the conceptualization makes sense in context. We most certainly would be surprised if the next piece of information would be 'I think I ought to have fish for dinner.' It is knowing what we do and do not expect at any point in any analysis which allows us to be surprised, shocked, or whatever other emotional attribute by a piece of information. You are not able to be surprised if you don't anticipate and it is, therefore, necessary for a system such as this to anticipate.

What we anticipate here are the following four types of statements based on their contextual likelihood: (1) hurt someone, (2) end relationship with somebody, (3) go to someplace, and (4) emote.

These are classes of actions. We don't know which sentential form 'hurt,' 'go,' or 'emote' will take but we can estimate the likelihood of the class on the basis of the conceptual category and the prevailing semantic categories that have been used in context. All of these above actions are predicted on the strength of their likely consequences. That is, a desired consequence is known (John feel better) and the above actions would each lead to John's feeling better, but each in a different way.

A fourth type of expectation or prediction is conversational. That is, people talk for a reason, usually to communicate something or to gain some desired effect in the hearer. Here, it is either to arouse sympathy or to inform about something he is about to do. But the use of ought implies he might not do this, so that his probable reason in making this statement has to do with the effect which it will create on the hearer. Thus, we can predict what kind of effect is intended to be made by the speaker and then expect certain types of utterances.

A fifth kind of expectation information has to do with a world view of the situation based on his own individual memory model. Thus, if he knows John to be a convicted murderer, his expectation of John's completion of this sentence ought to be different from his expectation if John were an avowed pacifist.

A sixth type of expectation is based on a memory structure that is common to the cultural norm rather than the particular language or particular individual. The results of this kind of expectation have to do with the options that Fred can take as a result of the expected input from John. That is, the conversation is heading toward death (this idea will be explained below) and Fred's expectation of this can avert the situation by appropriate action, either physical informative conversational or emotional conversational. It is his expectation that decides the appropriate action.

Basically then, we must recognize that any complete processing system for a natural language utterance takes place within a context that is extremely complex because there are humans in the conversation. Each has a complex memory to begin with and is now in a new complex situation. Part of this problem is being able to anticipate. The anticipation with respect to linguistic processing then is a function of a set of different types of expectations at any point in the analysis. These expectations are of various kinds and aid the basic analysis capability tremendously. Our predictions are of the following type:

(1) sentential—what syntactic category is likely to occur
(2) conceptual—what conceptual element is needed at this point in the parse to help complete the C-diagram
(3) contextual—what information type fits in the structure created for information (kind of C-diagram) at this point in the overall parse of the conversation
(4) conversational—similar to (3) but 'what answers a question' or responds to the input in any of the ways mentioned on the previous page would fit here
(5) world view—what we expect of the substance of the information rather than its type, dependent on the presuppositions and biases of the hearer
(6) memory structure—total correlation of this memory model. The process of 'living' is important here, i.e., is this statement tending to describe information or events that will 'satiate' or 'hunger.' That is, 'Am I pleased by this?'

The first two expectation types are an intrinsic part of the sentential and conceptual levels, respectively. Contextual expectations are part of the conceptualization–memory interface in that they aid the formation of complete conceptualizations by using information from memory. The other three are a part of the intermediate memory structure that deals with input and decides what to do with it with respect to generating internal and external responses.

7.2 *Functional Associations*

The simplest type of prediction that can be made as to the nature of a missing action or object in a conceptualization is from the function of that item. Consider sentence (53);

(53) I like books

$$\text{I} \leftrightarrow \text{like} \overset{o}{\leftarrow} \text{books}$$

This analysis is not an allowable construction conceptually because the ACT 'like' is of two possible conceptual types, each with its own semantic restriction. The EACT sense of 'like' (like_1) allows conceptual objects but requires that these objects be of the class 'animal.' The other sense of 'like' (like_2) is conceptually an SACT which requires an entire conceptualization as object. Since a conceptualization must have an actor and an ACT and we are thus faced with the problem of uncovering these in the analysis of the above sentence. We have then:

$$\begin{array}{ccc} \text{I} & \leftrightarrow & \text{like}_2 \\ & & \uparrow \\ & & \leftrightarrow \end{array}$$

We know that 'books' is part of this conceptualization and by the heuristics of the conceptual dependency system we know that 'I' is as well. The problem is what arrangement and what ACT is correct.

Now we, as speakers, know that the most reasonable answer to this problem is:

$$\begin{array}{ccccc} \text{I} \leftrightarrow \text{like}_2 & & & & \\ \uparrow & & & & \\ \text{I} \leftrightarrow \text{read}_1 & \overset{o}{\leftarrow} & \text{books} & & \end{array}$$

The question is how the system is to arrive at such a conceptualization.

