CHAPTER 3

CONCEPTUAL DEPENDENCY THEORY

3.1. Introduction

We are now ready to consider what a meaning representation should look like. We have said that it must consist of concepts and relations between concepts. There should be restrictions as to what qualifies as either. Consider the sentence:

John ate a frog.

Consider this sentence word by word. The concept underlying the word "John" is basically a set of features some of which are known. "John" is a human. Humans have sex and "John" is "male". Humans have names and John's is "John". Notice that already much of what I said could be wrong. "John" could be a female flea. We must make assumptions in order to understand, so off we will go.

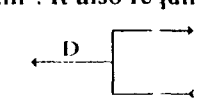
In a conceptual memory, that is, a memory that has in it only concepts and no words, "John" is represented by the above set of features plus some other ones not yet ascertained (height, for example). We shall use the symbol "John" in our conceptual diagrams to indicate that this is a pointer to all the information that we know about John. Throughout this book, we will sloppily say "John" when we mean "our full concept of John with all his known features". In the conceptual structures, we will simply write "John", but it is important to realize that in actual computer use we connect the new information being stated to everything else that we know about John, including the fact that "John hates pineapples" and "John went to the doctor yesterday". Thus, when we say "John", we don't really mean John, we mean John No. 21, some specific reference to John. Really what this is is some kind of pointer to a lot of information about John-21. If we can't figure out which John is meant then we create a new token until we can combine it with an old one.

"Eat" cannot be considered apart from the *conceptual syntax* rule that

will combine it with "John". The syntax of the conceptual level consists of all the rules for constructing relationships between concepts on the conceptual level. Our first conceptual syntax rule is that objects in the world (John) can perform actions (eating). This rule is denoted by an arrow (⇔) which is called a two-way dependency link. Two way dependency links only occur between concepts that are in the role of actors and actions.

Before we go on with this type of analysis it is well to consider just what these units are that we are combining at the conceptual level. "John" we said was an object. We allow that objects are a class of concepts at the conceptual level, which we call PPs (for picture-producer). We require that a PP be a physical object. Since nouns are often physical objects, it might seem that a PP is basically a noun. Certainly many nouns at the syntactic level map into PPs at the conceptual level, but not all. No abstract noun is a PP because no abstract noun denotes a physical object. Also certain nouns denote much more than just a physical object. Thus, "doctor" is mapped conceptually into a PP (human) plus other information describing the particular types of human that a doctor is.

We have said that there is a two way dependency (⇔) between "John" and the action that he has performed. But although the word "eat" describes that action, labeling the action "eat" at the conceptual level would simply beg the question of what "eat" means. We use, in Conceptual Dependency, a class of primitive actions (ACTs) that is strictly limited. (There are eleven of them.) All verbs are broken down into their basic conceptual elements, often in terms of one or more of these eleven ACTs. We require of a physical ACT that it be something that a PP which can ACT (animate PPs mostly) can do to another PP. A mental ACT is an operation that a PP can perform on an idea (a conceptualization). An ACT refers only to what the actor has actually done and is treated apart from the possible consequences of his action. For "eat" the ACT that is most usually performed is what we call INGEST. INGEST means in Conceptual Dependency (CD) "to take inside the body". INGEST requires that some PP must serve as object for it, that is, something must be INGESTed. In the above sentence, it is the "frog" that is INGESTed by "John". It also required a DIRECTION, denoted



which indicates the old and new locations of the object being INGESTed. This has been accomplished by some unstated means, probably involving John moving his hand, which contains the frog, to his mouth. This *instrumental* conceptualization was not explicitly stated by the sentence, and we thus consider it to be an *inference*. We define inferences as conceptualizations which are likely to be true but are not necessarily true for a given input. We do not attempt to make them until conceptual analysis is completed. However, we include inferences here to illustrate the various types of conceptual relations possible in our meaning representation.

Thus, we have established the following conceptual syntax rules:

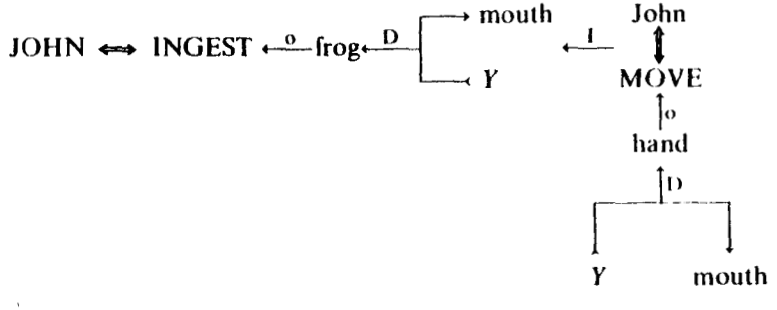
PP ⟷ ACT — PPs can perform actions.

ACT ←o— PP — ACTs can have objects of PPs. The dependency here indicates that the object further explains or specifies the ACT.

ACT ←D— PP_1, PP_2 — ACTs can have directions that are the locations of PPs. PP_1 indicates the final location, PP_2 the initial location of the object.

ACT ←I— ↕ — ACTs have Instruments that are themselves entire conceptualizations. The actor of the main conceptualization and the subordinate instrumental conceptualization must be the same.

These rules are used to describe the ACT performed (I and D arrows are considered to be pointing at the ACT):

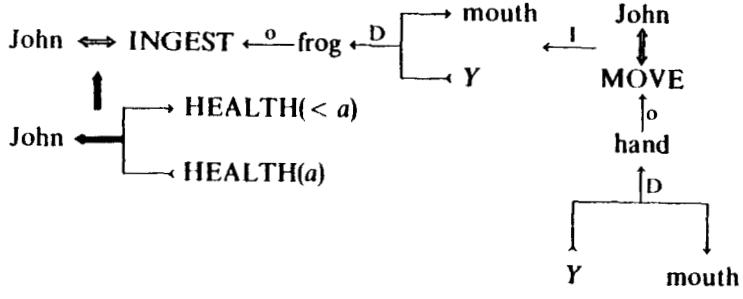


Here *Y* indicates an unknown location.

We can infer from this conceptualization a consequence. For example, possibly John got sick.

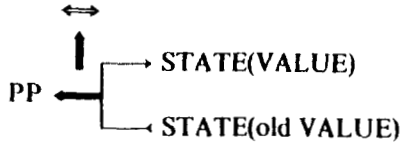
Consequences are denoted in CD by ⬆ pointing towards the causing conceptualization. These causal arrows may only relate conceptualizations. Conceptualizations come in two forms, actor-action and object state descriptions. For the above inference a new object-state was caused by the action (or dependent on the action for its existence, which is why the causal dependency arrow points towards the causer).

Thus we have:



Here we have the following new conceptual syntax rules:

PP ⟷ STATE(VAL) — This indicates that a PP can be described by a specified state and a value for that state (denoted by STATE(VALUE)).



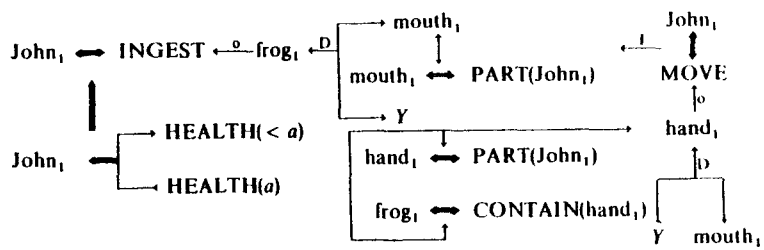
This indicates that an action can cause a VALUE change within a given STATE.

Two things left out of this analysis are the relation between "John" and "hand" and the containment relation between "hand" and "frog". One of these relations is denoted by PART(inalienable possession) and

the other by CONTAIN(containment). These relations are also considered to be states so that the following conceptual statements are true:

hand ⟷ PART(John) and frog ⟷ CONTAIN(hand).

These state relationships can be predicated of PPs by relating them to the PPs by the ↔ arrow. Thus the completed diagram for "John ate a frog" is:



(where the subscript indicates that the same object exists in each point of the total conceptualization. These subscripts will henceforth be assumed.)

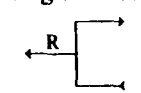
Now consider the sentence "The man took the book". Let us consider it one word at a time. What is the conceptual representation of "the"? In fact "the" has no conceptual representation as such. Conceptually it is a command. A computer memory system must see "the" and do something with it, rather than represent it. "The" creates an expectation. It says that a noun is coming. We also know that the noun that is coming has been heard before. It is present in the hearer's memory model and should be referenced so that new information can be added to that token in memory. (There are some cases where that is not true, "I went to the barber" for instance. "I went to the barber" does not refer to some specific "barber" because it is a generic term just like doctor, where we have a class name and it is not particularly important which member of the class it was. But, if we have "I went to the big house on the hill" or "I went to the prom", you are presumed to know which prom is being referred to, and which big house on the hill is being referred to.)

"Man" is understood as being a PP. "Man" is assumed to be the object sense of man because that is the most likely expectation. Just as

in hearing English one expects sentences, in Conceptual Dependency one expects conceptualizations. We predict that the first PP is likely to be the actor of a conceptualization. This forces us to look for a verb that represents an action.

The "the" has set up the prediction of "man" as noun rather than as verb (as in "man the barricades"). This syntactic information is useful as well as conceptual information. The syntactic information here will tell you which syntactic sense of man is most likely. We thus can expect a noun and treat "man" accordingly. Upon encountering "took" we look it up and see that we have "take" plus past. "Past" modifies the relationship between "man" and "take". It indicates that this relationship occurred in the past. Since the ⇔ arrow represents that relationship, we put a "p" over it to indicate that it is different than the unmarked ⇔ arrow, which indicates a present relationship. So, we have established a relationship between "man" and "take" which occurred in the past. Here again, though, "take" is not a concept of action but a verb. In order to consider exactly what action "take" represents we must consider what information is implicit in this sentence, and how the available objects could relate to this action.

"Book" would seem to be the object of the action, in that it was actually acted upon, i.e., something happened to it. What exactly did happen to it? One thing that is possible is that the possession of the book changed. It is possible that the "man" now has the book, and that whoever used to have it doesn't have it anymore. All this is present implicitly in one sense of the word "take". For this sense of "take" there is thus a recipient relationship. We represent the recipient by an arrow that has a "to" part and a "from" part, indicating the new and old possessors:



(Recipients are dependent on the action but since we are in the habit of writing Conceptual Dependency diagrams linearly, we write it with the arrow pointing to the object.)