Consider the dictionary entry in an ACT dictionary for 'read_1.' The ACT 'read_1' is listed in our system as requiring a 'human' subject and an object that is chosen from the set of objects that have been made by men for exactly the purpose of 'reading' them. That is, while we could list all possible such objects (books, newspapers, etc.) or categorize them in some artificial hierarchical structure, conceptually the object of 'reading' is 'that which is read.' Specifically, this class could include anything with printing on it or whatever. The point here is that we can call the potential object a member of the class '$read_1$-PP_o.' Then, in any listing of the elements of the world, their semantic category would be the place that fit in our ACT-based model. 'Book' would be:

$$\text{book: N; } \text{read}_1\text{-PP}_o;$$

where '$read_1$-PP_o' denotes that it is the conceptual object of the ACT 'read.' Then our diagram must become:

$$\begin{array}{lll} \text{I} \leftrightarrow & \text{like}_2 & \\ & \uparrow & \\ & \leftrightarrow \text{read}_1 \overset{o}{\longleftarrow} \text{book} & \end{array}$$

The only thing missing is the actor, which is 'I' due to the heuristic which governs these situations.

The categorization of 'book' as '$read_1$-PP_o' is not ad hoc. 'Book' belongs to no other semantic category, and this particular semantic category is in the hierarchy as a physobj. That is, because there are other ACT's that can be done to 'books,' this does not include them as part of the category of 'book.' This category, then, is indicative of the function for which the object was created in the world. The fact that secondary functions may exist is of no concern since what we want to do here is predict redundant information. Usually, if formation was left out, it is because it can be predicted simply on the basis of such natural function information. If a mistake is made, then it can be discovered by inquiry in interactive mode. We wish to make the most likely guesses for the given context rather than the 'right' ones.

Thus, many other objects can be categorized in this manner. For example, consider 'knife.' 'Knife' is the object of the ACT in the instrument of cutting. A funny way to say 'I sliced the meat with a knife' is to say 'I cut the cuttee with a cutter.' Now, of course, the specificity of the particular concepts is lost with this paraphrase, but a 'knife' is a potential 'cutter' and that is what is important here. That is, when 'knife' or any other cutting instrument is mentioned the association with 'cut' or some specific 'cut' term must be made. A context aids this process considerably, but regardless of context some association will be made by the human and must, therefore, fit in with any theory of a system of expectation for conceptual predictive analysis.

Thus, we can say that 'knife' is an instance of 'cut-PP_I.' This means that it serves as the object in the conceptual instrumental case in conceptualizations involving 'cut.' More accurately, we can say that a 'knife' can be expected to be used in this way and also that conceptualizations involving 'cut' will have as instrument a member of the class 'cut-PP_I.'

The primary point is that there are associations between objects and the action for which they are made which are fairly straightforward that are an important part of the process of expectations, and more importantly, are part of what has been understood from an utterance.

7.3 *The Relationship Between SACT's and ZPA's*

SACT's are interesting in that they communicate a feeling about a conceptualization. When they express the notions of 'wanting' or 'fearing' they are at the same time expressing a mental state attribute which the actor believes will come to be true of himself if the conceptualization being referred to occurs. In other words for sentence (54)

(54) John wants Mary to come home.

a likely implication is that 'John' will be pleased by this action's occurrence. That is, we can generate a

$$\begin{array}{ccc} & \uparrow\uparrow \text{ cf} & \\ \text{John} & \leftrightarrow & \text{pleased} \end{array}$$

off the two-way dependency in 'Mary ↔ go' that expresses that this could result in John being pleased. We claim that is part of the meaning of 'want.'

Now consider sentence (55):

(55) I fear bears.

As in (54), 'fear' is an SACT which requires a conceptualization as object. Since 'bears' are not made for a use they qualify as actors in the needed conceptualization. 'Bears' can do many things, so we can't be sure what it is they do that is frightful. Thus, we have:

$$\begin{array}{ccc} \text{I} & \leftrightarrow & \text{fear} \\ & & \uparrow \\ \text{bears} & \leftrightarrow & \text{do} \end{array}$$

This expresses that 'fear' of objects is not related to the object itself, but rather to the action that a 'bear' might do. We can make a similar implication from 'fear' as we did from 'want.' Namely, 'fear' implies possibly 'harm.' Thus, we have:

$$\begin{array}{ccc} \text{I} & \leftrightarrow & \text{fear} \\ & & \uparrow \\ \text{bears} & \leftrightarrow & \text{do} \\ & \uparrow\uparrow \text{ cf} & \\ \text{I} & \rightleftarrows & \text{hurt} \end{array}$$

In other words, you 'fear' consequences, not particulars.

The main point here is that there is more to the understanding process than ascertaining the conceptualizations expressed directly by a sentence. It is necessary also for a theory of understanding to account for concepts and conceptualizations expressed indirectly.

The relationship that we have made between an SACT and a ZPA mediated by another conceptualization would appear to be valid whenever an SACT or ZPA are present. Furthermore, certain ACT's have consequents that are either good or bad for either the actor or object.

For example, 'eat,' 'drink,' 'love,' 'fight,' and 'hit' are all positive with respect to the subject. That is, when these actions occur we can assume that the actor wanted them to happen and that the attribute 'became more satisfied' would apply to the actor. On the other hand 'eat,' 'hit,' 'cut,' and 'attack' are negative with respect to the object. That is, we can expect that the object was damaged in some way from them.