In this sentence, "man" is the "to" recipient and the "from" recipient was left unstated. It is important to realize that we know and must leave a place for the unrealized "from" part. This kind of conceptual prediction plays an important role in parsing. It is necessary to know what you don't know. For example, this sentence could have ended with "from

John". A conceptual analyzer would have already predicted a missing recipient and would know just where to place "John" in the conceptual diagram. (Alternatively, we could end with "from the table" or "to John". But these change some predictions about the ACT that occurred and we shall ignore that problem for now.)

Let us consider the sentence: "The man gave the book to John." Basically, we have the same structure as we had before: "man"; past action: "give"; object: "book", "to John", and "from the man". It is important to realize that not only does language have paraphrase, it also has similarities in meaning. "Give" and "take" are similar. For example, if we have "I took a book from John" and "John gave me a book" we know that we have two sentences that are similar in important ways. In order to account for this we claim that one must treat the ACT underlying "give" and "take" as the same. We call this ACT ATRANS which stands for "abstract transfer (of possession)". ATRANS is one of the most useful primitive acts. "Taking" involves ATRANS, as does "giving", "buying", "stealing", "trading", and so on. ATRANS is an action which requires a recipient and an object.

If the "from" part of the recipient is the same as the actor, the word we use in English is "give". Whenever ATRANS plus an identity of actor and "to" recipient are present, the word "take" can be used. Only one sense of "take" is parsed into this structure. Other senses are represented by structures using other primitives. "Take an aspirin", for example, is INGEST in its most common sense.

In order to talk about meaning representation, it is useful to talk about breaking things down into some set of basic primitive elements. These basic underlying pieces allow us to represent similarity of meaning, and allow the recognition of sentences identical in meaning as being the same. Ideally, the set of primitive actions that we establish should be universal. That is, they should be independent of any particular language, conforming more to what people do, rather than the language that they describe their actions in.

Thus, we would claim that any sentence that expresses the idea that

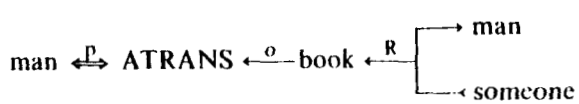


Fig. 3.1. The man took the book.

somebody took a book will be represented in part by part of the diagram in Fig. 3.1, no matter what language it came from and no matter what phraseology was used.

It is important to realize that verbs in English very often reflect only a very small part of what actually happened. Part of the reason for this is often that it is unimportant what actually happened. If we have "John gave Mary a book", it may not matter at all if John handed it to her, threw it at her or kicked it to her. English does not require that much specificity, it just concentrates on the possession change.

One of the reasons that language has ambiguities is because many of the pieces that are being referred to are not ever explicitly stated. So the major pieces of an event may not have been stated. Consider the sentence "I hurt John". If we represented the ACT in this sentence as being "hurt", we would have a very inadequate treatment. Actually, "hurt" is quite ambiguous with respect to the ACT that was actually performed. "I hurt John" does not tell you at all what "I" did. Since we consider actions to be things that one does to objects we must realize that "hurt" and verbs like "hurt" can't be actions. There is no reason to believe that another language has to talk about "hurt" as a verb. What is "hurt" then? First we claim that we don't know what ACT actually occurred. We do know that the unknown ACT resulted in John being "hurt" but we do not know what "I" did. In the conceptual diagram we use the notion of a dummy ACT, (DO) to indicate that an unstated action took place.

"I hurt John" means that "I" did something. DO means the specific ACT that the actor did was unstated. Thus, the sentence means that whatever "I" may have done, it caused John to be hurt. For example, the DO could be "Kiss his wife".

Whatever ACT "I" did, it had the effect of causing John to change state. This state change is along some unstated scale. For "hurt" we have two choices: either physical hurt (PHYS. ST. scale), or mental hurt (JOY or MENTAL STATE scale). In either case, we represent "hurt" as a negative change along a scale.

If we knew what the "DO" was, we would have a better idea of which scale was meant. Thus, if "I hit John", then the PHYS. ST. scale is more likely than the JOY (but not necessarily).

It is necessary to explicitly represent the causal relationship between the I $\Leftrightarrow$ DO and the "hurting of John".

In other words, in English it was "I" that caused John to be hurt; but conceptually it was no more I that caused John to be hurt than the doing that caused John to be hurt. It was a combination of the I and the doing. What we are saying is the only thing that can cause something is a conceptualization.

The final analysis (assuming a physical hurt) then is as shown in Fig. 3.2.

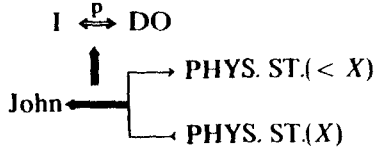


Fig. 3.2. I hurt John.

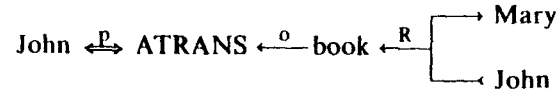
Thus, a principle issue in the creation of meaning representations is the delimitation of what can be considered to be an action. The separation of actions and states in an explicit manner enables us to write rules that predict missing information. Such missing information can serve as the core of analysis programs that must predict in order to effectively act.

Actions, in Conceptual Dependency, are things that are done to objects. Each action that we posit must have a conceptual object. Often, actions have direction (for example, any motion action must have a path that that action takes). We define the *conceptual cases* of an action to be the set of such additional modifications of an action. There are four conceptual cases: OBJECTIVE, DIRECTIVE, RECIPIENT and INSTRUMENTAL. Each ACT in Conceptual Dependency requires a specific number of cases (either two or three).

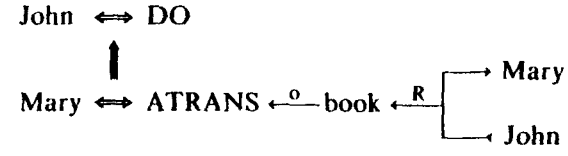
Some work has been done on syntactic cases (Fillmore, 1968, and others) that discusses what cases are required and what cases are optional in order for a sentence using a given verb to be well formed. Conceptual cases are analogous to the extent that we are concerned with forming complete conceptualizations using a given ACT. However, whether or not certain syntactic cases are present in a sentence, the conceptual cases must always be there. That is, one could have the sentence: "Go." Conceptually, the ACT underlying "go" requires three conceptual cases (Directive, Objective and Instrumental). In other

words, in the conceptualization underlying "go", there must be some means of effecting that motion, by the actor moving the actor's feet for example (Instrumental). If these cases for an ACT are unstated, an empty slot is held open for them, often with some prediction about what probably belongs in the conceptualization but was unstated. ("Money" is such a predicted Objective case filler for one of the ATRANSs underlying "buy" or "sell' for example.)

We have analyzed "John gave Mary a book" as follows:



Actually, this analysis is not quite correct for this sentence since the sentence is conceptually ambiguous. The conceptual diagram above is correct for one sense of the sentence but it is possible that the transition was not done physically by John. Rather John could have said "you can have the book" and Mary could have taken it herself. Since we don't know what specifically John may have done, we represent this sense as:

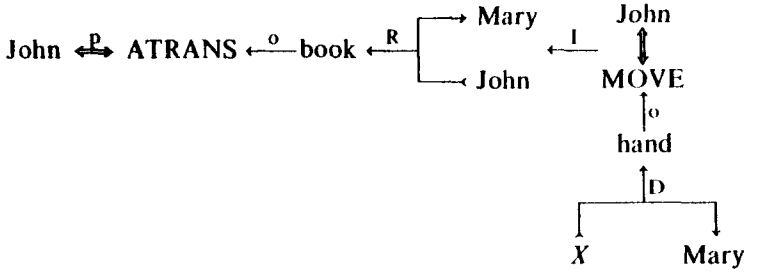


Either of these two structures may have been the intended one, but we assume unless given information to the contrary that the first is correct. Verbs are given an ordering of alternative meanings which can be altered by the context. This is discussed by Riesbeck. Suppose the sentence had been:

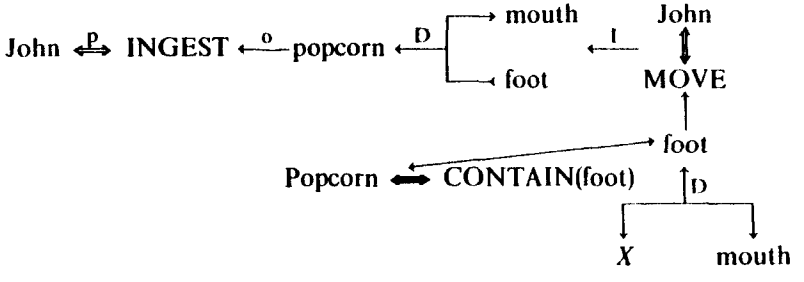
John gave Mary a book by handing it to her.

Here, the sentence is disambiguated by the "by" clause. (All actions require an instrument that is itself another conceptualization.) When the action in the main conceptualization is known, it is possible to delimit the set of possible instrumental actions. For ATRANS the ACT is most often the instrument "MOVE". "MOVE" represents the physical motion

of a body-part (which may be holding an object) by an actor, together with the direction that that action takes. (Other kinds of motion are represented by ATRANS or other physical ACTs.) The conceptual analysis then is:



Sometimes only the object of an instrumental conceptualization is specified. In that case the ACT must be inferred. "John ate popcorn with his foot":

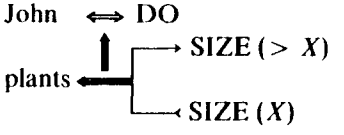


Presumably, there would be an Instrument for MOVE action that was "GRASP popcorn to foot" and an Instrumental conceptualization for that something like "MOVE toes around popcorn" and so on.

The other type of conceptual realization for a syntactic instrument can be illustrated by: "John grew the plants with fertilizer."

Traditionally, linguists would consider "fertilizer" to be an instrument of the verb "grow". Conceptually, however, "grow" is simply a state change and is not an action that can be performed by someone on something else. Rather, a person can do something that effects this

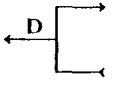
state change. Thus we have as the basis of the underlying conceptualization:



The ⬆ in this conceptualization represents the extremely important fact that something was done by John. Thus the plants were not "growed" they "grew". It was not John that "caused"; rather what he did caused something else to happen.