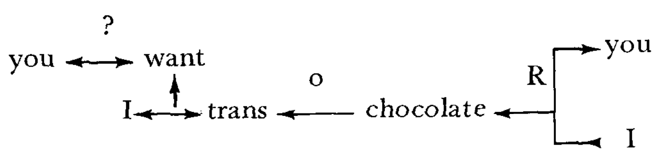
7.4 *Intentions*

Consider a sequence such as this:

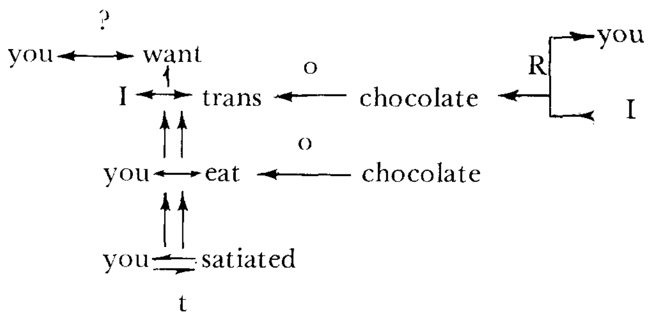
(56) Q: Do you want a piece of chocolate?
(57) A: I just had an ice cream cone.

In a model of natural language understanding, it is unreasonable to claim that the system has understood the utterance unless it is capable of producing for (56) not only a conceptual diagram of the information just stated, but also something like the answer 'no I don't want a piece of chocolate.' That is what a human could understand in the above situation and it is incumbent upon any so-called understanding model to understand the same.

We can actually do this as follows. The conceptual dependency analysis of (56) is:



However, the model that we have been discussing would be charged with taking the conceptual representation of the input and drawing the necessary implications that can be said to be understood implicitly. In this case, chocolate is discovered in the dictionary to be an 'eat:PP_o.' The association between 'want' and 'eat' fits into the SACT–ACT–ZPA paradigm and yields the implications that the ZPA 'satiate' is caused by the connection with respect to the subject of 'want.' This gives us:



Now it is also true that people eat for reasons other than satiation, particularly, for pleasure. So the causal connection

$$\begin{array}{c} \uparrow\uparrow \\ \text{you} \rightleftarrows \text{pleased} \\ t_f \end{array}$$

is also a consequence of the 'eat' conceptualization. But this is not necessary here.

Now we are ready to analyze the answer (A). The conceptual diagram associated with the input is:

$$\begin{array}{lll} \text{I} & \leftrightarrow \text{eat} \overset{o}{\leftarrow} & \text{ice cream} \\ t_f & & \quad \upharpoonleft \text{CONT-BY} \\ & & \text{cone} \end{array}$$

This diagram is obtained by utilizing the dummy quality of the verb 'have' and finding the ACT associated with 'ice cream,' again 'eat.' Here again, 'eat' implies the causal for satiation and we have:

$$\begin{array}{lll} \text{now} & & \\ \downarrow & & \\ \text{I} \leftrightarrow & \text{eat} \overset{o}{\leftarrow} & \text{ice cream} \\ t_f & & \quad \upharpoonleft \text{CONT-BY} \\ \uparrow\uparrow & & \text{cone} \\ \text{I} \rightleftarrows & \text{satiated} & \\ t_f & \qquad \text{PHYS} & \end{array}$$

Now we can compare the question and the answer. The question can be matched with the answer by looking at:

$$\begin{array}{ll} & ? \\ \text{you} & \leftrightarrow \text{want} \\ & \quad\ \vdots\uparrow \\ & \text{you} \rightleftarrows \text{satiated} \\ & \quad t_f \qquad \text{PHYS} \end{array}$$

from the question, and:

$$\mathrm{I} \underset{t_f}{\rightleftarrows} \underset{\mathrm{PHYS}}{\text{satiated}}$$

from the answer. Since 'you' and 'I' represent the same token in memory, the answer to a question about desired transition (t) has been answered with a statement of completed transition (t_f). In other words, we can assume that we have, 'do you want to be satiated?,'–'I have just been satiated.' Thus, we have the simple implied negative.

The point here is that the implications that are to be found here are part and parcel of the understanding process and, in fact, make little sense without them. We can expect that a natural language-analysis system must be continually making these associative implications in order to be able to use them when they are needed.

Essentially we are setting up a peculiar kind of world model here. We are saying that people do things for reasons and that people say things for reasons and understanding these reasons is an important part of understanding natural language utterances. It is the analysis of the intention of an utterance or ACT that is the primary element necessary to correctly respond to that utterance or ACT.

8. CONNECTION WITH MEMORY

8.1 *Idiosyncratic Definitions*

If we begin to talk about the meaning of a sentence with reference to the intention of the utterance, we open a box of problems that have as a general solution the setting up of an entrance into the memory structure and the defining operations within that structure. Previously, we have said that the conceptual diagrams are intended to convey the content of what was said. But it has been seen that what was said is often not quite what was 'meant' in the intentional sense of that word. In order to have an effective program that can converse with a human, it is necessary for the program to know what the speaker 'means' at any given point. This notion could be carried to the logical absurdity of trying to figure out what the speaker 'really' meant. Was he lying for example. This, in fact, is what a sophisticated psychiatric interviewing program must do. But a program which is intended to simulate language understanding ability must start at the beginning, that is, it must first carry out the logical implication and inferences that a normal speaker performs. What are these then?