Since the "DO" represents an unknown action, it might be of interest to find out what that action might have been. But since that information was unstated, finding it is the job of the inference mechanism.

The instrumental case is indicated by ←I— and the conceptualization that is the instrument is dependent upon (written perpendicular to) the main conceptualization. The directive case, indicated by



shows the physical direction of the action. Thus "the book was moved towards Mary". (It is necessary to indjcate here that the hand is holding the book also, but we shall not discuss that here.)

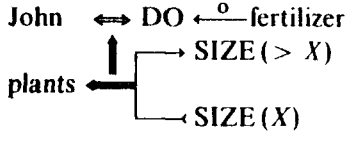
Since every ACT has an instrumental conceptualization that can be said to be part of that ACT, we can see that it should therefore be impossible to ever actually finish conceptually diagramming a given sentence. That is, every ACT has an instrument which has an ACT which has an instrument and so on. Conceptually we might have something like: "John ATRANSed the book to Mary by moving the book towards Mary, by moving his hand which contained the book towards Mary, by grasping the book, by moving his hand, moving the muscles, by thinking about moving his muscles" and so on. Since an analysis of this kind is not particularly useful and is quite bothersome to write, we do not do so. Rather, whenever we represent a conceptualization we only diagram the main conceptualization and such instrumental conceptualizations as might be necessary to illustrate whatever part we

are making. (MARGIE only outputs Instruments when some part of the Instrumental conceptualization was specifically mentioned in the sentence. MARGIE's memory can always trace its Instrumental Chain when asked to.) It is quite possible that we might need many of these instrumental conceptualizations in a program that was intended to simulate certain body motions (such as Winograd's (1971) block moving program). Thus, the ACT in a conceptualization is really the name of a set of sequential actions that it subsumes (and are considered to be a part of it). These instrumental conceptualizations are not causally related since they are not actually separable from each other. In actuality, they express one event and thus are considered to be part of one conceptualization. The rule is then, that one conceptualization (which may have many conceptualizations as a part of it) is considered to be representative of one event.

In ordinary English usage, the syntactic instrument (denoted by a "by" or "with" phrase) of a given sentence corresponds most frequently to either one of two potential places in a conceptualization. Either it represents the object of an instrumental conceptualization (usually the first instrumental conceptualization) or it is the object of a conceptualization most directly related to the verb of which it is an instrument syntactically. Conceptually an instrument can never be only a physical object, but must be an ACT complete with its cases. Thus as an illustration of the first instance we have:

John grew the plants with fertilizer.

The syntactic instrument of "grow" is treated conceptually then as the object of the causing action. Thus we have:



We can, in fact, make an educated guess as to what John could have done with fertilizer that would have caused the growing. Probably

he moved it to the ground where the seeds were. Since this is an inference we shall only mention it here without further analysis.

3.2. Instruments and causation

Thus far, we have been fairly loose with our notions of instrument and cause, and at times they appear to be quite similar. In fact, there are three types of causal bonds in Conceptual Dependency. One of these causal links looks considerably like the Instrumental case and we shall discuss the distinction between them below.

An action can be said to have caused another action only when it serves as the reason for the occurrence of this action. This type of causation is called *reason causation* and is denoted by ⬆ R. The common English realization of reason causation is the word "because" as in "John hit Mary because she kicked his sister" or "John cried because he had red hair". Although we shall use the above notation for reason causation between two conceptualizations in this paper, we should like to point out that this notation is really an abbreviation for a larger conceptualization. For the above sentences, we more accurately should have: "John had on his mind that Mary kicked his sister and he thought of the idea of vengeance and decided that he would be pleased if he effected a hurt state in Mary and this served as a reason for his hitting Mary." For the other sentence we should have either: "John thought about the fact that there was some bad consequence for him as a result of his having red hair and this was the reason he cried"; or: "John cried because he was sensitive and he was sensitive because he has red hair."

It is a problem for the memory to find what the likely reasons are in a given situation. This problem is attacked to some extent by Rieger and we shall not discuss it here. We shall simply use reason causation without expanding the actual reason involved.

The second kind of causation is called *result causation*. This occurs whenever a state is caused by an ACT. So, the operating rule is that if a state is caused by an ACT, we have result causation (indicated by ⬆r). This distinction corresponds to the distinction between the mental and physical world. We are claiming that two ACT can serve to cause another ACT physically. (Remember that all actors are animate.) If one ACT is said

to cause another, it could only be as reason and has no physical basis.

There is a third kind of causation that we use in Conceptual Dependency called *enabling causation* (denoted ⬆ E). We have an instance of enabling causation when the completion of one ACT results in some new state which provides the necessary conditions for the second ACT to take place.

Enabling causation is thus a relationship between a state and an action where the performance of that action depends upon the existence of the state.

Often enabling causation is expressed without any syntactic causal marking present. Thus enabling causation is present in both of the following: "John bought the book to give it to Mary"; and "John stole the apple in order to eat it".

Because enabling causation is related so deeply to the nature of the ACTs involved, there is some danger of confusing it with the notion of Instrumental case presented earlier. That is, if we have "John gave Mary the book by handing it to her", it would seem that we might have a case of enabling causation here. However, it is the nature of an ACT itself that is the problem here. We define an ACT as being a series of little actions that make up a whole. That is, writing, running, shooting, talking, and so on, are actually achieved by doing a great many small actions. Thus, although it is proper to say in English that opening your mouth and moving your tongue enable you to talk, or that grasping a pen and moving your hand over paper enables you to write, in Conceptual Dependency these are considered to be instruments.

We define an ACT as a whole combined action composed of constituent actions executed in a specific order. We require that these actions be separated in time by only a minute amount of time and that they be done by the same actor. If any of these constraints are violated, then we have an instance of enabling causation. Otherwise, in the series of ACTs each ACT is treated as being Instrumental to the ACT that follows it in time.

3.3. Conceptual roles and conceptual rules

We have been trying to establish up until now, in an informal way, a conceptual syntax or rules for combinations of concept types. We will now make a complete list of these rules.

There are the following conceptual roles:

Conceptualization:	The basic unit of the conceptual level out of which thoughts are constructed. A conceptualization is made up of the following:
Actor:	The notion of the doer or performer of an ACT.
ACT:	An action done to an object.
Object:	A thing that is acted upon.
Recipient:	The receiver of an object as the result of an ACT. Included within recipient is the donor of the object.
Direction:	The location that an ACT is directed towards.
State:	The state that an object is in.

The conceptual rules make use of the following conceptual categories or types of concepts:

PPs:	Conceptual Nominals – only physical objects are PPs. PPs may serve in various roles in a conceptualization. PPs that are animate, or have animate qualities (like "machines") may be *actors*. (Natural forces, a special kind of PP (like "wind"), may also be actors.) Any PP may serve in the role of object. A PP may be written in the role of direction, in which case it is considered to indicate that the location of that PP is what is intended. Animate PPs may also serve as recipients.
ACTs:	Actions – are what can be done by an actor to an object. There are only eleven of these ACTs, details of which will be given below.
LOCs:	Locations – every physical ACT has a location that modifies the place of occurrence of the conceptualization that included it. Locations

are considered to be coordinates in space. LOCs can modify conceptualizations as well as serve in the role of direction.

Ts: Times – most conceptualizations have a time. The time is considered to be a point or a segment on a time line. This point or segment may be absolute (2PM on 3/14/72) or relative (before yesterday).

AAs Action Aiders – these are modifications of features of an ACT. For example, PROPEL has a speed factor which is an AA. There are very few AAs.

PAs: Attributes of an object. PAs take the form: STATE(VALUE). That is, a PA is an attribute characteristic (like color or size) plus a value for that characteristic (red or 10 feet). PPs are considered to consist of a set of PAs that define them. That is, every physical object can be defined by a set of attribute STATES with specific values.

The above conceptual categories combine in certain specified ways. Just as the rules for combination of lexical categories are called the syntactic rules of the lexical level, so the rules for combination of conceptual categories are called the *conceptual syntax* rules.

Conceptual categories can combine in *only* the following ways:

(1) PP ⟺ ACT — Certain PPs can ACT.

(2) PP ⟹ PA — PPs (and some conceptualizations) can be described by an attribute.

(3) ACT ←o— PP — ACTs have objects.

(4) ACT ←D— LOC, LOC — ACTs have direction.

(5) ACT ←R— PP, PP — ACTs have recipients.

(6) ACT ←o— ⇕ — MTRANS requires conceptualizations or combinations of conceptualizations as objects, and MBUILD has its own special object type.

(7) ACT ←I— ⇕ — ACTs have conceptualizations as instruments.

(8) PP ↕ ⟺, PP ↕ ⟹ — PPs can be described by conceptualizations in which they occur.

(9) T ↓ ⟺ — Conceptualizations have times.

(10) LOC ⇓ ⟺ — Conceptualizations have locations.

(11) ⟺ ↑r ⟹ — Conceptualizations can result in state changes for PPs.

(12) ⟺ ↑R ⟺ — Conceptualizations involving mental ACTs can serve as reasons for conceptualizations.

(13) ⟹ ↑E ⟺ or ⟹ ↑E ⟺ — States or state changes can enable conceptualizations to occur.

(14) PP ⟹ PP — One PP is equivalent to or an instance of another PP.

(15) ACT ↑ AA — ACTs can be varied along certain dimensions (e.g., speed for motion ACTs).

These conceptual syntax rules account for the concept combinations that make up meaningful sentences. In actual use the syntax rules are combined with a *conceptual semantics* or rules about which particular PPs or class of PPs can combine with which ACTs. This will be discussed in detail later.

Conceptual Dependency also makes use of a set of modifications of conceptualizations that correspond to tenses in a language. These modifications are often only notational conveniences for more complicated constructions. Thus we use "p" for past where actually, stored in the computer memory, is that the time of the conceptualization is previous to the time of utterance.

The conceptual tenses are:

p	past	?	interrogative
f	future	∞	timeless
/	negation	nil	present
ts	start of a transition		
tf	end of a transition		
c	conditional		
k	continuous		

3.4. The primitive actions

Just as lexically words are put into sentences, conceptually concepts are put into what we call conceptualizations. A conceptualization consists of an actor and an action plus a specific set of conceptual cases. A conceptualization can also consist of an object and a description of a state that is in, or a state change that it has undergone.

The notions of conceptual action and conceptual actor are crucial to our discussion of conceptualizations. We define an actor as any animate object or natural force. If an inanimate object is stated as being the actor in a sentence, we would still not regard it that way in a Conceptual Dependency representation.

A conceptual action is defined as something that can be done to an object by an actor. There are two main categories of action: physical actions, or actions performed on physical objects, and mental actions, or mental manipulations performed on ideas or more concrete mental entities such as percepts.

Thus an actor is anything that can be said to be "doing" something to something else. What exactly it is that he is doing is the subject of this section. However, we shall discuss this with the viewpoint of modelling what a speaker says or thinks about his actions rather than trying to place any absolute model of the world in our system. Thus, our notions of conceptual action correspond to the way we imagine people conceive of their own actions. Our notion of objects corresponds to how people view real world objects and such abstract mental objects as "thoughts".

Any action that we posit must be an actual action that can be performed on some object by an actor. Nothing else qualifies as an action and thus as a basic ACT primitive. Since the only actors that are allowed in this schema are animate, an action is something that is done by an actor to an object.

The main point to be made by Conceptual Dependency then is this: often the syntactic structure of a language is misleading as to the underlying concept of utterances expressed in that language. Conceptual structures have as their core underlying primitive actions. It is often the case that verbs, in a language, express those actions, however, this is far from always the case. Many verbs in English only express final states of objects and leave the action involved as an inference. In addition, many nouns and adjectives refer directly to actions. As an example of the former we have the following verbs that specifically reference states conceptually and only infer actions: hurt, like, hate, upset, prevent. As an example of nouns and objectives that refer to actions we have: transportation, desire, gambling, subterfuge, strategy, edible, sincere, honest.

Using the Conceptual Dependency framework for meaning representation, the total number of ACTs necessary to adequately represent any natural language sentence is only eleven. In stating this, we are placing no great emphasis on the actual number eleven. We feel that the order of magnitude is correct rather than the actual number. The concept of action as postulated above forces a severe restriction in what can stand as an action.

There are five ACTs that describe the physical actions that people can perform:

PROPEL,
MOVE,
INGEST,

EXPEL,
GRASP.

There are restrictions on what kinds of objects can be used with any given ACT, which constitutes what we have called the *conceptual semantics* for each ACT.

Each ACT listed above also has a specific set of conceptual cases that it takes. While we have given English definitions for each ACT it is important to bear in mind that the notion of the meaning of an ACT can only really exist with respect to the effect of a given ACT on the system that employs it. Thus the real meaning of each ACT is the set of inferences that are possibly true when that ACT is present.

PROPEL: means "apply a force to", PROPEL takes objective and directional case. Its object must be a physical object, and there is a rule in the memory that tests to see if the size of the object is small enough with respect to the force being exerted on it in order to establish if the object will now be in a new location. The Directive case for PROPEL indicates the direction of the force being exerted. Unlike other ACTs, PROPEL permits inanimate actors (machines, for example).

MOVE: means "move a body part", the only possible objects for MOVE are body parts. MOVE requires Directive case which is used to describe the path followed by the body part.

INGEST: means "take something to the inside of an animate object". The object of INGEST must be smaller than the particular body opening of the actor that is entering. If the object is bigger then it can be inferred that it was divided up somehow into smaller bits previous to INGESTing. The Directive case for INGEST is always to a body opening and from the original position of the object.

EXPEL: means "take something from inside an animate object and force it out", the object of EXPEL must previously have been INGESTed, Directive case is also present, the "from" part being the body opening that the object is EXPELed from.

GRASP: means "to physically grasp an object", the object must be within certain size limits, and the Directive case is always to the body part doing the GRASPing.

Often in speaking, people tend to focus more on the result of an action than on the action itself. Since we are trying to describe a model of human thought as opposed to some notion of absolute truth, it is necessary to have ACTs that account for this focus. We thus use the following two

ACTs that have no real world correlates except for the state changes that they cause, but nonetheless are real in the sense that they help account for what people talk about:

PTRANS,
ATRANS.

PTRANS: means "to change the location of something", any physical object may be PTRANSed. PTRANS requires Objective, Directive and Instrumental case. The Directive case for PTRANS contains the old location of the object and the intended new location. The concept of Instrument is very important for PTRANS since the actual ACT that was performed is specified in it.

ATRANS: Means "to change some abstract relationship with respect to an object". The object is a combination of a physical object and an abstract relationship that that physical object has with some animate object. The animate object is indicated in the Recipient case.

Two of the ACTs occur almost entirely as instruments for other ACTs in actual use:

SPEAK,
ATTEND.

These ACTs are used as the Instruments of some other ACT, usually MTRANS (which will be discussed next).

SPEAK: means "to produce a sound". Its object is therefore always some type of sound. Since sounds can be directed, Directive case is always present, the "from" part being the source of the sound and the "to" part the direction towards which it was produced.

ATTEND: means "to direct a sense organ or focus organ towards a particular stimulus". The object of ATTEND must be a sense organ (nose, eyes, ears, tactile receptors). ATTEND takes Directive case. The "to" part of the Directive case is always the location of the stimulus being focussed upon. Thus, we write in the Directive slot, a physical object or percept, when we actually mean that the direction is towards the location of that object or percept. The ACT ATTEND cannot be used alone and is almost always the Instrument of MTRANS.

We use two Mental ACTS:

MTRANS,
MBUILD.

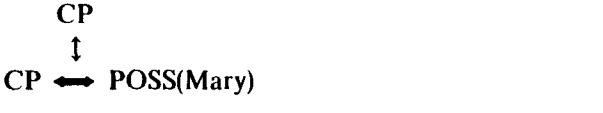
In order to discuss these ACTs we shall need to first divide up memory into pieces that we perceive that humans talk about. We treat the memory

that people talk about as having three main divisions: The Conceptual Processor (CP), the Intermediate Memory (IM), and the Long Term Memory (LTM). The CP is where all conscious thought take place. We require of the CP that it admits only one item at a time.

The Intermediate Memory is a holding place for all the items that are currently being used. We will not use the IM in any of the examples discussed here. It corresponds in English to phrases like "have on one's mind" or "assume for now". It is discussed in Schank et al. (1972). The LTM contains all information that is known by a person. We postulate that only true facts are stored in LTM and that false things are derived from them. We have no short term memory in this division because people do not talk about it.

MTRANS: means "to transfer information". Therefore objects of MTRANS are always conceptualizations. MTRANS takes Recipient case, where the possible receivers are parts of people's heads such as LTM and the possible senders (the "from" part of the Recipient) are sense organs or parts of people's heads (either the same or different person).

MTRANS is the most important of the mental ACTs because it is used in nearly all mental verbs. It is used whenever information is moved about within one person or between people. In these examples we shall use the shorthand notation CP(Mary) to stand for



MBUILD: means "to create or combine thoughts". It requires a different kind of object arrow than the other ACTs. MBUILD takes conceptualizations as objects and creates new conceptualizations from them. MBUILD also takes Recipient case that always has its "to" part the CP. That is, whenever a new thought is generated it is thought of. Often verbs that reference MBUILD refer to the conclusion of the MBUILD, other times they refer to the input.

3.5. States

We have payed far less attention to the problem of the representation of the states of objects than to the representation of actions. Consequently,

what is presented below is less worked out and is more likely to be in error as well as to be missing many possible states. We present it here because it is an important part of the representation problem and we have had to use the state scales that we have created, in our program.

Many states of objects can be described by scales which have numerical values. In so doing, we do not claim that humans represent states in this way, but rather that they can detect differences between adjectives that these scales suggest. That is, they can tell you that "angry" is just a little less of the same thing than "furious" is. We have chosen to treat these things by scales.

We use the following scales:

HEALTH:	goes from −10 to +10.		
	Examples:	dead	−10
		gravely ill	−9
		sick	−9 to −1
		under the weather	−2
		all right	0
		tip top	+7
		perfect health	+10
FEAR:	goes from −10 to 0.		
	Examples:	terrified	−9
		scared	−5
		anxious	−2
		calm	0
ANGER:	goes from −10 to 0.		
	Examples:	furious	−9
		enraged	−8
		angry	−5
		irked	−3
		upset	−2
		calm	0
MENTAL STATE:	goes from −10 to +10.		
	Examples:	catatonic	−9
(same as JOY in MARGIE)		depressed	−5
		upset	−3
		sad	−2

		OK	0
		pleased	+2
		happy	+5
		ecstatic	+10
PHYSICAL STATE:	goes from −10 to +10.		
	Examples:	dead	−10
		harmed	−9
		injured	−5
		broken (for objects)	−5
		harmed	−1 to −7
		hurt	−1 to −7
		OK	10
CONSCIOUSNESS:	goes from 0 to +10.		
	Examples:	unconscious	0
		asleep	5
		awake	10
		"higher drug consciousness"	>10
HUNGER:	goes from −10 to +10.		
	Examples:	starving	−8
		ravenous	−6
		"could eat a horse"	−5
		hungry	−3
		no appetite	0
		satisfied	3
		full	5
		stuffed	8
		satiated	3-10
DISGUST:	goes from −10 to 0.		
	Examples:	nauseated	−8
		revolted	−7
		disgusted	−6
		bothered	−2
SURPRISE:	goes from 0 to 10.		
	Examples:	surprised	5
		amazed	7
		astounded	9

The list here is in no way claimed to be complete. For example, we have left out certain drives (e.g., sexual) and other states that might be useful. We have listed here only the ones that we have used frequently. Certain words are combinations of scales. For example:

shocked = SURPRISE (6)
DISGUST (−5)
calm = SURPRISE (0)
DISGUST (0)
FEAR (0)
ANGER (0)
CONSCIOUSNESS (> 0)

We should point out that in dealing with the world in this absolute fashion, we may be giving a false impression. Not every speaker would agree with the classifications given here. Indeed many people use these words quite differently. We have simply chosen one description of these words because one is forced to do so in computer programs.

The main justification of these representations is their use. "Angry" leads to certain predictions about what a person might do. Certain words refer to shifts along a scale rather than specific places on it. So rules are written such as: if a person is on a negative spot on the ANGER scale and we hear that something has been done that "makes him angry", we move him lower down the anger scale and predict his actions on the basis of his new position on that SCALE.

Much of the work shown above was influenced by the work of Plutchik (1962) and by the thesis of Hemphill (forthcoming).