The answer to that question is manifold. The first part of the problem is what structure or type the solutions conform to. That is, are conceptual dependencies the representation of the entire situation? Here we must make the differentiation between the meaning of the sentence and the meaning of the speaker. That is, conceptual dependency representation is a characterization of the conceptual content of a sentence (i.e., 'what was actually said'). The meaning of the speaker is the intention of that content. This corresponds to the statement 'I don't understand what you mean.' We often say this, when the conceptualizations that we have derived from what a speaker has said do not fit in with our previous experience or do not have enough information to let us know how to interpret the utterance. We thus make the distinction between interpretation and understanding (as have others, e.g., Deese (1967)). Understanding is capable of being characterized by conceptual dependency networks. The interpretation process utilizes these networks in conjunction with the overall memory structure so as to produce the impetus for the generation routine. That is, the end result of the interpretation process is used in conjunction with the 'reasons for talking,' and the structure of the conversation in order to begin the generation of a response either verbal or physical. For example, the meaning of (58) is:

(58) Fire.

$$\begin{array}{c}
\text{something} \overset{\text{tk}}{\leftrightarrow} \text{burn} \\
\uparrow \\
\text{here}
\end{array}$$

but the interpretation process utilizes this network in addition to its knowledge of what happens when 'something ↔ burn' to produce a result. Here we have:

$$\begin{array}{c}
\text{something} \leftrightarrow \text{burn} \\
\uparrow\uparrow \\
\text{something} \rightleftarrows \text{die}
\end{array}$$

and

$$\begin{array}{c}
\text{x} \\
\downarrow \text{LOC} \\
\text{something} \leftrightarrow \text{burn} \\
\uparrow\uparrow \\
\text{something} \leftrightarrow \text{burn} \\
\uparrow \text{LOC} \\
\uparrow \quad \uparrow \quad \text{x} \\
\text{other} \quad \text{combustible}
\end{array}$$

and

$$\text{human} \rightleftarrows \text{combustible}$$

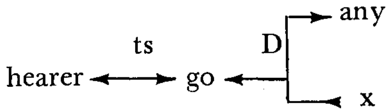
For the hearer this means:

$$\begin{array}{c}
\text{something} \overset{\text{tk}}{\leftrightarrow} \text{burn} \\
\uparrow\uparrow \\
\text{hearer} \underset{\text{ct}}{\leftrightarrow} \text{die}
\end{array}$$

This coupled with

$$\begin{array}{c}
\text{hearer} \leftrightarrow \text{want} \\
\uparrow \\
\text{hearer} \underset{\text{k}}{\leftrightarrow} \text{live}
\end{array}$$

yields



That is, 'Fire' initiates the response in the hearer of getting out of the vicinity of the fire.

Sometimes then, there is a clear distinction between the meaning of the sentence and the meaning of the speaker. This distinction becomes slightly fuzzy in a sentence such as (59):

(59) He acts like Harry.

We can say that a sentence such as this is meaningless in the case that the hearer has no idea who 'Harry' is or how 'Harry acts.' This conforms to the oft heard statement 'I hear what you're saying but I don't get what you mean.' That is, the hearer doesn't understand.

In terms of conceptual structures, the network representation is 2-fold. First, we have the notion that 'he' acts in some manner (x):

$$\begin{array}{ccc} \text{he} & \leftrightarrow & \text{do} \\ & & \uparrow \\ & & \text{x} \end{array}$$

For 'Harry' we have the same conceptualization:

$$\begin{array}{ccc} \text{Harry} & \leftrightarrow & \text{do} \\ & & \uparrow \\ & & \text{x} \end{array}$$

Now, this is virtually meaningless, as is this sentence unless we know something about Harry. If we do, then the second conceptualization acts as a pointer into memory to retrieve the set of ACT's known to be associated with Harry. For instance, we could have in memory:

$$\begin{array}{rcl} \text{Harry} & \rightleftarrows & \text{cat} \\ \text{Harry} & \leftrightarrow & \text{pounce on} \xleftarrow{o} \text{birds} \\ & \uparrow\uparrow & \\ \text{birds} & \leftrightarrow & \text{die} \\ \text{Harry} & \leftrightarrow & \text{eat} \xleftarrow{o} \text{cat food} \\ \text{one} & \leftrightarrow & \text{pet} \xleftarrow{o} \text{Harry} \\ & \uparrow\uparrow & \\ \text{Harry} & \leftrightarrow & \text{purr} \end{array}$$

Here we see that the statement 'He acts like Harry' is still meaningless unless the range of remembered ACT's about Harry is delimited. In actual conversation the delimitation is often made by the context. That is, if I note that 'he is acting like Harry' when I see him watching birds, I might be saying that:

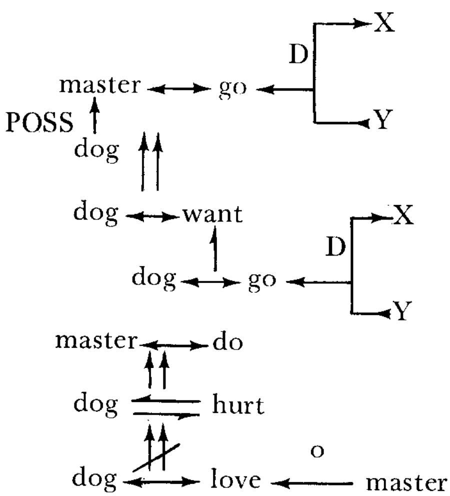
$$\begin{array}{l} \text{He} \leftrightarrow \text{look—at} \overset{o}{\leftarrow} \text{birds} \\ \quad\;\uparrow\uparrow \\ \text{he} \leftrightarrow \text{pounce—on} \overset{o}{\leftarrow} \text{birds} \\ \quad\;\uparrow\uparrow \\ \text{birds} \leftrightarrow \text{die} \end{array}$$

and furthermore that

$$\begin{array}{c} \text{he} \\ = \\ \text{Harry} \end{array} \leftrightarrow \text{look—at} \overset{o}{\leftarrow} \text{birds}$$

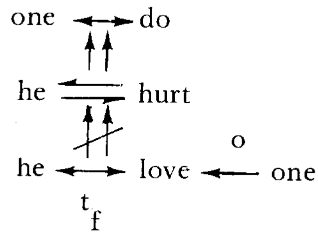
That is, the first set of conceptualizations are obtained from a direct memory search, where information about 'Harry' is retrieved with respect to the particular context. This is the partial intention of the speaker. We can assume that the rest of the statement is intended to draw the parallel between 'he' and 'Harry.' The second conceptualization equates 'Harry' and 'he' with respect to a particular action. (This uses the representation of comparatives (where = can be realized sententially as 'like') described in Schank (1969).)

Often the kind of memory retrieval to which we are referring can be assumed to be directly derivable as the meaning of the sentence when the contextual delimitation needed for such a retrieval is provided by the sentence itself. Consider (62): 'He is doglike in his devotion.' This sentence is effectively a command to memory to seek out any knowledge of the devotion of dogs. Clearly, this statement is meaningless if such knowledge is lacking. But, assume an item in memory about the behavior of dogs, e.g.,



Now, 'devotion' is an English word which keys into this memory structure for 'dog.' That is, in some sense it can be said to be an English idiom with a conceptual heuristic for a realizate.

So the meaning of the above sentence is that 'he' should be substituted in the memory structure keyed by 'devotion–dog.' A plausible inference then is



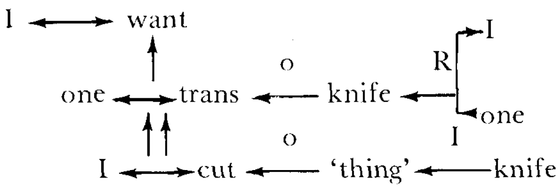
Thus, certain words and word-pairs can cause procedures in the memory to be called into operation. Usually, the operation is based on the immediately previous established context, but often this context is established by the common particular structure in the long-term memory of each conversant. That is, cultural definitions of how dogs behave with respect to devotion facilitate communication for this sentence. If the conversation were conducted in English by members of two radically different cultures, it might be possible that communication would be stymied. Consider, for example, a hypothetical culture where dogs are a constant threat to children and food supply and are thus hated and feared. Clearly, to such a person the above statement, when heard, would be misunderstood with respect to the intention of the speaker. Thus, a definition of 'devotion' would not match in structure any item in the memory of the hearer having to do with 'dogs.'

8.2 *Interaction With Belief Structures*

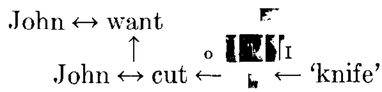
It is now reasonable to go back to the types of expectation with which we were concerned earlier. In the conversation between 'John' and 'Fred' we noted that the context predicts what kinds of conceptualizations are likely to be asserted. That is, what do we expect him to say that would fit in with the contextual situation?

We answered by claiming that what was likely was that John would say 'I think I ought to $\left\{\text{kill}\left\{\begin{matrix}\text{Mary}\\ \text{you}\end{matrix}\right.(\text{Fred})\right\}\right\}$' or 'I think I ought to $\left\{\text{end my relationship with}\left\{\begin{matrix}\text{Mary}\\ \text{you}\end{matrix}\right.(\text{Fred})\right\}\right\}$.' It should be clear that the particular words that would be used here are not at issue, but only their conceptual content. Now, the question is, how do we get a machine to make these predictions?