Hemphill deals with the relative scales that must be created to handle one sense of the English word "for". In the sentence "George is smart for a truck driver", we have a comparison to a norm on a scale. If we consider INTELLIGENCE to be a scale running from −10 to 10 (where 9 is genius, −8, moron, etc.), we can say that X is the norm for truck drivers and George's intelligence rating is $> X$. It then remains for the inference mechanism to establish what actual value X might be presumed to have.

Other states exist that are not scales from −10 to 10, but rather, have more usual absolute measures. These are:

LENGTH (sometimes called SIZE),
COLOR,
LIGHT INTENSITY,

MASS,
SPEED.

Still other states exist that are not scales at all but simply relationships between objects:

CONTROL,
PART (Inalienable Possession),
POSS (Possession),
OWNERSHIP,
CONTAIN,
PROXIMITY,
LOCATION (special form of PROXIMITY),
PHYS. CONT (special form of PROXIMITY).

Another state is used in this book called MFEEL, that is intended to express the relationship between two people and an emotion. MFEEL is a kind of bastard in Conceptual Dependency in that we have no other way to express emotions in the system, but we feel this one is quite inadequate. Nonetheless it is used in the computer programs since something must be.

The states presented here are intended to provide a mechanism for the use of and comparison of adjectival terms. There is a fairly obvious point that we spell out anyway. Unlike the rest of Conceptual Dependency structures, these state scales do not really explain what a state means. That is, −8 ANGER tells us nothing about the properties of being angry. This description is useful solely as a means of providing a norm for comparisons. It is necessary to have a detailed description of ANGER in the memory *in addition to* scale information in order to use it. This description includes what causes people to get angry, what they do when they get angry, and so on. Such information is highly idiosyncratic of course. It is probably not the case that each of us understands the same thing by anger. Detailed idiosyncratic information such as this is necessary for the description of many PPs in the system as well. "Doctor", for example, would require a list in the memory, including how one gets to be a doctor, one's personal opinion of doctors, and quite a bit more. How such idiosyncratic information is used in the memory will be discussed in Chapter 5, but we should point out that that discussion is really only the tip of an iceberg.

We also use state scales for descriptions of non-idiosyncratic states that nonetheless are too complicated to write out or diagram. Thus,

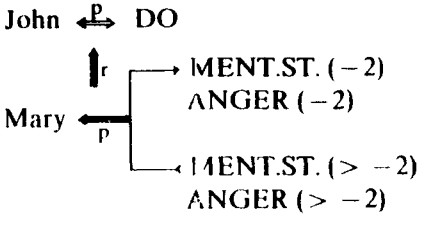
"a broken leg" indicates a negative position on the physical state scale, but such a statement in no way describes a broken leg. The actual physical description of a broken leg would be found in the memory and could be written out in Conceptual Dependency. We choose to write only the state description for convenience sake. This causes broken legs to look much like kidney trouble, so it should not be taken too seriously.

3.6. Examples

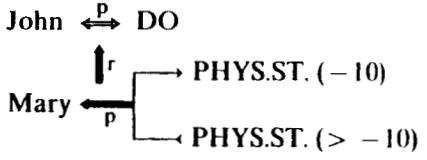
The problem of how one knows what is a correct Conceptual Dependency diagram for a given sentence is not entirely straightforward. We shall try here by means of examples and discussion to demonstrate how one can know what the best representation for a sentence is. It must be stated that we ourselves cannot resolve all the issues of meaning representation. We have chosen to ignore some of the stickier issues like quantification. The representation problem depends to a large extent on the intent of the representor. If it is desired, as it is in Conceptual Dependency theory as practiced by the authors, to account for the meaning and focus and intent of sentences that we have heard in the way that they were intended by the speaker, then what follows should reveal the procedures for doing that.

The first basic principle in Conceptual Dependency is that an ACT is something that is done by an actor to an object. All verbs that leave out the actual ACT that was done must be treated as DOs with causals connected to a change of state.

(1) John annoyed Mary.

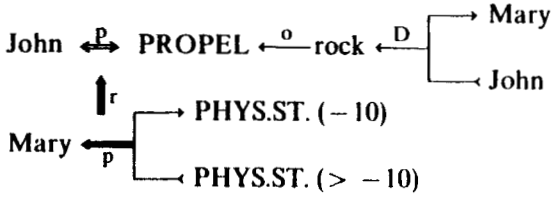


(2) John killed Mary.



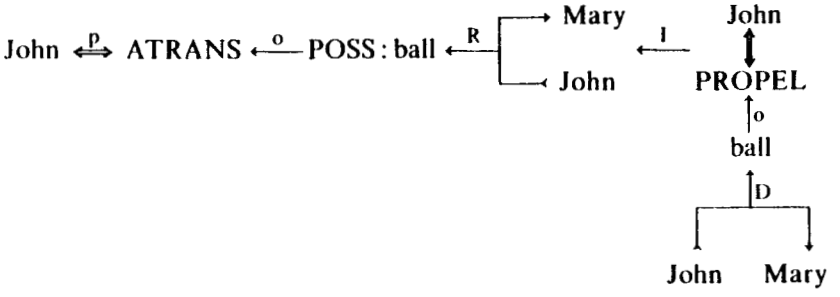
The analysis of (2) is perfectly correct for the output of a parsing program. There is an article in the literature that discusses why "kill" is not "cause to die" (Fodor, 1970), but it refers to generation. It is true that some structures of the form given for (2) with the DO filled in in certain ways would not be accurately labeled "kill". But result causality is so defined in Conceptual Dependency that we know that Mary's change of state in (2) is the direct result of what John did, so "kill" is appropriate.

(3) John killed Mary by throwing a rock at her.



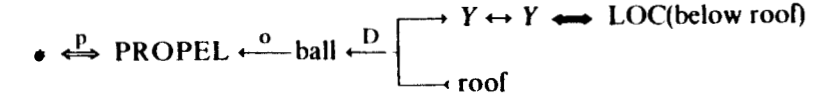
In the analysis program "DO causes" set up predictions about the role of prepositions. In this case "by" is used to indicate that the verb that follows it refers to the ACT that replaces the DO. The word "throw at" is PROPEL. It is a reasonable inference here that the rock hit Mary and this is not in the diagram because it is an inference made at memory time (see Section 3.7). This diagram expresses only that the "throwing of the rock" somehow "caused Mary's death". In actual computer use it would be up to the memory to fill in the missing causal relations.

(4) John threw a ball to Mary.



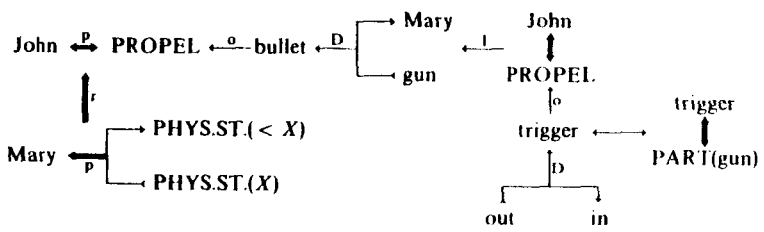
We have left the instrument of (3) out of the diagram above because it was unstated and thus figuring it out is a job for the inference program. In (4) the instrument is present because "throw to" is a specific kind of ATRANS. That is, ATRANS indicates that possession is *intended* to be changed by the ACT performed. "Throw to" says that PROPEL was used as the means for this possession change. Since (4) does not say if Mary ever caught the ball, we leave this out of the diagram. Neither (3) or (4) say how the throwing was accomplished but it is safe to assume that ending a GRASP and MOVEing John's arm were the instruments of the PROPEL. We place no great importance on the division of tasks between memory and analysis since they were somewhat artificially divided by us. We might have just as well decided that the instruments of PROPEL be indicated in the diagrams (as analysis output). We note that the actual ACT performed, from an outside observer's point of view would possibly be the same in (3) and (4). ATRANS denotes an intension of change of possession. "Throw to" indicates therefore that the PROPEL was only instrumental, whereas "throw at" indicates that the PROPEL was done for its own sake. (The POSS : ball notation will be explained in example (11).)

(5) The ball fell from the roof.



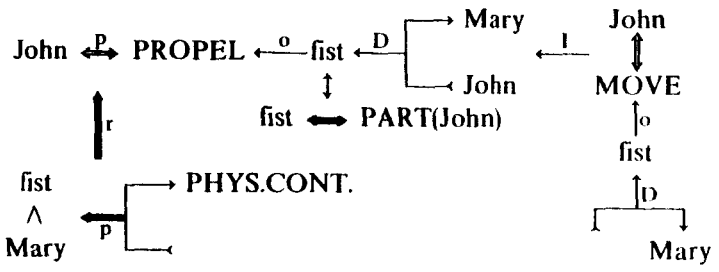
(5) makes use of a notation for unknown actor (*) where either an animate object or a natural force would do. "Fall" then is to be PROPEL-ed to a position lower than the initial one.

(6) John shot Mary.



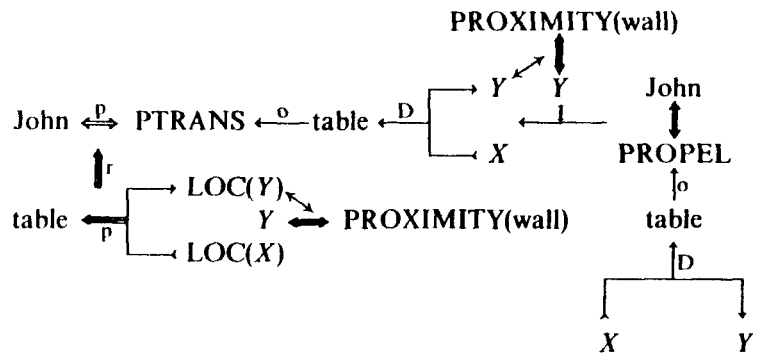
The verb "shoot at" indicates the propulsion of bullets from a gun. "Shoot" alone indicates that the "shoot at" was successful and presumably the changed state that was intended was accomplished. We have written in this diagram the inferred state, which is the PHYSICAL STATE scale which indicates the general state of an object. We have written in here, in addition, the instrument of ACT, but it actually is an inference. "Shoot" could as easily involve remote control.

(7) John punched Mary.



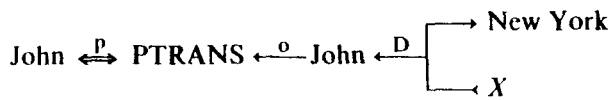
Here we use the state PHYS. CONT. to indicate that the PROPELing of the fist was a "punch" and not just a "swing at". The only way to PROPEL a bodypart is by MOVEing it. Thus, we are almost certain that the instrument is known, so we fill it in.