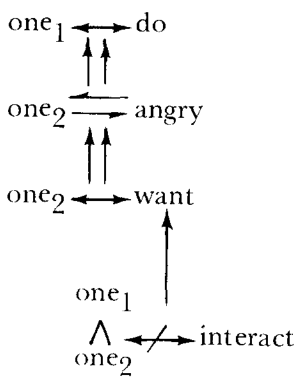
The problem is one of derivation. That is, where would this information come from? Consider the statement made by John previous to the one under discussion ('I could use a knife right now'). This is represented as:



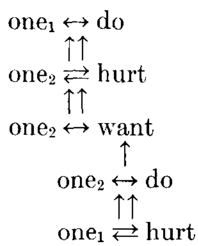
Here the first causal implication comes from the SACT–ACT–ZPA paradigm, or, in this case—'want–ACT–ZPA.' Now, we can say that we have a conceptualization in the intermediate memory that will affect the context. That is,



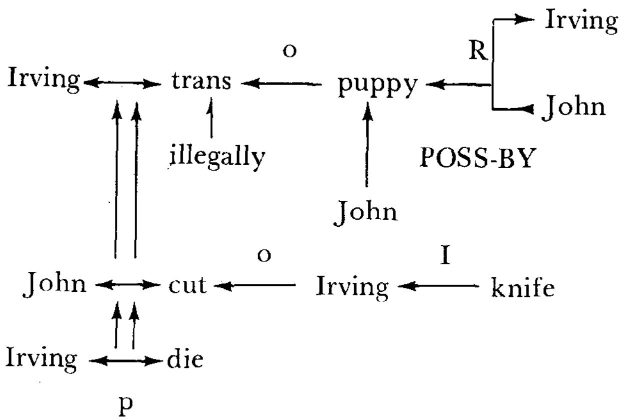
In order to make accurate use of this information, it is necessary to have at the system's disposal a belief that could be characterized as part of the world view expectation. This belief is of the general order:



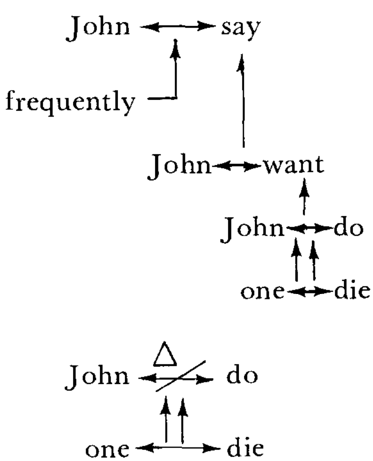
That is, this rule explains that if one is angry at someone that means that one doesn't want to interact with that person right now. Now there could also be a rule that says:



In other words, if one is hurt one wants to retaliate. Now, of course, this rule is not always true for every individual. We would like to note the conditionality of this rule by placing a 'c' over the causal link preceding the 'one$_2 \leftrightarrow$ want' and then using the rule if it is the case that in our memory of the individual to whom we are talking we have, for example:



That is, if we know that John already killed for some reason like this, we might guess that John will retaliate again. On the other hand we might have the rule from memory:



That is, John talks about killing people but never has done it.

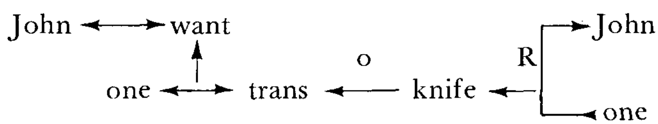
The point is that if we can decide that it is the case that John will at least say that he believes that:

one ↔ do
↑↑
John ⇄ hurt
↑↑
John ↔ want
↑
John ↔ do
↑↑
one ⇄ hurt

and, we know that:

one ↔ cut $\overset{o}{\leftarrow}$ ‘human’ $\overset{I}{\leftarrow}$ ‘knife’
↑↑
human ⇄ hurt

and, we know that:



then we can conclude that:

John ↔ want
↑
John ↔ cut $\overset{o}{\leftarrow}$ ‘human’ $\overset{I}{\leftarrow}$ knife
↑↑
human ⇄ hurt

Now the question is, who fits the paradigm:

one ↔ do
↑↑
John ⇄ hurt
↑↑
John ↔ cut $\overset{o}{\leftarrow}$ one $\overset{I}{\leftarrow}$ knife
↑↑
one ⇄ hurt

Since John has said that Mary angered him, she fits the paradigm by definition of ‘angered.’ Since Fred has just convinced John that:

Fred ↔ agree
Mary ↑
⤢ ⇄ good
do

we can say that ‘Fred’ and ‘Mary’ are in the same situation in the paradigm. This is done by yet another belief that says:

$$
\begin{array}{l}
\text{one}_1 \leftrightarrow \text{do} \\
\qquad \uparrow\uparrow \\
\text{one}_2 \rightleftarrows \text{hurt} \\
\qquad \wedge \\
\text{one}_3 \leftrightarrow \text{agree} \\
\qquad \Uparrow \quad \text{one}_1 \uparrow \\
\qquad \| \quad \swarrow\!\nearrow \quad \rightleftarrows \text{good} \\
\qquad \| \quad \text{do} \\
\text{one}_2 \leftrightarrow \text{angry}
\end{array}
$$

That is, if one sides with one's enemy then one is angry at the enemy's compatriot also. Thus, we can say that John is likely to say that he will kill either Fred or Mary. Also, we can say that the context of the knife aside, he is likely to say that he doesn't want to interact with either Fred or Mary.

The important point here is that it is possible to make contextual predictions as to the content of expected conceptualizations, but that this process of prediction is based on a belief system that includes generalized rules for operating in the world, and idiosyncratic beliefs about the behavior of an individual in the world based upon one's view of people and the particular person under discussion.

9. CONCLUSION

The goal of the research described here is to develop a model which accurately simulates a human being in a natural language understanding situation. Whereas, I am primarily interested in how humans understand, the computer serves as a useful tool for forcing one to make explicit the processes that one describes as being part of understanding. Computer simulation then, turns out to be a good impetus to the generation of theories about human behavior which are testable. The model described here can be tested only in conjunction with some other computer model of a particular kind of interaction. A cohesive system is being developed that will test this model as part of two different psychological models, one of a psychiatric interview where the computer functions as psychiatrist and the other of a psychiatric interview where the computer models a paranoid patient (see Colby *et al.* (1971)).

Since our desire is to enable computers to use natural language in any manner that one might want them to, it is necessary to understand how it is that people do these things that we would like our machines to do. In order to achieve this goal, I claim that it is not possible to separate language from the rest of the intelligence mechanisms of the human mind. Language simply does not work in isolation. It is a nice idea that one should in principle be able to fully describe and characterize language by itself as most linguists are trying to do, but in fact it is just not possible. The ability of linguists to ignore this while trying to separate language into neat formal rules has caused an unbelievable number of unrealistic studies to take place under the banner of linguistics. People neither randomly generate sentences nor do they attempt to assign syntactic markers to input discourse. It is certainly true that humans may perform some of the subtasks that are needed in order to have a formal model do these things, but the overriding question is one of purpose. What are we trying to do, and might not there be a better way?

The answer to these and other like questions is that language exists as a medium for expressing thoughts. In order to deal with thoughts on a machine it is necessary to characterize them in some way. That is, we must extract the inherent ideas from the linguistic input and characterize these ideas in some fashion so to be able to use them. It is the use of these ideas that has been sorely neglected by linguists, yet it is precisely the use of ideas that is the communication process. In order to claim that we have understood what somebody has been telling us, we must process the received input in a certain way. Now this does not mean that we must react to the input in the correct way in order to claim to understand it. If I say 'go get me a pickle,' the hearer's lack of motion does not indicate that he doesn't understand me. It may simply indicate his recalcitrance at being ordered around. But, if the above statement is the punchline to a joke, and the hearer does not laugh, it might well mean that he has not made the correct inferences necessary to 'understand' my joke. In some sense, even a different sense of humor is an inability to understand my speech. This is, in fact, what communication is all about. Certain pairs of people find it harder to communicate than other pairs. This is indicative of a lack of certain common memory structures and inference relations. We cannot 'understand' somebody whose initial assumptions and cultural background are radically different from our own, even if we share a common language. That is, understanding language is a misnomer or at least is only a small part of the problem. Understanding what one has heard is a complex process that necessitates connecting words with certain conceptual constructions that exist in one's memory. The entire linguistic process uses the output of such understanding and interpreting mechanisms in order to produce reasonable replies (verbal or not). What constitutes a reasonable reply is an intrinsic part of the linguistic process, but yet is still a conceptual process and is, therefore, I suppose, out of the domain of traditional linguistics. Yet it is unreasonable for it to remain in that scientific no-man's-land. A computer model must respond as well as understand. Of course, its response must be connected to a powerful responding mechanism that is, in fact, the point of the entire computer program, that is, why the program was written in the first place. These then are the problems of computer understanding of natural language.

In a complete automatic linguistic system the responses that are generated will be dependent on the corroboration of the predicted input as compared to the actual input and the memory structure. That is, we respond differently to different people saying the same things, and differently to the same people saying the same things in different contexts. These contexts include, physical, conversational, and time contexts. In other words, no person is really the same at any given point in time as he was at some other time with respect to the viewer's own memory model of that person. So, in some sense, the context is always different and the responses should always be potentially different according to the time of the conversation. It is precisely the predictive ability that permits this difference in response. And, the difference in response is caused by the difference in analysis. That is, in order to effectively analyze a given linguistic input, it is necessary to make predictions as to what that input might look like, compare the actual input to the expected input, and coordinate both with the memory model. Understanding is, therefore a complicated process which cannot be reasonably isolated into linguistic and memory components but must be a combined effort of both.

I have avoided discussing conversational predictions in this paper because the work that we have begun to do on them is still even more sketchy than that presented here and, more importantly, is of a very different character.

To a large extent the conversational expectations are dependent on generative mechanisms, that is, a sort of 'why are we talking' apparatus must be used. As an example of the kind of mechanism that we are talking about, an illustration from some recent research that we have been doing will help.

We spent some time with a child of age 2.2 years, talking to her and endeavoring to understand her understanding mechanism. During discussions with her we obtained some interesting examples of unusual answers to questions that suggest a model for generation of responses in the child.

Mother: Did you go to the toilet?
Child: I go home.
Mother: Did Peter go to the bathroom?
Child: Peter cry.
Interviewer: Did you ever go in a plane?
Child: I go in a bus.

Responses of this kind indicate an answering mechanism in this child that has as its primary purpose the making of true statements. A procedure that would generate this behavior would simply check the proposed conceptualization with memory, and if it is not found, check to see if a new case dependent will fit in the conceptualization and make it true. Two factors are important in choosing this new object: first, the immediate context or intermediate memory is checked for similar conceptualizations; if that fails, a true conceptualization with the same semantic category is checked for. If no possible case dependent is found, the case is eliminated altogether and a new ACT is looked for, again by the same standards.