(8) John pushed the table to the wall.



(8) is like (4) in that the intention of the action done requires two ACTs listed instrumentally to handle it. "To push" something is to change its physical location, thus PTRANS is the ACT that was intended. The resultant causal indicates that the location change was accomplished. (This resultant state change was not known in (4) because the word used was "throw to" which does not change possession unless completed. In (4) however, PTRANS can be inferred from PROPEL (this is true whenever the object PROPELed is movable). Thus a location change for the ball in (4) can be inferred as well.) In (8) the location change is the intent and thus PTRANS is the ACT that was specifically stated and need not be inferred.

(9) John went to New York.



We treat "go" a bit differently than is usual.

Most semantic analyses deal with "John went", "the car went" and "the plane flew" as if the sentential subject is also the actor or agent semantically. In fact, "John" is the actor in "John went". But "John" serves a dual role conceptually. "John" is also the object of the sentence "John went".

Whenever PTRANS is present, it can be inferred that the object of PTRANS is probably now located at the location that served as the Directive case for PTRANS.

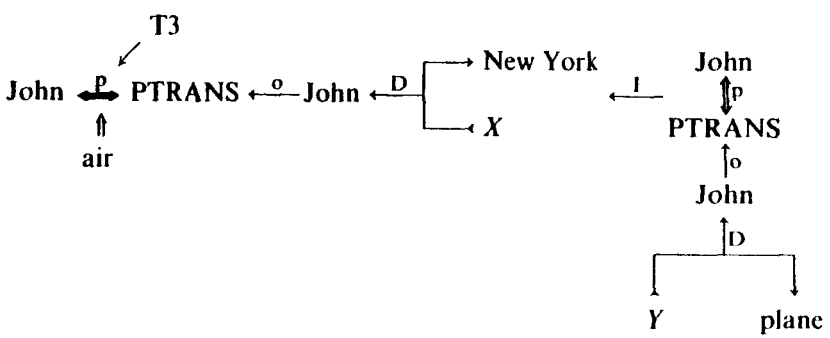
Thus since it is true that John is the actor when he "goes", "John" must be in the actor slot. But, it is also true that the location of John has been changed and that, just as for "move" and "pick up", John is now probably located at the Directive case location.

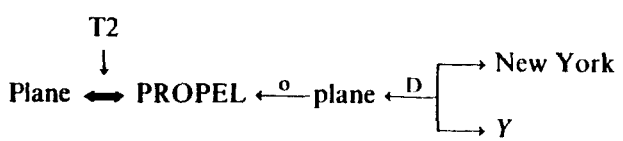
Actually our analysis indicates that the direction is towards N.Y. An inference would be made that the following state result (⇑r) would be valid. Here we would have:

That is, John is in New York.

(10) John flew to New York.

"Flying" to New York is also PTRANS, but here the instruments have been stated:





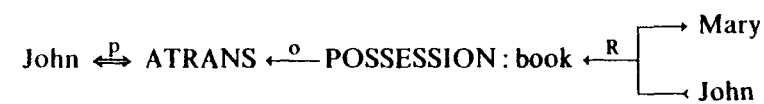
That is, "John PTRANSed John to New York by means of PTRANSing himself to a plane and the plane PROPELing itself to New York.

We treat John as object here because his location gets changed. We treat John as an actor because he has intentionally performed the necessary Instrumental actions to effect the PTRANS of himself (note that the plane is also PTRANSed, but John is not the actor there unless he is the pilot).

Like PTRANS, ATRANS is often expressed in language without the Instruments that specify what actual physical ACTs took place. The abstract transfer itself is what is focussed upon. The state relationship that we have been writing as $X \Longleftrightarrow$ STATE(Y) is written for ATRANS examples as object STATE: X with the Ys in the recipient case. The Ys are changed by the ATRANS from the donor in Recipient case to the receiver. Thus we have:

(11) John gave the book to Mary.

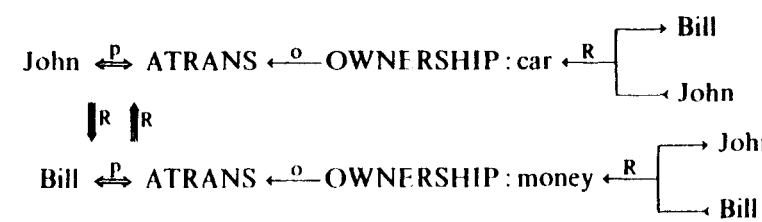
(12) John loaned the book to Mary.



In other words, ATRANS changes one of the parts of a two party abstract relationship. ATRANS can be actually effected in the real world by many means, not all of them physical. A frequent instrument for ATRANS is "MOVE ← hand" where the hand is grasping the object being transferred. Often, however, OWNERSHIP is transferred by signing a paper or by simply saying so. That is, ATRANS can take place and the world can appear exactly as it was. For this reason, ATRANS is the one ACT presented here that is not necessarily universal. That is, it is possible to conceive of a culture and therefore a language that would have a different set of those abstract relations or none at all (and thus so ATRANS).

(13) John sold his car to Bill.

ATRANS operates with a small set of abstract objects. We treat "sell" as a change in the ownership relations.



Thus we are saying that two abstract relationships change because of some mutual causality. Any physical ACTs that took place (i.e., signing a check and handing it to John) are the instruments of the abstract action ATRANS.

(14) John let Bill use his desk.

Another abstract relationship that can be ATRANSed is "control". Thus the most likely interpretation of (14) is that this is an ATRANS of control rather than ownership (the desk might belong to the university) or possession (it is still John's).

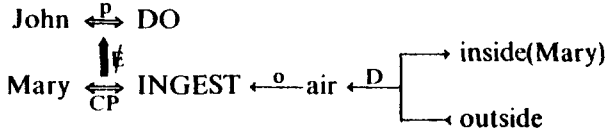
The problem here is that the use of the above primitives makes clear an ambiguity that exists in English that is not otherwise always accounted for in semantic representations. Namely: "give" can mean a change in possession that required no physical change as in "John gave Mary the Empire State Building". "Give" can also refer to a change in control without a change in possession. Additionally, "give" can refer to a change in physical location without a change in the abstract notion of possession, as in "I gave him my handkerchief". Basically then whether "give" means ATRANS or PTRANS or both is dependent on the nature of the object and is often simply ambiguous. This conforms with the notion shown in Rieger's chapter that a great deal of the information needed to process language is based on the object involved rather than the action.

We note that it would be possible to represent the events for which we use PTRANS and ATRANS as "DO cause state change". That is, in effect "go" seems to be "DO cause be at a new location" and "give" can be considered to be "DO cause a change in possession". However, we represent these things with these abstract ACTs and it is pertinent to consider why.

One of the operating assumptions in this work has been that people are essentially ACT-based systems. We agree that it is certainly possible to treat them and the language that they use as state based (indeed Rumelhart, Lindsay and Norman, 1972, have developed an interesting conceptual system that is state based) but it seems that the shift in focus presents problems.

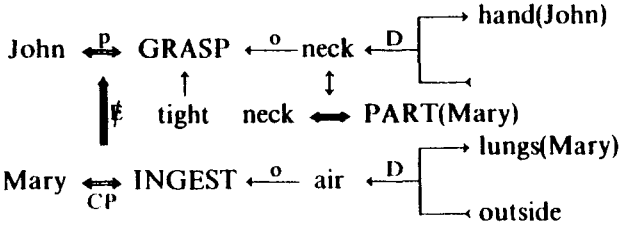
Consider the verb "give" in its most usual sense. When John gives a book to Mary it probably means that Mary has the book. The key word here is "probably". Similarly if John goes to New York, it is only probably true that he got there. It is important to be able to express the initiation or intent of ACTs such as PTRANS and ATRANS that is apart from the completion of the intended results of these ACTs.

(15) John choked Mary.



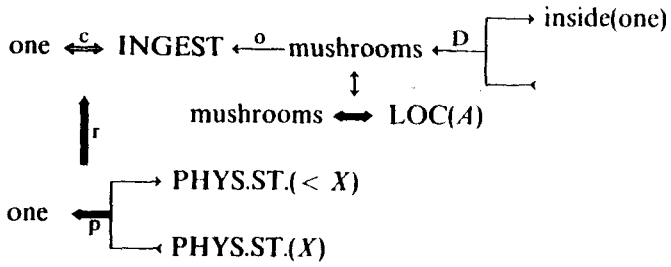
"Choke" is the doing something that unenables (⋿) another ACT to occur. "Breathe" is the ACT that was unenabled. The notation "inside (Mary)" is a shorthand for:

(16) John strangled Mary.



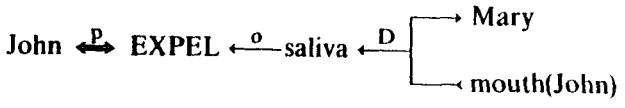
"Strangle" is choke plus a "tight GRASP" of the neck.

(17) Those mushrooms are inedible.



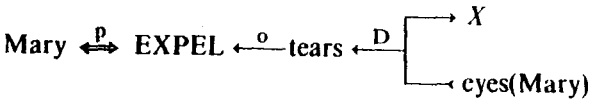
"Those" means that some specific items located in a specific place (A) are referred to. "Inedible" although an adjective, refers to an ACT and the consequences of that ACT. That is, "inedible" is the same as "eating it would make you sick". "One" stands for any human, "c" for conditional (if then, when combined with causation).

(18) John spit at Mary.

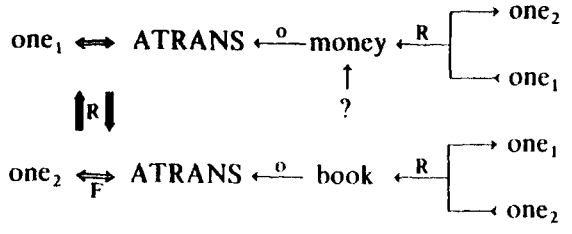


EXPEL is like PROPEL (in that many inferences attached to it are the same) except that the source of the object is always from inside the body.

(19) Mary cried.

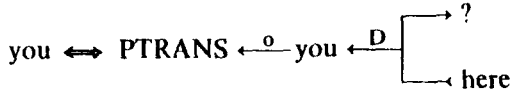


(20) How much does the book cost?

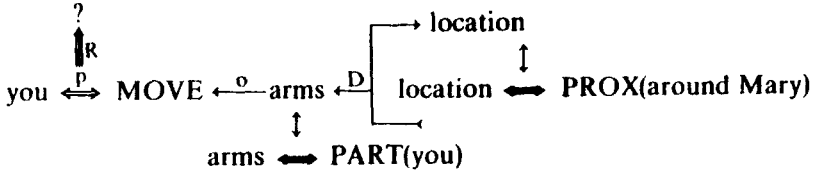


One_1 denotes the speaker and one_2 the potential seller. A paraphrase of this conceptual might be what quantity of money must be ATRANSed to you to get you to ATRANS the book to me. (When we leave out the abstract relationship from the ATRANS, OWNERSHIP is assumed.) Questions are handled by putting a question mark in the conceptual spot being inquired about.

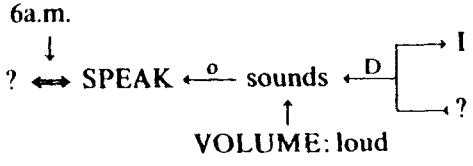
(21) Where are you going?



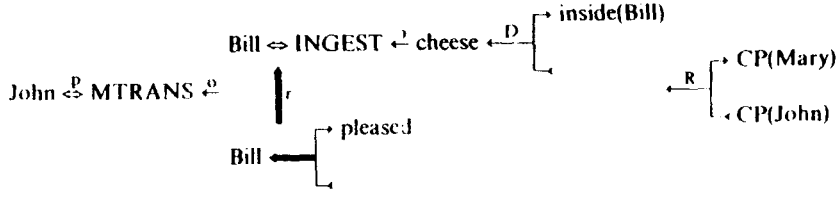
(22) Why did you hug Mary?



(23) Who yelled at me at six in the morning?



(24) John told Mary that Bill likes cheese.

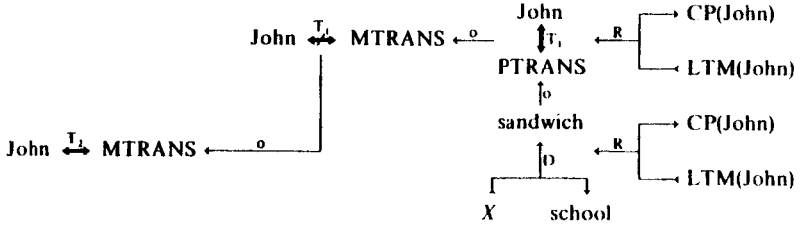


"Like" is treated as "cause to be pleased" and we have placed the inferred ACT, INGEST in the diagram although the parser would return only DO. MTRANS goes between pieces of minds. Here the MTRANS or transfer of information is from the CP (or conscious thoughts) of John to the CP of Mary. We could now infer that Mary "knows" this fact. "Know" is represented as "being in the LTM of". In order to infer this, then we use a rule that says that most things that are MTRANSed to the CP are later transferred to the LTM (by another MTRANS).

(25)Mary knows that Nixon is President.

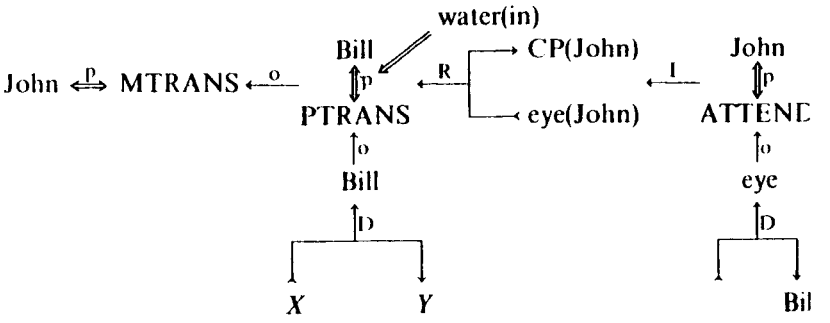
MLOC stands for mental location. We have then that this fact is in Mary's LTM.

(26) John remembered that he forgot to bring his sandwich to school.



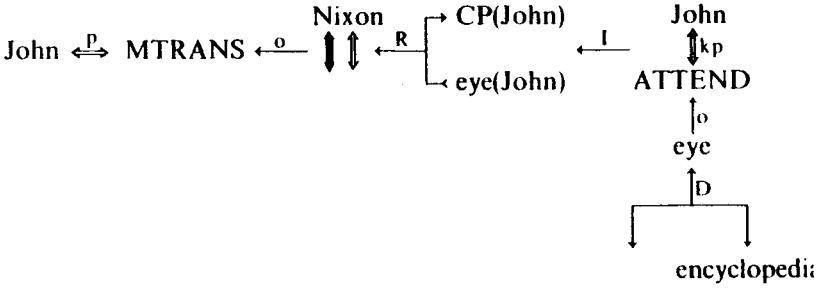
"Remember" is the MTRANSing of information from the LTM to the CP, or alternatively, "to try to remember something" can also be to attempt to transfer it from the CP to the LTM for later use. "Forgetting" is not doing the MTRANS from LTM to CP. This sentence is important from an inference standpoint in that the crux of it had not been expressed and must be inferred, namely that John has since gone to school and that forgetting his lunch means he does not have it and, therefore, cannot eat it and will possibly go hungry. How to do this kind of thing is treated in Chapter 5.

(27) John saw Bill swimming.



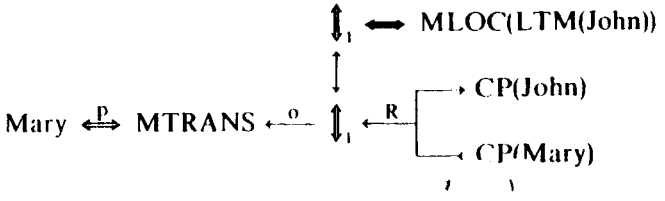
"Swim" is actually PTRANS by PROPEL by MOVE hands and fee in a certain way, in the water. "See" is the MTRANSing of informatio by means of ATTENDing one's eye in the direction of the informatior

(28) John read about Nixon in the Encyclopedia.



What John MTRANSed here were assorted unknown facts abou Nixon. He did this by looking (for a long period of time) at an encyclo pedia. We have spent little time coding complicated nouns like encyclo pedia, but in actuality, the memory would treat this as a book where on could read many facts about many subjects. "Book" would be coded i terms both functional (read) and physical (made of paper, etc.).

(29) John believes what Mary told him.

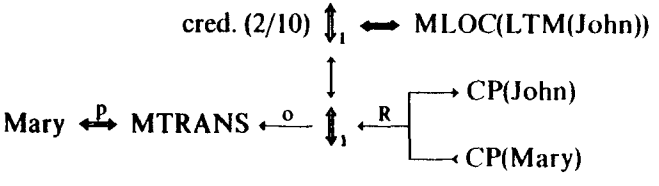


(The subscript denotes that these ⟷ are the same.)

This says that a fact is in John's memory and that this fact is one that was MTRANSed to John by Mary. We treat "know" and "believe", therefore, virtually identically. The reasons for this are too complicated to get into here and there is little effect on the understanding system in so doing.

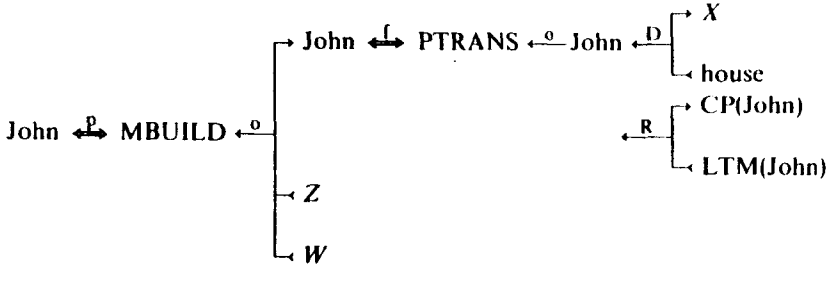
We consider that only true conceptualizations are stored in LTM, as anything present there is believed. Credibility weights can be attached to facts, but credibility of zero is not allowed. "The world is not flat" would have to be derived from some "true" conceptualization.

(30) John thought that Mary was probably lying.



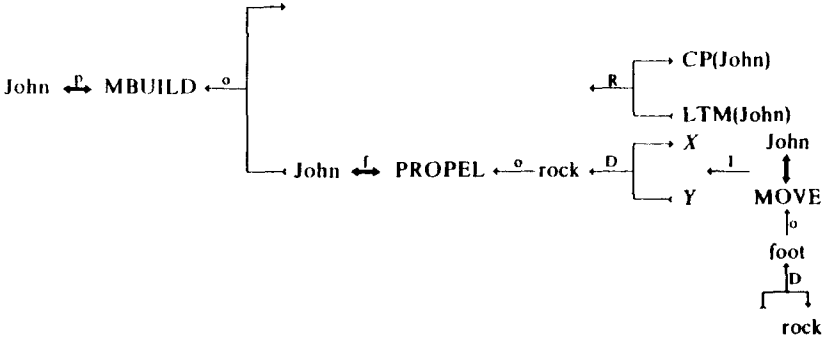
Unstated credibility is assumed to be 1. The only difference then between (29) and (30) is the credibility weight.

(31) John decided to leave the house.



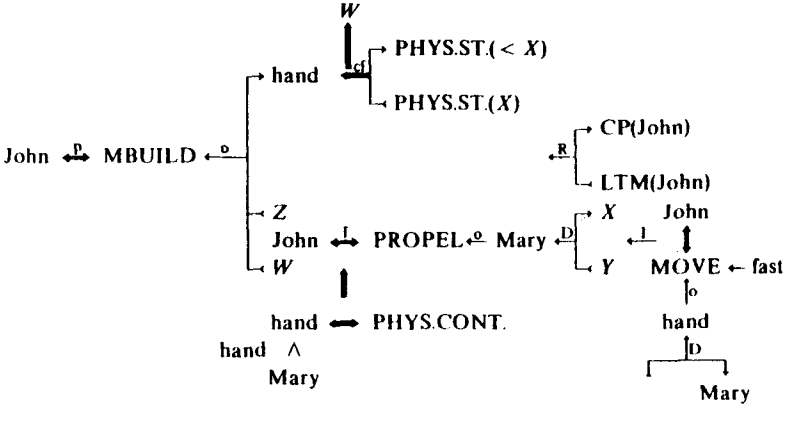
MBUILD is the mental ACT that is responsible for combining old facts to produce new ones. Because of this, it uses a special objective arrow that has input (*Z* & *W*, etc.) and output. The new output is transferred to the CP where it then usually serves as the reason for doing whatever was decided. The input must come from the LTM.