Another interesting insight into the understanding mechanisms of this child was provided by the following two exchanges:

Interviewer: What's that? (pointing to a picture of butter)
Child: Butters.
Interviewer: And what do you do with butter?
Child: Eat it.
Interviewer: How do you eat it?
Child: On a spoon.
Interviewer: On bread?
Child: Yes.

The association between 'bread' and 'butter' was then used by the child in the following sequence that occurred half an hour later.

Mother: (to another child) What did you eat for lunch?
Other child: Sandwich
Interviewer: What do you want to eat?
Child: Sandwich too.
Mother: What kind of sandwich?
Child: Butter on it.
Mother: She has never asked for butter before.

Here we see the child making statements that may, in fact, not even be true for her. She might very well object to receiving a butter sandwich if one was made for her. She seems here to be testing the new association (butter–bread) that she heard, and is, in fact, expanding it (butter–bread–sandwich). We hope to be able to build a program that can learn, as a child does, how to do what we have described in this paper instead of being spoon-fed the tremendous information necessary.

In order to do this it might be necessary to await an effective automatic hand–eye system and an image processor. Until then we shall attempt to put in the huge amounts of information that is necessary in order to more effectively test our model.

REFERENCES

ANDERSON, J. *Recognition confusions in sentence memory*, unpublished paper, Stanford University, Stanford, California, 1971.

BOWER, G. Imagery as a relational organizer in associative learning. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 529–533.

CHAFE, W. *Meaning and the structure of language*. University of Chicago, Illinois: Chicago Press, 1970.

CHOMSKY, N. *Syntactic structures*. Mouton and Co., 1957.

CHOMSKY, N. *Aspects of the theory of syntax*. M.I.T. Press, 1965.

COLBY, K., & ENEA, H. Heuristic methods for computer understanding of natural language in context-restricted on-line dialogues. *Mathematical Biosciences*, 1967, **1**, 1–25.

COLBY, K., & SMITH, D. Dialogues between humans and an artificial belief system. *In* Walker & Norton (Eds.), Proceedings of the International Joint Conference on Artificial Intelligence, 1969.

COLBY, K., WEBER, S. & HILF, F. Artificial paranoia. *Artificial Intelligence*, 1971, **2**, 1–25.

DEESE, J. *Some contributions of psycholinguistic studies to content analysis*, presented to National Conference on Content Analysis, Philadelphia, 1967.

FILLMORE, C. The Case for Case. *In* Bach & Harms (Eds.), *Universals in linguistic theory*, Holt, Rinehart and Winston, 1968.

FLOYD, R. Nondeterministic algorithms. Journal of the ACM, **14**, No. 4. Pp. 636–644.

FURTH, H. *Thinking without language*. Free Press, 1966.

HAYS, D. Dependency theory: A formalism and some observations. *Language*, 1964, **40**, 511–525.

INHELDER, B., & PIAGET, J. *The growth of logical thinking from childhood to adolescence*. Basic Books, 1958.

KATZ, J., & FODOR, J. The structure of a semantic theory. *Language*, 1963, **39**.

KLEIN, S. Automatic paraphrasing in essay format. *Mechanical Translation*, 1965. Pp. 68–83.

KUNO, C., & OETTINGER, A. "Multiple path syntactic analyzer" in *Information Processing* 1962, North Holland.

LAKOFF, G. On generative semantics. *In* Steinberg and Jakobovits (Eds.), *Semantics: An interdisciplinary reader in philosophy, linguistics, anthropology and psychology*. Cambridge University Press, 1971.

LAKOFF, G. *Linguistics and natural logic*. Department of Linguistics, University of Michigan, 1970.

LAMB, S. The sememic approach to structural semantics. *American Anthropologist* (special issue), 1964.

LAMB, S. *Outline of stratificational grammer*. Georgetown University Press: Washington, D. C., 1966, pp. 57–73.

LENNEBERG, E. *Biological foundations of language*. John Wiley, 1967.

QUILLIAN, R. *Semantic Memory*. Cambridge, Massachusetts: Bolt Beranek and Newman, 1966.

SCHANK, R. *A conceptual dependency representation for a computer-oriented semantics*. AI Memo-83, Computer Science Department, Stanford University, Stanford, California, 1969.

SCHANK, R., & TESLER, L. A conceptual dependency parser for natural language. *Statistical Methods in Linguistics*, 1970, **6**, 33–51.

WEBER, SYLVIA *The processing of conceptual nominals in a conceptual dependency system.* Proceedings of the 1971 International Conference on Computational Linguistics, Debrecen, Hungary (forthcoming).

WEIZENBAUM, J. ELIZA—a computer program for the study of natural language communication between man and machine. *Communication of the ACM,* 1966, **9**, 36–45.

WINOGRAD, T. *Procedures as a representation for data in a computer program for understanding natural language.* Technical Report MAC TR-84, M.I.T., 1971.

WOODS, W. *Semantics for a question-answering system.* Report No. NSF-19, Harvard University Computation Center, 1967.