(32) John considered kicking a rock.



"Consider" is MBUILDing also, but no result has been stated. Thus, we know only the input.

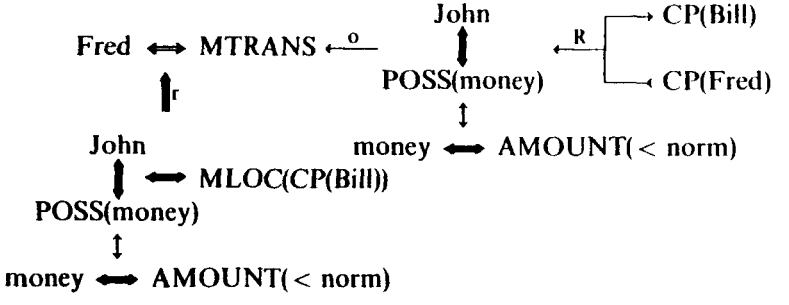
(33) John thought about hitting Mary but realized that he would hurt his hand.



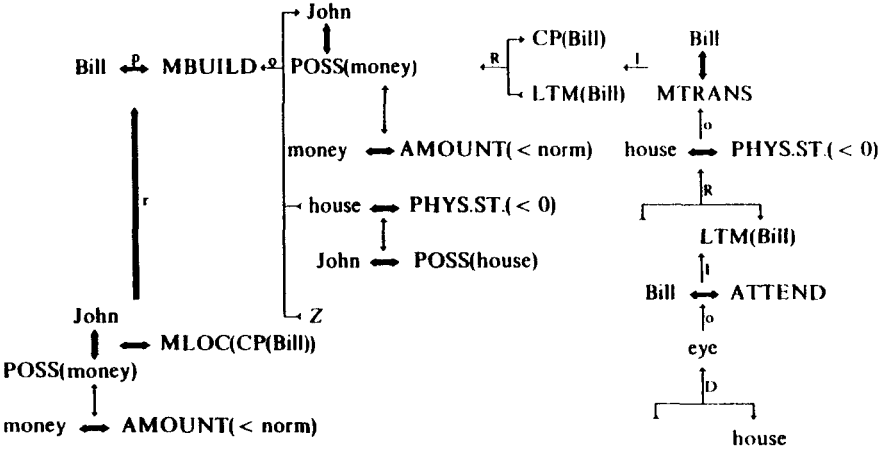
This diagram says that John took inputs *Z* (unstated) and *W* (the hitting act) and concluded that *W* would cause his hand to be damaged. *Z* is likely the knowledge that hitting people with one's hand can cause harm to the hand. The inference program assumes an order to MBUILDing that tries to predict what ideas would come from what ideas. This diagram does not include the obvious inference that he then decided not to do this action. That inference is made by knowing that MBUILDs can be the instrument for other MBUILDs. The MBUILD in (33)

provides the input for another MBUILD that uses the world knowledge that potential harm is a good reason not to do things.

(34) Bill became aware of John's poverty when Fred told him about it.



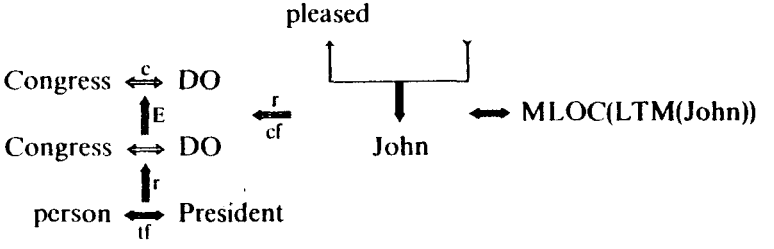
(35) Bill became aware of John's poverty when he saw the state of his house.



"Awareness" of a fact, is the presence of that fact in the CP (or the active memory called IM). Things can get into the CP as a result of either MTRANSes or MBUILDs. In (34) the new fact was simply told to Bill. In (35) Bill deduced it from some facts about the world (Z) and what he

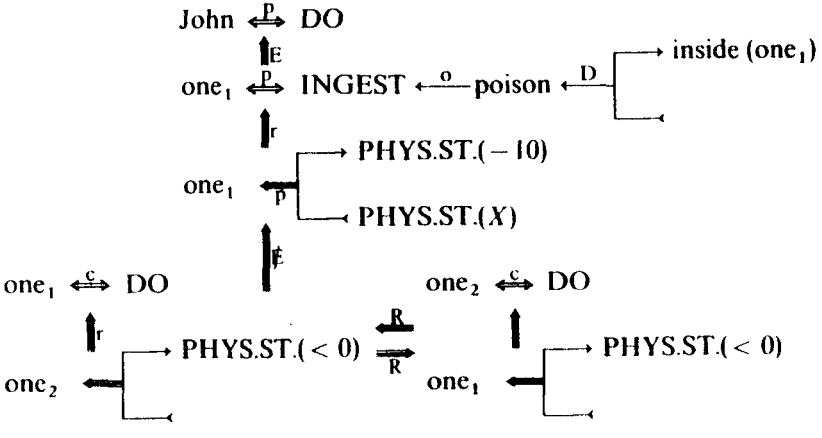
saw. (We have left out one of the instrumental MTRANSes (from CP to LTM) in the diagram for (35).) The negative state of the house in (35) is purely an inference and might be wrong.

(36) John wants the Congress to impeach the President.



"Congress" is DOing here because there are sets of predefined ACTs that constitute impeachment. We could, of course, list them all, but John may not even know what they are. Rather he knows that these ACTs would enable Congress to DO other ACTs (of conviction) that would result in the person who is the President becoming not the President. All this, if it happened, would please John. All of this is in John's head.

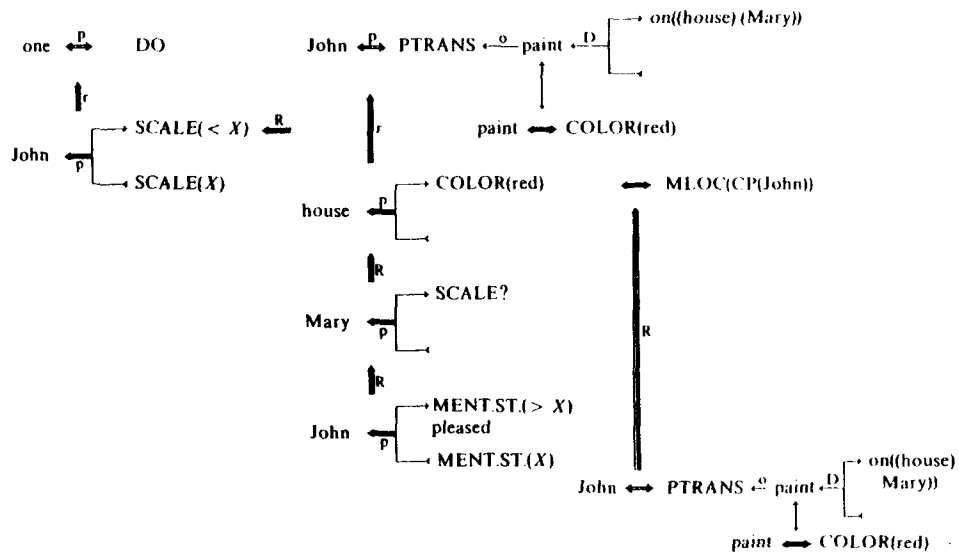
(37) To prevent the fight, John poisoned one of the participants.



"Prevent" is to do something to end the necessary conditions for (unenable: ∉) another event. A "fight" is when two or more participants

do things to hurt each other. Eliminating one of the participants, then, unenabled the event.

(38) John got revenge by painting Mary's house red.



Implicit in (38) and also in (37) is the notion of intention. We treat intention as the presence of a thought about an action in the CP serving as the reason for doing that action. That is, intended results exist in the mind of the actor. We have used in (38) what we call the "revenge belief pattern". This is called up for words like "revenge", and means that "somebody doing something that has hurt you can justify doing something to hurt them". In (38), we are saying that John's action was part of this paradigm, i.e., it was intended to hurt Mary. Furthermore we can infer that Mary's being hurt (represented as a negative value on an unknown scale (SCALE?)) will please John since this is a usual part of revenge.

We have attempted to show here how some sentences are handled using Conceptual Dependency. In trying to be specific about memory representations, it is easy to leave oneself open to sticky points about many issues that we have left unhandled or oversimplified. We realize this, but have felt that it is necessary in order to build computer programs

that understand language, to get a workable meaning representation as opposed to a perfect one. That is to say, it will be a long time before each and every issue of meaning representation is resolved. We cannot wait until that time to write programs. What we have done, therefore, is to define a meaning representation that is both adequate for the domains with which we want to deal and expandable into other domains without radical alterations. It is this half theoretical, half pragmatic approach to computational linguistics that we feel leads to the best results.

3.7. Inferences

Rieger's chapter deals with the computer implementation of the problem of inference. Inference is probably one of the main problems facing us in the years ahead, so we would consider both this section and Rieger's chapter merely first attempts. That is, with respect to inference, we have decided to attack the simplest things first. The inferences that follow directly from primitive ACTs are the most straightforward and therefore the simplest.

It should be noted before we start out here, that unlike many other problems in Artificial Intelligence and computational linguistics, the domain of inference is a highly idiosyncratic one. That is, the inference that we make can be wrong and in fact might not be made by all speakers. In attempting to develop a model of intelligence, we must recognize that all people's intelligence are not alike. Rather than search for some "idealized speaker", we chose here to present the general inference types that would facilitate the simulation of an intelligent speaker. So, whereas an inference could be wrong, even a wrong inference can form the basis for reasonable conversations. For example, the following conversation is based entirely on wrong inferences that are quite reasonable to make:

A: John hit Mary yesterday.
B: What did Mary do to upset him?
A: Nothing, they were practicing judo and his hand slipped.
B: Was she badly hurt?
A: No he barely grazed her.
B: I'll bet she was mad though.
A: She thought it was pretty funny.